

Modeling of Peak Hour Spreading with an Activity-Based Micro-simulation Model

Rebekah S. Anderson, P.E., Ohio Department of Transportation
Robert M. Donnelly, PB Consult

Introduction

Over the last decade in all metropolitan areas, growing peak period congestion has been accompanied by the spread of demand from the peak hour into the shoulder hours of the peak period. Conventional forecasting models generally adopt static diurnal factors and do not model time-of-day choice, and furthermore are generally not well formulated to extend their capabilities to model travel by hour of the day as function of level of service and other factors, including the simulation of peak hour spreading. As an activity-based / micro-simulation model, the MORPC travel forecasting system fully incorporates a time of day choice model, and models travel by hour of day, for a nineteen hour average weekday. Because the time of day model is sensitive to travel times, peak hour spreading as the consequence of increased levels of peak period congestion should be evident in the model's application. This paper explores this aspect of the MORPC activity-based model in application, comparing observed traffic data with the simulated hourly demand results from a series of tests of the model.

MORPC Time of Day Model

In October 2001, the Mid-Ohio Regional Planning Commission (MORPC) contracted PB Consult to develop a new set of regional travel forecasting models. The new model is a disaggregate tour-based model applied with the micro-simulation of each individual household, person or tour, mostly using Monte Carlo realization of each possibility estimated by the models, with use of a random number series to determine which possibility is chosen for that record.

The model consists of nine separate models that are linked and applied sequentially. In order, these nine models are: Population Synthesis, Auto Ownership, Daily Activity Pattern (mandatory tour generation), Joint Tour Generation, Individual Non-Mandatory Tour Generation, Tour Destination Choice, Time of Day Choice (TOD), Tour Mode Choice, and finally, Stops and Trip Mode Choice.

The Tour Destination Choice, Time of Day Choice and Tour Mode Choice models are all logit based and applied together. The "LogSum" composite impedance measure from the Mode Choice model is available to the other choice models, making them sensitive to changes in travel times due to congestion. The Time of Day model is based on the "time windows" concept, accounting for the use of a person's time budget over the day (16 hours available per person). These models are applied at the tour level, yielding the primary destination, time of day, and mode choice for the entire tour, and consider both the out-bound and in-bound portions of the tour.

The TOD model is a hybrid discrete choice departure time and duration model. The model has a temporal resolution of 1 hour for the modeled period between 5 am and 11 pm. All tour departures before 5 am were shifted to the 5 am hour, and all tour arrivals after 11 pm were shifted to 11 pm. The TOD model is applied sequentially among tours, with mandatory (work, university and school) tours being scheduled first. The model determines the departure time of each tour and the duration of the activity associated with the tour. Therefore, the 190 departure and arrival time combinations can be applied with relatively few variables. As a result of this time-windows constrained formulation, the timing of the departure and arrival times on both legs of the tour is determined by both the duration of the activities and by the travel times to and from them. (See Vovsha and Bradley.)

Status of the Time of Day Model Validation

In the development of the MORPC TOD model, a disaggregate validation was achieved using the Home Interview Survey (HIS) data records. The MORPC Validation Report shows the model results for the TOD model vs. the observed values from the HIS, which, as expected, match very well. The TOD model, however, has not yet been fully validated against external data. Currently, MORPC does not have a sufficient number of traffic counts by peak hour or peak period to validate either the hour-grained TOD model or the period-level traffic assignments. To date, only the 24 hour traffic and transit assignments have been validated with respect to counts and been used for official planning purposes. It is important to note that the hour-level detail in the MORPC micro-simulation results, are currently aggregated to four general time periods (3 hour AM and PM peaks, Midday, and Night/Early morning) for highway and transit network loading. The hourly detail, however, is available in the final simulated tour-record level disaggregate output.

Time of Day Comparison between the TOD Model and Traffic Counts

The Ohio Department of Transportation (ODOT) collects traffic monitoring data for Interstate, United States, and State Routes in the state of Ohio. Traffic monitoring data include vehicle volume, vehicle classification, and weigh-in-motion. Data are collected using manual, portable (road tube), and permanent Automatic Traffic Recorders (ATR) and Intelligent Transportation Systems (ITS) methods. Traffic Count data are published by hour and vehicle type by functional class on a statewide basis.

Table 1 shows the percent of half tours (departures and arrivals) and trips from the model and the percent of passenger vehicle traffic by hour of day for the base year 2000. As noted earlier, the model schedules tours between 5:00 and 23:00. Therefore, the 5:00 and 23:00 hours account for traffic between midnight and 5:00, and are therefore not directly comparable to the traffic count data. The traffic data by functional class are accumulated on a statewide basis; as such, the summary tables may not be as representative as data solely from the Columbus region. To calculate the average, the share by functional class was weighted by VMT share, as reported in the Highway Performance Monitoring System (HPMS).

Although number of tours or trips cannot be compared directly to traffic counts, several observations can be garnered. As seen from **Table 1**, the model is showing more tours starting or concluding in the AM peak hour and period than the PM peak hour and period. Part of this observation can be explained by the model simulating an average weekday, as opposed to an average day. Furthermore, because both the HIS and the model show that people are more likely to make a stop on the inbound half of the tour, the trips from the model are more balanced to the PM peak than the half tours. However, it is suspected that part of the apparent underestimation can be explained from the underreporting of non-mandatory tours in the HIS. While the model has been calibrated to take the underreporting into account, it is possible that some tours are still being missed.

Table 1: Percent of Tours, Trips and Passenger Vehicle Traffic by Hour of Day – Base Year 2000

Hour	MORPC Model		Traffic Counts by Functional Class Total Urban Areas Statewide					
	Half Tours	Trips	Average	11	12	14	16	17
5	2.1%	1.9%	1.8%	1.9%	2.4%	1.7%	1.6%	1.4%
6	2.7%	2.6%	4.6%	5.2%	5.5%	3.9%	3.8%	3.7%
7	8.1%	7.7%	6.9%	7.7%	7.2%	6.0%	6.0%	5.9%
8	9.0%	8.5%	5.6%	6.1%	5.6%	5.2%	5.2%	5.2%
9	5.8%	5.5%	4.7%	4.8%	4.5%	4.8%	4.6%	4.6%
10	4.4%	4.4%	4.7%	4.4%	4.8%	5.1%	4.8%	4.8%
11	4.3%	4.4%	5.3%	4.8%	5.1%	5.9%	5.8%	5.8%
12	4.6%	4.6%	5.7%	5.3%	5.3%	6.2%	6.2%	6.3%
13	5.3%	5.4%	5.8%	5.7%	5.4%	6.0%	5.9%	6.0%
14	5.3%	5.2%	6.4%	6.4%	6.1%	6.5%	6.5%	6.7%
15	6.4%	6.1%	7.6%	7.7%	7.5%	7.5%	7.6%	7.9%
16	7.5%	7.4%	8.1%	8.2%	8.2%	7.8%	8.1%	8.2%
17	7.0%	7.3%	8.2%	8.3%	8.3%	7.9%	8.2%	8.3%
18	6.7%	7.1%	6.2%	6.1%	6.0%	6.2%	6.5%	6.5%
19	5.5%	5.7%	4.6%	4.2%	4.3%	4.9%	5.1%	5.1%
20	4.4%	4.5%	3.8%	3.5%	3.6%	4.1%	4.3%	4.3%
21	4.5%	4.7%	3.2%	3.0%	3.1%	3.4%	3.5%	3.3%
22	3.2%	3.4%	2.3%	2.2%	2.4%	2.3%	2.4%	2.3%
23	3.4%	3.7%	1.6%	1.5%	1.8%	1.6%	1.5%	1.5%
Total	100.0%	100.0%	97.3%	97.2%	97.1%	97.1%	97.6%	97.8%

The formulation of the model also affects the TOD distribution obtained. The MORPC models are structured and applied in an ordered manner determined by a hierarchy of tour purposes. A tour activity lower in the hierarchy is not permitted to start until all tours with higher priority are scheduled. Therefore, if a person has both a joint eating-out tour and an individual shopping tour, that person is required to complete the joint tour before the shopping tour can be scheduled. Consequently, the scheduling of the shopping tour is dependant on the available time windows for the other parties in the joint tour. As Vovsha and Bradley mention, there is a dearth of information regarding travel prioritization (page 14). Given that deficit of information, this is probably the best we can expect this model to perform at this point in time. In addition to travel prioritization, the temporal granularity of the TOD model means there is a constraint of only one half

tour per hour. Therefore, if a person arrives home from work at 5:15 pm, that person is not permitted to start another tour until 6:00. However, this definition only affected 1% of the cases from the HIS and is probably not a major issue. (Vovsha and Bradley, page 14).

Peak Hour Spreading

Over the last decade or more, as congestion has increased in urban transportation networks such as those in Ohio, peak traffic levels have grown to increasingly extend beyond the peak hour to the shoulder hours of the peak period. **Table 1** shows that the peak hour in Ohio’s urban areas is 17:00-18:00 and the peak three hour period is 15:00-18:00. Despite the lack of direct comparability of the measures in this table, it is apparent that the model is not simulating the same PM peak period as is seen in the statewide urban area traffic counts, and may also be somewhat skewed with respect to diurnal patterns in the Columbus region. The PM peak three hours in the 2000 model run are between 16:00 and 19:00. This could be a consequence of various and imperfect temporal definitions of travel in both the model and the count data, as mentioned above.

Table 2 shows the time series count data available for Ohio’s urban areas and the share of traffic in the peak hour of the peak period by functional class. Also shown is the general trend of that share.

Table 2: Share of Traffic during the PM Peak Hour – Ohio Urban Areas

Functional Class	1997	1999	2000	2001	2002	2003	2004	Trend
11	34.2%	35.7%	34.3%	36.4%	35.1%	34.9%	34.1%	-0.015%
12	34.9%	32.2%	34.6%	35.5%	34.2%	34.2%	33.8%	-0.012%
14	34.2%	33.6%	34.0%	33.6%	33.4%	33.3%	34.1%	-0.054%
16	32.9%	34.6%	34.5%	34.0%	34.1%	34.1%	34.1%	0.097%
17	N/A	34.4%	34.0%	35.0%	33.6%	34.1%	34.8%	0.011%

As seen in this table, the peak hour share of peak period traffic is trending towards a fully flat 3 hour peak period, approaching a one-third share, with declines on the freeways and major arterials to other hours and to lower class facilities. This phenomenon is impossible to simulate with static diurnal factors, and very difficult to model in an aggregate travel forecasting model.

Because the MORPC activity-based micro-simulation TOD model simulates tour durations and incorporates the feed-back of travel skims, the model accounts for peak spreading as a result of travel time changes due to congestion. **Table 3** shows the number of half tours and trips by hour of the modeled day for both 2000 and 2030. Note that trips are segments of tours broken by model stops, and are the units of demand that are aggregated to zone-to-zone trip tables for use in the highway and transit assignments.

Table 3: MORPC Model – Tours and Trips by Hour of Day – 2000 and 2030

Hour	2000				2030			
	Half Tours	% of Total	Trips	% of Total	Half Tours	% of Total	Trips	% of Total
5	86,111	2.08%	110,241	1.95%	133,320	2.22%	165,170	2.07%
6	112,980	2.72%	145,468	2.57%	179,695	3.00%	224,773	2.81%
7	336,104	8.10%	435,320	7.68%	497,961	8.31%	636,165	7.95%
8	374,728	9.04%	480,570	8.48%	534,396	8.91%	676,048	8.45%
9	239,492	5.77%	312,174	5.51%	331,749	5.53%	424,625	5.31%
10	181,222	4.37%	249,196	4.40%	252,912	4.22%	336,512	4.21%
11	180,142	4.34%	246,680	4.35%	254,557	4.25%	337,227	4.22%
12	189,910	4.58%	258,258	4.56%	272,788	4.55%	360,854	4.51%
13	221,694	5.35%	303,500	5.36%	320,789	5.35%	426,945	5.34%
14	218,487	5.27%	295,771	5.22%	307,827	5.14%	406,733	5.09%
15	266,148	6.42%	347,570	6.14%	359,270	5.99%	461,114	5.77%
16	309,215	7.46%	420,063	7.42%	429,524	7.17%	574,106	7.18%
17	288,419	6.95%	415,649	7.34%	430,805	7.19%	605,927	7.58%
18	276,453	6.67%	399,523	7.05%	418,370	6.98%	590,080	7.38%
19	227,278	5.48%	320,808	5.66%	329,388	5.49%	451,780	5.65%
20	180,435	4.35%	256,601	4.53%	262,883	4.39%	363,319	4.54%
21	185,671	4.48%	264,169	4.66%	268,817	4.48%	370,925	4.64%
22	133,058	3.21%	195,234	3.45%	199,684	3.33%	283,582	3.55%
23	139,771	3.37%	208,019	3.67%	209,693	3.50%	301,945	3.78%

Table 4: MORPC Model - Hourly Shares of Half Tours and Trips in the PM Peak Period

Hour	2000		2030	
	% Tours	% Trips	% Tours	% Trips
16	35.38%	34.01%	33.59%	32.43%
17	33.00%	33.65%	33.69%	34.23%
18	31.63%	32.34%	32.72%	33.34%

The hourly base year and forecast distributions of modeled tours for 2000 and 2030 traffic are shown in **Table 4**. One important finding that can be seen in this table, is that the model does respond to the growth in demand over time and the concomitant increases in congestion by spreading the peak hour demand as expected it should. The 2030 tour arrival times are later in the day than are modeled for 2000. Also, while 16:00 is the definitive peak hour in 2000, 16:00 and 17:00 carry almost the same proportion of tours in 2030, showing that the demand is neither fixed or diminished, but is shifted to utilize capacity in other hours of the day with higher level of service.

So while the alignment of the simulated peaking patterns in the base year may be somewhat skewed compared to the best available counts, it is demonstrated that the activity-based nature of the MORPC model supports a time of day model that forecasts a reasonable response to growth in congestion – a desirable model feature that would be difficult to implement within the platform of a conventional model.

Future Research and Potential Applications

As noted above, more data and research need to be developed and applied before it can be determined if all of the explicit time-of day information that is produced by the disaggregate MORPC travel model can be validated and productively used in practice for planning and policy analysis. Very little external data exists at this time with which to validate the TOD component other than traffic counts, and unfortunately traffic counts and tours are not directly comparable. If more hourly traffic counts were collected and the trip tables were generated and assigned on an hourly basis, the model could be further calibrated and eventually validated.

Eventually, the output of the activity-based micro-simulation MORPC model could be exported to dynamic traffic assignment procedures, used in refining the application of matrix estimation results to future demand matrices, and in the development of design hour traffic. As shown in this specific exploration of the MORPC TOD model, it can already be used to provide an estimate of peak spreading for planning studies.

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