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Paper Title & Number

An intermediate stop duration model for the Atlanta Activity-based Model [ITM # 78]

Abstract

We describe an intermediate stop timing model developed as a component of the Atlanta Regional Commission's (ARC) activity-based travel forecasting model, a member of the Coordinated Travel – Regional Activity-Based Modeling Platform (CT-RAMP) family of models. This model component employs an innovative approach to the modeling of the duration of intermediate stops. First, the stop purposes and locations are generated. Next, stop durations are all generated together in a single two-stage model, taking into account the travel times and stop purposes for every stop in the tour. The resulting model has the advantage of being able to incorporate information about future events, such as the number and types of stops on tours and the travel time between them, into the duration modeling for each stop.

Statement of Financial Interest

The authors do not have any direct financial interest with regard to this research. The described methods are used in the CT-RAMP (Coordinated Travel and Regional Modeling Platform) software that is open source. The data and results are owned by the public agency (Atlanta Regional Commission) who sponsored the work. The work was performed by a consultant team comprised of Parsons Brinckerhoff and Atlanta Analytics, on behalf of ARC. However, the paper focuses on the technical merits of the work performed and is free of any advertisement.

Statement of Innovation

This paper presents an innovative approach to modeling the duration of activities on tours which considers the number, purpose, and travel time to all activities simultaneously. The authors are not aware of other models that take into account all three dimensions in one model; most models resort to sequential approaches which represent the duration of each stop in turn, which implies an importance hierarchy according to chronological order of the stop on the tour, which may be misleading. Our approach overcomes this limitation and should be of great interest to the activity-based model development community.

An intermediate stop duration model for the Atlanta Activity-based Model

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Introduction

We describe an intermediate stop timing model developed as a component of the Atlanta Regional Commission's (ARC) activity-based travel forecasting model, a member of the Coordinated Travel – Regional Activity-Based Modeling Platform (CT-RAMP) family of models. This model component employs an innovative approach to the modeling of the duration of intermediate stops. First, the stop purposes and locations are generated. Next, stop durations are all generated together in a single two-stage model, taking into account the travel times and stop purposes for every stop in the tour. The resulting model has the advantage of being able to incorporate information about future events, such as the number and types of stops on tours and the travel time between them, into the duration modeling for each stop.

Background

The activity-based models available in the literature adopt various approaches for finding intermediate stop durations. The CEMDAP model [1] considers the characteristics of intermediate stops on a tour sequentially, so that the purpose, duration, and location of the first stop are determined first, then they are determined for the second stop, and so forth. Although the total number of stops on the tour is known when considering the first stop, all the other information about the subsequent stops is not yet determined, and cannot be used to influence the first stop. The FAMOS model [2] operates in a similar sequential fashion, employing a time-space prism to constrain the duration and location of activities. In FAMOS, the number of activities is not determined separately, but the duration of each activity is jointly determined alongside a binary choice of whether the activity is the last activity in the chain (i.e., filling up the remaining time-space prism).

The ARC model is based upon the CT-RAMP family of activity-based travel models, described in sufficient detail elsewhere [3,4]. The ARC model determines the number, location, and purpose of all stops before considering stop duration. As demonstrated in the estimation results below, the availability of information on future stops is invaluable in determining stop durations – if the traveler has very time-consuming stops to make later in a tour, they are more likely to complete earlier stops more quickly.

The ARC model represents time in a discrete manner, defined by a set of 48 half-hour time periods which span the entire model day, starting with 3:00 AM to 3:29 AM (Period 1) and ending with 2:30 to 2:59 AM (Period 48). As a result, all trip and activity durations are measured in the number of discrete time periods elapsed (which may be zero, e.g. if an activity begins at 8:05 AM and completes at 8:25 AM, then all activity occurred within a single time period).

Lastly, while the generalized tour mode is determined in the ARC model before stop durations, the mode for individual trips is determined afterwards. Not knowing the trip mode (car, bus, walk, etc.) makes it difficult to model the travel time for trip. Even if mode choice were assumed to be private auto (not always but often true in metropolitan Atlanta), noise from the discretization of time and space results in imprecise measurements of trip travel time; the correlation between reported travel times and network zone to zone free-flow auto travel times is only about 0.35.

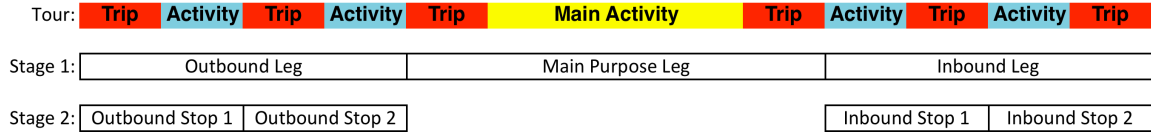
Methodology

Instead of a hazard-based model common in prior activity-based models, we adopt a logit-based discrete duration choice model. The motivation for this is two-fold: the discrete representation of time in moderately large intervals works well with the discrete choice structure, and a simultaneous model for all stop durations is relatively simple to create.

The natural simultaneous discrete model that captures the stop duration problem would be one where each alternative represents a unique combination of discrete durations for all stops. However, with tours having as many as nine modeled stops over more than 12 hours, the number of possible combinations is intractably large without sampling.

Instead, we predict the stop timings during a tour using a two stage choice model. The first stage predicts the durations of the main activity, as well as the outbound and inbound tour legs in aggregate. The second stage predicts the durations of the individual stops within the outbound and inbound legs. A schematic for this structure is shown in Figure 1. By dividing the stops in this manner, we are able to capture the various effects, such as the number of stops, time of day, and tour purpose, while still maintaining a manageable set of alternatives for simulation.

Figure 1: Tour Timing Breakdown



We also remove a layer of complexity by merging the modeling of trip durations (i.e., time spent actually moving from one location to the next) and the stop durations (time at a single location participating in an activity). Since trip times cannot be included as a deterministic function of network travel times, they are incorporated as explanatory variables in the duration choice model.

The first stage of the model decomposes the tour into three major components: outbound leg, main activity leg, and inbound leg.¹ The outbound leg of the tour begins when the tour departs the anchor location (often home) and ends when the traveler departs the last outbound stop prior to the primary destination. If there are no outbound stops, the outbound leg has time length zero. The main activity leg begins where the outbound leg departs and ends when the traveler arrives at the first inbound stop after the primary destination. The inbound leg consists of the remainder of the tour. If there are no inbound stops, the inbound leg has time length zero, and the main activity leg ends when the traveler arrives at the final destination.

By splitting the tour in this manner, we ensure that the outbound and inbound legs each contain one trip and one activity for each relevant stop, while the main activity leg contains two trips and one activity, regardless of the number of inbound or outbound stops on a tour. This is convenient from the perspective of model estimation, as the symmetric nature of the breakdown ensures that outbound and inbound legs are treated similarly. This does introduce a minor complication in application: for trips before the main stop on the tour, the trip start time is modeled, but for trips after the main stop, only the trip end time is modeled. Trip start times can be constructed for these trips after trip mode choice and network congestion have been accounted for later.

Each traveler is modeled as choosing between every possible combination of durations for the three legs of the tour, constrained only such that the total tour duration must match the exogenously provided value, and if there are zero outbound or inbound stops, then the duration of the outbound or inbound leg respectively must also be zero. Even with both outbound and inbound stops on an all day tour, the number of relevant combinations for this first stage numbers only in the hundreds, which is computationally feasible for simulation.

For example, if the tour begins at 8:00AM (period 11) and ends at 9:45AM (period 14), then the total tour duration is 3 time periods (14 minus 11). Those 3 time periods can be distributed in any combination among outbound leg, main activity leg, and inbound

¹ In the ARC model, the determination of which activity in a multi-stop tour is the “main” activity is made outside this model component.

leg; with the constraint that the duration of the outbound and inbound legs must be zero if the number of intermediate stops on that leg is zero. So, if both outbound and inbound legs have stops, there would be 10 possible alternatives.

The MNL model was selected over a more complex GEV structure to represent the choice process mainly to ease model estimation and application. Although there is obviously a relationship between certain sets of alternatives sharing a common duration for a particular leg, a fair bit of that relationship is captured explicitly in the deterministic portion of utility. More complex models with correlated error terms might fit the data better and provide a marginally better forecast, but they were not considered within the project scope.

Once the leg durations are established, we model the timing of individual stops within each leg. There are separate models for outbound and inbound legs. Each stop's duration is modeled to consist of the duration of the actual stop activity plus the duration of the associated trip. For outbound stops, the associated trip is the trip that precedes the stop; for inbound stops, it is the trip that follows the stop. The alternatives available to each traveler are every combination of durations for which the cardinality of the durations totals the number of stops taken on the leg and the sum of the durations totals the length of the leg. For example, on an outbound leg where the total duration is 2 and the number of stops is 3, the six possible alternatives are 2-0-0, 1-1-0, 1-0-1, 0-2-0, 0-1-1, and 0-0-2.

Estimation Results and Discussion

The intermediate stop duration models were estimated using data from the 2011 ARC Regional Travel Survey.² Only tours with more than one stop were considered in the estimation data, as there is no intermediate timing decision when a tour consists of a single stop. The estimated parameters for the stage 1 duration model are shown in Table 1. The log likelihood at convergence for this MNL model is -22154, against a log likelihood of a null model of -32247, yielding a rho-squared value of 0.313.

As should be expected, the purpose of the main activity on the tour significantly effects the duration of the main leg. Tours with the main purpose of work and school are most represented in the estimation data, and have the most detailed functional form for utility. When escort is the main purpose, the main activity leg tends to be very short. Conversely, when the main purpose is discretionary or social/visit, the longer the better! For other activities, the main leg typically has a duration of 2-4 hours. The principal result is that the main activity tends to want to fill up its "usual" time; when the overall tour length is longer, the extra time tends to occur more on intermediate stops. Similarly, when the tour is too short, spending time at intermediate stops is less desirable.

Another important part of the stage 1 model represents the aggregate effect of other stop purposes on the outbound and inbound legs. For each leg, there is a baseline

² For details on the survey methodology and results, see <http://www.atlantaregional.com/transportation/travel-demand-model/household-travel-survey>

coefficient on the duration per stop. There is also a marginal coefficient for duration per stop multiplied by the number of stops for each purpose.

The stop purpose parameters can be thought of as “time pressure” factors. Adding an additional intermediate stop on a given leg generally increases the probability that the traveler will choose to spend additional time on that leg. When there is plenty of time in the tour to comfortably complete all other activities, the increase in leg duration from adding the stop will tend to be large. When there is a shortage of time on the tour (the total preferred length of other activities exceeds the tour length) then the added stop will tend to add less extra time to the leg.

The utility of intermediate stops is represented in the model as linear and mostly (depending on the purpose) increasing, although the trade-off against a necessarily decreasing duration of the other legs (as total tour duration is exogenous and fixed) generally limits the time for intermediate stops in an appropriate manner. However, three intermediate stop purposes (discretionary, eat out, and shopping) were found to have particularly peaked duration distributions, with durations that were commonly one or two time periods, but almost never more. These purposes are modeled with piecewise linear utility in the stage 1 model, with a spline point at duration 2.

As most trips in Atlanta are made by auto, the zone-to-zone free flow auto travel time is employed as an indicator of the actual travel time. Interestingly, the coefficient for the travel time in the outbound leg is significantly higher than the coefficients for the other two legs, which are quite similar. This difference could be attributed to congestion, or to travelers adding extra time on outbound legs when the travel times are high, to account for concomitant decreases in travel time reliability, so as to be sure to arrive at the main purpose on time. However, we explored segmenting this coefficient on main purpose, and did not find that the outbound leg’s difference was significantly tied to any particular purpose; the effect remained for all tour purposes.

The impact of time-of-day is modeled using a four component Fourier series (two sines and two cosines, each with full and half day frequencies). This is a method for incorporating cyclic time-of-day effects in choice models, as it generates a smooth function representing changes in preferences across times of day [5]. This avoids any discontinuities that can cause unusual effects when modeling small changes in timing.

We investigated incorporating socio-economic attributes of the traveler; only one had any significant effects: full-time versus part-time status of workers.³ Otherwise, stop duration is framed by the overall tour length, the number of stops, the purpose of those stops, and the location and ordering of those stops. Socio-economic factors surely play a significant role in determining these inputs to the intermediate stop duration model, but once the tour activity picture is established, that picture is what controls the timing of stops, and not the details of the traveler's persona.

After initial application of the model, we found that a series of alternative-specific constants are useful to describe the steep duration curves for the first five time periods

³ We define a full time work as a regular work schedule of 35 or more hours per week.

for relatively short-duration activities such as discretionary and eating out, as well as a set of alternative-specific constants that describe the peaking nature of longer term activities such as work and school help to better match observed temporal distributions.

Once leg duration has been chosen in the first stage, there are only two principle factors that were found to affect stop duration in the second stage: stop purpose and travel times. Any duration effect in intermediate stop ordering appears to be subsumed in stop purpose. Therefore, the stage two models for outbound and inbound legs are relatively simple compared against the stage 1 model, and for space the results are omitted here. Also, there is no stage 2 model for the main purpose leg, as it has only a single stop.

Conclusions

The stop duration model described here was developed to be reasonably simple to implement and to fit into the framework of the ARC CT-RAMP activity-based model. The results indicate that the number of stops and the travel time to each stop is an important determinant in stop duration, which sequential approaches may miss. A key future direction for this research is whether it would be feasible to use smaller time increments in the model, and the extent to which more realistic travel times (for example, time-dependent travel times constrained by tour mode) can be incorporated into the approach.

Table 1: Stage 1 Model Parameter Estimates

Parameter	Estimate	StdError	t-Stat
<i>Main Tour Purpose</i>			
Discretionary: MainLegTime=0	-6.5884	0.94953	-6.9386
Discretionary: MainLegTime=1	-5.0326	0.54564	-9.2232
Discretionary: MainLegTime=2	-2.0526	0.20661	-9.9348
Discretionary: MainLegTime=3	-1.0313	0.15482	-6.6614
Discretionary: MainLegTime=4	-0.46489	0.1256	-3.7014
Discretionary: MainLegTime	0.060382	0.065643	0.91984
Eat Out: abs(MainLegTime-4.5)	-0.7508	0.081895	-9.1678
Eat Out: MainLegTime	0.53247	0.09005	5.913
Maintenance: MainLegTime=0	-3.6079	0.26053	-13.848
Maintenance: MainLegTime=1	-1.9376	0.19561	-9.9057
Maintenance: MainLegTime=2	-0.99484	0.16164	-6.1548
Maintenance: MainLegTime=3	-0.29166	0.13428	-2.172
Maintenance: MainLegTime=4	0.18669	0.11365	1.6427
Maintenance: MainLegTime	-0.03572	0.066484	-0.5372
School: MainLegTime=14	1.2449	0.13532	9.1993
School: MainLegTime=15	1.8492	0.11521	16.05
School: MainLegTime=16	2.0672	0.11127	18.578
School: MainLegTime=17	1.8571	0.11709	15.86
School: MainLegTime=18	1.3826	0.13225	10.454
School: MainLegTime=19	0.92034	0.15105	6.093
School: MainLegTime=20	0.37001	0.17919	2.0649
School: MainLegTime	1.7393	0.37267	4.6672
School: max(MainLegTime-3,0)	-1.5696	0.36967	-4.2458
School: max(MainLegTime-23,0)	-0.43764	0.095517	-4.5818
Escorting: MainLegTime=0	-1.2273	0.27675	-4.4347
Escorting: MainLegTime=1	0.48815	0.2288	2.1335
Escorting: MainLegTime=2	0.37136	0.20288	1.8304
Escorting: MainLegTime=3	-0.29005	0.20585	-1.409
Escorting: MainLegTime	-0.0054991	0.073186	-0.0751
Shopping: MainLegTime=0	-4.5136	0.29898	-15.097
Shopping: MainLegTime=1	-1.8461	0.22822	-8.0893
Shopping: MainLegTime=2	-0.81101	0.18832	-4.3066
Shopping: MainLegTime=3	-0.42265	0.15528	-2.7218
Shopping: MainLegTime=4	-0.25089	0.13296	-1.8869
Shopping: MainLegTime	-0.30597	0.074379	-4.1137
Social/Visit: MainLegTime	1.1482	0.13118	8.7525
Social/Visit: max(MainLegTime-5,0)	-0.94185	0.12821	-7.3459
University: MainLegTime	0.56244	0.10305	5.4578
University: max(MainLegTime-8,0)	-0.55984	0.10379	-5.3938
University: max(MainLegTime-16,0)	-0.22445	0.091049	-2.4652
Work: MainLegTime	0.45055	0.067863	6.6392
Work: max(MainLegTime-9,0)	-0.27206	0.040198	-6.768
Work: max(MainLegTime-14,0)	0.009149	0.034807	0.26285
Work: MainLegTime=17	0.12954	0.090217	1.4358
Work: MainLegTime=18	0.54498	0.082688	6.5908
Work: MainLegTime=19	0.64445	0.08519	7.5649
Work: MainLegTime=20	0.56793	0.092815	6.119
Work: MainLegTime=21	0.16153	0.10614	1.5219
Work: MainLegTime=22	-0.15183	0.11917	-1.2741
Work: max(MainLegTime-22,0)	-0.57964	0.052574	-11.025
Work Related: max(MainLegTime-16,0)	-0.20496	0.084587	-2.423
Work Related: max(MainLegTime-18,0)	-0.16742	0.10547	-1.5873
Work Related: MainLegTime	0.23067	0.063856	3.6123
Work Related: MainLegTime=0	-1.7688	0.25141	-7.0354

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Parameter	Estimate	StdError	t-Stat
<i>Travel Attributes</i>			
IsFullTimeWorker*IsWorkTour	0.037065	0.015593	2.3771
<i>Total of Trips Free Flow Travel Time</i>			
MainLegTime*FFT	0.0038699	0.00027978	13.832
InboundLegTime*FFT	0.0029356	0.00018371	15.979
OutboundLegTime*FFT	0.0058104	0.00041529	13.991
MainLegTime*MAIN_OUTSIDE	0.21224	0.030457	6.9686
InboundLegTime*INBOUND_OUTSIDE	0.24167	0.033936	7.1212
OutboundLegTime*OUTBOUND_OUTSIDE	0.35432	0.039805	8.9013
<i>Time of Day Effects</i>			
OutboundLegTime*SIN(2 π *TourStartPeriod/48)	-0.20702	0.032874	-6.2975
OutboundLegTime*COS(2 π *TourStartPeriod/48)	0.18594	0.035298	5.2677
OutboundLegTime*SIN(4 π *TourStartPeriod/48)	-0.11703	0.025276	-4.6301
OutboundLegTime*COS(4 π *TourStartPeriod/48)	-0.014628	0.022206	-0.65873
MainLegTime*SIN(2 π *TourStartPeriod/48)	-0.0075678	0.032375	-0.23376
MainLegTime*COS(2 π *TourStartPeriod/48)	0.11681	0.032864	3.5544
MainLegTime*SIN(4 π *TourStartPeriod/48)	0.019579	0.022702	0.86242
MainLegTime*COS(4 π *TourStartPeriod/48)	0.01919	0.015352	1.25
<i>Stop Purpose Effects</i>			
Outbound Average Stop Duration	-0.31564	0.025494	-12.381
Inbound Average Stop Duration	-0.44644	0.018459	-24.186
AvgStopTime*nWork	0.34505	0.078049	4.421
AvgStopTime*nWorkRelate	0.51248	0.060286	8.5008
AvgStopTime*nSchool	0.48727	0.063622	7.6588
AvgStopTime*nEscort	-0.012751	0.060278	-0.2115
AvgStopTime*nDiscretion	1.5282	0.085955	17.779
AvgStopTime*nEatOut	1.274	0.074006	17.214
AvgStopTime*nMainten	0.16135	0.059695	2.7029
AvgStopTime*nShopping	0.74173	0.063839	11.619
AvgStopTime*nSocialVisit	0.46026	0.060648	7.589
max(AvgStopTime-2,0)*nDiscretion	-1.3133	0.068904	-19.059
max(AvgStopTime-2,0)*nEatOut	-1.2604	0.053978	-23.35
max(AvgStopTime-2,0)*nShopping	-1.2137	0.045113	-26.904
=====			
Log Likelihood at Convergence	-22153.69		
Log Likelihood at Null Parameters	-32247.43		
=====			

Table 1 Variable Definitions

MainLegTime: An alternative-specific variable equal to the number of periods allocated to the main leg of the tour.

InboundLegTime: An alternative-specific variable equal to the number of periods allocated to the inbound leg of the tour.

OutboundLegTime: An alternative-specific variable equal to the number of periods allocated to the outbound leg of the tour.

TourStartPeriod: The departure period for the tour (1->48)

FFT_MainLeg: The sum of MTAZ to MTAZ free flow travel times for both trips on the main purpose leg. For any trip where either the start or end MTAZ is indicated as 7777, that trip contributes 0 to this sum.

FFT_InboundLeg: The sum of MTAZ to MTAZ free flow travel times for all trips on the inbound leg. For any trip where either the start or end MTAZ is indicated as 7777, that trip contributes 0 to this sum.

FFT_OutboundLeg: The sum of MTAZ to MTAZ free flow travel times for all trips on the outbound leg. For any trip where either the start or end MTAZ is indicated as 7777, that trip contributes 0 to this sum.

MainOutside: Dummy variable, taking a value of 1 if the main activity location MTAZ is 7777, otherwise 0.

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Table 1 Variable Definitions, continued

InboundOutside: Dummy variable, taking a value of 1 if the activity location MTAZ is 7777 for any inbound stop, otherwise 0.

OutboundOutside: Dummy variable, taking a value of 1 if the activity location MTAZ is 7777 for any inbound stop, otherwise 0.

OutboundAvgStopTime: *OutboundLegTime* divided by the number of outbound stops, if the number of outbound stops is > 0, otherwise 0.

InboundAvgStopTime: *InboundLegTime* divided by the number of inbound stops, if the number of inbound stops is > 0, otherwise 0.

AvgStopTime: Either *OutboundAvgStopTime* or *InboundAvgStopTime*, as appropriate. For each component of utility that includes *AvgStopTime*, the utility function includes both inbound and outbound components (either may be 0 if there are no stops on that leg), and all other variables in that utility component are leg-specific for the same leg (i.e., inbound or outbound).

nWork: The number of work activities on the tour leg

nWorkRelate: The number of work-related activities on the tour leg

nSchool: The number of school activities on the tour leg

nEscort: The number of escort activities on the tour leg

nShopping: The number of shopping activities on the tour leg

nMainten: The number of other maintenance activities on the tour leg

nEatOut: The number of eating out activities on the tour leg

nSocialVisit: The number of social\visiting activities on the tour leg

nDiscretion: The number of other discretionary activities on the tour leg

isFullTimeWorker: 1 if traveler is full-time worker, else 0

isWorkTour: 1 if tour purpose is work, else 0

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