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Activity Based Model Calibration

Coordinated Travel – Regional Activity Based Modeling Platform (CT-RAMP) for Atlanta Regional Commission

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Introduction

Atlanta Regional Commission, the metropolitan planning agency for the 20 county Atlanta region, is actively developing a comprehensive travel demand model to equip itself with a powerful forecasting tool that will be adequate for new socioeconomic environments and meeting emerging planning challenges. The ABM developed for ARC uses the Coordinated Travel – Regional Activity Based Modeling Platform (CT-RAMP) to model the activity travel patterns of all individuals in the region. The basic tenets of activity based model system is the representation of space and time – the CT-RAMP model developed for ARC uses a new 5000+ zone system and a temporal resolution of half-hour. Modeling at this fine spatial-temporal resolution greatly improves the accuracy of activity-travel patterns estimates. Thus, the ARC-ABM is designed to serve as a robust tool for evaluating conventional highway and transit projects as also to test a variety of policies including land use scenarios, highway pricing and HOV analysis.

This document describes the ARC-ABM model system calibration. ARC-ABM utilizes econometric models specifically tailored for the region. Most of the models are estimated while a few are asserted (for example, the mode choice models). Calibration of these models involves attuning certain alternative specific model parameters to ensure consistency with the observed data. The data for the model calibration is primarily drawn from the ARC Regional Travel Survey conducted in 2011. There were a total of 26,203 individual tours and 2,199 joint tours derived from the travel survey data from 10,278 households and 25,810 persons. This data was supplemented with data from the 2010 Census and 2011 Transit On-Board Survey.

The model calibration process was guided by a general philosophy with the following tenants:

1) ***Look for underlying causes of poor model fit and address via explanatory variables***. Poor model fit was explored via additional summaries and explicit utility calculation traces in an attempt to identify underlying problems in model specification or implementation. Sometimes this revealed software bugs that, once addressed, fixed the poor model fit. In a few cases, this process revealed an underlying problem with the model specification that needed to be addressed via additional estimation. For example, the stop duration model was re-estimated with a set of period-specific constants in order to better match the observed non-linear duration distributions.

2) ***Avoid alternative-specific constants tied to specific geographies***. In general, we avoid constants that are tied to specific geographic areas, and instead look for underlying causes that explain why certain geographic areas are over or under-estimated. For example, the old workplace location choice models had an alternative-specific constant for intra-Fulton County work flows. New workplace location choice models were developed this year with occupation-specific size terms, and the new models do not require the term. The only geography-specific constant in the model system is a CBD constant for transit, which reflects the increased non-auto accessibility of the CBD to all other destinations.

3) Evaluate magnitude of constants for reasonableness. Sometimes, very large magnitude constants are necessary because certain alternatives are observed very infrequently. For example, there are few households with two or more joint tours, and a large negative constant is needed to reflect this behavior even after accounting for previously scheduled mandatory activities and other household characteristics. However, some types of constants, such as those that represent the non-included attributes of premium transit, should be in a reasonable range considering the types of non-included attributes compared to the base alternative. In general, when it comes to evaluating the appropriate size of such constants, we believe that it is better to have a model with reasonable constants, even though the model may not match observed data, as well as a model with unreasonable constants, and to formulate a plan for potential future enhancements that may eventually improve the accuracy of the model.

4) ***Avoid alternative availability rules that result in elasticity 'cliff effects'***. Examples of such rules include cutting off the availability of transit if the trip distance is less than a certain threshold. Such rules are convenient ways to ensure that the model matches observed data, but can cause illogical results when using the model in forecasting. In such cases, we would prefer to use a continuous function in which disutility is high at short distances and low, or eventually zero, at long distances.

In general, the procedure for calibrating a choice model is as follows. First, the model output is aggregated along the dimensions we want to compare. For instance, in the context of auto ownership models, a few dimensions of interest would be the total number of households by number of vehicles owned and the number of households by number of workers and vehicles owned. The corresponding observed distributions are obtained from the ARC Regional Travel Survey. Based on the comparison between the observed and the predicted distributions adjustment factors are calculated. These adjustment factors are computed by taking the natural log of the observed shares divided by the predicted shares. Further, the adjustments are normalized by setting one alternative as a baseline and subtracting it's adjustment from all the alternatives. The adjustment factors so computed are believed to explain for the difference between observed and predicted shares (arising due to significant unobserved factors (to the analyst) at the time of model estimation). The new model alternative specific constants are derived by adding these adjustments to the existing constants and are applied to the Utility Expression Calculator (UECs). The steps described till now are repeated till the predicted and the observed distributions are satisfactory close. A dampening factor (typically set to 0.5) is applied to the constants to help eliminate oscillating patterns between iterations of the calibration routine.

A slightly different approach is used to calibrate the models where the response variable follows a continuous distribution. A good example of this is the tour length frequency distributions for destination choice models or out-of-direction distance distributions for the stop destination choice models. In such cases, the variable is grouped into bins (say, 0.5 mile distance bins) and an adjustment factor is computed for each bin as the natural log of observed divided by estimated. These adjustments are then regressed on the linear and the polynomial terms of the variable which are in the destination choice model (such as linear distance, distance-squared, distance-cubed and log of distance). The coefficients obtained on each of the terms in this regression would serve to explain the difference in the observed and the predicted distributions. Additionally, bin specific constants are applied to explain peaks and valleys in the distribution. As with the previous method, the coefficients from the regression are added to the existing coefficients before updating the UECs.

In the next sections, the details of calibration and results for each of the ARC-ABM model component is discussed.

Mandatory (workplace/university/school) Activity Location Choice

Work Location Results

The work destination choice model predicts the usual work location for all workers in the population. The model uses size terms to capture the "attractiveness" of the region as a usual work location. The model uses size terms developed for total employment by occupation as opposed to total employment by income from the earlier model. These size terms were developed from 2007-2011 ACS PUMS data. Each worker was coded according to their occupation category, consistent with PECAS occupations, and their NAICS industry category, consistent with the model input employment data. Then the size terms were calculated by cross-tabulating workers by occupation and industry and calculating row percentages, indicating the share of workers by occupation who work in each industry. The size terms are shown in Table 1.

Table 1: Work Location Choice Size Terms

Industry	Occupation				
	White Collar	Services	Health	Retail And Food	Blue Collar
Agr,Forest,Fish	0.3005	0.0908	0.0111	0.0171	0.5805
Mining,Oil	0.4115	0.0573	0.0000	0.0663	0.4649
Utilities	0.5500	0.0226	0.0027	0.0200	0.4047
Construction	0.2212	0.0100	0.0007	0.0125	0.7556
Manufacturing	0.4031	0.0232	0.0025	0.0676	0.5036
Wholesale	0.3682	0.0112	0.0011	0.3788	0.2407
Retail	0.2471	0.0264	0.0268	0.5602	0.1395
Transport,Warehouse	0.4008	0.0528	0.0014	0.0202	0.5249
Information	0.6219	0.1366	0.0005	0.1225	0.1184
Finance,Insur	0.7912	0.0125	0.0064	0.1830	0.0068
RealEstate	0.4207	0.0740	0.0004	0.3993	0.1055
Prof,Scien,Tech	0.8401	0.0721	0.0174	0.0436	0.0269
Management	0.8676	0.0493	0.0042	0.0347	0.0442
Admin,Support,WasteMa	0.3514	0.4302	0.0192	0.0549	0.1444
Educ	0.8199	0.0780	0.0219	0.0405	0.0397
HealthCare	0.3841	0.1146	0.4595	0.0216	0.0201
Arts,Enter,Rec	0.1738	0.6212	0.0121	0.1503	0.0426
Accom,FoodService	0.1786	0.0595	0.0003	0.7264	0.0352
OtherNonPubAdmin	0.3029	0.3837	0.0128	0.0607	0.2399
PublicAdmin	0.6251	0.2617	0.0273	0.0062	0.0796

After implementation of the revised size terms, the results from this model was compared against the ACS county to county worker flows data and the 2011 ARC Regional Travel Survey.[1] No calibration was necessary for this model, as comparisons indicated that the estimated model replicated observed worker flows very well in the base year.

[1] The ACS data was sourced from (Accessed on 2013-09-27): www.census.gov/population/metro/files/commuting/Table1.xlsx

Table 2 and **Table 3** shows the County to County worker flows data from the ACS data and the estimated data respectively. The ACS data has been scaled to match the origin county totals (row totals). **Table 4** shows the differences in percentages between these two sets of data. As can be seen from these differences, the estimated data does not deviate much from the observed data. This fact is further established by visualizing this data as a scatterplot – the fitted line (black line) closely follows the best fit 45 degree line (green line). The correlation coefficients for these two sets of data points is 0.996. Finally, the distance length frequency distribution for the model is compared with the observed in **Figure 1**. The observed data appears to have a high percentage of workers in 0 to 1 mile. On inspecting the survey data, around 8.89% of the people who were employed worked from home (please note the difference in the observed frequency distributions with and without the "work-from-home" segment). In these cases the survey summaries uses the home MTAZ as the work MTAZ and hence we observe the higher percentage of work locations in 0 to 1 miles. However, the ABM does not model work from home explicitly and hence treats every worker the same. The average distance to work location suggested by the survey is 11.98 miles while that of the model is 13.28 miles. The slightly higher average distance can be attributed to the issue with the work-from-home market segment. A work from home model is a potential avenue to explore in future model development.

Table 2: Scaled Observed ACS Worker Flows of Home County to Work County

Home County	Work County										
	Barrow	Bartow	Carroll	Cherokee	Clayton	Cobb	Coweta	DeKalb	Douglas	Fayette	Total
Barrow	11,523	-	-	8	28	223	-	675	11	-	25,501
Bartow	-	26,489	23	1,629	87	7,470	-	532	145	39	40,009
Carroll	-	178	29,324	79	484	2,785	1,089	731	4,404	192	44,641
Cherokee	66	1,339	69	43,579	350	23,411	44	3,267	296	37	100,698
Clayton	-	34	23	347	42,723	4,220	496	10,188	589	4,810	116,198
Cobb	40	2,497	704	6,685	3,791	202,984	212	17,276	4,879	561	350,897
Coweta	13	38	738	50	3,402	1,133	26,151	1,506	270	8,903	56,358
DeKalb	312	157	203	419	6,209	12,117	146	155,500	606	419	335,575
Douglas	-	157	2,490	59	1,777	9,378	217	2,843	21,573	275	58,785
Fayette	-	19	52	31	5,250	1,181	1,425	2,064	143	22,481	49,501
Forsyth	68	24	16	738	249	1,868	13	2,921	65	43	77,456
Fulton	149	494	285	1,365	9,981	24,538	1,562	39,850	1,789	2,268	437,077
Gwinnett	1,907	168	72	431	2,474	8,787	145	50,530	404	232	377,776
Hall	398	18	-	93	128	440	8	1,449	51	29	75,006
Henry	-	65	-	112	16,829	2,014	234	8,289	183	1,377	90,031
Newton	42	22	-	5	677	332	56	5,566	45	26	41,379
Paulding	-	1,253	1,137	841	733	24,044	113	1,708	4,807	71	63,827
Rockdale	107	-	29	31	784	594	-	7,461	174	121	36,633
Spalding	-	20	-	6	2,022	124	572	464	27	1,572	24,506
Walton	967	28	136	13	167	317	13	3,316	128	-	20,875
Total	15,592	33,000	35,300	56,523	98,146	327,958	32,494	316,137	40,588	43,455	2,422,730

Table 2: Scaled Observed ACS Worker Flows of Home County to Work County [continued.]

Home County	Work County										
	Forsyth	Fulton	Gwinnett	Hall	Henry	Newton	Paulding	Rockdale	Spalding	Walton	Total
Barrow	267	1,214	10,348	991	-	76	-	137	-	-	25,501
Bartow	177	2,499	294	38	14	-	516	58	-	-	40,009
Carroll	55	4,389	242	22	64	-	565	37	2	-	44,641
Cherokee	2,745	21,907	2,782	89	116	24	511	66	-	-	100,698
Clayton	167	42,095	2,475	163	6,141	101	162	924	521	19	116,198
Cobb	1,461	94,815	9,804	190	457	216	3,853	356	118	-	350,897
Coweta	99	12,919	553	34	355	28	-	45	108	14	56,358
DeKalb	1,233	123,082	28,434	486	1,951	1,105	72	2,894	216	13	335,575
Douglas	132	17,126	1,058	51	319	28	1,137	164	-	-	58,785
Fayette	34	14,723	436	-	1,012	9	-	92	550	-	49,501
Forsyth	38,494	23,249	7,904	1,604	84	-	11	71	25	9	77,456
Fulton	6,329	324,666	20,871	386	1,273	274	301	614	59	22	437,077
Gwinnett	5,759	69,408	227,362	6,138	641	1,039	88	2,061	132	-	377,776
Hall	2,665	3,237	10,258	56,035	49	3	18	127	-	-	75,006
Henry	77	20,133	1,768	-	35,476	613	22	1,246	1,595	-	90,031
Newton	33	4,573	1,984	66	1,303	17,476	107	8,951	115	-	41,379
Paulding	213	10,476	1,181	18	49	35	17,095	11	17	26	63,827
Rockdale	74	5,542	2,032	-	885	2,990	-	15,807	-	-	36,633
Spalding	-	2,193	144	20	2,918	14	51	38	14,322	-	24,506
Walton	62	1,584	9,897	318	232	1,773	-	1,912	14	-	20,875
Total	60,077	799,830	339,825	66,646	53,338	25,806	24,509	35,610	17,794	102	2,422,730

Table 3: Modeled Worker Flows of Home County to Work County

Home County	Work County										
	Barrow	Bartow	Carroll	Cherokee	Clayton	Cobb	Coweta	DeKalb	Douglas	Fayette	Total
Barrow	10,401	-	-	31	53	337	-	1,666	6	2	30,595
Bartow	-	24,590	97	2,763	86	11,078	2	764	360	5	45,492
Carroll	-	169	32,062	71	650	3,265	1,613	594	4,188	485	48,307
Cherokee	17	2,253	29	30,666	467	28,418	4	3,898	334	25	101,716
Clayton	3	7	44	45	44,581	3,703	442	10,758	431	3,858	110,365
Cobb	16	2,751	497	7,178	4,658	185,801	145	19,309	5,893	407	329,663
Coweta	-	7	1,971	16	4,784	2,034	25,761	1,898	1,305	8,282	59,826
DeKalb	111	52	26	199	13,924	12,165	115	128,672	585	414	320,775
Douglas	-	178	2,613	140	2,550	10,832	683	3,517	17,984	712	60,249
Fayette	1	2	207	14	8,160	2,086	2,559	2,560	647	19,168	51,583
Forsyth	173	107	-	2,139	85	3,282	1	3,373	32	4	82,441
Fulton	98	226	304	2,131	20,662	30,601	915	55,514	2,441	2,034	436,275
Gwinnett	3,184	36	7	703	3,310	9,075	20	48,220	291	122	360,721
Hall	787	5	-	234	50	485	-	1,597	5	3	77,614
Henry	34	3	9	22	17,602	2,359	295	11,309	247	2,428	94,012
Newton	185	-	-	8	2,285	642	11	5,421	49	204	43,853
Paulding	-	2,353	2,730	1,214	1,000	22,129	197	2,376	6,333	185	64,179
Rockdale	71	-	2	14	2,451	948	17	7,569	84	148	38,324
Spalding	1	-	16	2	2,872	332	497	813	52	1,762	28,691
Walton	1,669	2	-	19	481	371	-	3,709	19	20	38,049
Total	16,751	32,741	40,614	47,609	130,711	329,943	33,277	313,537	41,286	40,268	2,422,730

Table 3: Modeled Worker Flows of Home County to Work County [continued.]

Home County	Work County										
	Forsyth	Fulton	Gwinnett	Hall	Henry	Newton	Paulding	Rockdale	Spalding	Walton	Total
Barrow	768	1,788	10,640	2,871	44	241	1	325	-	1,421	30,595
Bartow	398	3,520	302	12	4	-	1,506	3	-	2	45,492
Carroll	5	3,977	101	-	30	1	1,065	12	19	-	48,307
Cherokee	5,407	24,623	4,377	570	17	-	587	11	-	13	101,716
Clayton	53	38,280	1,607	13	4,989	132	44	544	800	31	110,365
Cobb	2,016	88,789	7,268	139	256	20	4,349	135	19	17	329,663
Coweta	10	11,623	220	-	706	14	128	49	1,016	2	59,826
DeKalb	752	138,423	19,545	329	1,744	544	88	2,681	90	316	320,775
Douglas	63	18,675	694	6	170	4	1,326	71	27	4	60,249
Fayette	10	12,325	424	1	1,953	34	56	104	1,267	5	51,583
Forsyth	30,994	22,983	12,940	6,183	10	6	30	40	1	58	82,441
Fulton	8,800	285,378	24,615	952	734	66	317	295	108	84	436,275
Gwinnett	9,906	59,000	208,072	10,801	714	987	46	3,295	35	2,897	360,721
Hall	3,716	3,375	12,001	55,131	3	22	1	71	-	128	77,614
Henry	53	16,829	2,619	11	31,873	1,791	18	3,280	2,885	345	94,012
Newton	57	4,197	3,722	91	3,201	14,106	4	7,739	294	1,637	43,853
Paulding	207	11,414	753	4	41	-	13,209	29	4	1	64,179
Rockdale	69	6,477	3,647	68	1,789	1,928	11	12,399	132	500	38,324
Spalding	1	2,336	129	1	3,806	106	-	221	15,729	15	28,691
Walton	449	2,486	10,770	639	431	2,342	1	2,363	19	12,259	38,049
Total	63,734	756,498	324,446	77,822	52,515	22,344	22,787	33,667	22,445	19,735	2,422,730

Table 4: Differences in percentage between Modeled Worker Flows and ACS Worker Flows

Home County	Work County									
	Barrow	Bartow	Carroll	Cherokee	Clayton	Cobb	Coweta	Dekalb	Douglas	Fayette
Barrow	-11.19%	0.00%	0.00%	0.07%	0.06%	0.23%	0.00%	2.80%	-0.03%	0.01%
Bartow	0.00%	-12.15%	0.16%	2.00%	-0.03%	5.68%	0.00%	0.35%	0.43%	-0.09%
Carroll	0.00%	-0.05%	0.68%	-0.03%	0.26%	0.52%	0.90%	-0.41%	-1.20%	0.57%
Cherokee	-0.05%	0.89%	-0.04%	-13.13%	0.11%	4.69%	-0.04%	0.59%	0.03%	-0.01%
Clayton	0.00%	-0.02%	0.02%	-0.26%	3.63%	-0.28%	-0.03%	0.98%	-0.12%	-0.64%
Cobb	-0.01%	0.12%	-0.05%	0.27%	0.33%	-1.49%	-0.02%	0.93%	0.40%	-0.04%
Coweta	-0.02%	-0.05%	1.98%	-0.06%	1.96%	1.39%	-3.34%	0.50%	1.70%	-1.95%
DeKalb	-0.06%	-0.03%	-0.05%	-0.06%	2.49%	0.18%	-0.01%	-6.23%	0.00%	0.00%
Douglas	0.00%	0.03%	0.10%	0.13%	1.21%	2.03%	0.76%	1.00%	-6.85%	0.71%
Fayette	0.00%	-0.03%	0.30%	-0.04%	5.21%	1.66%	2.08%	0.79%	0.97%	-8.26%
Forsyth	0.12%	0.10%	-0.02%	1.64%	-0.22%	1.57%	-0.01%	0.32%	-0.04%	-0.05%
Fulton	-0.01%	-0.06%	0.00%	0.18%	2.45%	1.40%	-0.15%	3.61%	0.15%	-0.05%
Gwinnett	0.38%	-0.03%	-0.02%	0.08%	0.26%	0.19%	-0.03%	-0.01%	-0.03%	-0.03%
Hall	0.48%	-0.02%	0.00%	0.18%	-0.11%	0.04%	-0.01%	0.13%	-0.06%	-0.04%
Henry	0.04%	-0.07%	0.01%	-0.10%	0.03%	0.27%	0.05%	2.82%	0.06%	1.05%
Newton	0.32%	-0.05%	0.00%	0.01%	3.57%	0.66%	-0.11%	-1.09%	0.00%	0.40%
Paulding	0.00%	1.70%	2.47%	0.57%	0.41%	-3.19%	0.13%	1.03%	2.34%	0.18%
Rockdale	-0.11%	0.00%	-0.07%	-0.05%	4.25%	0.85%	0.04%	-0.62%	-0.26%	0.06%
Spalding	0.00%	-0.08%	0.06%	-0.02%	1.76%	0.65%	-0.60%	0.94%	0.07%	-0.27%
Walton	-0.24%	-0.13%	-0.65%	-0.01%	0.46%	-0.54%	-0.06%	-6.14%	-0.56%	0.05%
Total	0.05%	-0.01%	0.22%	-0.37%	1.34%	0.08%	0.03%	-0.11%	0.03%	-0.13%

Table 4: Differences in percentage between Modeled Worker Flows and ACS Worker Flows [continued.]

Home County	Work County									
	Forsyth	Fulton	Gwinnett	Hall	Henry	Newton	Paulding	Rockdale	Spalding	Walton
Barrow	1.46%	1.08%	-5.80%	5.50%	0.14%	0.49%	0.00%	0.53%	0.00%	4.64%
Bartow	0.43%	1.49%	-0.07%	-0.07%	-0.03%	0.00%	2.02%	-0.14%	0.00%	0.00%
Carroll	-0.11%	-1.60%	-0.33%	-0.05%	-0.08%	0.00%	0.94%	-0.06%	0.03%	0.00%
Cherokee	2.59%	2.45%	1.54%	0.47%	-0.10%	-0.02%	0.07%	-0.05%	0.00%	0.01%
Clayton	-0.10%	-1.54%	-0.67%	-0.13%	-0.76%	0.03%	-0.10%	-0.30%	0.28%	0.01%
Cobb	0.20%	-0.09%	-0.59%	-0.01%	-0.05%	-0.06%	0.22%	-0.06%	-0.03%	0.01%
Coweta	-0.16%	-3.49%	-0.61%	-0.06%	0.55%	-0.03%	0.21%	0.00%	1.51%	-0.02%
DeKalb	-0.13%	6.47%	-2.38%	-0.04%	-0.04%	-0.16%	0.01%	-0.03%	-0.04%	0.09%
Douglas	-0.12%	1.86%	-0.65%	-0.08%	-0.26%	-0.04%	0.27%	-0.16%	0.04%	0.01%
Fayette	-0.05%	-5.85%	-0.06%	0.00%	1.74%	0.05%	0.11%	0.02%	1.35%	0.01%
Forsyth	-12.10%	-2.14%	5.49%	5.43%	-0.10%	0.01%	0.02%	-0.04%	-0.03%	0.06%
Fulton	0.57%	-8.87%	0.87%	0.13%	-0.12%	-0.05%	0.00%	-0.07%	0.01%	0.01%
Gwinnett	1.22%	-2.02%	-2.50%	1.37%	0.03%	0.00%	-0.01%	0.37%	-0.03%	0.80%
Hall	1.24%	0.03%	1.79%	-3.67%	-0.06%	0.02%	-0.02%	-0.08%	0.00%	0.16%
Henry	-0.03%	-4.46%	0.82%	0.01%	-5.50%	1.22%	-0.01%	2.10%	1.30%	0.37%
Newton	0.05%	-1.48%	3.69%	0.05%	4.15%	-10.07%	-0.25%	-3.99%	0.39%	3.73%
Paulding	-0.01%	1.37%	-0.68%	-0.02%	-0.01%	-0.06%	-6.20%	0.03%	-0.02%	-0.04%
Rockdale	-0.02%	1.77%	3.97%	0.18%	2.25%	-3.13%	0.03%	-10.80%	0.34%	1.30%
Spalding	0.00%	-0.81%	-0.14%	-0.08%	1.36%	0.31%	-0.21%	0.62%	-3.62%	0.05%
Walton	0.89%	-1.06%	-19.11%	0.16%	0.02%	-2.34%	0.00%	-2.95%	-0.02%	32.22%
Total	0.15%	-1.79%	-0.63%	0.46%	-0.03%	-0.14%	-0.07%	-0.08%	0.19%	0.81%

Figure 1: Scatter Plot of Worker flows for Home County to Worker County between Estimated and Scaled ACS Data (0.995 Correlation Coefficient)

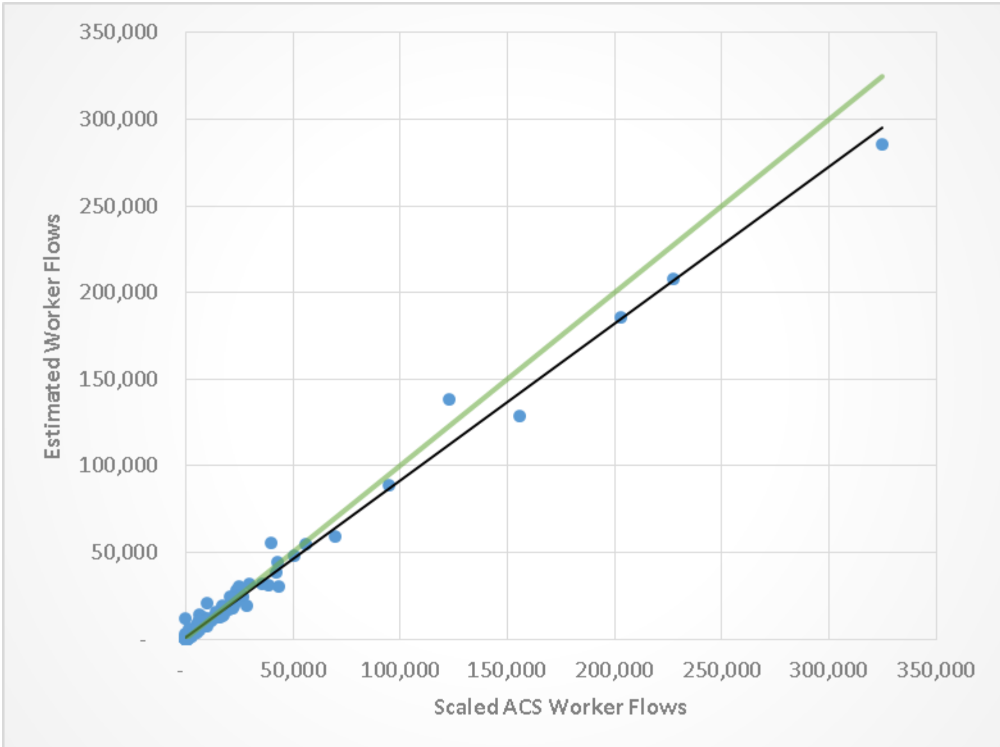
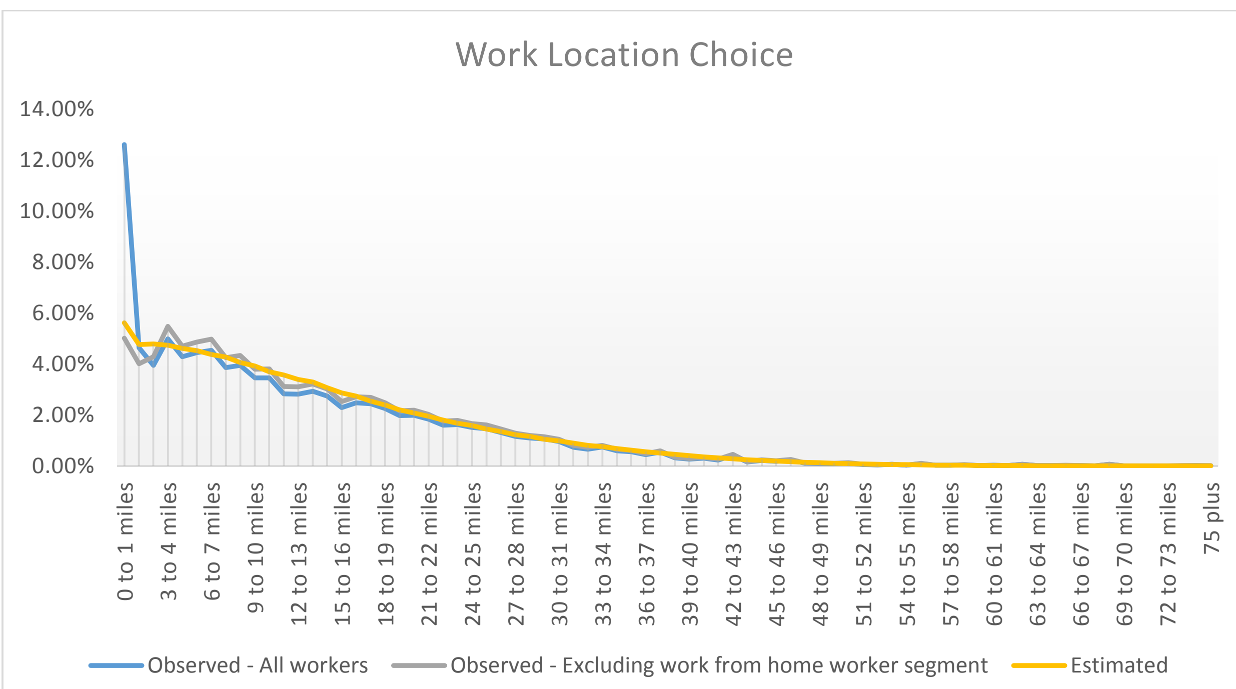


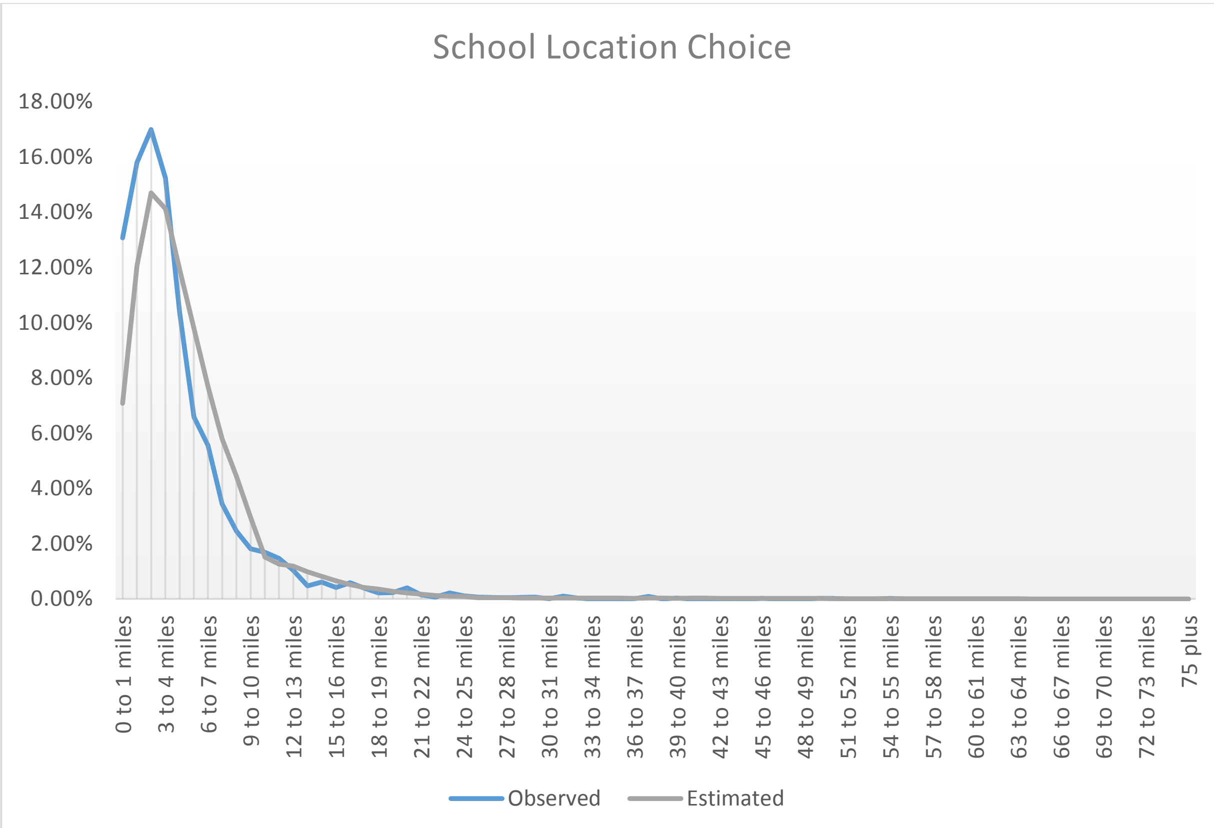
Figure 2: Distance Length Frequency Distribution for Work Location Choice



School Location Results

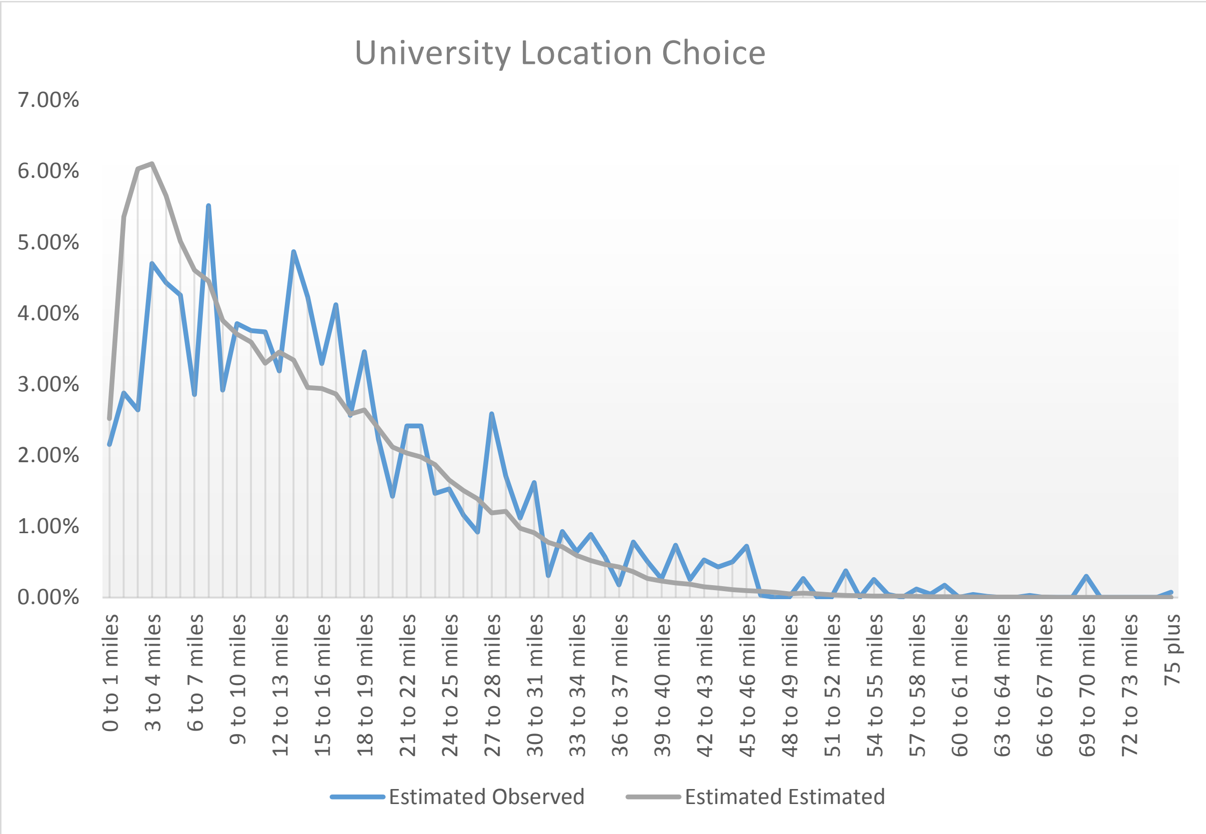
The school destination choice model predicts the usual school location for all student types. The school location models were not calibrated as the estimated distance length frequency distributions matched the observed distributions closely. The average distance to school location compares as 4.42 miles (survey) to 5.25 miles (model).

Figure 3: Distance Length Frequency Distribution for School Location Choice



The University location choice results are shown in **Figure 4**. The average distance to University was calculated to be 12.70 miles from the model. The survey places the value at 15.45 miles. Though this difference is substantial, it was decided not to calibrate this model using the survey data because the reliability of the survey for the University market segment is questionable owing to the small sample size. This becomes evident from **Figure 4** – see how the distance length frequency data has many spikes and does not follow any discernable pattern.

Figure 4: Distance Length Frequency Distribution for University Location Choice



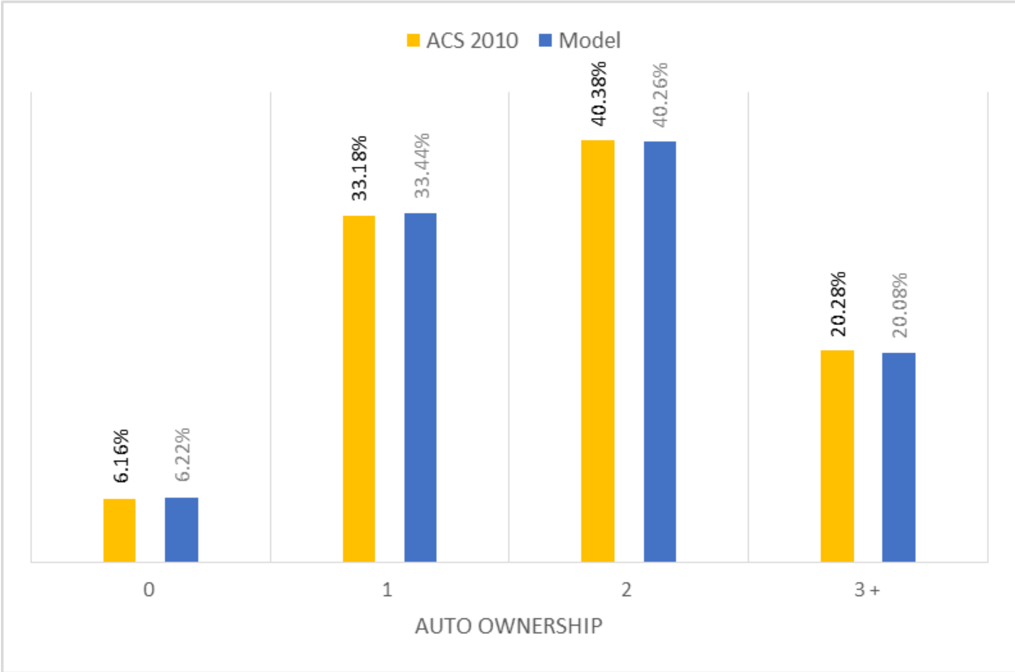
Auto-Ownership Model

The auto-ownership model predicts the total number of vehicles available in a household. 2010 Census data was used as a benchmark. The auto-ownership model required several rounds of calibration because of a change in the accessibility calculations. **Table 5** shows the results of the calibrated auto-ownership model.

Table 5: Auto Ownership Calibration Results

Auto Ownership	Census	Model	Final Adjustments
0 auto households	6.16%	6.22%	-0.6759
1 auto households	33.18%	33.44%	0.0023
2 auto households	40.38%	40.26%	BASE
3+ auto households	20.28%	20.08%	1.0149
Total	**100%**	**100%**	

Figure 5: Auto Ownership Results



Also, the distributions of number of households by number of workers and vehicles owned were developed and calibration was done in order to ensure that the right number of zero auto households by number of workers were being generated. This is important as this market segment would tend to use transit more and hence would naturally impact the total transit tours being generated. These adjustments were made simultaneously with calibration of the overall distribution. **Table 6a** and **b** compares the observed and the estimated percentage shares respectively. The final calibration adjustments are reported in **Table 6c**.

Table 6a: Auto-ownership by number of workers in HH Census 2010

#Workers	Number of Vehicles Owned				Total
	0	1	2	3	
0	50.62%	26.04%	12.85%	8.13%	18.64%
1	37.37%	62.78%	37.36%	26.82%	43.81%
2	9.35%	9.91%	47.01%	44.24%	31.67%
3+	2.66%	1.27%	2.78%	20.81%	5.88%
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table 6b. Auto-ownership by number of workers in Model

#Workers	Number of Vehicles Owned				Total
	0	1	2	3	
0	48.89%	29.38%	11.70%	7.78%	19.14%
1	38.40%	60.41%	39.98%	26.75%	44.06%
2	9.61%	7.79%	47.29%	42.09%	30.70%
3+	3.10%	2.42%	1.02%	23.38%	6.11%
Total	**100.00%**	**100.00%**	**100.00%**	**100.00%**	**100.00%**

Table 6c. Final calibration adjustments for Auto-ownership by number of workers in HH

#Workers	Number of Vehicles Owned			
	0	1	2	3
0	BASE	BASE	BASE	BASE
1	0.7323	-	-	-0.4407
2	1.2553	-	-	-0.8753
3+	1.4845	-	-	-2.6306

Finally, the model results were compared to the observed data at a county level to establish the correctness of the spatial distribution. **Table 7a** and **b** shows the observed and the estimated shares of auto-ownership level for each of the 20 county. We can conclude from the differences in shares (see **Table 7c**) that the model is performing reasonably well at a county level.

Table 7a: Observed Auto ownership shares at a county level

	Number of vehicles owned			
County	0	1	2	3
Barrow County, Georgia	4.13%	25.83%	41.28%	28.77%
Bartow County, Georgia	4.03%	30.17%	41.43%	24.37%
Carroll County, Georgia	5.50%	29.90%	37.50%	27.10%
Cherokee County, Georgia	2.42%	24.85%	48.00%	24.73%
Clayton County, Georgia	7.52%	41.03%	34.52%	16.92%
Cobb County, Georgia	3.74%	33.27%	42.76%	20.24%
Coweta County, Georgia	3.64%	25.08%	43.71%	27.57%
DeKalb County, Georgia	9.39%	41.03%	35.78%	13.80%
Douglas County, Georgia	3.15%	29.40%	40.74%	26.70%
Fayette County, Georgia	2.34%	22.34%	42.97%	32.35%
Forsyth County, Georgia	2.21%	19.95%	53.99%	23.85%
Fulton County, Georgia	12.19%	39.96%	34.88%	12.98%
Gwinnett County, Georgia	2.80%	29.72%	45.05%	22.43%
Hall County, Georgia	5.49%	27.83%	39.96%	26.72%
Henry County, Georgia	2.24%	27.75%	43.75%	26.25%
Newton County, Georgia	3.19%	30.13%	42.32%	24.36%

Paulding County, Georgia	1.85%	23.60%	45.58%	28.98%
Rockdale County, Georgia	5.62%	29.76%	39.40%	25.22%
Spalding County, Georgia	8.59%	33.35%	34.82%	23.25%
Walton County, Georgia	4.95%	22.83%	40.33%	31.89%

Table 7b: Estimated Auto ownership shares at a county level

	Number of vehicles owned			
County	0	1	2	3
Barrow County, Georgia	3.49%	31.50%	42.33%	22.67%
Bartow County, Georgia	4.87%	33.65%	41.76%	19.73%
Carroll County, Georgia	5.31%	33.59%	41.32%	19.77%
Cherokee County, Georgia	2.85%	26.98%	47.48%	22.69%
Clayton County, Georgia	5.71%	38.40%	35.50%	20.39%
Cobb County, Georgia	4.31%	32.44%	42.43%	20.82%
Coweta County, Georgia	3.81%	30.21%	42.22%	23.77%
DeKalb County, Georgia	9.11%	38.58%	36.55%	15.76%
Douglas County, Georgia	5.19%	31.12%	41.20%	22.49%
Fayette County, Georgia	2.09%	24.62%	45.90%	27.38%
Forsyth County, Georgia	2.93%	24.45%	50.41%	22.20%
Fulton County, Georgia	11.70%	38.98%	35.38%	13.94%
Gwinnett County, Georgia	3.73%	29.16%	41.81%	25.30%
Hall County, Georgia	3.91%	30.11%	43.00%	22.99%
Henry County, Georgia	3.14%	29.99%	42.53%	24.35%
Newton County, Georgia	3.61%	31.92%	40.49%	23.98%
Paulding County, Georgia	3.33%	28.57%	44.62%	23.48%
Rockdale County, Georgia	4.60%	31.18%	40.31%	23.91%
Spalding County, Georgia	5.62%	34.81%	40.34%	19.24%
Walton County, Georgia	4.12%	29.72%	43.58%	22.58%

Table 7c: Difference in auto-ownership shares: Estimated v. observed at a county level

County	Number of vehicles owned			
	0	1	2	3
Barrow County, Georgia	-0.63%	5.67%	1.05%	-6.09%
Bartow County, Georgia	0.84%	3.48%	0.33%	-4.64%
Carroll County, Georgia	-0.19%	3.69%	3.82%	-7.32%
Cherokee County, Georgia	0.43%	2.13%	-0.52%	-2.04%
Clayton County, Georgia	-1.81%	-2.63%	0.98%	3.47%
Cobb County, Georgia	0.57%	-0.83%	-0.32%	0.58%
Coweta County, Georgia	0.16%	5.12%	-1.49%	-3.80%
DeKalb County, Georgia	-0.28%	-2.45%	0.77%	1.96%
Douglas County, Georgia	2.04%	1.72%	0.45%	-4.21%
Fayette County, Georgia	-0.25%	2.28%	2.93%	-4.96%
Forsyth County, Georgia	0.72%	4.50%	-3.58%	-1.64%
Fulton County, Georgia	-0.49%	-0.99%	0.51%	0.97%
Gwinnett County, Georgia	0.93%	-0.56%	-3.24%	2.87%
Hall County, Georgia	-1.59%	2.28%	3.04%	-3.73%
Henry County, Georgia	0.90%	2.23%	-1.23%	-1.90%
Newton County, Georgia	0.42%	1.80%	-1.83%	-0.38%
Paulding County, Georgia	1.48%	4.97%	-0.96%	-5.50%
Rockdale County, Georgia	-1.01%	1.42%	0.91%	-1.31%
Spalding County, Georgia	-2.97%	1.46%	5.52%	-4.01%
Walton County, Georgia	-0.83%	6.89%	3.25%	-9.31%

CDAP Model

DAP Model Results

The Daily Activity Pattern model determines the daily activity pattern type of each household member. The model assigns one of the three daily activity pattern to each household member – mandatory (M), non-mandatory (N) and home (H). The models were calibrated with the at home pattern as the base category. The results of the DAP model is presented below in **Table 8a** through **c**. **Table 8a** and **Table 8b** presents the observed and the estimated shares of DAP by person type. **Table 8c** shows the final adjustments used to arrive at the results.

Table 8a. DAP Observed Shares by person type

Person type	M	N	H	Total
Full-time worker	74%	13%	13%	100%
Part-time worker	53%	33%	14%	100%
University student	59%	22%	19%	100%
Non-worker	0%	62%	38%	100%
Retired	0%	52%	48%	100%
Student of driving age	82%	8%	10%	100%
Student of non-driving age	84%	9%	7%	100%
Child too young for school	39%	37%	24%	100%
Total	**55%**	**26%**	**19%**	**100%**

Table 8b. DAP Estimated Shares by person type

PersonType	M	N	H	Total
Full-time worker	74%	13%	13%	100%
Part-time worker	53%	33%	15%	100%
University student	59%	23%	19%	100%
Non-worker	0%	62%	38%	100%
Retired	0%	52%	48%	100%
Student of driving age	82%	8%	10%	100%
Student of non-driving age	84%	8%	8%	100%
Child too young for school	39%	36%	25%	100%
Total	**54%**	**26%**	**20%**	**100%**

Table 8c. CDAP Final Adjustment Factors by person type

PersonType	M	N	H
Full-time worker	0.0664	-0.1033	BASE
Part-time worker	0.2117	-0.3692	BASE
University student	-0.4168	0.2869	BASE
Non-worker	N/A	-0.3844	BASE
Retired	N/A	0.1265	BASE
Student of driving age	0.5345	1.0327	BASE
Student of non-driving age	0.8836	0.7575	BASE
Child too young for school	2.1927	3.1352	BASE

Tour Frequency Models

The tour frequency class of models is used to determine the number of tours for each of the activity purposes for which tour making is predicted using the DAP model. This model is segmented by person type and separate models are estimated for mandatory tours, individual non-mandatory tours and joint non-mandatory tours. The next three sections describe the calibration results for the three models.

Individual Mandatory Tour Frequency

The mandatory tour frequency model is applied to those persons in the population who has been assigned a mandatory daily activity pattern. This model will generate, at a minimum, one mandatory tour for the person with the different alternatives being – one work tour, one school tour, two work tours, two school tours, one work tour plus one school tour. The alternative specific constants for this model is segmented along person types. The model results was found to match the survey results closely and hence no calibration adjustments were incorporated into the model.

Table 9a shows the 2011 ARC Regional Travel Survey mandatory tour frequencies by person type while **Table 9b** shows the same for the estimated model. A comparison was done by calculating the differences in probability (see **Table 9c**) from these two data sets and it was found to be satisfactorily close. However, it should be noted here that there is mismatch for the University student person type – an additional 27% of students undertake "one school tour" while the survey suggests that they should be assigned "one work tour" pattern. As described earlier, this market segment was left un-calibrated given the small sample size in the survey and the likelihood that the survey over-represents older, part-time university students who have higher workforce participation rates than full-time, younger students.

Table 9a: Survey Mandatory Tour Frequency by Person Type

Person type	Pattern				
	1 Work Tour	2 Work Tours	1 School Tour	2 School Tours	Work and School Tours
Full-time worker	96%	4%	0%	0%	0%
Part-time worker	94%	5%	0%	0%	0%
University student	51%	1%	40%	1%	6%
Non-working adult	N/A	N/A	N/A	N/A	N/A
Non-working senior	N/A	N/A	N/A	N/A	N/A
Driving age student	2%	0%	92%	3%	2%
Pre-driving student	0%	0%	99%	1%	0%
Pre-school	0%	0%	99%	1%	0%

Table 9b: Model Mandatory Tour Frequency by Person Type

Person type	Pattern				
	1 Work Tour	2 Work Tours	1 School Tour	2 School Tours	Work and School Tours
Full-time worker	96%	4%	0%	0%	0%
Part-time worker	95%	5%	0%	0%	0%
University student	26%	1%	65%	4%	3%
Non-working adult	N/A	N/A	N/A	N/A	N/A
Non-working senior	N/A	N/A	N/A	N/A	N/A
Driving age student	0%	0%	96%	2%	2%
Pre-driving student	0%	0%	99%	1%	0%
Pre-school	0%	0%	100%	0%	0%

Table 9c: Difference in Probability of Mandatory Tour Frequencies for Estimated vs. Observed by Person Type

Person type	Pattern				
	1 Work Tour	2 Work Tours	1 School Tour	2 School Tours	Work and School Tours
Full-time worker	0%	0%	0%	0%	0%
Part-time worker	1%	0%	0%	0%	0%
University student	-25%	0%	25%	3%	-4%
Non-working adult	N/A	N/A	N/A	N/A	N/A
Non-working senior	N/A	N/A	N/A	N/A	N/A
Driving age student	-2%	0%	4%	-1%	0%
Pre-driving student	0%	0%	0%	0%	0%
Pre-school	0%	0%	1%	-1%	0%

Individual Non-Mandatory Tour Frequency

The individual non-mandatory tour frequency model predicts the number of non-mandatory tours by tour purpose for each household member who has been assigned a mandatory or a non-mandatory daily activity pattern. As with the mandatory tour frequency mode, this model is also segmented by person type. It is a two-stage model. First, by tour purpose, it predicts the total number of tours undertaken by the person on a restricted alternative set. The alternatives are 0, 1 and 2 plus for escorting tours and 0 and 1+ for shopping, maintenance, eating out, visiting and other discretionary tours. Second, the model uses observed probability distributions to assign 0, 1 or 2 tours conditional on the tour purpose, person type, whether or not the person has a mandatory tour and whether or not the person has a joint tour in her/his activity pattern. This approach reduces the large number of potential alternatives significantly.

For model calibration, the model that predicts the choice among the restricted set of alternatives was calibrated. It was found that once this was reasonably close to the observed, the observed probability distributions ensured the correct match with the overall number. The base alternative for the calibrating the non-mandatory tour frequency model is the 0 frequency alternative for each tour purpose.

Table 10a: Survey Non-Mandatory Tour Frequency by Person Type

Person Type	Tour Purpose Frequency												
	Escorting			Shopping		Maintenance		Eating Out		Visiting		Discretionary	
	0	1	2+	0	1	0	1	0	1+	0	1+	0	1
Full-time worker	93%	5%	2%	94%	6%	95%	5%	98%	2%	99%	1%	94%	6%
Part-time worker	86%	9%	5%	87%	13%	91%	9%	98%	2%	96%	4%	89%	11%
University student	92%	6%	2%	91%	9%	93%	7%	98%	2%	97%	3%	95%	5%
Non-working adult	86%	7%	7%	83%	17%	84%	16%	98%	2%	96%	4%	93%	7%
Non-working senior	95%	4%	2%	84%	16%	89%	11%	98%	2%	97%	3%	92%	8%
Driving age student	97%	3%	0%	99%	1%	97%	3%	99%	1%	96%	4%	95%	5%
Pre-driving student	96%	3%	1%	99%	1%	99%	1%	99%	1%	99%	1%	94%	6%
Pre-school	88%	9%	3%	98%	2%	98%	2%	99%	1%	98%	2%	96%	4%

Table 10b: Model Non-Mandatory Tour Frequency by Person Type

Person Type	Tour Purpose Frequency												
	Escorting			Shopping		Maintenance		Eating Out		Visiting		Discretionary	
	0	1	2+	0	1	0	1	0	1+	0	1+	0	1
Full-time worker	93%	5%	2%	94%	6%	95%	5%	98%	2%	98%	2%	94%	6%
Part-time worker	85%	9%	6%	87%	13%	91%	9%	98%	2%	96%	4%	88%	12%
University student	85%	10%	5%	95%	5%	92%	8%	97%	3%	95%	5%	93%	7%
Non-working adult	83%	8%	9%	82%	18%	83%	17%	98%	2%	95%	5%	92%	8%
Non-working senior	94%	4%	2%	82%	18%	88%	12%	98%	2%	96%	4%	91%	9%
Driving age student	96%	4%	1%	98%	2%	97%	3%	99%	1%	95%	5%	93%	7%
Pre-driving student	95%	4%	1%	99%	1%	98%	2%	99%	1%	98%	2%	92%	8%
Pre-school	87%	6%	7%	98%	2%	98%	2%	99%	1%	98%	2%	96%	4%

Table 10c: Difference in Probability of Non-Mandatory Tour Frequencies for Estimated vs. Observed by Person Type

Person Type	Tour Purpose Frequency													
	Escorting			Shopping		Maintenance		Eating Out		Visiting		Discretionary	
	0	1	2+	0	1	0	1	0	1+	0	1+	0	1
Full-time worker	-0.20%	0.06%	0.13%	0.08%	-0.08%	-0.07%	0.07%	-0.03%	0.03%	-0.03%	0.03%	0.08%	-0.08%
Part-time worker	-0.99%	0.20%	0.79%	-0.19%	0.19%	-0.14%	0.14%	0.00%	0.00%	0.00%	0.00%	-0.40%	0.40%
University student	-6.93%	4.46%	2.47%	3.74%	-3.74%	-0.62%	0.62%	-0.92%	0.92%	-2.45%	2.45%	-2.31%	2.31%
Non-working adult	-2.91%	0.76%	2.15%	-1.40%	1.40%	-0.84%	0.84%	-0.21%	0.21%	-0.53%	0.53%	-0.64%	0.64%
Non-working senior	-0.68%	0.13%	0.55%	-1.55%	1.55%	-0.60%	0.60%	-0.07%	0.07%	-0.40%	0.40%	-0.97%	0.97%
Driving age student	-1.21%	0.80%	0.40%	-0.43%	0.43%	-0.68%	0.68%	-0.14%	0.14%	-1.20%	1.20%	-1.95%	1.95%
Pre-driving student	-0.96%	1.08%	-0.12%	-0.24%	0.24%	-0.33%	0.33%	-0.14%	0.14%	-0.40%	0.40%	-2.02%	2.02%
Pre-school	-0.67%	-3.29%	3.96%	-0.08%	0.08%	-0.12%	0.12%	-0.02%	0.02%	0.06%	-0.06%	-0.24%	0.24%

Table 10d: Non-Mandatory Tour Frequency Adjustment Factors by Person Type

Person Type	Tour Purpose Frequency													
	Escorting			Shopping		Maintenance		Eating Out		Visiting		Discretionary	
	0	1	2+	0	1	0	1	0	1+	0	1+	0	1
Full-time worker	BASE	-0.682	0.024	BASE	-0.710	BASE	-0.557	BASE	-1.934	BASE	-1.053	BASE	-0.488
Part-time worker	BASE	-1.049	-0.908	BASE	-0.932	BASE	-0.864	BASE	-1.707	BASE	-0.884	BASE	-0.561
University student	BASE	2.422	3.817	BASE	0.738	BASE	1.196	BASE	1.283	BASE	1.436	BASE	0.913
Non-working adult	BASE	-1.170	-0.475	BASE	-0.646	BASE	-0.543	BASE	-1.837	BASE	-0.736	BASE	-1.090
Non-working senior	BASE	-0.817	0.903	BASE	-0.344	BASE	-0.643	BASE	-1.928	BASE	-0.609	BASE	-0.747
Driving age student	BASE	-1.478	-0.081	BASE	-2.487	BASE	-1.964	BASE	-2.512	BASE	-1.323	BASE	-2.134
Pre-driving student	BASE	-1.687	0.678	BASE	-2.163	BASE	-2.036	BASE	-2.199	BASE	-1.943	BASE	-1.178
Pre-school	BASE	2.700	7.422	BASE	2.498	BASE	2.386	BASE	1.050	BASE	2.479	BASE	2.747

In addition to calibrating by number of tours by purpose, it was also ensured that the totals number of tours by person type matched the observed distributions. This was done by constraining the 0 tours undertaken as the base category and specifying alternative specific constants on total tours equal to 1, 2 and 3 plus. The calibration of this dimension was performed simultaneously when calibrating the tour frequencies by tour purpose. The results of this calibration is presented below in **Table 11a** and the final adjustment factors are presented in **Table 11b**:

Table 11a: Non-Mandatory Tour Frequency Adjustment Factors by Person Type

Person Type	Observed				Estimated				Difference			
	0	1	2	3+	0	1	2	3+	0	1	2	3+
Full-time Worker	75%	20%	4%	1%	75%	20%	4%	1%	0%	0%	0%	0%
Part-time Worker	54%	26%	13%	7%	56%	27%	11%	5%	2%	1%	-1%	-1%
University Student	49%	20%	6%	25%	73%	12%	8%	6%	24%	-8%	3%	-19%
Non-worker	43%	34%	15%	8%	46%	35%	13%	6%	3%	1%	-2%	-2%
Retired	57%	33%	8%	3%	57%	33%	8%	3%	0%	0%	0%	0%
Driving School Child	74%	22%	4%	0%	79%	18%	3%	0%	4%	-3%	-1%	0%
Pre-driving School Child	79%	19%	2%	0%	82%	16%	2%	0%	2%	-3%	1%	0%
Pre-school Child	91%	7%	1%	0%	80%	12%	4%	4%	-11%	4%	3%	4%

As with the previous models, the coefficients for the University student person type were not adjusted. It can also be noted from the table that the final adjustments made for the pre-school child person type is higher in magnitude while at the same time we are unable to match the shares as closely as with the other person types. This could be explained by the fact that pre-school children are a small market segment and their activities are usually dictated by the activities of adults in the household (people do not tend to leave pre-schoolers unsupervised and they tag along with the adult on tours).

Table 11b: Non-Mandatory Tour Frequency Adjustment Factors by Person Type

Person Type	Observed			
	0	1	2	3+
Full-time Worker	BASE	-0.1307	-0.0766	0.2375
Part-time Worker	BASE	-0.3068	0.2375	0.8714
University Student	BASE	0.0000	0.0000	0.0000
Non-worker	BASE	-0.0220	0.5456	1.0481
Retired	BASE	-0.1050	-0.0947	0.0388
Driving School Child	BASE	0.5749	1.1322	-0.3620
Pre-driving School Child	BASE	0.4455	-0.6617	-0.1411
Pre-school Child	BASE	-3.3545	-5.1504	-4.7750

Joint Tour Frequency

The joint tour frequency models are applied to determine the total number of joint tours undertaken by the household. The model uses tour frequency (0, 1, 2+) and purpose combinations as the alternatives. Additionally, the characteristics of the joint tour is also determined by sequentially applying a tour composition model and then a participation model that satisfies the composition for each of the joint tour generated by the household. The model calibration was done to ensure that the observed distributions form the survey were being matched satisfactorily for all three model components identified just now.

The models were calibrated along the following dimensions:

1. Joint tour frequency: along the 21 main model alternatives. The alternative – "No Joint Tour" – was used as the base alternative. The results are presented in **Table 12a**.
2. Joint tour frequency by household size: The two person household was held as the base alternative. The adjustments to the overall model was performed in conjunction with this calibration. See **Table 12b** for the results.
3. Joint tour composition: the alternatives for this model are Adult only, Children only and Mixed. It should be remembered that the Mixed alternative is available to households with at least one child. Accordingly, the targets are confined to include only that set of households that has at least one child. The Adults only alternative was held as the base category and the model was calibrated to match the observed shares. **Table 12c** presents the results for this exercise.
4. Joint tour composition by party size: The final component of the joint tour calibration involves getting the right share in terms of tour composition and tour party size. The person participation model – a binary logit model – that determines if a person in the household participates in that joint tour is used to control for the party size. Keeping the "not participating" category as the base, tour composition specific constants were applied to get the party size correct.

   Please note here that the response variable of interest is tour party size while the participation model itself is a person level model determining if a person participates in the tour or not. Thus the response variable is a function of the sum of the outcomes applied to each person in the household. There is no mathematical approach that can inform us of the magnitude of constants to apply to the primary model based on the observed and the predicted distribution of a secondary variable. The constants applied here are based on intuition. For example, if it was observed that the tour party size was higher than what the survey suggested, a negative constant is added to the person level model in the hope that it would uniformly dis-incentivize anyone who would otherwise choose to participate in a joint tour thus, on average, reducing the party size. **Table 12d** shows the global adjustment factors applied and **Table 12e** shows the results.

Table 12a: Joint Tour Frequency Model Results

	Observed	Estimated	Difference	Adjustments
No Joint Tours	76.47%	76.97%	0.50%	BASE
1 Shopping	5.84%	5.78%	-0.07%	-0.0300
1 Maintenance	4.13%	4.17%	0.05%	-0.0803
1 Eating Out	2.74%	2.70%	-0.04%	-0.0847
1 Visiting	1.17%	1.17%	0.00%	-1.7195
1 Other Discretionary	5.88%	5.66%	-0.22%	-0.6512
2 Shopping	0.53%	0.50%	-0.02%	-0.4291
1 Shopping / 1 Maintenance	0.36%	0.36%	0.00%	0.2448
1 Shopping / 1 Eating Out	0.26%	0.25%	-0.01%	-0.6854
1 Shopping / 1 Visiting	0.20%	0.18%	-0.02%	-1.6315
1 Shopping / 1 Other Discretionary	0.47%	0.44%	-0.03%	-0.8070
2 Maintenance	0.40%	0.37%	-0.03%	-0.1974
1 Maintenance / 1 Eating Out	0.15%	0.14%	-0.01%	-0.4966
1 Maintenance / 1 Visiting	0.06%	0.06%	0.01%	-3.0585
1 Maintenance / 1 Other Discretionary	0.50%	0.45%	-0.05%	-0.9786
2 Eating Out	0.01%	0.02%	0.01%	-0.3112
1 Eating Out / 1 Visiting	0.05%	0.03%	-0.02%	-2.0902
1 Eating Out / 1 Other Discretionary	0.22%	0.21%	-0.01%	-0.5383
2 Visiting	0.03%	0.03%	0.00%	-3.1642
1 Visiting / 1 Other Discretionary	0.11%	0.10%	-0.02%	-2.5330
2 Other Discretionary	0.42%	0.41%	-0.01%	-1.4465

Table 12b: Joint Tour Frequency by Household Size

TOTAL JOINT TOURS	HOUSEHOLD SIZE				
Observed	**2**	**3**	**4**	**5**	**6**
0	44%	24%	19%	10%	4%
1	30%	22%	26%	15%	7%
2	20%	22%	28%	17%	13%
Total	41%	23%	20%	11%	5%
Estimated	**2**	**3**	**4**	**5**	**6**
0	44%	23%	19%	8%	5%
1	29%	22%	25%	14%	10%
2	19%	20%	27%	15%	20%
Total	40%	23%	20%	10%	7%
Difference	**2**	**3**	**4**	**5**	**6**
0	0%	0%	0%	-1%	1%
1	-1%	0%	-1%	-2%	3%
2	-1%	-2%	-1%	-2%	7%
Total	0%	0%	0%	-1%	2%
Adjustments	**2**	**3**	**4**	**5**	**6**
0	BASE	0.0026	0.0755	0.5114	-1.3448
1	BASE	-0.0763	-0.2724	0.4168	-1.4302
2	BASE	0.0209	-0.7602	-0.4531	-2.4027

Table 12c: Joint Tour Composition

Tour Composition	Observed	Estimated	Difference	Adjustment
Adult only	14%	15%	0.52%	BASE
Children only	2%	2%	-0.05%	-4.4697
Mixed	84%	83%	-0.47%	-2.3546

Table 12d: Global Adjustment Factor for Person's Participation in Joint Tours

Participation	Adjustments
No participation in Joint Tour	BASE
Participate in Joint Tour (Adult only)	-2.000
Participate in Joint Tour (Children only)	-2.400
Participate in Joint Tour (Mixed)	-1.850

Table 12e: Joint Tour Composition by Party Size

TOUR COMPOSITION	PARTY SIZE				
Observed	**2**	**3**	**4**	**5**	**6**
Adult only	96%	4%	1%	0%	0%
Children only	87%	4%	9%	0%	0%
Mixed	50%	33%	11%	4%	2%
Total	57%	28%	10%	3%	2%
Estimated	**2**	**3**	**4**	**5**	**6**
Adult only	90%	10%	1%	0%	0%
Children only	86%	12%	2%	0%	0%
Mixed	47%	29%	18%	5%	1%
Total	54%	25%	15%	4%	1%
Difference	**2**	**3**	**4**	**5**	**6**
Adult only	-6%	6%	0%	0%	0%
Children only	-1%	8%	-7%	0%	0%
Mixed	-3%	-4%	7%	1%	-1%
Total	-3%	-3%	6%	1%	-1%

As we can see from the differences in probabilities, we are matching the observed summaries very closely along all the identified dimensions.

Finally, we compare the total number of tours by each person type implied by the survey and the model in **Table 13**. The expanded number of persons in the survey does not match the total number of persons in the synthetic population. Hence to assess the performance, the average number of tours per person is also shown. The model is performing reasonably well in generating the right number of tours by person type as can be seen from the table.

Table 13: Total tours by person type

	Observed			Estimated		
	Tours	Percentage	Average # of tours per person	Tours	Percentage	Average # of tours per person
Full-time worker	2,264,793	36.09%	1.32	3,017,616	45.12%	1.55
Part-time worker	793,595	12.65%	1.43	552,080	8.25%	1.51
University student	492,212	7.84%	1.17	281,160	4.20%	1.31
Non-working adult	742,344	11.83%	1.01	818,637	12.24%	1.02
Non-working senior	252,342	4.02%	0.72	287,401	4.30%	0.76
Driving age student	291,108	4.64%	1.21	258,134	3.86%	1.22
Pre-driving student	1,055,512	16.82%	1.23	1,003,941	15.01%	1.26
Pre-school	382,776	6.10%	1.00	469,356	7.02%	1.02
Total	6,274,681	100.00%	1.19	6,688,325	100.00%	1.29

Tour Time of Day Choice Models

Tour time-of-day choice is the composite choice made up of the tour start and end times. In the ARC activity based model, the tour-start and end times are represented by several temporally contiguous discrete time periods with a resolution of 30 minutes (resulting in 48 time-bins per day). In order to control for reasonability of travel schedule, all the alternatives where the tour-start time period is before the tour-end time period is discarded from the choice set.

The time of day choice model was estimated using the 2011 ARC Regional Travel Survey. The model is segmented by tour purposes. Some tour purposes are lumped together based on the observed distributions.[2] The models did not require calibration for the mandatory tour purposes. The non-mandatory tour purposes required minor adjustments to the alternative specific constants. Specifically, the tour purpose that were jointly estimated (for example – Maintenance/shopping and Social/Discretionary) required some additional constants to clearly capture individual peaking patterns.

The model employed shift effects to capture the tails of the distributions. Such a specification would ensure that extreme periods (very short durations or very long durations) would have the maximum disutility and hence is less likely to be chosen. However, in application mode the alternative would still get a finite probability even though the observed percentage share might be zero – in order to fix this some of the alternatives were given a negative coefficient of high magnitude.

The calibration of time-of-day choice model involved the following steps:

1. The model has three primary dimensions – departure, arrival and duration. Of these, if we adjust any two dimensions, the third would fall in line. The dimensions to adjust were chosen based on which profile required most adjustment.
2. Alternative specific constants were applied to periods that were off – please note that here the base would be all those periods for which no alternative specific constant is being specified. There is no need to explicitly define one and scale all others as was done with some of the previous models.

The models did not require many rounds of calibrations – the estimated shares converged very fast to the observed shares. This can be seen in the figures shown below. **Figure 6** through **Figure 15** compares the observed and the predicted temporal profiles of tours by purpose.

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[2] For more details on the assumptions made during model estimation, estimations approach and estimation results please refer to *Time of Day Model Estimation for ARC* memo.

Figure 6: Tour Time of Day Results: Work Tours

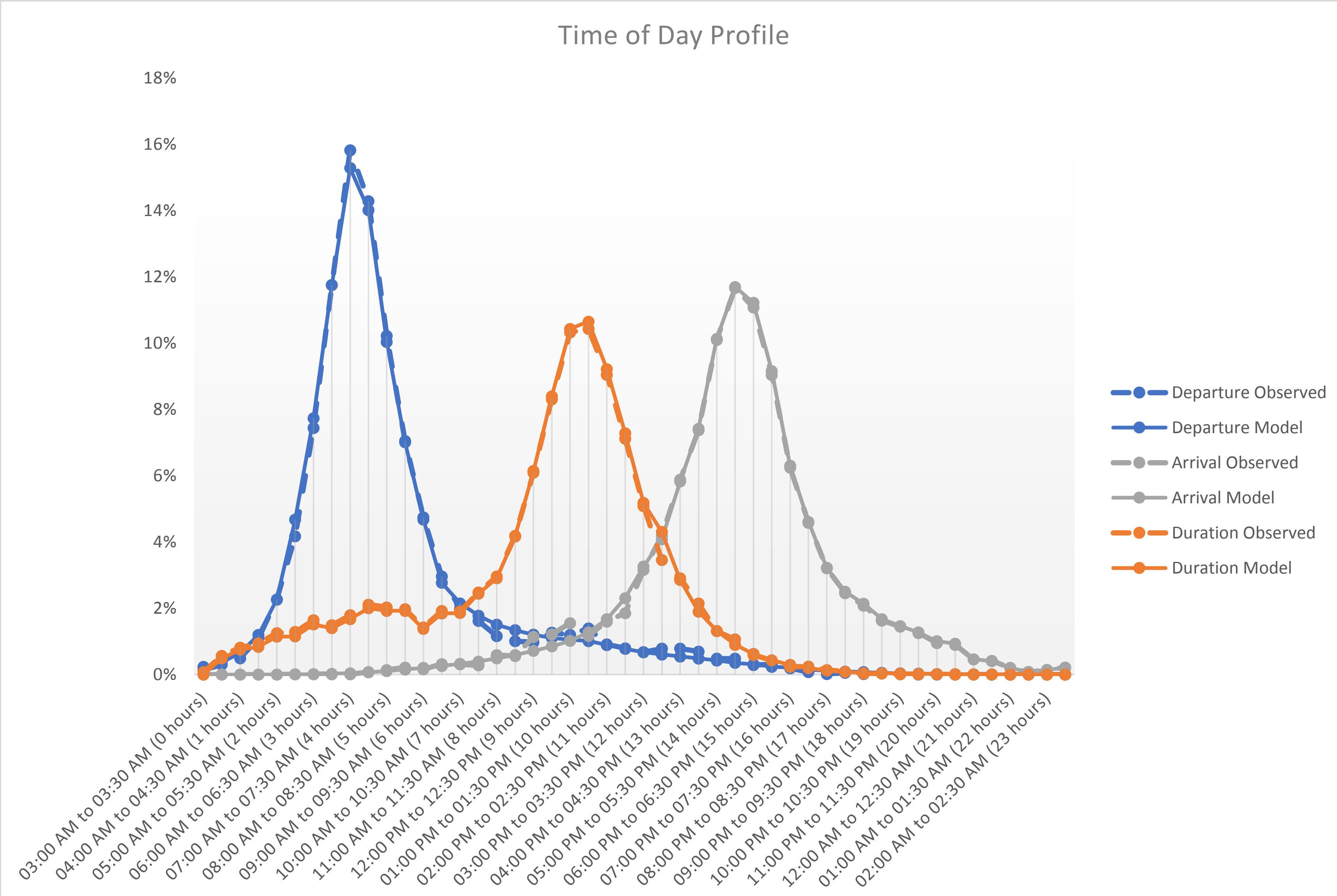


Figure 7: Tour Time of Day Results: University Tours

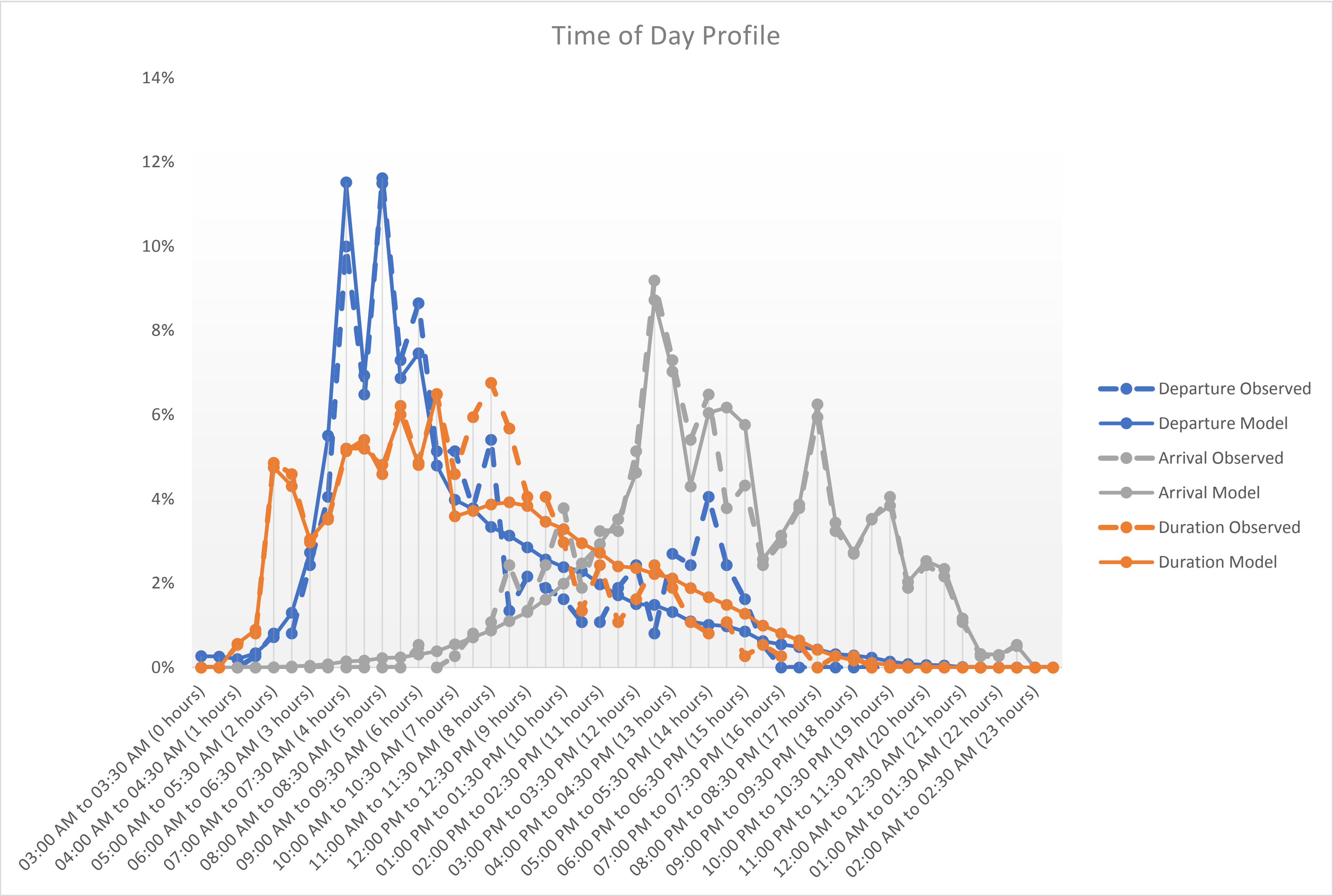


Figure 8: Tour Time of Day Results: School Tours

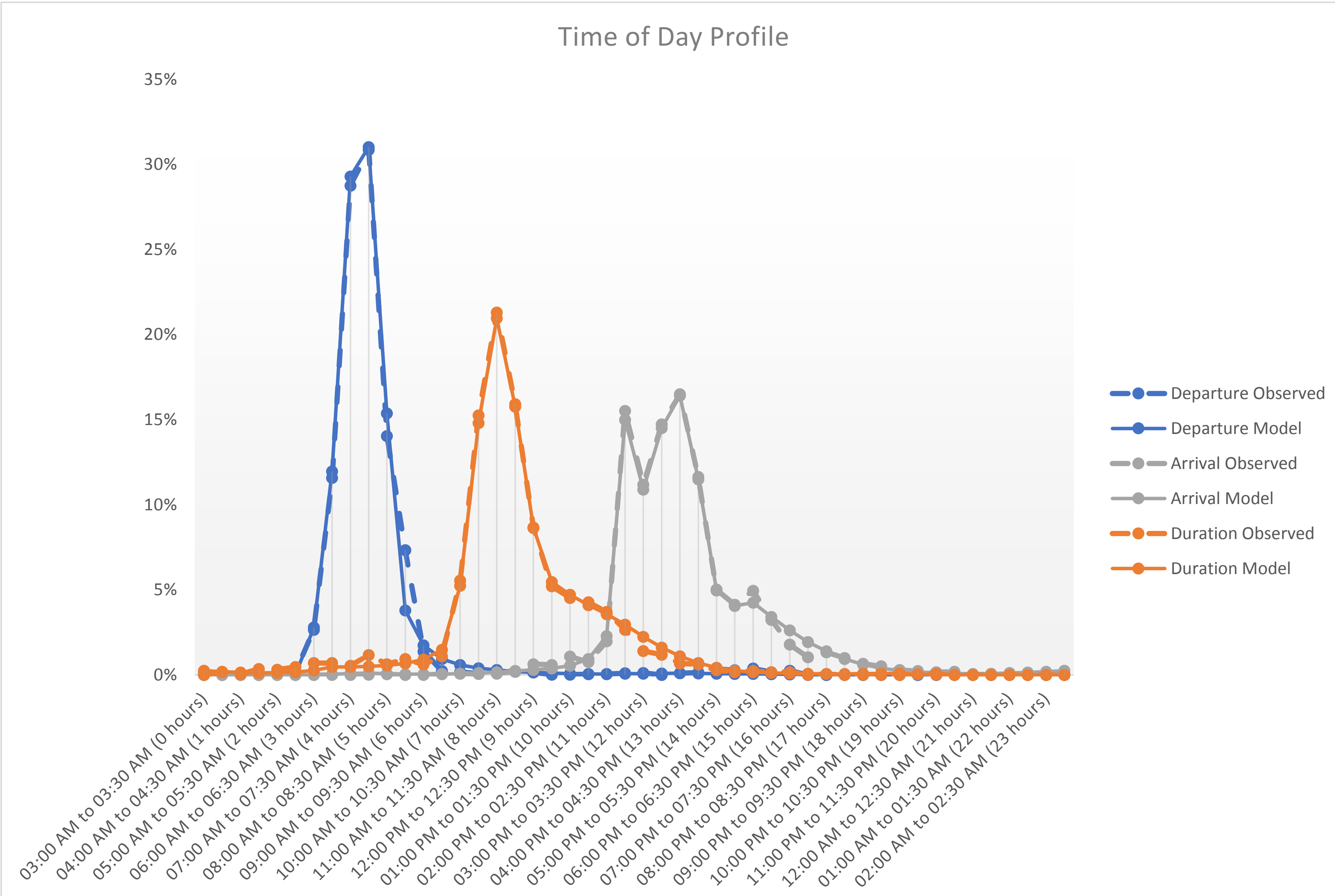


Figure 9: Tour Time of Day Results: Escort Tours

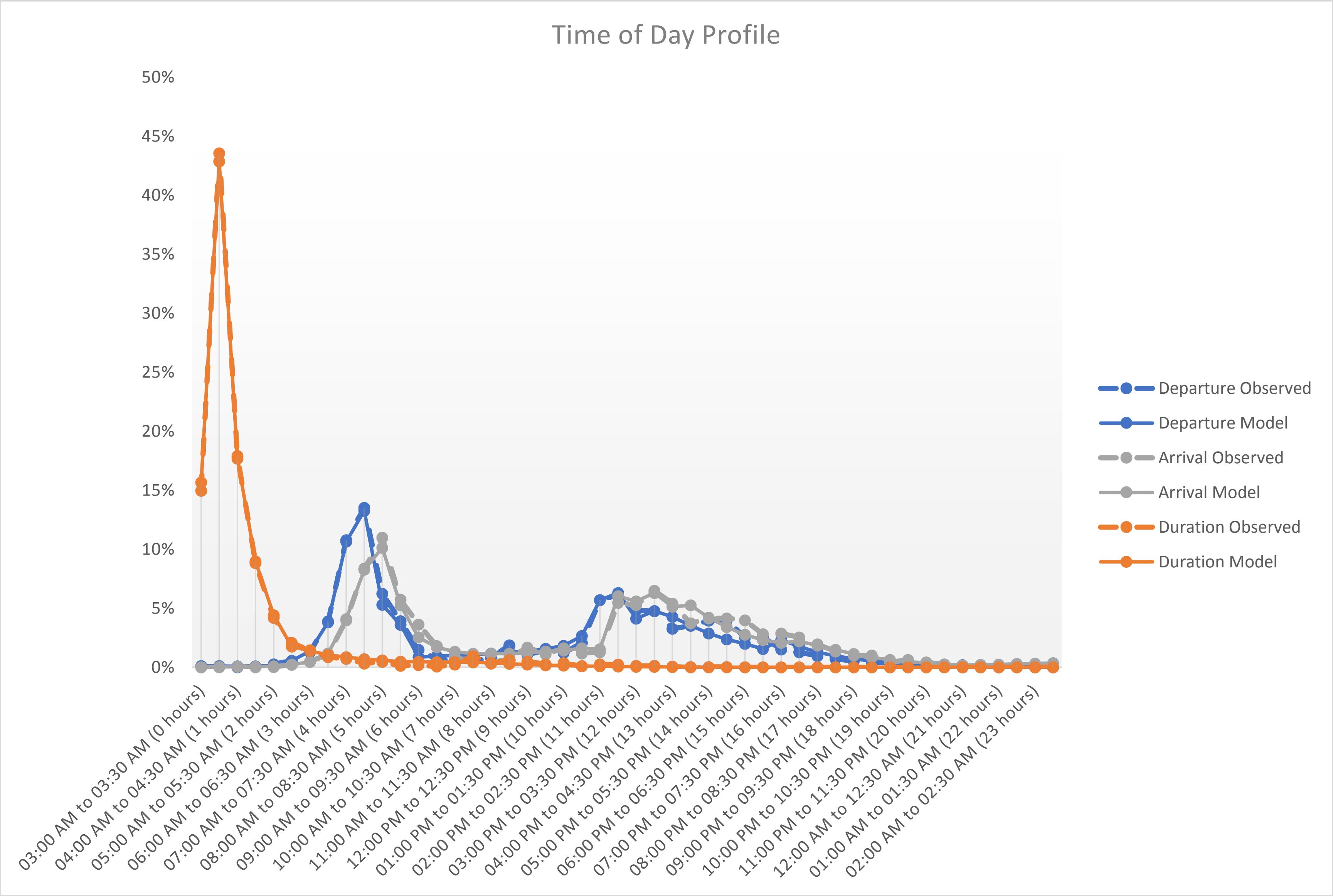


Figure 10: Tour Time of Day Results: Maintenance Tours

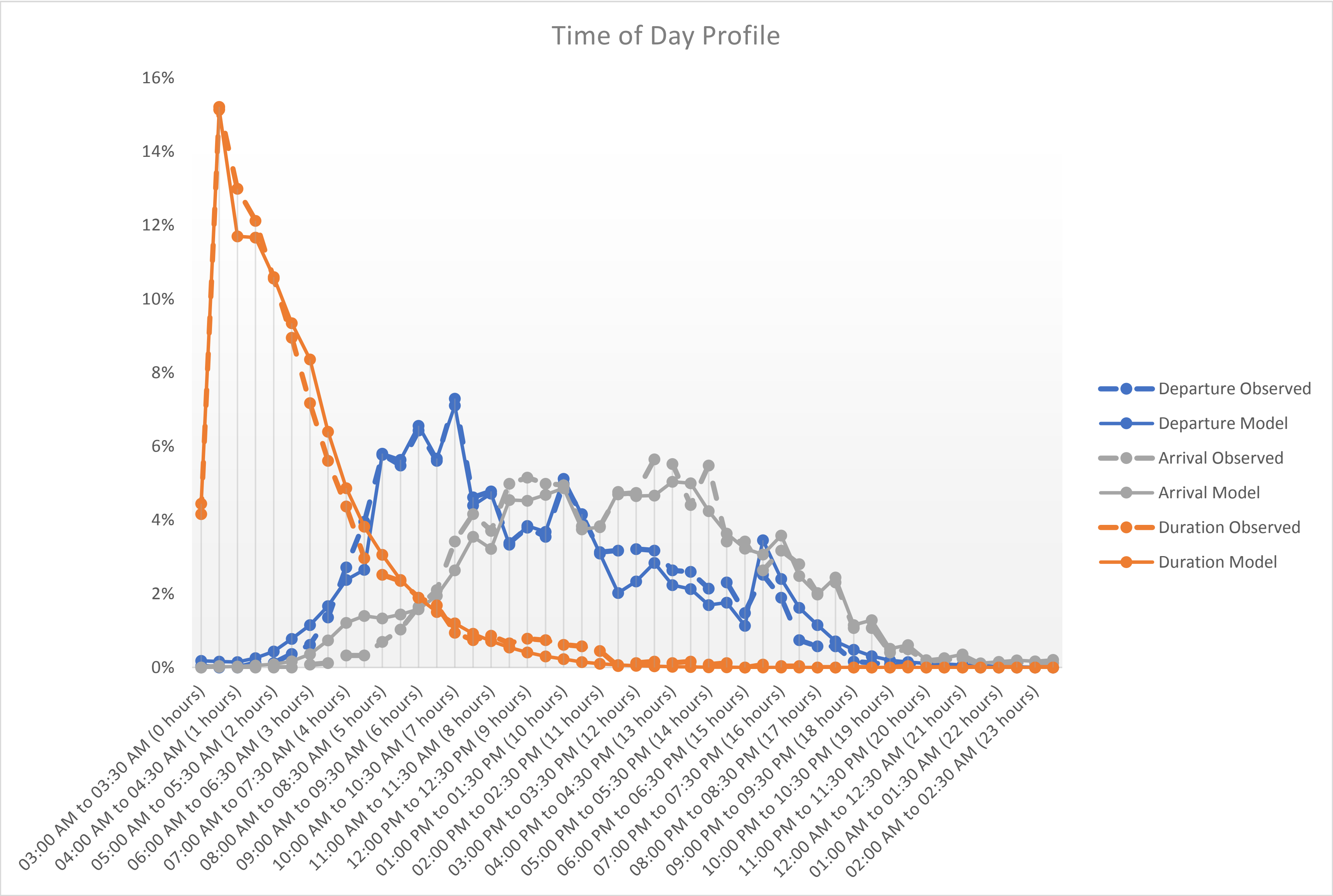


Figure 11: Tour Time of Day Results: Shopping Tours

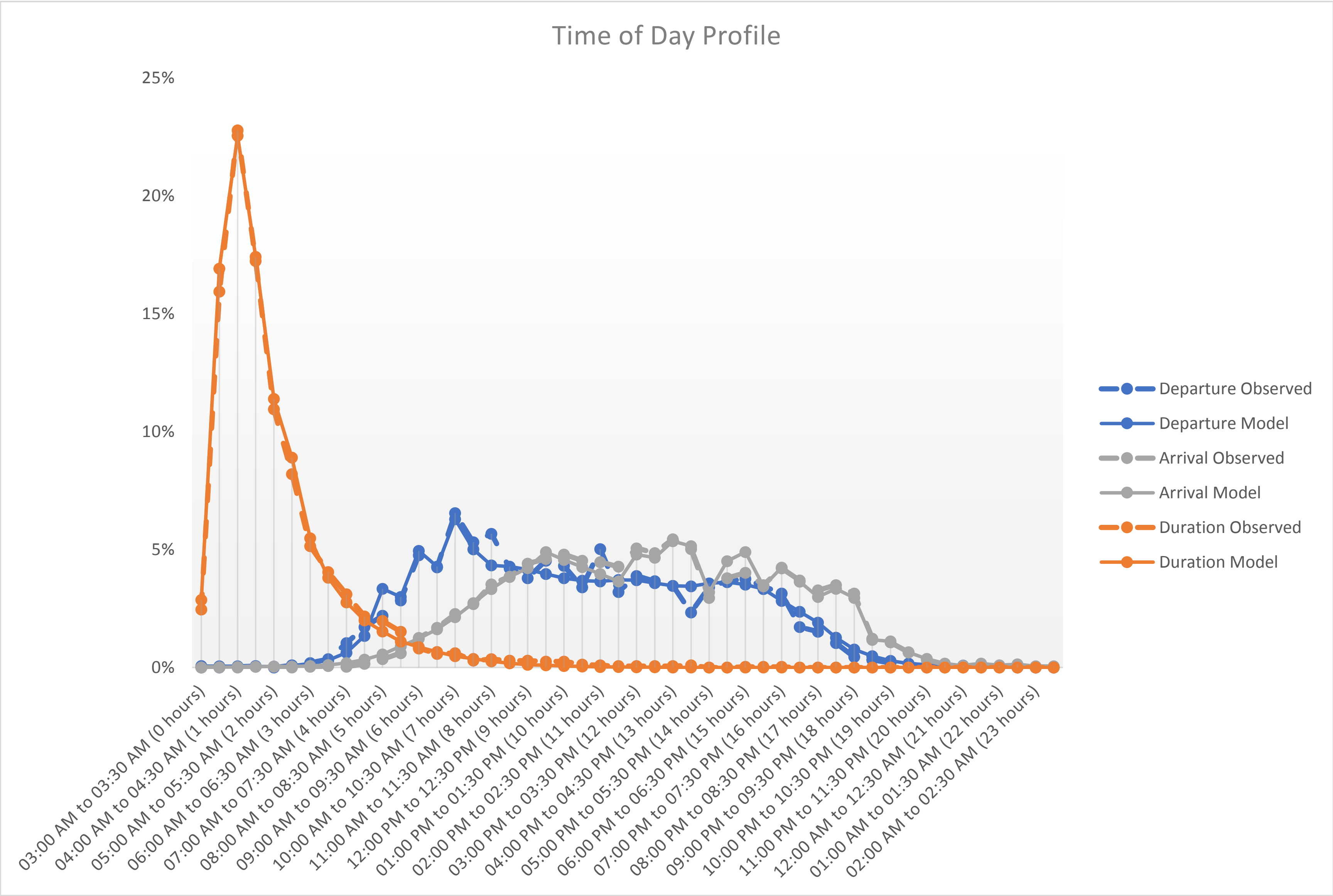


Figure 12: Tour Time of Day Results: Eatout Tours

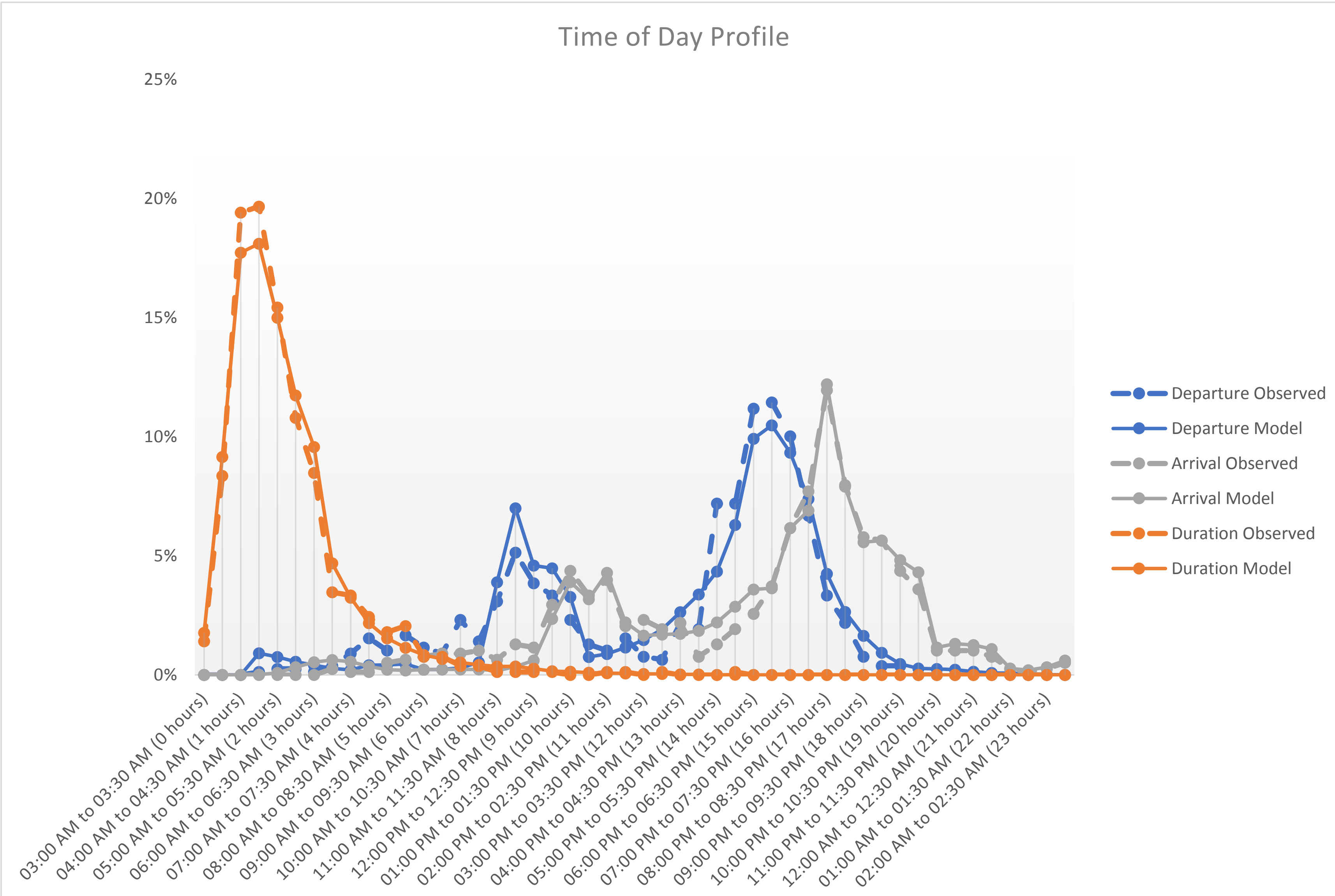


Figure 13: Tour Time of Day Results: Social Tours

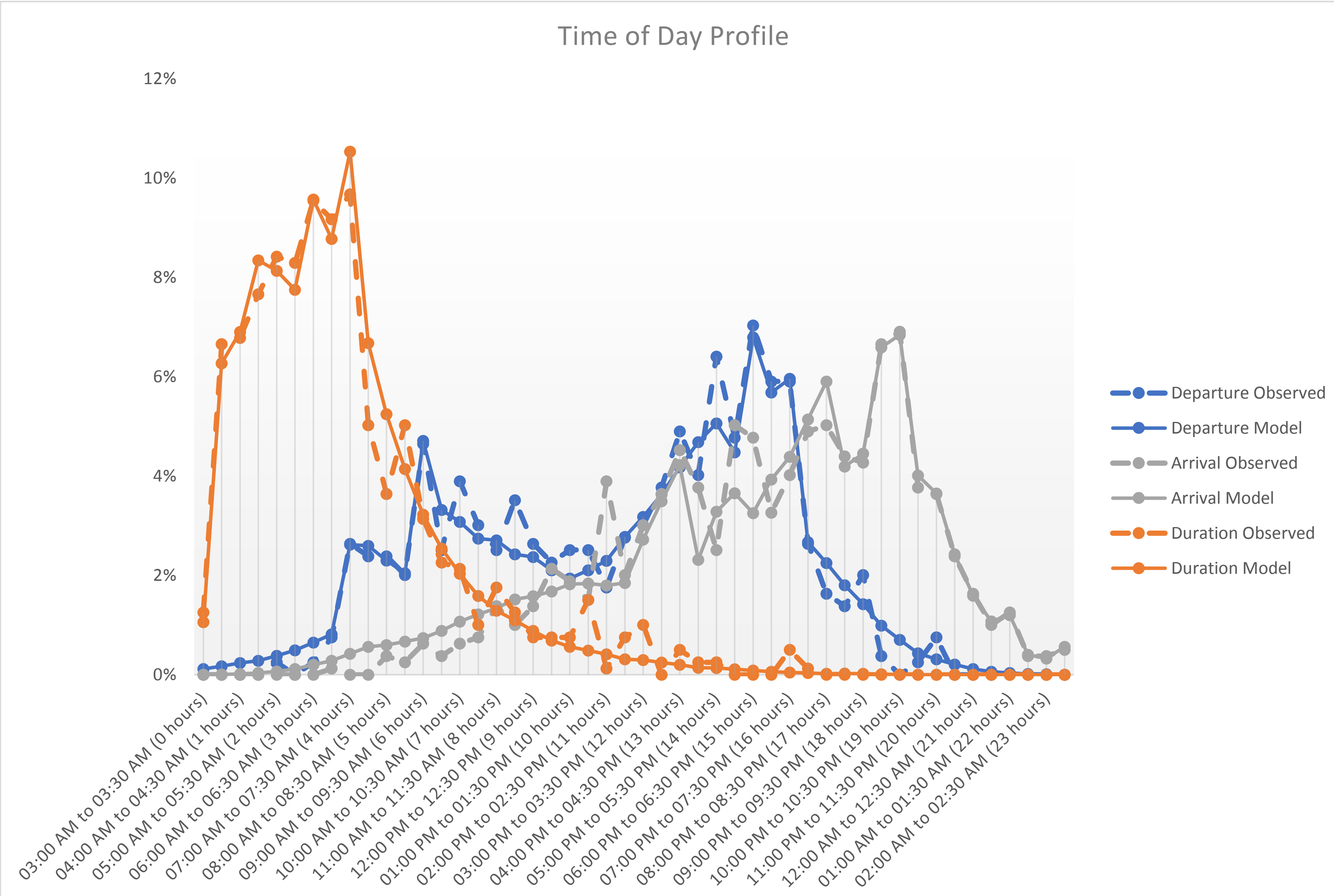


Figure 14: Tour Time of Day Results: Discretionary Tours

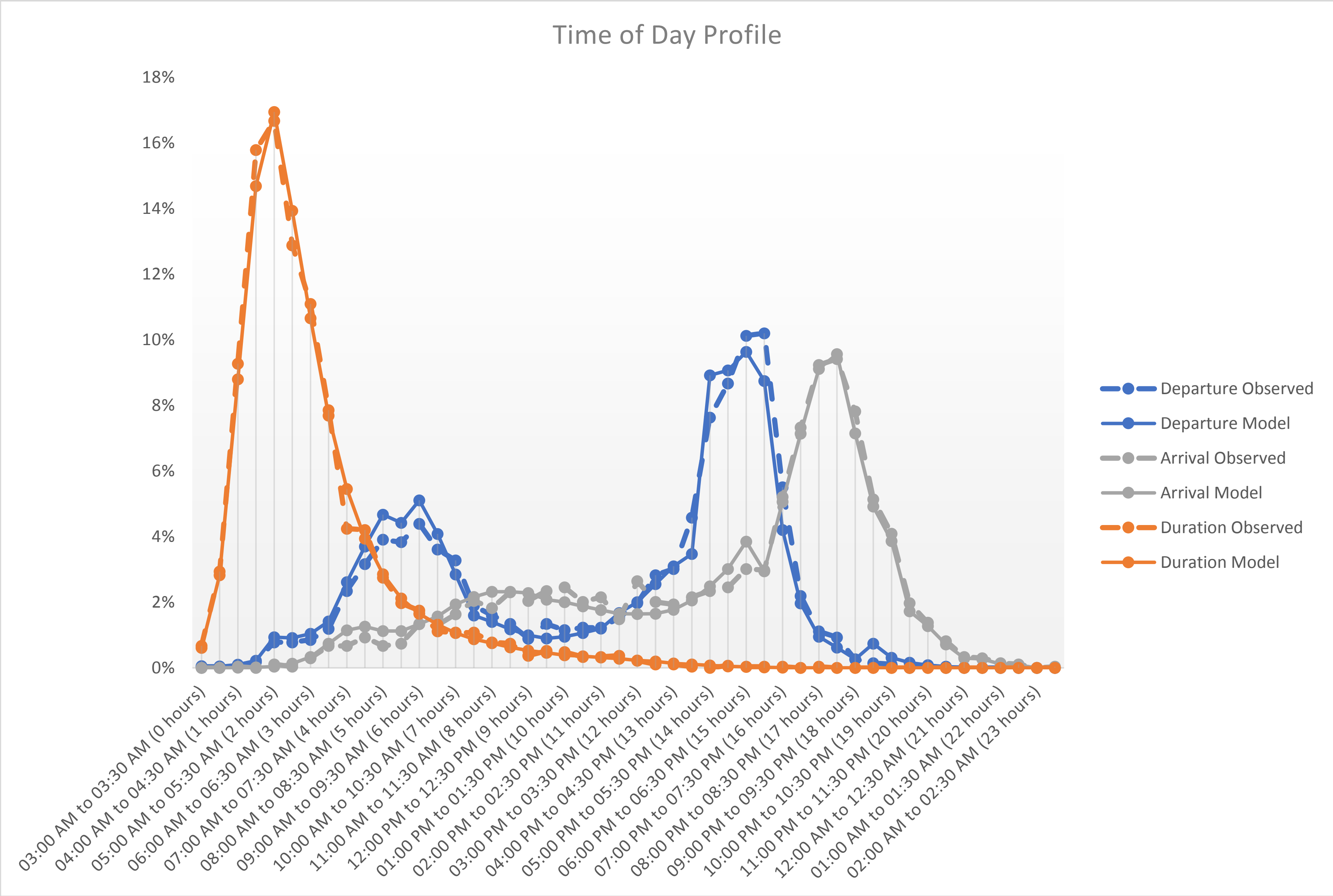
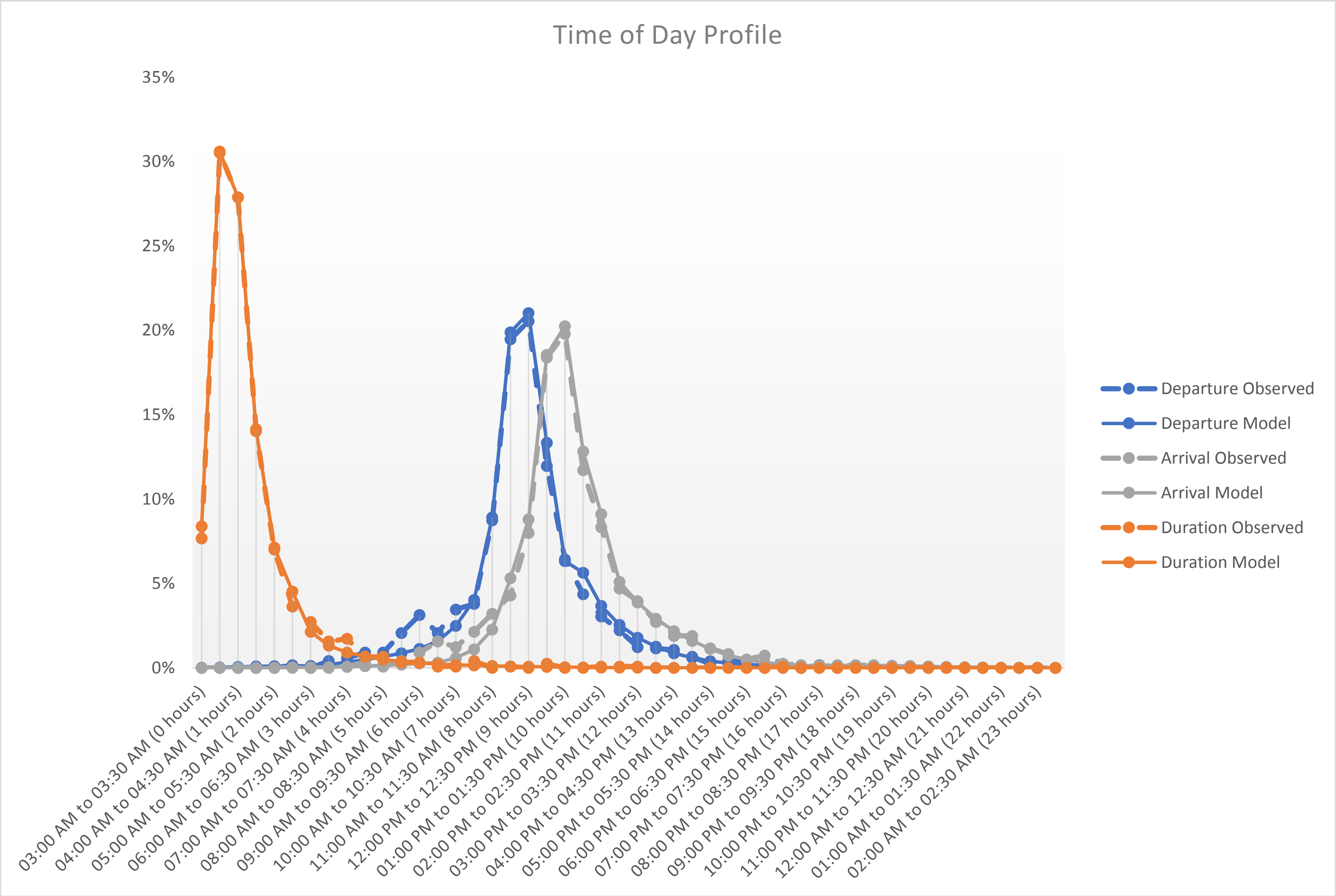


Figure 15: Tour Time of Day Results: At-work Sub-Tours



The following section details the calibration constants applied to each of the TOD models by tour purpose.

The escorting tours TOD distributions matched the observed very closely. However, the morning peak was a little underestimated while the noon peak was overestimated by small amount. The adjustment factors were applied to departure and duration to better match the observed distributions.

Table 14a: Escorting Tours Calibration Constants

Parameters	Adjustment
Departure Constants	
07:00 AM to 07:30 AM	0.107
07:30 AM to 08:00 AM	0.215
02:00 PM to 02:30 PM	-0.255
02:30 PM to 03:00 PM	-0.297
Duration Constants	
0 hours	-0.047
0.5 hours	0.036

The maintenance and shopping tours were estimated jointly. Hence, the shift effects on duration were based on a single reference. This caused some of the alternative specific constants in the model to have a weaker effect on matching the shares of shorter duration. The model was predicting more shorter tours than observed. Hence, negative coefficients were arrived at for the two purposes for short durations. The values are reported in **Table 14b** and **c**.

Table 14b: Maintenance Tours Calibration Constants

Parameters	Adjustment
Duration Constants	
0 hours	-0.125
0.5 hours	-0.104
1 hours	-0.225
1.5 hours	-0.145
2 hours	-0.019

Table 14c: Shopping Tours Calibration Constants

Parameters	Adjustment
Duration Constants	
0 hours	-0.138
0.5 hours	-0.093
1 hours	-0.088

There were two issues in the modeled TOD distributions for eatout tours. The first has to do with the extreme periods as discussed earlier. The survey data did not have any eatout tour departures for the very early AM periods (3:00 AM to 4:30 AM) – however, the model assigned finite probability to these periods and some tours were being observed. This was fixed by applying a constant of -20 to these periods for departure.

The second issue was the peak pattern for the lunch was not as pronounced as the observed data. It is possible that overlapping shift effects defined based on the dinner peak might be dampening the effect of the alternative specific constants defined in the model. Hence, these adjustments were computed and applied to get these two distributions to match.

Table 14d: Eatout Tours Calibration Constants

Parameters	Adjustment
Departure Constants	
03:00 AM to 03:30 AM	-10.000
03:30 AM to 04:00 AM	-10.000
04:00 AM to 04:30 AM	-10.000
11:00 AM to 11:30 AM	0.707
11:30 AM to 12:00 PM	0.634
12:00 PM to 12:30 PM	0.584
12:30 PM to 01:00 PM	0.470
01:00 PM to 01:30 PM	0.395
Duration Constants	
0 hours	-0.334
0.5 hours	-0.246
1 hours	0.053
1.5 hours	0.042

The issue with the social and discretionary tours is similar to the maintenance and shopping tours. As these models were jointly estimated, additional adjustments were necessary to improve goodness-of-fit to observed distributions for each purpose individually.

Table 14e: Social Tours Calibration Constants

Parameters	Adjustment
Duration Constants	
0 hours	-1.347
0.5 hours	0.377
1 hours	0.180
1.5 hours	-0.283
2 hours	-0.104
2.5 hours	-0.037
3 hours	-0.062
3.5 hours	0.048
4 hours	0.284

Table 14f: Discretionary Tours Calibration Constants

Parameters	Adjustment
Departure Constants	
05:00 PM to 05:30 PM	0.233
05:30 PM to 06:00 PM	0.306
06:00 PM to 06:30 PM	0.286
06:30 PM to 07:00 PM	0.116
Duration Constants	
1.5 hours	-0.133
2 hours	-0.013

Finally, the at-work sub-tours were adjusted to better match the observed distribution. Note that the calibration coefficients have very small magnitude – these were applied to get better data fit around the peaks.

Table 14g: At-Work Sub-Tours Calibration Constants

Parameters	Adjustment
Departure Constants	
11:30 AM to 12:00 PM	-0.046
12:00 PM to 12:30 PM	-0.099
Arrival Constants	
12:30 PM to 01:00 PM	-0.070
01:00 PM to 01:30 PM	-0.064

Non-Mandatory Tour Primary Destination Choice

The non-mandatory tour primary destination choice model determines the location of the tour primary destination for each of the 6 non-mandatory tour purposes. Size terms for non-mandatory tours were re-estimated using household survey data and base-year employment data. Total tours by purpose were summed by TAZ, and maximum likelihood estimation was used to calculate new size terms for each purpose. The revised size terms are shown in **After implementation** of the revised size terms, non-mandatory (escort, shop, other maintenance, eating out, visiting, other discretionary, and at-work subtours) tour primary destination choice was calibrated to match summaries from the 2011 ARC Regional Travel Survey.

Summaries of the tour length frequency distributions and average tour length were developed for both estimated and observed data. The calibration was done with the aim of matching the shape of the observed tour length curves (the distance between the tour origin and primary destination). All of the models required additional adjustments to the constants on the distance terms in order to better match observed trip length frequency distributions.

Table 15.

After implementation of the revised size terms, non-mandatory (escort, shop, other maintenance, eating out, visiting, other discretionary, and at-work subtours) tour primary destination choice was calibrated to match summaries from the 2011 ARC Regional Travel Survey.

Summaries of the tour length frequency distributions and average tour length were developed for both estimated and observed data. The calibration was done with the aim of matching the shape of the observed tour length curves (the distance between the tour origin and primary destination). All of the models required additional adjustments to the constants on the distance terms in order to better match observed trip length frequency distributions.

Table 15: Non-Mandatory Destination Choice Size Terms

Variable	Escort, Kids	Escort, No Kids	Shop	Other Maint.	Eating Out	Social	Other Disc	At-Work
pop	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
hshld	0.000	0.000	0.000	0.000	0.000	1.000	0.083	0.000
Agr, Forest, Fish	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Mining, Oil	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Utilities	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Construction	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Manufacturing	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Wholesale	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Retail	0.000	0.000	1.000	0.000	0.000	0.000	0.000	0.395
Transport, Warehouse	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Information	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Finance,Insur	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
RealEstate	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Prof,Scien,Tech	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.541
Management	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Admin,Support	0.000	1.638	0.000	0.000	0.000	0.000	0.000	0.000
Educ	1.000	1.000	0.000	0.000	0.000	0.000	0.000	0.000
HealthCare	0.000	0.000	0.000	0.267	0.000	0.000	0.000	0.151
Arts,Enter,Rec	0.000	0.054	0.000	0.000	0.000	3.469	1.000	0.000
Accom,FoodService	0.000	0.504	0.000	0.000	1.000	0.000	0.210	1.000
OtherNonPubAdmin	0.000	0.000	0.000	1.000	0.000	0.000	0.803	1.157
PublicAdmin	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
University Enrollment	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

The adjustment factors were calculated for each tour purpose, as follows:

$$A_d = \ln\left(\frac{Obs_d}{\sum_d Obs_d} \Big/ \frac{Est_d}{\sum_d Est_d}\right)$$

Where:

A_d = An adjustment factor for each one-mile increment of distance (d) where distance is less than 20 miles (roughly corresponding to the maximum observed distance for non-mandatory tours).

Obs_d = The number of observed tours at distance increment (d)

Est_d = The number of estimated tours at distance increment (d)

The coefficients so computed when added to the respective distance bin would change their probability such that the estimated trip length will more closely match the observed trip length.

These adjustments are then regressed on the linear and the polynomial terms of the variable which are in the destination choice model (such as linear distance, distance-squared, distance-cubed and log of distance). The coefficients obtained on each of the terms in this regression would serve to explain the difference in the observed and the predicted distributions. In addition, a few of the tour purposes required bin specific constants to capture the steep observed trip length frequency curve in the short distance bins. Also, it was ensured that the utility functions so computed resulted in a monotonically decreasing function with respect to distance. If that was not the case, distances were capped accordingly. The process was done for multiple iterations with the adjustments in each iteration being a cumulative sum of all iterations up until that point. The results of the calibration are discussed now.

Initially, the tour length frequencies were different from the observed with more longer (>5 miles) tours being predicted. Recall that for this iteration of model development the number of zones were almost doubled up to a 5000+ zone whereas the earlier model was estimated on the older, more coarse 2000+ zone system. A more aggregate zone system would mask the variation in distances as a larger area would get approximated to the zonal centroid. The zonal enhancement to the model reduces this variation substantially – the estimates on the previous model cannot fully explain this richer choice set. The calibration constants applied here is helping us compensate for that variation, unobserved at the time of estimation of the older model.

Figure 16: Tour Length Frequency Distribution: Escort Tours

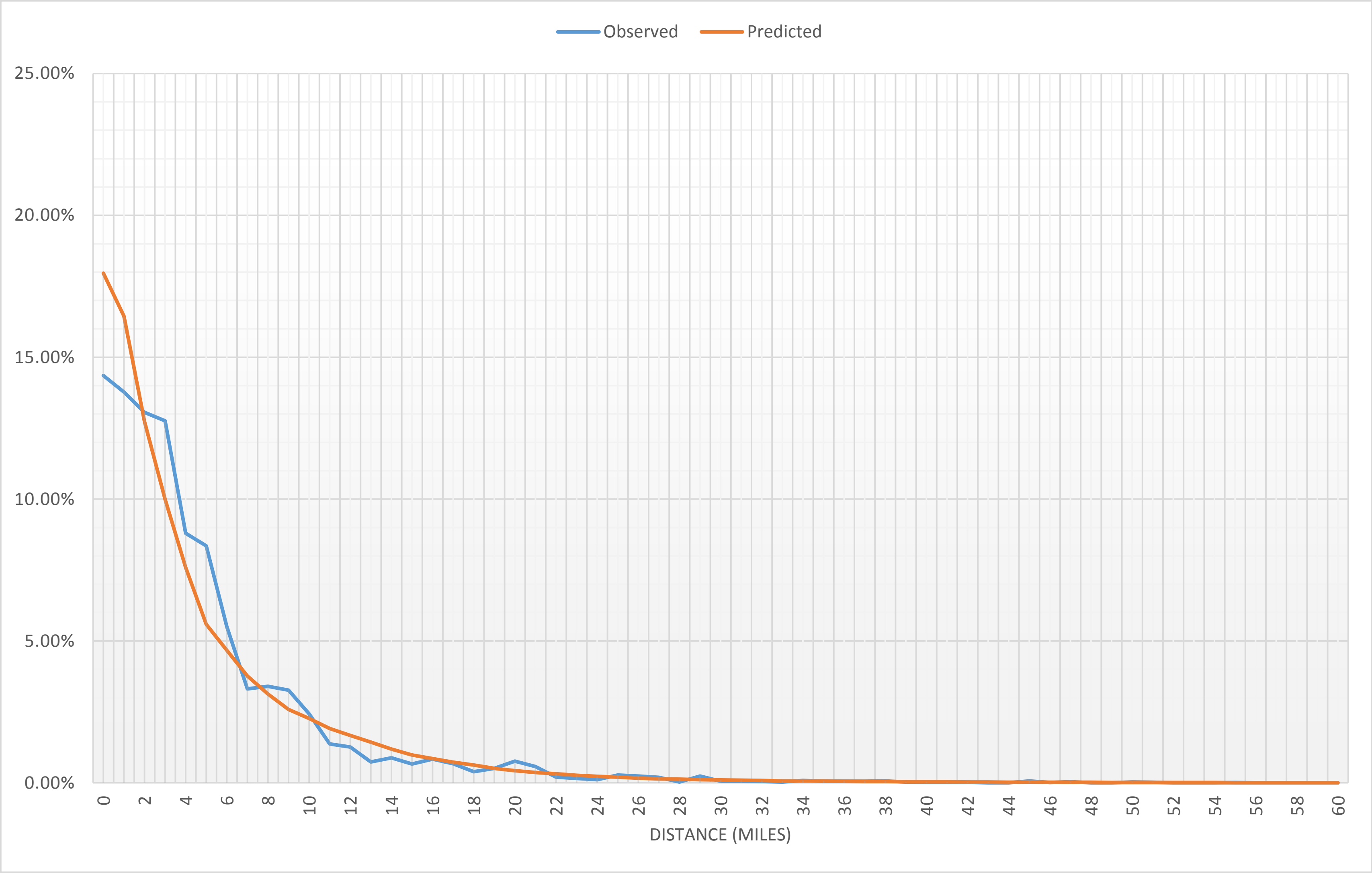


Figure 17: Tour Length Frequency Distribution: Maintenance Tours

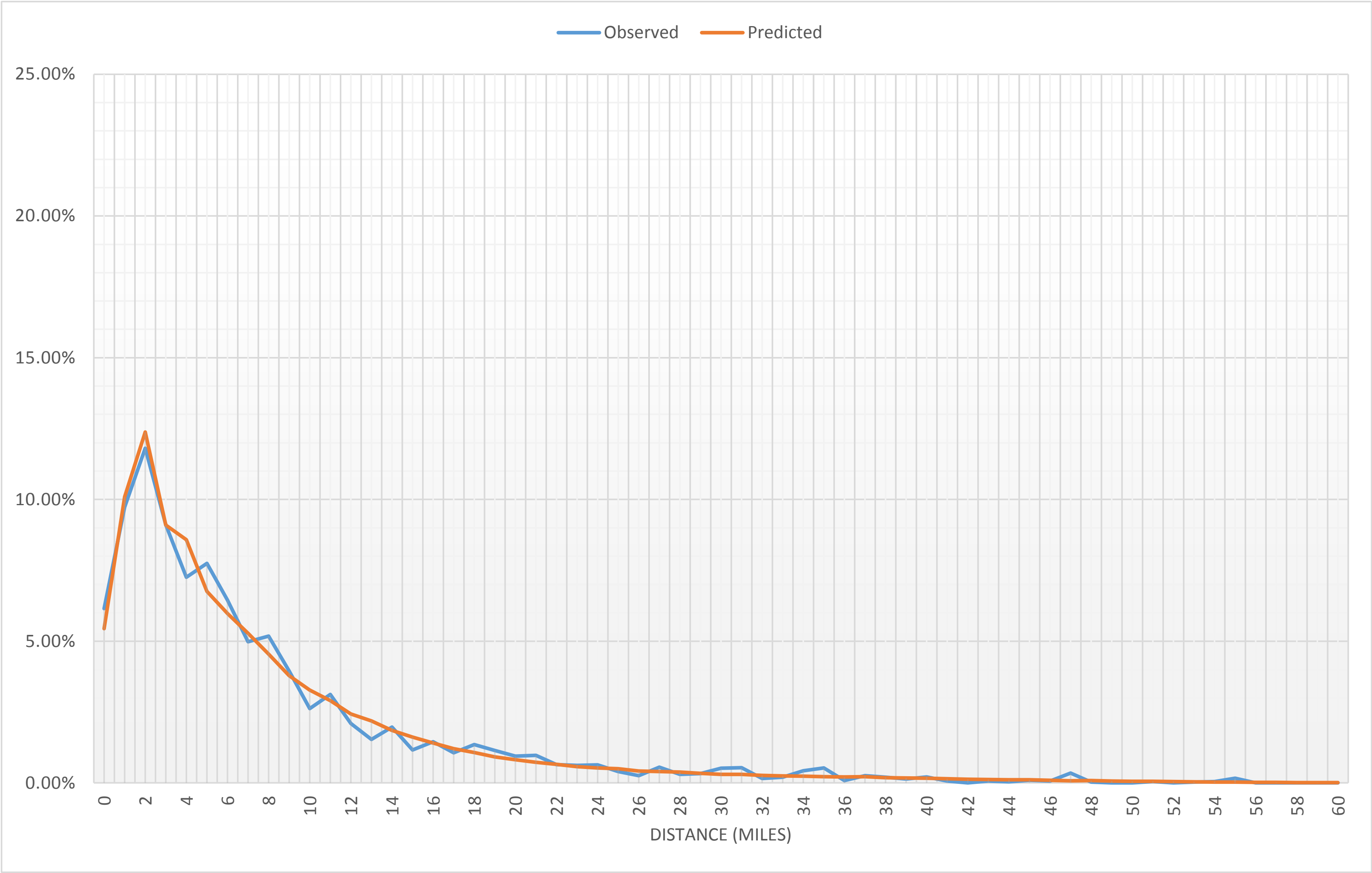


Figure 18: Tour Length Frequency Distribution: Shopping Tours

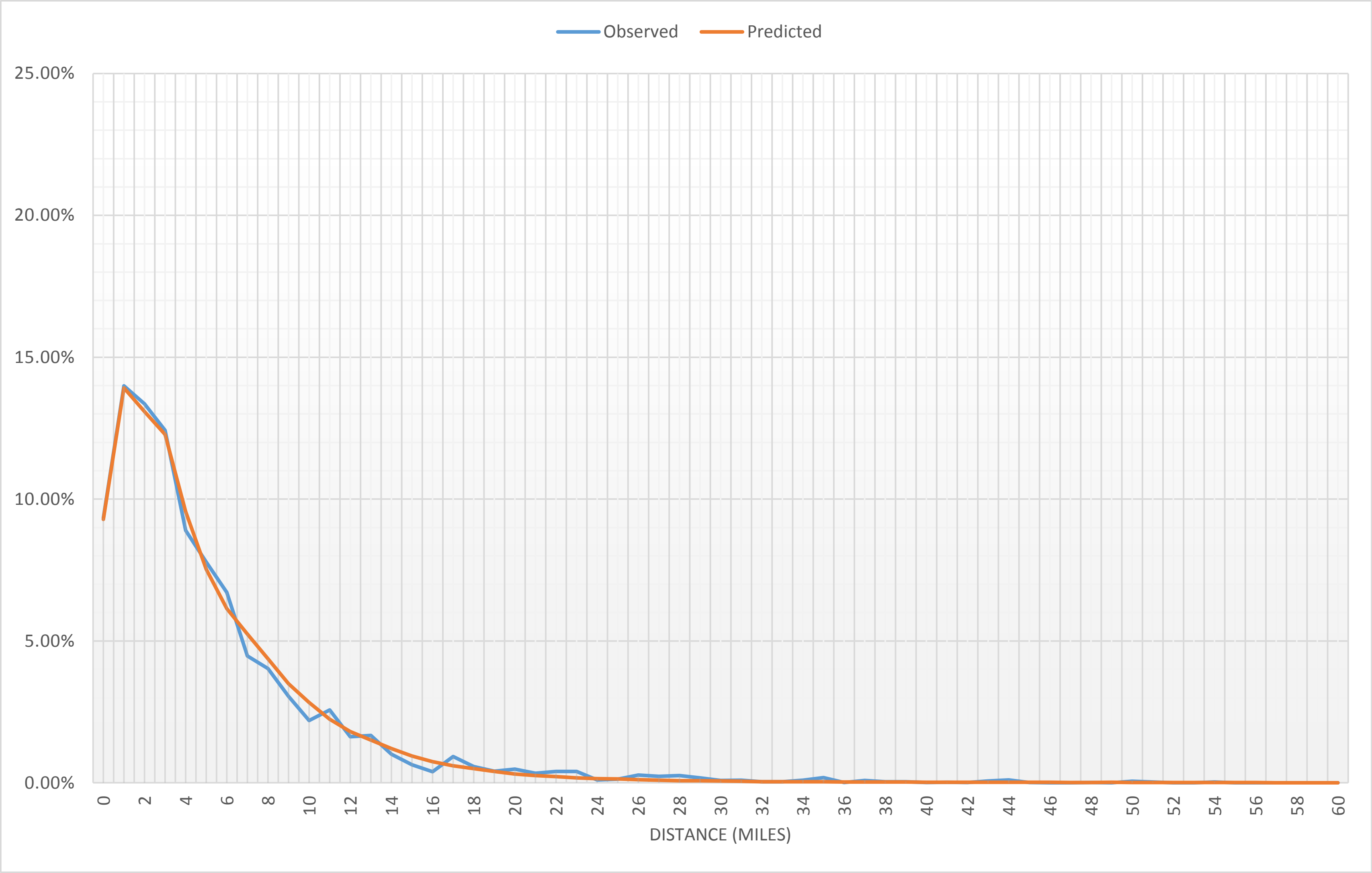


Figure 19: Tour Length Frequency Distribution: Eatout Tours

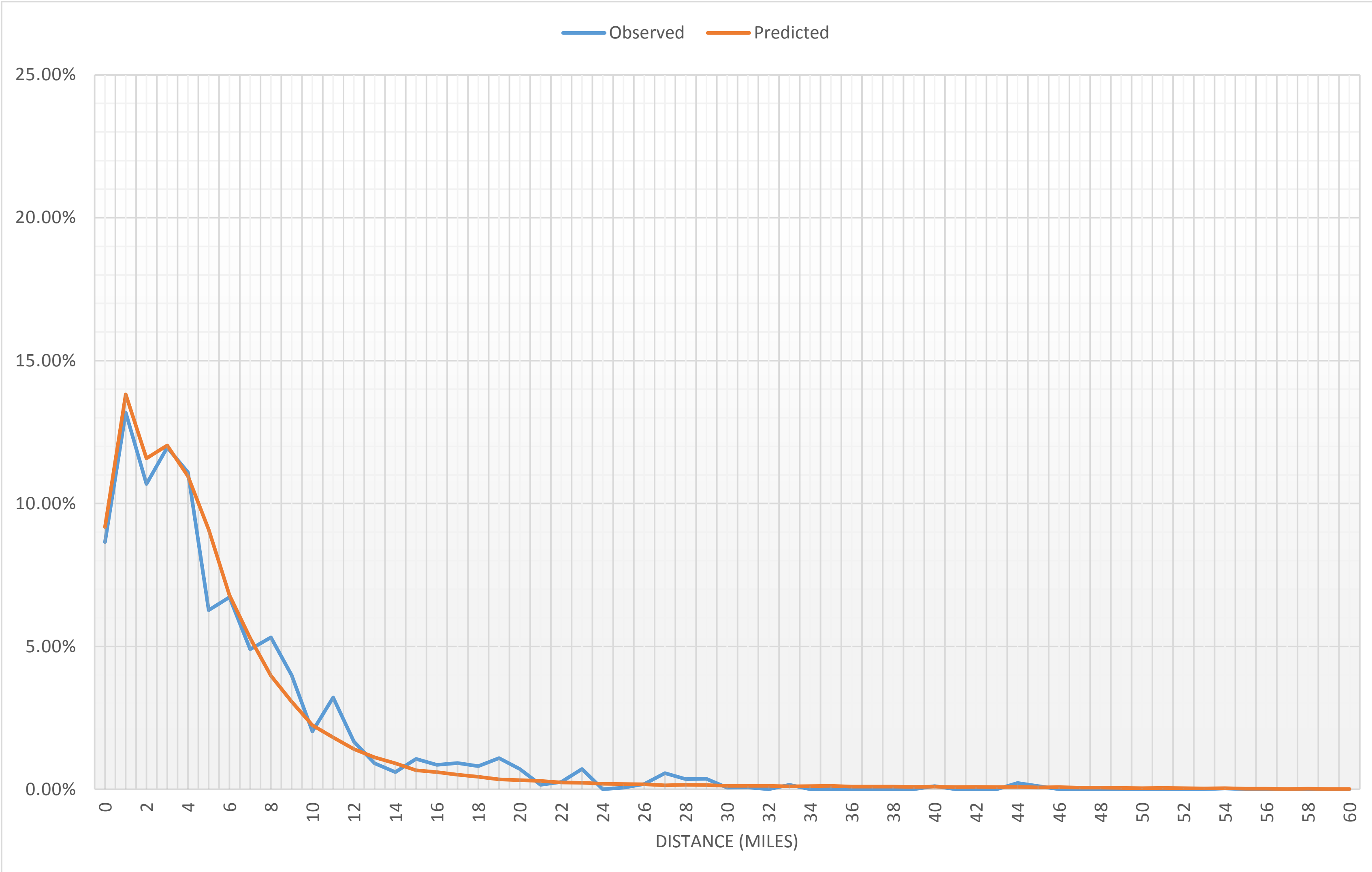


Figure 20: Tour Length Frequency Distribution: Social Tours

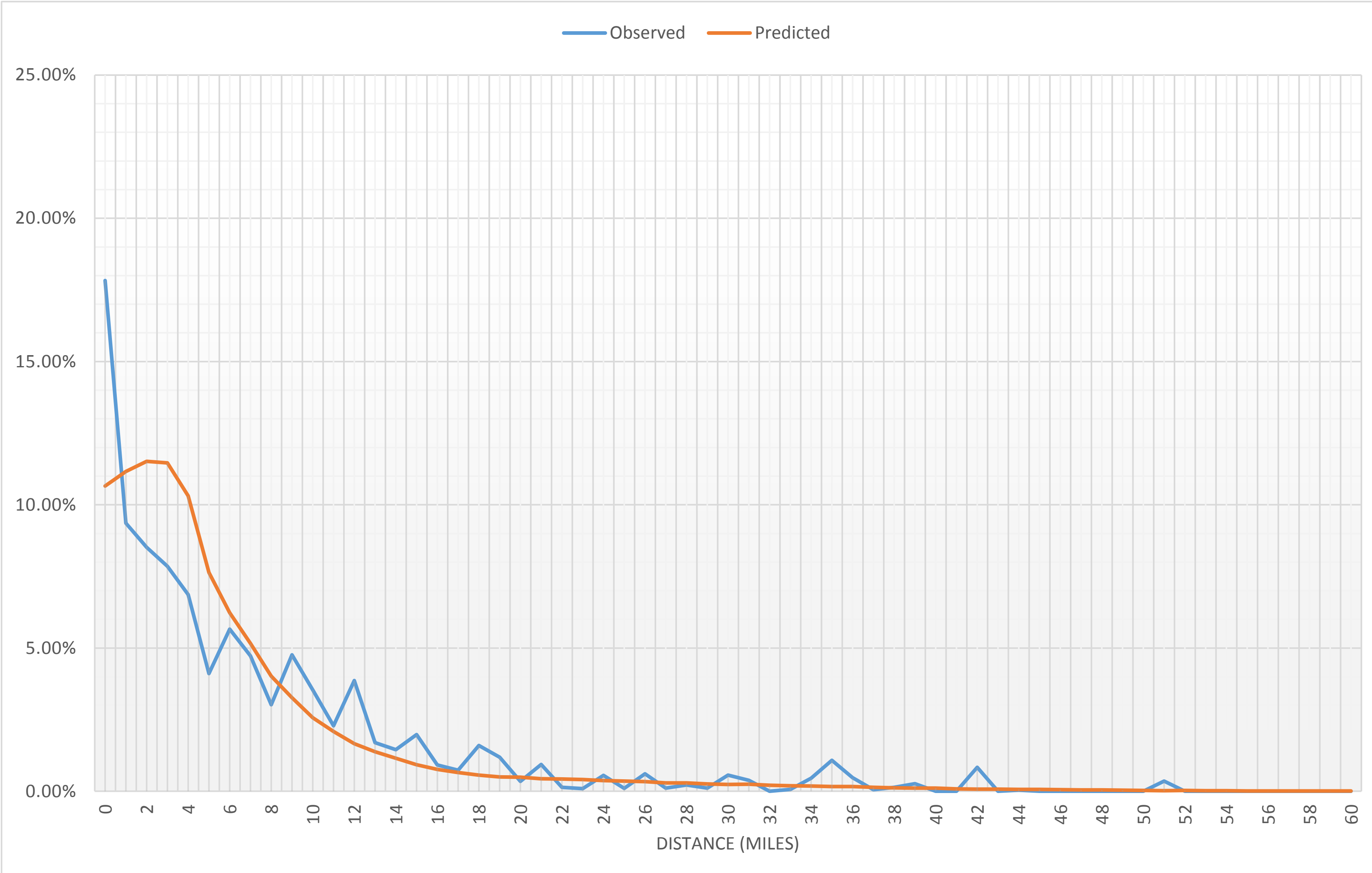


Figure 21: Tour Length Frequency Distribution: Discretionary Tours

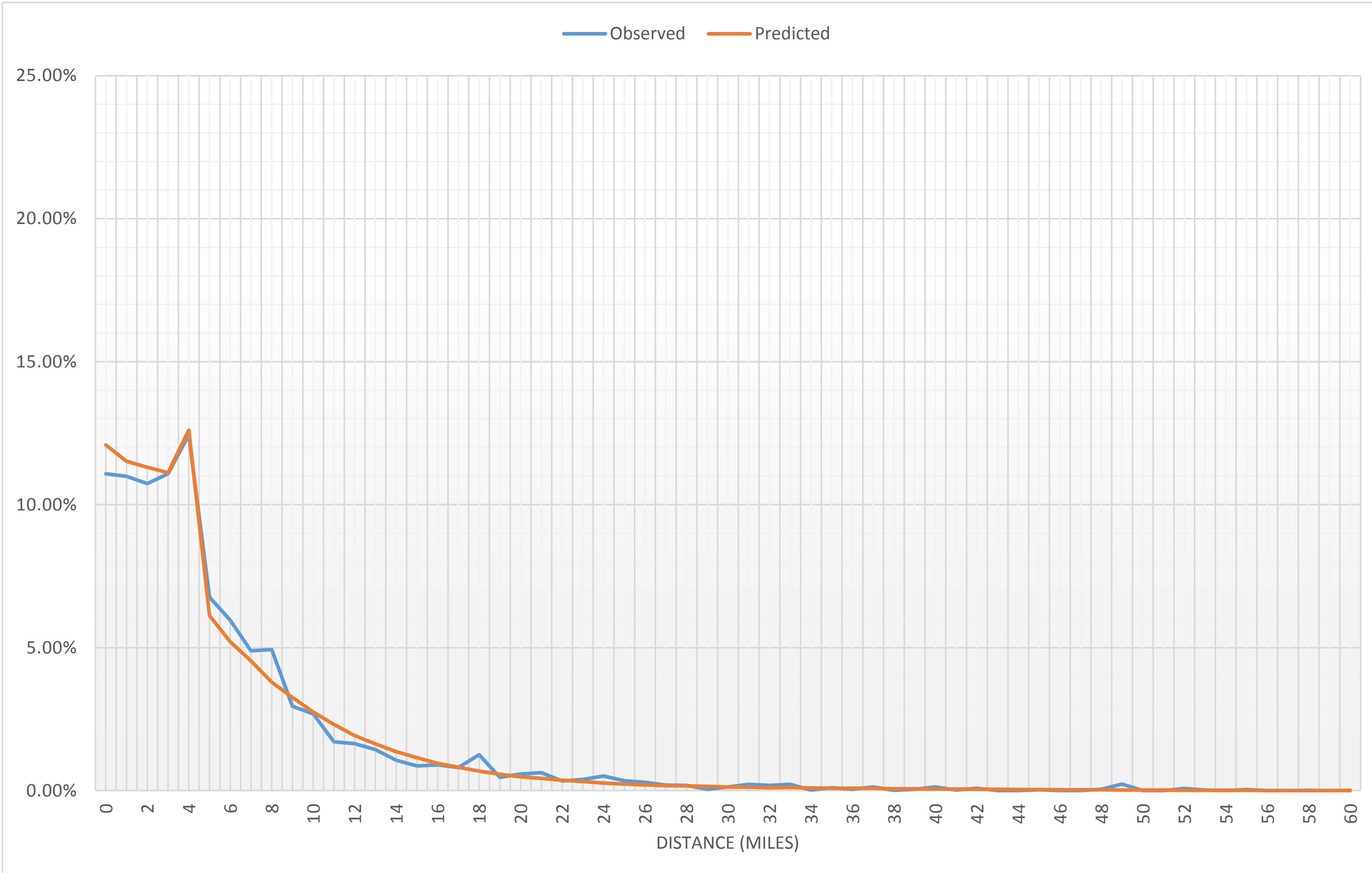
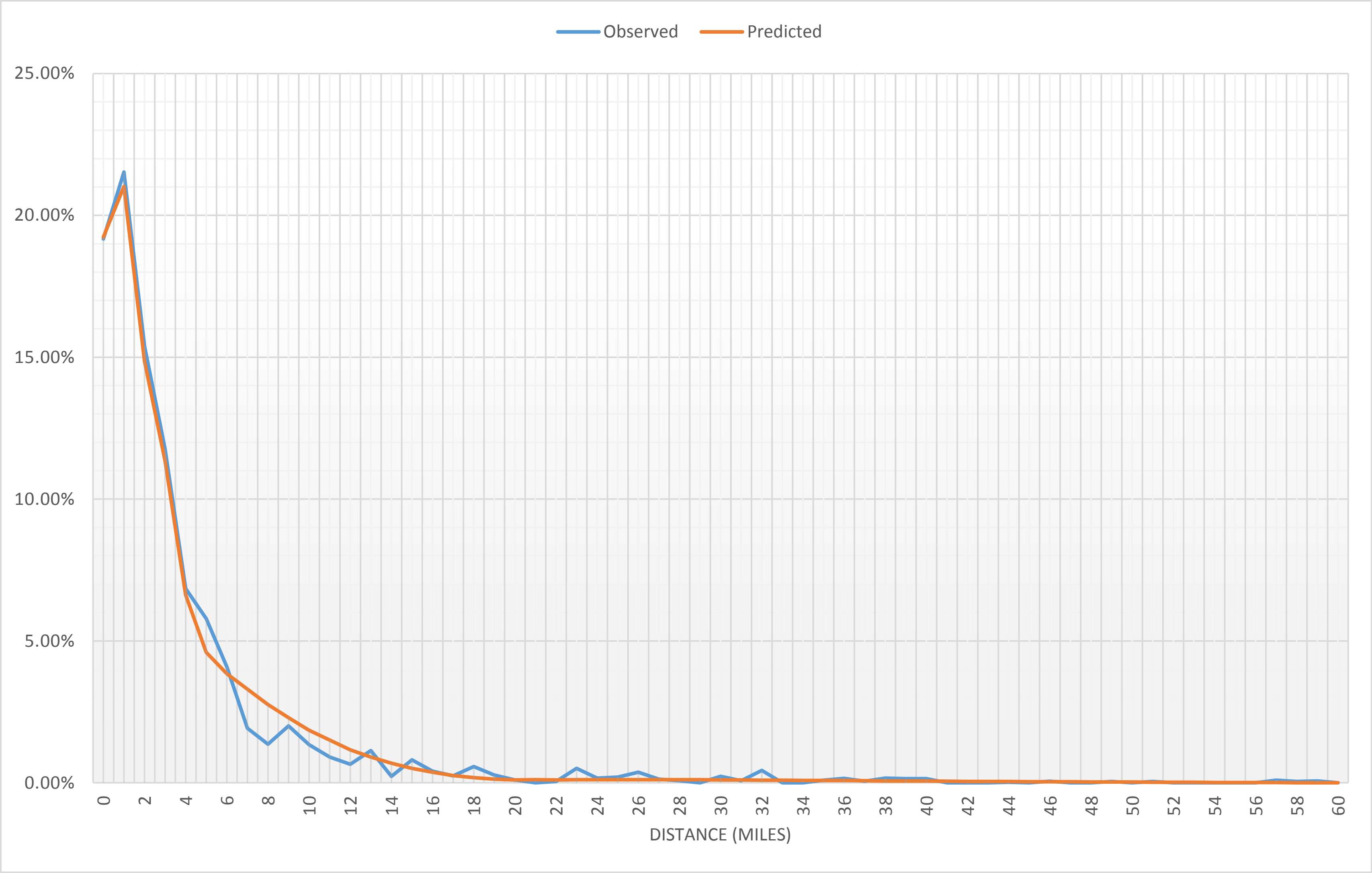


Figure 22: Tour Length Frequency Distribution: At-work Sub-Tours



We can see from **Figure 16** through **Figure 22** that the tour length frequency closely matches the observed distributions for all the tour purposes. Specifically, the observed escort tour purpose follows a step-like pattern for up to 10 miles while the estimated curve approximates this distribution with a smooth curve. This approximation results in slight over estimation of trips in the 0 to 2 miles and 9 to 16 miles range and underestimation of distances in between. The estimated maintenance purpose distribution also closely follows the observed data. The observed tour length frequency distribution for the maintenance purpose starts off by sloping up, peaks at 2 to 3 miles and then slopes down. In order to model this peak, bin-specific constants were introduced for the first three distance bins. In case of shopping tours, we are slightly underestimating some of the shorter tours while overestimating the longer tours (the differences between the observed and estimated shares for all bins are within 0.9% - the scale on the graph exacerbates this difference). Also, the observed tour length distribution of shopping tours peaks at 1 to 2 miles. To capture the shape of the distribution, bin-specific constants were introduced for the first four distance bins. The distribution of the eating out tours match the observed distributions reasonably well. The tail of the observed data exhibits spikes and the model does well to generate a curve that best fits the observed. Again, distance bin-specific constants for 1-mile bins up to 5 miles were necessary to get the peaks correct. The social tour length frequency is generally decreasing in nature. Hence, no distance bin-specific constants were necessary. The estimated curves approximates the spikes in the observed data – but we are slightly low on tours in the 0 to 1 mile bin. Estimated distributions for discretionary tours and at-work subtours match the observed distributions well – in both cases bin specific constants were applied for distance bins up to 5 miles.

Another measure of accuracy of these models are the average tour lengths. It is usually desired to get the average tour length of the models to within 5% of the observed or 0.5 miles whichever is smaller. The table below reports this information for the destination choice models discussed so far. We are well within the desirable limits for all tour purposes.

Table 16a: Average tour lengths for the different tour purpose (distances in miles)

Average tour length	Survey	Model	Difference	Percentage Difference
Escorting	5.376	5.373	-0.003	-0.05%
Maintenance	8.675	8.519	-0.156	-1.80%
Shopping	6.006	5.727	-0.279	-4.65%
Eatout	6.327	6.135	-0.193	-3.05%
Social	7.502	6.815	-0.687	-9.16%
Discretionary	6.534	6.299	-0.235	-3.60%
At-Work	4.627	4.496	-0.131	-2.84%

Table 16b: Final Adjustment Factors Applied to the Destination Choice Models

	Escort	Maintenance	Shopping	Eatout	Social	Discretionary	At-work
Distance Cap (miles)	35.000	34.000	37.000	33.000	20.000	33.000	20.000
Distance Coefficient							
Distance	0.255	-0.159	-0.108	-0.604	-0.265	0.016	0.136
Distance squared	-0.010	0.002	-0.003	0.016	0.000	-0.006	-0.012
Distance cubed ($x10^{-4}$)	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Log of distance	-2.529	-0.593	-0.957	-0.230	0.110	-0.993	-2.084
Distance Bin Constants							
0 to 1 mile		-0.268	-0.017	-0.267		-0.282	-0.266
1 to 2 miles		0.243	0.317	-0.170		0.025	0.743
2 to 3 miles		0.332	0.139	-0.499		0.167	0.665
3 to 4 miles			0.161	-0.239		0.224	0.630
4 to 5 miles				-0.111		0.505	0.226

Intermediate Stop Frequency Model

The individual tour stop frequency model predicts the number of stops for each person by primary tour purpose (work, school, university, shopping, escorting, maintenance, discretionary, visiting, and eating). The number of stops is predicted by tour direction – outbound (stops made between home and the primary destination) versus inbound (stops made on the way back home). Thus the models have 16 alternatives: the number of inbound (0 through 3) combined with the number of outbound (0 through 3) stops. The base alternative for calibrating the individual tour stop frequency model is the 0 outbound and 0 inbound stops alternative. Several runs through the model were done to achieve satisfactory levels of calibration.

Table 17a shows the 2011 ARC Regional Survey tour stop frequency percentages by tour purpose. **Table 17b** shows the estimated model tour stop frequency probabilities by tour purpose. The comparison of stop frequencies by tour purpose shows that the modeled probability of outbound and inbound stops for each purpose match closely to survey (**Table 17c**). **Table 17d** displays the final adjustment factors by tour purpose and stop frequency alternative.

Finally, **Table 17e** shows the average number of stops per tour by tour purpose generated by the calibrated model compared with the observed data. As expected, the model appears to generate the correct number of stops by tour purpose.

A few important points to note here:

1. In the observed data there were some tours with more than 3 stops on either legs. This was a small fraction of the total and hence were grouped together with the 3 outbound/inbound category as the case might be.
2. Many alternatives were turned off for all tour purposes except work. For this calibration, all 16 alternatives were turned on for all tour purposes as there were significant observed shares in each category. These alternatives attracted high calibration adjustments (for instance, note the constants on the alternatives with 3 stops in either direction). This is because the constants are the only factors that explains that alternative.

Intermediate Stop Purpose Choice Model

The stop purpose choice model is a lookup table of probabilities based upon tour purpose, stop direction, departure time, and person type. This table was updated with the latest survey. As these are based on observed distributions, no calibration was necessary here.

Table 17a: Survey Tour Stop Frequency by Tour Purpose

Stop Frequency	Work	University	School	Escort	Shop	Maintenance	Social/Eating Out	Discretionary	Work-Based
0 outbound, 0 inbound	54.88%	62.94%	74.87%	71.19%	43.25%	51.90%	73.28%	68.90%	77.84%
0 outbound, 1 inbound	14.88%	11.29%	10.93%	11.17%	11.66%	16.39%	6.91%	12.44%	8.64%
0 outbound, 2 inbound	4.69%	6.34%	3.40%	2.60%	3.54%	5.30%	1.65%	2.71%	1.50%
0 outbound, 3 inbound	2.91%	4.40%	1.53%	1.32%	1.52%	3.96%	0.71%	1.15%	0.77%
1 outbound, 0 inbound	7.17%	5.00%	4.33%	5.90%	15.79%	7.61%	8.20%	6.90%	5.30%
1 outbound, 1 inbound	5.11%	2.56%	3.03%	2.24%	6.37%	4.89%	3.38%	2.86%	2.80%
1 outbound, 2 inbound	2.13%	0.35%	0.48%	0.72%	2.79%	1.34%	0.52%	0.96%	0.26%
1 outbound, 3 inbound	1.12%	1.33%	0.25%	0.44%	1.26%	1.72%	0.06%	0.33%	0.55%
2 outbound, 0 inbound	1.88%	1.98%	0.39%	2.30%	5.09%	2.34%	2.20%	1.35%	1.31%
2 outbound, 1 inbound	1.42%	1.30%	0.31%	0.19%	2.18%	1.40%	0.75%	0.67%	0.20%
2 outbound, 2 inbound	0.79%	0.58%	0.27%	0.13%	0.87%	0.33%	0.47%	0.12%	0.02%
2 outbound, 3 inbound	0.41%	0.20%	0.00%	0.07%	0.65%	0.24%	0.26%	0.23%	0.19%
3 outbound, 0 inbound	1.06%	0.95%	0.08%	1.51%	2.63%	1.35%	1.10%	0.87%	0.30%
3 outbound, 1 inbound	0.67%	0.15%	0.01%	0.17%	1.42%	0.44%	0.30%	0.37%	0.23%
3 outbound, 2 inbound	0.48%	0.63%	0.03%	0.01%	0.46%	0.29%	0.17%	0.05%	0.05%
3 outbound, 3 inbound	0.40%	0.00%	0.10%	0.03%	0.54%	0.48%	0.03%	0.10%	0.04%

Table 17b: Model Individual Tour Stop Frequency by Tour Purpose

Stop Frequency	Work	University	School	Escort	Shop	Maintenance	Social/Eating Out	Discretionary	Work-Based
0 outbound, 0 inbound	55.06%	80.87%	75.27%	71.17%	43.30%	54.44%	72.47%	68.20%	78.15%
0 outbound, 1 inbound	14.83%	11.07%	10.21%	11.05%	11.66%	15.06%	7.14%	12.66%	8.47%
0 outbound, 2 inbound	4.66%	0.00%	3.65%	2.72%	3.44%	5.16%	1.62%	2.66%	1.52%
0 outbound, 3 inbound	2.90%	0.00%	1.59%	1.34%	1.55%	4.09%	0.72%	1.16%	0.75%
1 outbound, 0 inbound	7.13%	4.55%	4.04%	5.85%	15.73%	6.92%	8.80%	7.06%	5.19%
1 outbound, 1 inbound	5.08%	3.51%	2.82%	2.29%	6.37%	3.75%	3.49%	2.97%	2.78%
1 outbound, 2 inbound	2.16%	0.00%	0.46%	0.71%	2.84%	1.43%	0.55%	1.00%	0.25%
1 outbound, 3 inbound	1.12%	0.00%	0.29%	0.42%	1.25%	1.73%	0.06%	0.40%	0.53%
2 outbound, 0 inbound	1.87%	0.00%	0.43%	2.36%	5.08%	2.67%	2.12%	1.41%	1.32%
2 outbound, 1 inbound	1.44%	0.00%	0.31%	0.16%	2.12%	1.42%	0.79%	0.73%	0.20%
2 outbound, 2 inbound	0.78%	0.00%	0.28%	0.14%	0.95%	0.33%	0.47%	0.14%	0.02%
2 outbound, 3 inbound	0.40%	0.00%	0.40%	0.06%	0.67%	0.25%	0.25%	0.25%	0.20%
3 outbound, 0 inbound	1.06%	0.00%	0.09%	1.49%	2.56%	1.41%	1.07%	0.88%	0.31%
3 outbound, 1 inbound	0.66%	0.00%	0.01%	0.20%	1.47%	0.49%	0.26%	0.32%	0.23%
3 outbound, 2 inbound	0.46%	0.00%	0.02%	0.00%	0.47%	0.34%	0.16%	0.04%	0.05%
3 outbound, 3 inbound	0.38%	0.00%	0.12%	0.03%	0.54%	0.50%	0.03%	0.10%	0.04%

Table 17c: Difference in Probability of Individual Tour Stop Frequencies for Estimated vs. Observed

Stop Frequency	Work	University	School	Escort	Shop	Maintenance	Social/Eating Out	Discretionary	Work-Based
0 outbound, 0 inbound	0.18%	17.92%	0.41%	-0.02%	0.05%	2.54%	-0.81%	-0.71%	0.31%
0 outbound, 1 inbound	-0.05%	-0.22%	-0.72%	-0.12%	0.00%	-1.33%	0.23%	0.22%	-0.17%
0 outbound, 2 inbound	-0.02%	-6.34%	0.24%	0.12%	-0.10%	-0.14%	-0.03%	-0.05%	0.02%
0 outbound, 3 inbound	-0.01%	-4.40%	0.06%	0.02%	0.03%	0.13%	0.00%	0.01%	-0.03%
1 outbound, 0 inbound	-0.05%	-0.44%	-0.29%	-0.06%	-0.06%	-0.69%	0.60%	0.17%	-0.11%
1 outbound, 1 inbound	-0.03%	0.94%	-0.20%	0.05%	0.00%	-1.14%	0.11%	0.11%	-0.03%
1 outbound, 2 inbound	0.03%	-0.35%	-0.02%	-0.01%	0.06%	0.10%	0.04%	0.03%	-0.01%
1 outbound, 3 inbound	0.00%	-1.33%	0.04%	-0.02%	-0.01%	0.00%	-0.01%	0.08%	-0.01%
2 outbound, 0 inbound	-0.01%	-1.98%	0.04%	0.06%	-0.01%	0.33%	-0.07%	0.06%	0.01%
2 outbound, 1 inbound	0.03%	-1.30%	0.00%	-0.03%	-0.06%	0.01%	0.04%	0.06%	0.01%
2 outbound, 2 inbound	-0.01%	-0.58%	0.02%	0.01%	0.08%	-0.01%	-0.01%	0.03%	0.00%
2 outbound, 3 inbound	-0.02%	-0.20%	0.40%	-0.01%	0.02%	0.01%	-0.01%	0.02%	0.01%
3 outbound, 0 inbound	0.00%	-0.95%	0.01%	-0.02%	-0.06%	0.06%	-0.03%	0.01%	0.01%
3 outbound, 1 inbound	0.00%	-0.15%	0.00%	0.03%	0.05%	0.05%	-0.04%	-0.04%	-0.01%
3 outbound, 2 inbound	-0.02%	-0.63%	-0.01%	0.00%	0.01%	0.05%	-0.01%	-0.01%	0.00%
3 outbound, 3 inbound	-0.01%	0.00%	0.02%	0.00%	0.01%	0.02%	0.00%	0.00%	0.00%

Table 17d: Tour Stop Frequency Final Adjustment Factors by Tour Purpose

Stop Frequency	Work	University	School	Escort	Shop	Maintenance	Social/Eating Out	Discretionary	Work-Based
0 outbound, 0 inbound	BASE	BASE	BASE	BASE	BASE	BASE	BASE	BASE	BASE
0 outbound, 1 inbound	0.219	0	0.363	-0.145	0.067	0.015	-0.554	-0.031	0.525
0 outbound, 2 inbound	0.347	0	-1.563	-0.162	0.103	0.130	-3.788	-3.243	-3.944
0 outbound, 3 inbound	0.464	0	-2.382	-3.969	-0.175	-2.583	-4.620	-4.067	-4.634
1 outbound, 0 inbound	0.162	0	0.738	-0.433	0.247	0.079	-0.187	-0.005	0.112
1 outbound, 1 inbound	-0.071	0	0.807	1.938	1.096	0.613	-0.287	0.183	1.286
1 outbound, 2 inbound	0.147	0	-3.635	0.166	1.897	-3.648	-4.892	-4.201	-5.720
1 outbound, 3 inbound	-0.006	0	-4.111	-5.104	0.116	-3.439	-7.212	-5.164	-4.970
2 outbound, 0 inbound	0.570	0	-3.705	-0.017	-0.045	0.402	-3.528	-3.888	-4.078
2 outbound, 1 inbound	0.200	0	-4.005	-1.614	1.210	-3.627	-4.525	-4.516	-5.947
2 outbound, 2 inbound	0.572	0	-4.109	-6.273	-3.800	-5.095	-5.104	-6.255	-8.338
2 outbound, 3 inbound	0.314	0	-3.801	-7.089	-4.176	-5.358	-5.658	-5.634	-5.993
3 outbound, 0 inbound	0.660	0	-5.315	-3.880	0.241	-3.658	-4.214	-4.344	-5.579
3 outbound, 1 inbound	0.015	0	-7.774	-5.870	0.320	-4.688	-5.649	-5.332	-5.855
3 outbound, 2 inbound	0.527	0	-6.730	-9.637	-4.536	-5.067	-6.081	-7.579	-7.472
3 outbound, 3 inbound	0.556	0	-4.982	-7.839	-4.391	-4.692	-8.018	-6.525	-7.482

Table 17e: Average number of stops per tour by tour purpose

Tour Purpose	Observed	Estimated
Work	0.92	0.85
University	0.73	0.23
School	0.40	0.41
Escorting	0.48	0.46
Maintenance	0.97	0.88
Shopping	1.14	1.09
Eatout	0.47	0.46
Social	0.56	0.42
Discretionary	0.57	0.50
At-Work	0.37	0.34
Total	0.71	0.65

Intermediate Stop Location Choice Model

This model predicts the location of each intermediate stop (each location other than the primary destination) on the tour. The total stops is determined by the stop frequency model described just now. The ARC stop location model was calibrated to match distributions from the 2011 Regional Travel Survey. The stop location choice is determined based deviation from the shortest path to the primary destination from the current origin. This technique, also known as “rubber-banding” relies on out-of direction distance to determine the stops.

The calibration of the stop location choice model involves generating the out of direction distributions for the stops from the survey and comparing it with the observed data. The calibration process is similar to what was described for the tour destination choice model – the distance terms are adjusted using regression based adjustments till the shape of the observed curves and estimated curves converge. Additional, bin specific adjustments are incorporated to get the shape correct.

Figure 23 through **Figure 32** shows the results of this calibration – we are matching the shapes of the survey data distributions very closely.

The initial model was modified substantially to arrive at these results. First, the model used stop distance instead of out-of-direction distance to define distance based effects. However, stop distance is independent of tour length, and penalizes stop distance on long tours the same as stop distance on short tours. Out-of-direction distance penalizes stop distance on short tours more than stop distance on long tours. Hence polynomial terms of out-of-direction distance (OOD terms) were introduced into the model.

The initial distributions had excess of long out-of–direction distances (> 10 miles). Introducing the OOD terms resulted in some of the distributions to respond correctly while for the rest effect was minimal. On a closer inspection at the constants that were previously applied (the stop distance constants), it was found that the utility curve was of monotonically increasing nature. To remedy this, the linear distance term on the stop distance was set to zero for those purposes that were not responding to the OOD terms. These included University, school, escort and discretionary purposes. Additionally, the stop distance terms were capped at 8 miles for University and escort purposes to ensure a monotonically decreasing utility curve with respect to stop distance.

By now, the school model converged and no further changes was made to that model. A bin specific constant was added to the negative OOD all other purposes. The OOD distance term was capped to ensure a monotonically decreasing function with respect to OOD. Also, it was noticed that there was difficulty in matching the tails of the distribution for some purposes – the model was having a fatter tail than the survey distributions. In these cases, the coefficient on the logarithm term, if negative, was allowed to propagate till a distance of 50 miles. A bin specific constant for the distance range 0 to 1 miles was applied for the Discretionary tour purpose. **Table 18b** summarizes the constants applied.

Figure 23: Out-of-Direction Distance Distribution: Work Tours

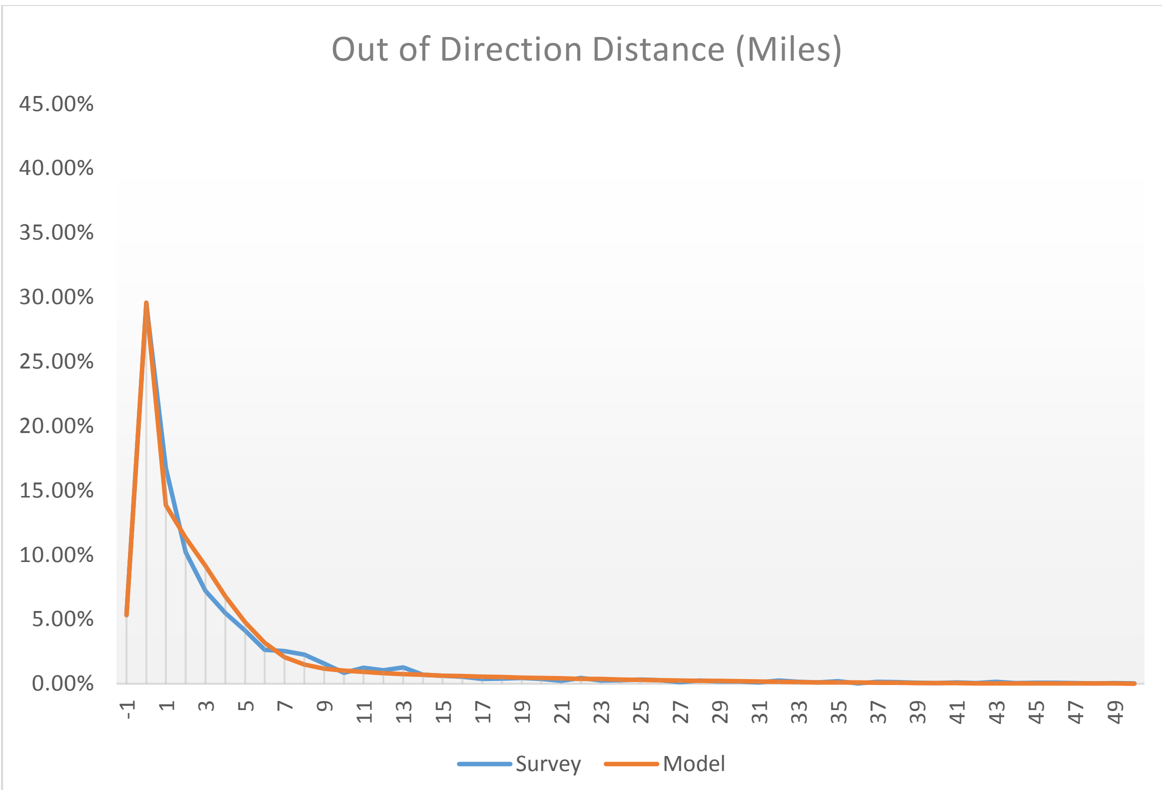


Figure 24: Out-of-Direction Distance Distribution: University Tours

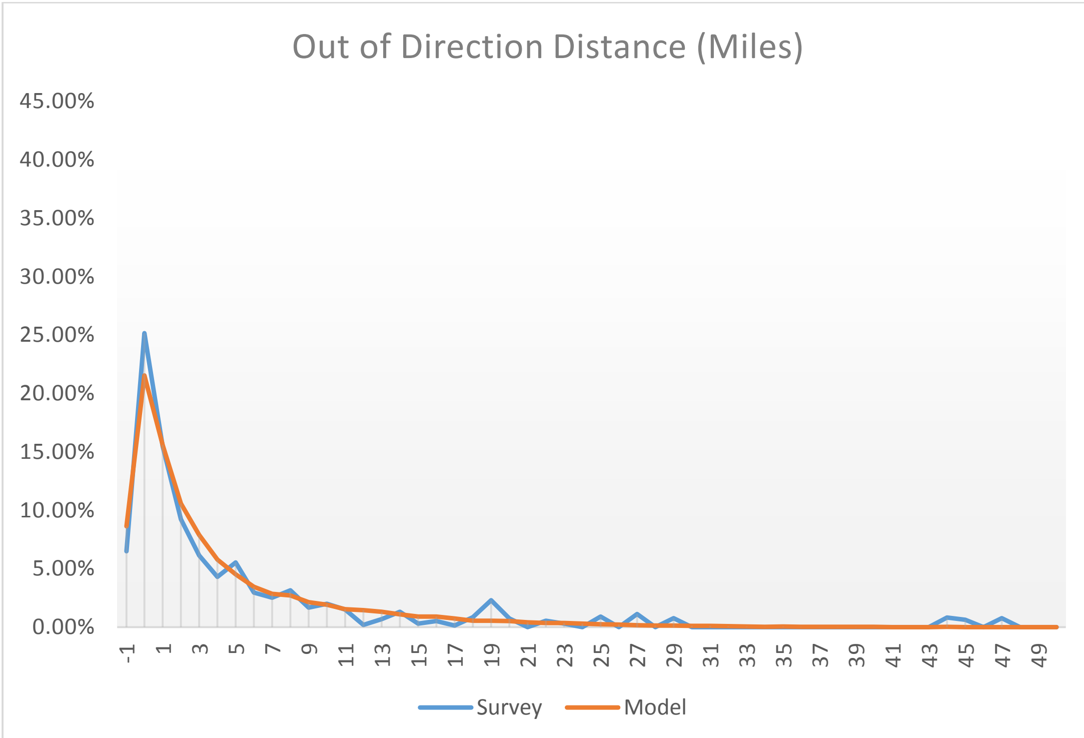


Figure 25: Out-of-Direction Distance Distribution: School Tours

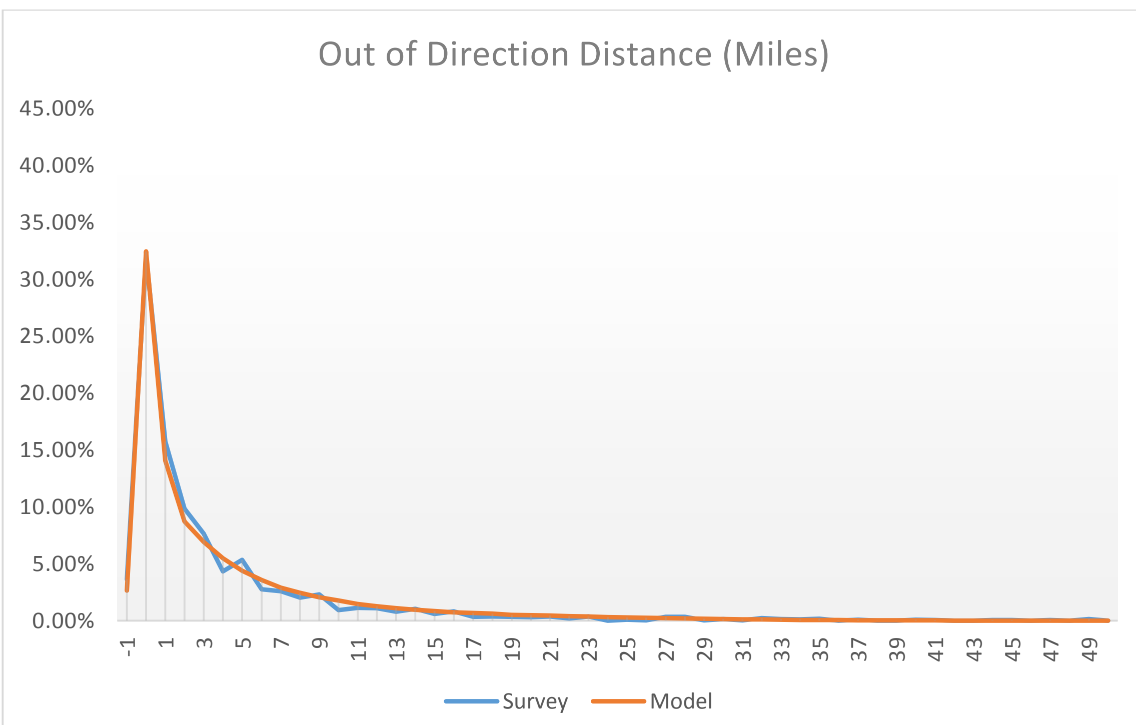


Figure 26: Out-of-Direction Distance Distribution: Escort Tours

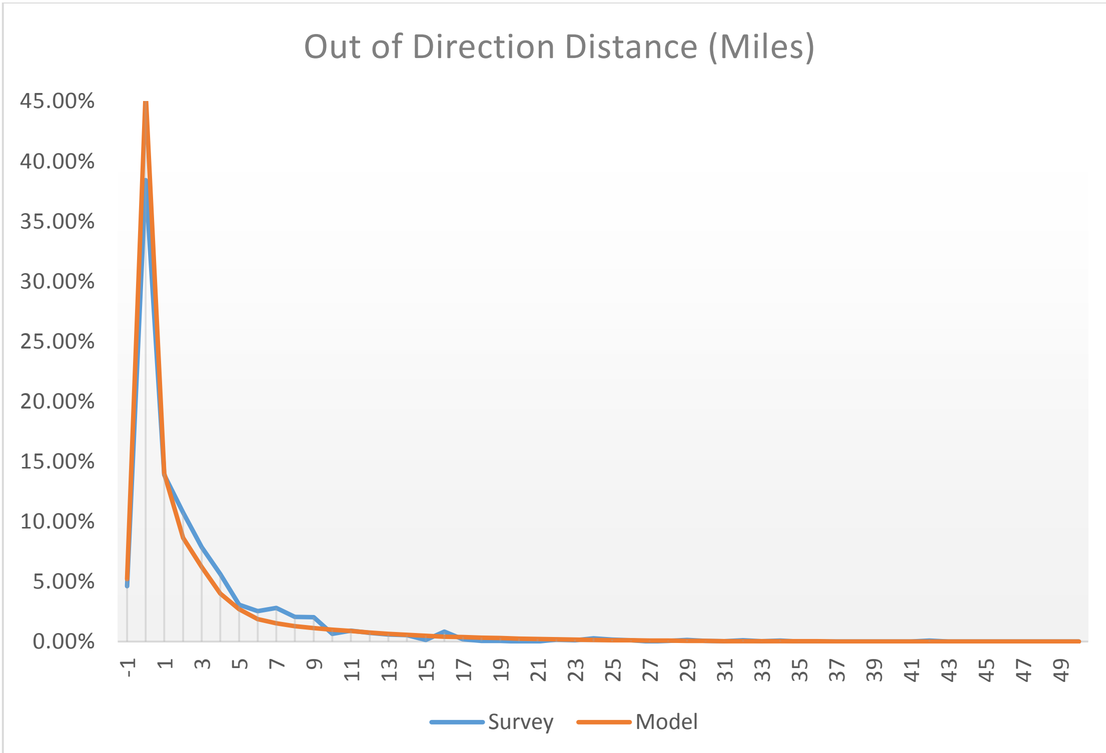


Figure 27: Out-of-Direction Distance Distribution: Maintenance Tours

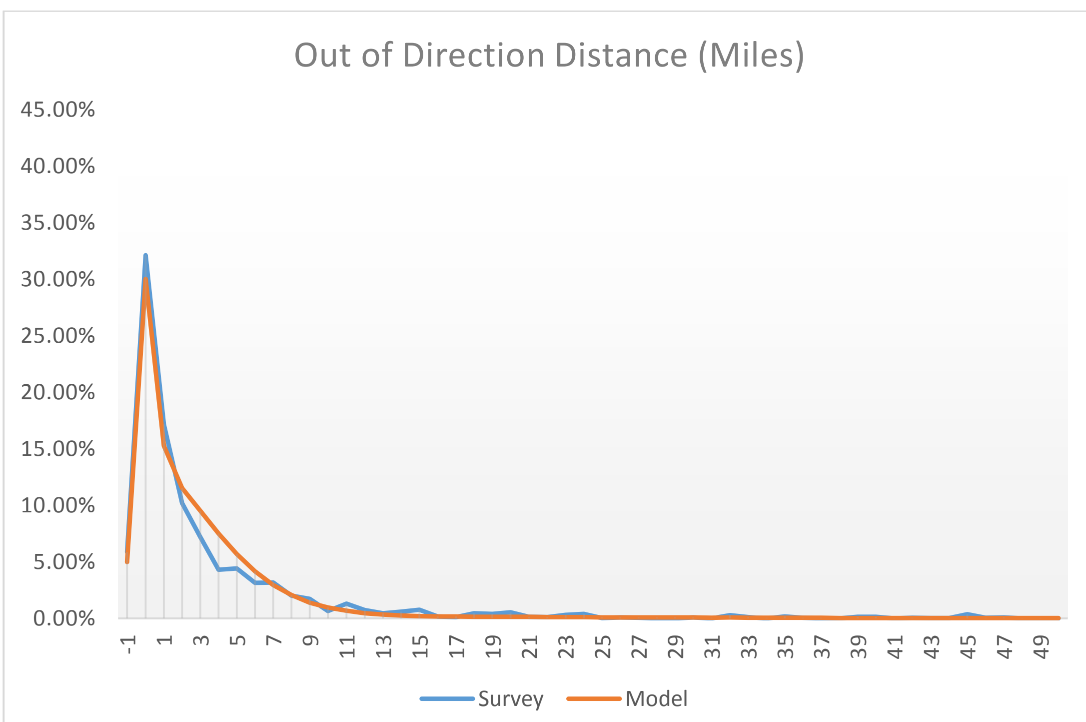


Figure 28: Out-of-Direction Distance Distribution: Shopping Tours

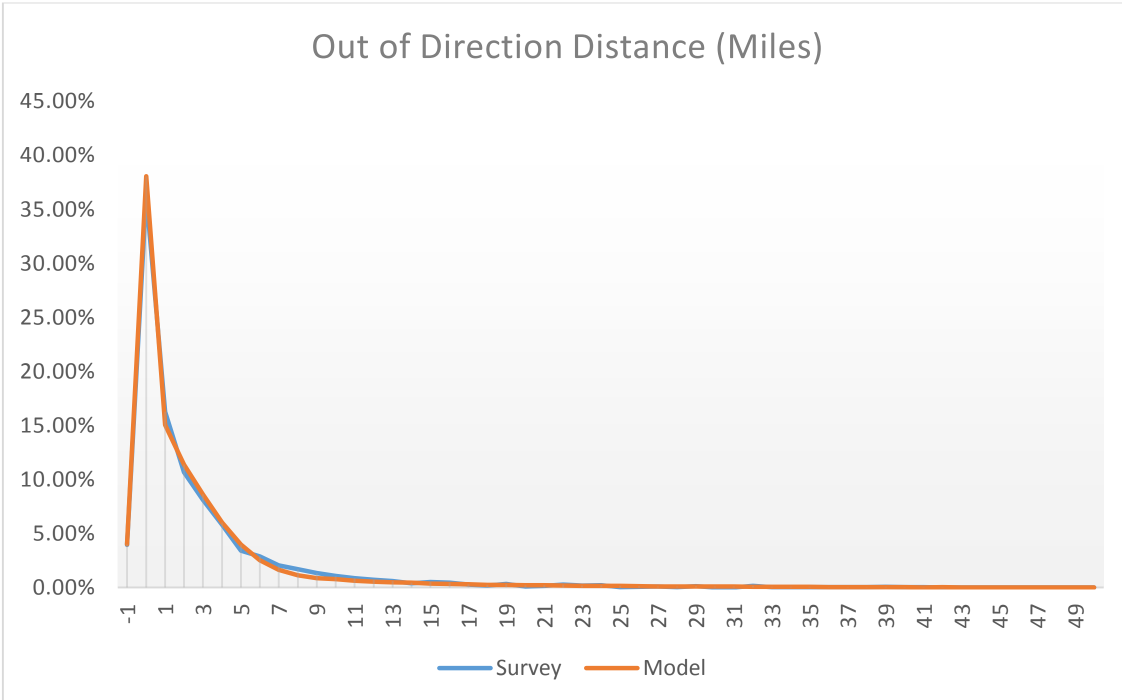


Figure 29: Out-of-Direction Distance Distribution: Eat-out Tours

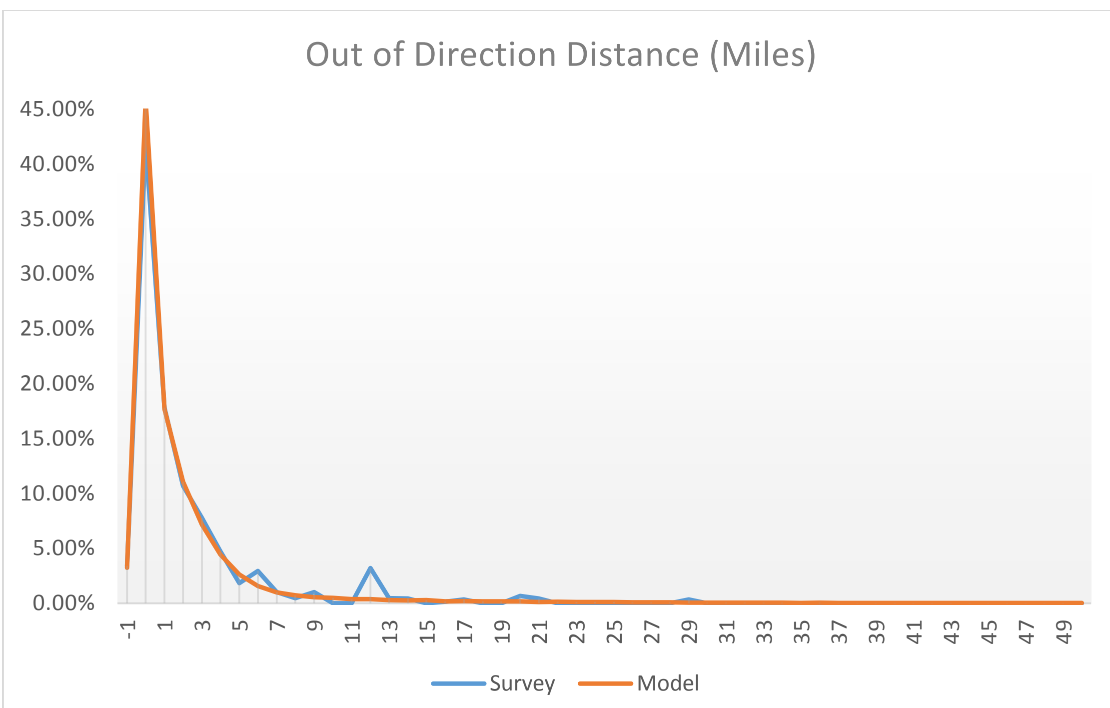


Figure 30: Out-of-Direction Distance Distribution: Social Tours

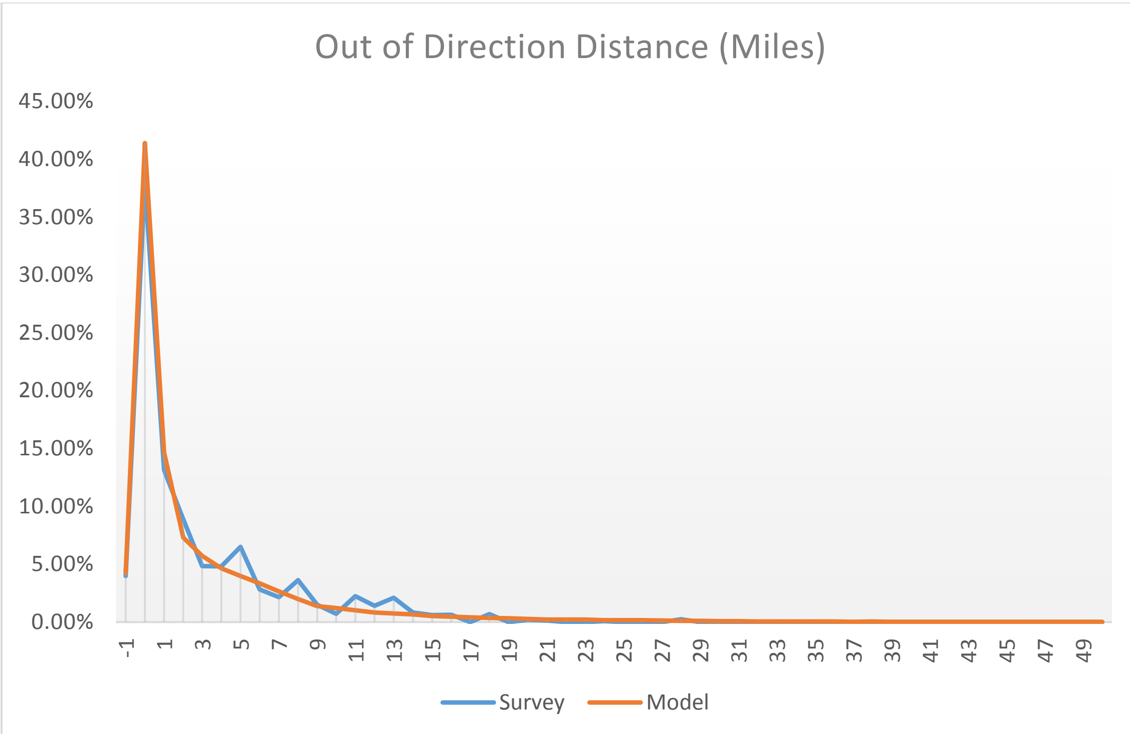


Figure 31: Out-of-Direction Distance Distribution: Discretionary Tours

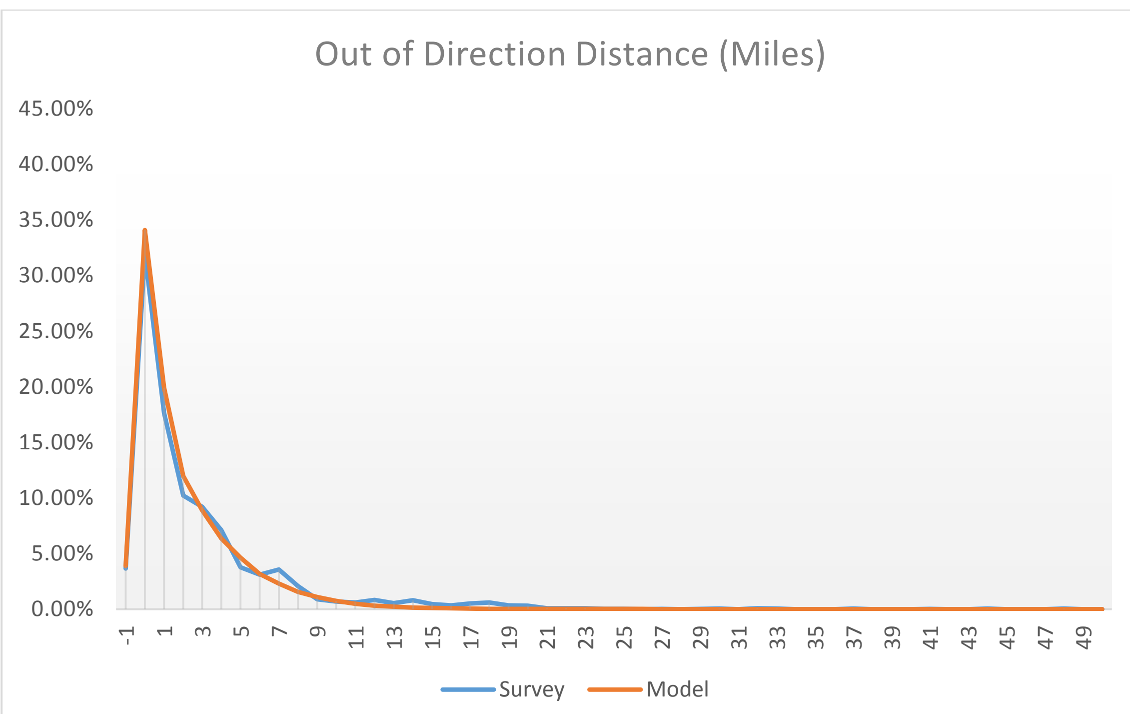


Figure 32: Out-of-Direction Distance Distribution: At-Work Tours

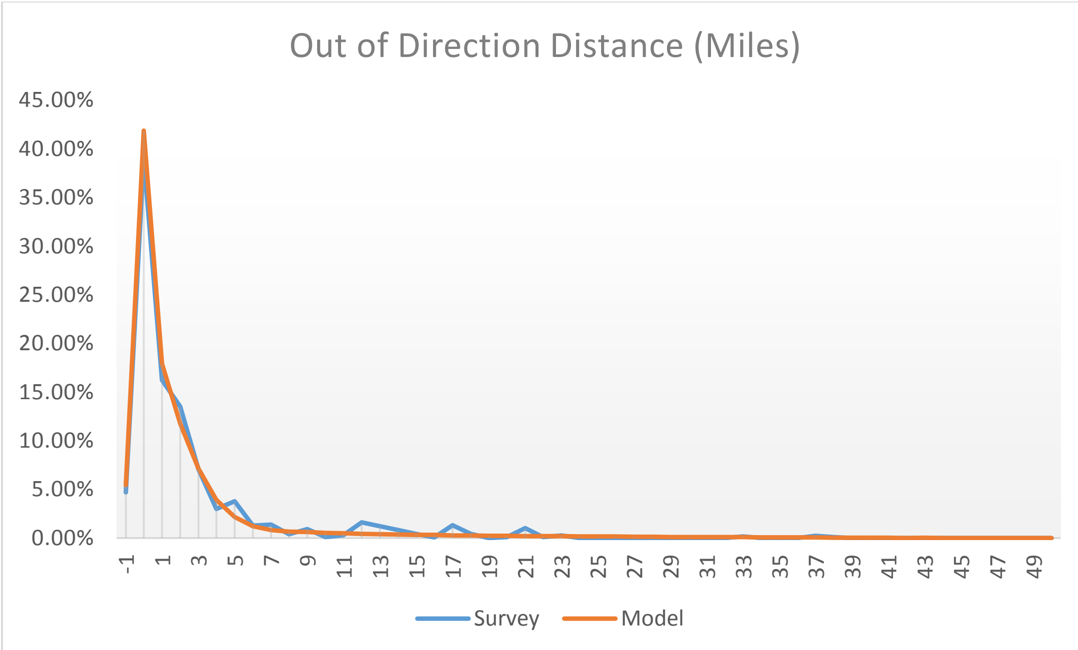


Table 18a presents the average out of direction distance by tour purpose. It is usually desired to get the average tour length of the models to within 5% of the observed or 0.5 miles whichever is smaller. The table below reports this information for the stop destination choice models. As can be seen we are close to 0.5 miles for most cases (except University)[3]. The purposes for which we are slightly over this are cases where the tail has spikes – it is possible to get those right by introducing more constants. But that approach would amount to a very restricted model with low elasticity. Based on the general shape of the modeled curves, it was deemed that the models are doing a good job predicting the stop locations.

Table 18a: Average out of direction distances by tour purpose (distances in miles)

Average tour length	Survey	Model	Difference	Percentage Difference
Work	4.743	4.277	-0.47	-9.82%
University	6.230	4.591	-1.64	-26.3%
School	4.574	4.699	0.13	2.74%
Escort	3.173	2.925	-0.25	-7.81%
Maintenance	3.889	3.306	-0.58	-14.99%
Shopping	3.367	3.221	-0.15	-4.35%
Eatout	2.857	2.438	-0.42	-14.66%
Social	3.491	3.454	-0.04	-1.05%
Discretionary	3.517	2.488	-1.03	-29.24%
At-work	3.155	2.848	-0.31	-9.73%

[3] Please note that the University observed distributions show sudden spikes for really long out-of-direction distances – the data for this model is not reliable enough to calibrate further.

Table 18b: Final Adjustment Factors Applied to the Stop Location Choice Models

	Work	University	School	Escort	Maintenance	Shopping	Eatout	Social	Discretionary	At-work
OOD Distance Cap (Miles)	10.000	10.000		11.000	16.000	9.000	9.000	9.000	27.000	9.000
Distance Coefficient										
OOD Distance	1.096	0.184	1.701	1.417	0.427	0.607	0.386	-0.437	0.158	0.008
OOD Distance squared	-0.191	-0.172	-0.310	-0.275	-0.064	-0.134	-0.127	0.109	-0.018	-0.129
OOD Distance cubed	0.009	0.010	0.016	0.015	0.002	0.007	0.008	-0.008	0.000	0.010
Log of OOD distance*	-0.737	1.755	-1.136	-0.891	-0.269	-0.272	-0.290	-0.108	-0.158	0.448
Distance Bin Constants										
Negative OOD	1.120	1.715	1.462	2.854	0.743	1.006	0.143	-0.072	-0.072	0.609
0 to 1 mile					-0.184				-0.574	
Negative propensity for OOD > 8 miles			-10.000							
Logarithm term applied to all distances				-0.322						

* The log term was allowed to propagate till 50 miles for work, university, escort, maintenance, shopping, eatout and social purposes.

Tour Mode Choice

The tour mode choice model uses a nested logit model to predict the tour mode for each tour. Tour mode share summaries were prepared by tour purpose and auto sufficiency. The data for the calibration of trip and tour mode choice uses the 2011 Regional Travel Survey as the primary source for the tour mode share information. The travel survey is a rich source of tour level information. However, the survey did not have sufficient coverage for transit trips – hence the 2010 Transit On-Board Survey data is used to augment the transit mode choice information. The transit survey is an origin destination based survey that gives us information about total transit trips. The following steps are used to process the transit trip data into tour data such that is consistent across the two datasets:

1. Summaries of the tour mode choice from the household survey was prepared by tour purpose and auto sufficiency. Transit trips by tour purpose and auto sufficiency are summarized from the on-board survey.

2. The summaries were inspected for logical consistency. The following updates were made to the summaries:
    a. The park and ride mode share for the school purpose was asserted as zero. Any observed data for this segment was added to the work tour as it is very likely that the survey was responded by individuals who worked at school (such as teachers) and hence got miscoded as school tours.
    b. The drive alone tour for joint tours was asserted as zero – the data was very sparse for this segment and hence there is no significant loss of data points because of this change.
    c. The drive alone tours under the zero auto household market were reallocated to the auto deficient market.
    d. School bus tours for non-school purposes were reallocated to the school tour purpose.

3. Next, the average number of trips per tour is derived for each access mode (walk access, park and ride, and kiss and ride) and tour purpose using the household survey. The implied number of transit tours from the on-board survey can be derived in a fairly straightforward manner by dividing the total transit trips by tour purpose and mode from the on-board survey by the average trips per tour by purpose and mode from the household survey. This approach ensures that the trips per tour is completely consistent with the home interview survey and that the transit tour targets are consistent with the transit trip targets observed in the on-board survey.
4. Further, the totals derived in step 3 were split into the different auto sufficiency segments based on the observed percentage of transit trips by your purpose, auto sufficiency and access mode as implied by the on board survey.
5. Finally, the number of transit tours by transit access mode and auto sufficiency were held fixed, and total tours for other modes were scaled to match the total number of tours generated in the model by tour purpose and auto sufficiency. This ensures that the total transit trips, which are based upon observed on-board survey data expanded to boardings, will be matched well when the model is applied.

A few changes were made to the model specification prior to calibration. Most of these changes were made based upon revisions made to the trip-based model to better match the transit on-board survey data. These include the following:

1) Transit alternatives were made consistent with the latest version of the trip-based model. The previous version of the model had two line-haul modes; local versus premium, The new specification also has two transit modes, all-transit (which includes local service with or without a premium transfer) versus premium-only (premium transit with no local transfers). The previous version also did not differentiate between park-and-ride versus kiss-and-ride; the new version does.
2) The previous version of the model had only two transit networks; A.M. Peak and Midday. The new transit networks are coded for all five time-of-day periods (Early A.M., A.M. Peak, Midday, P.M. Peak, Evening).
3) The previous version of the model used an auto operating cost of 8 cents per mile; the auto operating cost was updated to 13.85 cents/mile.
4) The new model specification includes revisions to model coefficients based upon the improvements made to the trip-based model, including:
    a. Changes to out-of-vehicle time parameters
    b. Mode-specific transit in-vehicle time factors
    c. Short transit trip disutility functions that vary by access mode
    d. A MARTA rail constant set at 1 minute of benefit for each minute of MARTA rail in-vehicle time, up to a maximum of 30 minutes of benefit at the tour level or 15 minutes of benefit at the trip level.

Base Category for Calibration

The tour mode choice model has all of the detailed modes represented in the trip mode choice model described below. The base modes include Drive alone, Shared Ride 2 Person, Shared Ride 3+, Bike, Walk, Walk-Transit, Park-and-Ride transit, and Kiss-and-Ride transit. Additionally, each auto mode includes both free and pay sub-modes, each transit mode includes both a all-transit and premium-only sub-mode option. However, the sub-modes are not considered in later models; in effect, even though utilities are being calculated for each sub-mode, only the base modes described above influence later choices such as stop location and trip mode.

The calibration process therefore focuses on matching the base modes by tour purpose and auto sufficiency. The sub-mode constants (such as the MARTA rail constant that measures the non-included attributes of MARTA rail compared to local bus) are introduced in tour mode choice, but held consistent from their calibrated trip mode choice value. That is, since tour mode choice is applied to round-trip travel characteristics, the sub-mode constants are doubled in terms of equivalent in-vehicle time minutes. This ensures consistent elasticities in tour mode choice and trip mode choice, and provides sensitivity in sub-mode options in tour mode choice, as well as time-of-day choice and destination choice through tour mode choice logsums. For the zero auto households market, Shared ride 2 person mode is used as the base category. In all other cases except for joint tours, the drive alone mode was held as the base category. For joint tours the shared ride 2 person mode is fixed as the base category for all auto sufficiency markets as drive alone is not available by default. In the next section the results of the calibration is discussed.

Tour Mode Choice Results

Table 19 through **Table 25** presents the tour mode calibration results for the tour purpose in this sequence: Work tours, University tours, School Tours, Individual non-mandatory tours, Joint non-mandatory tours and at-work subtours. For each tour purpose the following tables are documented:

Table a: Presents the targets for the calibration and the implied mode shares.

Table b: Presents the estimated number of tours by mode and the implied mode shares.

Table c: Presents the difference between the estimated and the observed data.

Table d: Presents the final adjustment factors applied to the model.

Table 19a. Tour Mode Choice by Auto Ownership – Observed Mode Shares Work Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers	Total	Zero Auto	Autos < Workers	Autos >= Workers	Total
Drive Alone	0	70,369	1,115,438	1,185,807	0%	43%	73%	68%
Shared2	15,440	51,862	244,170	311,472	31%	31%	16%	18%
Shared3+	5,486	20,997	118,217	144,699	11%	13%	8%	8%
Walk	3,489	3,140	7,170	13,799	7%	2%	0%	1%
Bike	0	1,990	9,212	11,202	0%	1%	1%	1%
Walk All Transit	20,209	7,522	6,626	34,356	41%	5%	0%	2%
Walk Premium Only	2,156	1,793	2,732	6,681	4%	1%	0%	0%
PNR All Transit	0	472	1,179	1,651	0%	0%	0%	0%
PNR Premium Only	0	3,149	15,919	19,068	0%	2%	1%	1%
KNR All Transit	1,766	1,552	1,544	4,862	4%	1%	0%	0%
KNR Premium Only	746	2,144	2,718	5,607	2%	1%	0%	0%
School Bus	0	0	0	0	0%	0%	0%	0%
Walk-Transit	22,365	9,315	9,358	41,037	90%	56%	30%	57%
PNR-Transit	0	3,621	17,098	20,719	0%	22%	56%	29%
KNR-Transit	2,512	3,696	4,261	10,469	10%	22%	14%	14%
Premium Transit	2,902	7,086	21,369	31,356	12%	43%	70%	43%
Total	49,291	164,988	1,524,924	1,739,203	100%	100%	100%	100%

Table 19b. Tour Mode Choice by Auto Ownership – Estimated Mode Shares Work Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers	Total	Zero Auto	Autos < Workers	Autos >= Workers	Total
Drive Alone	0	70,167	1,113,900	1,184,067	0%	43%	73%	68%
Shared2	15,042	52,375	244,664	312,081	31%	32%	16%	18%
Shared3+	5,223	20,810	119,139	145,172	11%	13%	8%	8%
Walk	3,373	3,016	7,283	13,672	7%	2%	0%	1%
Bike	0	1,815	9,324	11,139	0%	1%	1%	1%
Walk All Transit	19,508	7,362	6,091	32,961	40%	4%	0%	2%
Walk Premium Only	3,352	1,970	2,932	8,254	7%	1%	0%	0%
PNR All Transit	0	376	1,002	1,378	0%	0%	0%	0%
PNR Premium Only	0	3,253	16,308	19,561	0%	2%	1%	1%
KNR All Transit	1,641	1,893	1,911	5,445	3%	1%	0%	0%
KNR Premium Only	1,152	1,951	2,370	5,473	2%	1%	0%	0%
School Bus					0%	0%	0%	0%
Walk-Transit	22,860	9,332	9,023	41,215	89%	56%	29%	56%
PNR-Transit	0	3,629	17,310	20,939	0%	22%	57%	29%
KNR-Transit	2,793	3,844	4,281	10,918	11%	23%	14%	15%
Premium Transit	4,504	7,174	21,610	33,288	18%	54%	162%	64%
Total	49,291	164,988	1,524,924	1,739,203	100%	100%	100%	100%

Table 19c. Tour Mode Choice by Auto Ownership – Difference – Work Tours

	Absolute Difference				Percent Difference			
Mode	**Zero Auto**	**Autos < Workers**	**Autos >= Workers**	**Total**	**Zero Auto**	**Autos < Workers**	**Autos >= Workers**	**Total**
Drive Alone	0	-202	-1,538	-1,740	0%	0%	0%	0%
Shared2	-398	513	494	609	-3%	1%	0%	0%
Shared3+	-263	-187	922	473	-5%	-1%	1%	0%
Walk	-116	-124	113	-127	-3%	-4%	2%	-1%
Bike	0	-175	112	-63	0%	-9%	1%	-1%
Walk All Transit	-701	-160	-535	-1,395	-3%	-2%	-8%	-4%
Walk Premium Only	1,196	177	200	1,573	55%	10%	7%	24%
PNR All Transit	0	-96	-177	-273	0%	-20%	-15%	-17%
PNR Premium Only	0	104	389	493	0%	3%	2%	3%
KNR All Transit	-125	341	368	584	-7%	22%	24%	12%
KNR Premium Only	406	-193	-348	-134	54%	-9%	-13%	-2%
School Bus	0	0	0	0	0%	0%	0%	0%
Walk-Transit	495	18	-335	178	2%	0%	-4%	0%
PNR-Transit	0	8	212	220	0%	0%	1%	1%
KNR-Transit	281	149	20	450	11%	4%	0%	4%
Premium Transit	1,602	89	242	1,932	55%	1%	1%	6%
Total	0	0	0	0	0%	0%	0%	0%

Table 19d. Tour Mode Choice by Auto Ownership – Final Adjustments – Work Tours

Mode	**Zero Auto**	**Autos < Workers**	**Autos >= Workers**
Drive Alone		BASE	BASE
Shared2	BASE	-0.690	-1.372
Shared3+	-0.631	-1.243	-1.803
Walk	1.170	-0.873	-2.375
Bike	-999.000	-2.157	-3.133
Walk-Transit	8.189	3.600	0.260
PNR-Transit	-999.000	1.224	-0.933
KNR-Transit	4.341	1.319	-1.370
School Bus	--	--	--

Table 20a. Tour Mode Choice by Auto Ownership – Observed Mode Shares University Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers	Total	Zero Auto	Autos < Workers	Autos >= Workers	Total
Drive Alone	0	1,536	51,913	53,449	0%	21%	63%	55%
Shared2	1,222	878	13,851	15,952	15%	12%	17%	16%
Shared3+	0	0	6,421	6,421	0%	0%	8%	7%
Walk	0	141	828	969	0%	2%	1%	1%
Bike	968	0	962	1,930	12%	0%	1%	2%
Walk All Transit	4,071	2,037	2,559	8,667	51%	28%	3%	9%
Walk Premium Only	885	628	988	2,501	11%	9%	1%	3%
PNR All Transit	0	81	134	214	0%	1%	0%	0%
PNR Premium Only	0	984	2,834	3,818	0%	13%	3%	4%
KNR All Transit	496	579	625	1,699	6%	8%	1%	2%
KNR Premium Only	344	505	848	1,697	4%	7%	1%	2%
School Bus	0	0	0	0	0%	0%	0%	0%
Walk-Transit	4,956	2,665	3,547	11,167	86%	55%	44%	60%
PNR-Transit	0	1,065	2,968	4,032	0%	22%	37%	22%
KNR-Transit	840	1,084	1,473	3,396	14%	23%	18%	18%
Premium Transit	1,229	2,117	4,670	8,016	21%	44%	58%	43%
Total	7,985	7,368	81,962	97,315	100%	100%	100%	100%

Table 20b. Tour Mode Choice by Auto Ownership – Estimated Mode Shares University Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers	Total	Zero Auto	Autos < Workers	Autos >= Workers	Total
Drive Alone	0	1,355	51,837	53,192	0%	18%	63%	55%
Shared2	1,143	669	13,788	15,600	14%	9%	17%	16%
Shared3+	0	280	6,576	6,856	0%	4%	8%	7%
Walk	17	131	827	975	0%	2%	1%	1%
Bike	1,181	32	1,030	2,243	15%	0%	1%	2%
Walk All Transit	4,437	2,717	3,149	10,303	56%	37%	4%	11%
Walk Premium Only	356	186	426	968	4%	3%	1%	1%
PNR All Transit	0	696	570	1,266	0%	9%	1%	1%
PNR Premium Only	0	386	2,315	2,701	0%	5%	3%	3%
KNR All Transit	0	0	0	0	0%	0%	0%	0%
KNR Premium Only	851	916	1,444	3,211	11%	12%	2%	3%
School Bus					0%	0%	0%	0%
Walk-Transit	4,793	2,903	3,575	11,271	85%	59%	45%	61%
PNR-Transit	0	1,082	2,885	3,967	0%	22%	37%	22%
KNR-Transit	851	916	1,444	3,211	15%	19%	18%	17%
Premium Transit	1,207	1,488	4,185	6,880	21%	30%	53%	37%
Total	7,985	7,368	81,962	97,315	100%	100%	100%	100%

Table 20c. Tour Mode Choice by Auto Ownership – Difference – University Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers	Total	Zero Auto	Autos < Workers	Autos >= Workers	Total
Drive Alone	0	-181	-76	-257	0%	-12%	0%	0%
Shared2	-79	-209	-63	-352	-6%	-24%	0%	-2%
Shared3+	0	280	155	435	0%	0%	2%	7%
Walk	17	-10	-1	6	0%	-7%	0%	1%
Bike	213	32	68	313	22%	0%	7%	16%
Walk All Transit	367	680	590	1,637	9%	33%	23%	19%
Walk Premium Only	-529	-442	-562	-1,533	-60%	-70%	-57%	-61%
PNR All Transit	0	616	437	1,052	0%	765%	327%	492%
PNR Premium Only	0	-598	-519	-1,117	0%	-61%	-18%	-29%
KNR All Transit	-496	-579	-625	-1,699	-100%	-100%	-100%	-100%
KNR Premium Only	507	411	596	1,514	147%	81%	70%	89%
School Bus	0	0	0	0	0%	0%	0%	0%
Walk-Transit	-163	238	29	104	-3%	9%	1%	1%
PNR-Transit	0	18	-83	-65	0%	2%	-3%	-2%
KNR-Transit	12	-168	-29	-185	1%	-15%	-2%	-5%
Premium Transit	-22	-629	-485	-1,136	-2%	-30%	-10%	-14%
Total	0	0	0	0	0%	0%	0%	0%

Table 20d. Tour Mode Choice by Auto Ownership – Final Adjustments – University Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers
Drive Alone		BASE	BASE
Shared2	BASE	0.471	-0.686
Shared3+	-18.834	-0.109	-1.126
Walk	-6.596	-1.484	-6.779
Bike	-6.377	-6.852	-9.322
Walk-Transit	5.968	12.179	-0.120
PNR-Transit	-999.000	11.094	1.503
KNR-Transit	8.072	12.385	1.660
School Bus	--	--	--

Table 21a. Tour Mode Choice by Auto Ownership – Observed Mode Shares School Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers	Total	Zero Auto	Autos < Workers	Autos >= Workers	Total
Drive Alone	0	1,303	27,300	28,602	0%	2%	3%	3%
Shared2	2,595	3,665	128,517	134,777	6%	6%	14%	13%
Shared3+	770	12,356	231,573	244,699	2%	19%	25%	24%
Walk	3,453	3,081	16,441	22,975	8%	5%	2%	2%
Bike	0	115	4,239	4,354	0%	0%	0%	0%
Walk All Transit	4,951	2,031	3,146	10,128	11%	3%	0%	1%
Walk Premium Only	566	352	618	1,537	1%	1%	0%	0%
PNR All Transit	0	0	0	0	0%	0%	0%	0%
PNR Premium Only	0	0	0	0	0%	0%	0%	0%
KNR All Transit	424	431	787	1,641	1%	1%	0%	0%
KNR Premium Only	120	215	595	930	0%	0%	0%	0%
School Bus	32,772	41,468	508,628	582,868	72%	64%	55%	56%
Walk-Transit	5,517	2,383	3,765	11,665	91%	79%	73%	82%
PNR-Transit	0	0	0	0	0%	0%	0%	0%
KNR-Transit	544	646	1,382	2,571	9%	21%	27%	18%
Premium Transit	686	567	1,213	2,466	11%	19%	24%	17%
Total	45,650	65,016	921,845	1,032,511	100%	100%	100%	100%

Table 21b. Tour Mode Choice by Auto Ownership – Estimated Mode Shares School Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers	Total	Zero Auto	Autos < Workers	Autos >= Workers	Total
Drive Alone	0	1,343	25,946	27,289	0%	2%	3%	3%
Shared2	2,449	3,930	125,271	131,650	5%	6%	14%	13%
Shared3+	816	12,151	223,699	236,666	2%	19%	24%	23%
Walk	3,462	3,078	16,016	22,556	8%	5%	2%	2%
Bike	0	79	4,209	4,288	0%	0%	0%	0%
Walk All Transit	4,921	2,549	3,528	10,998	11%	4%	0%	1%
Walk Premium Only	435	140	224	799	1%	0%	0%	0%
PNR All Transit					0%	0%	0%	0%
PNR Premium Only					0%	0%	0%	0%
KNR All Transit	380	575	1,089	2,044	1%	1%	0%	0%
KNR Premium Only	89	121	364	574	0%	0%	0%	0%
School Bus	33,098	41,050	521,499	595,647	73%	63%	57%	58%
Walk-Transit	5,356	2,689	3,752	11,797	92%	79%	72%	82%
PNR-Transit	0	0	0	0	0%	0%	0%	0%
KNR-Transit	469	696	1,453	2,618	8%	21%	28%	18%
Premium Transit	524	261	588	1,373	9%	8%	11%	10%
Total	45,650	65,016	921,845	1,032,511	100%	100%	100%	100%

Table 21c. Tour Mode Choice by Auto Ownership – Difference – School Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers	Total	Zero Auto	Autos < Workers	Autos >= Workers	Total
Drive Alone	0	40	-1,354	-1,313	0%	3%	-5%	-5%
Shared2	-146	265	-3,246	-3,127	-6%	7%	-3%	-2%
Shared3+	46	-205	-7,874	-8,033	6%	-2%	-3%	-3%
Walk	9	-3	-425	-419	0%	0%	-3%	-2%
Bike	0	-36	-30	-66	0%	-31%	-1%	-2%
Walk All Transit	-30	518	382	870	-1%	26%	12%	9%
Walk Premium Only	-131	-212	-394	-738	-23%	-60%	-64%	-48%
PNR All Transit	0	0	0	0	0%	0%	0%	0%
PNR Premium Only	0	0	0	0	0%	0%	0%	0%
KNR All Transit	-44	145	303	403	-10%	34%	38%	25%
KNR Premium Only	-31	-94	-231	-356	-26%	-44%	-39%	-38%
School Bus	326	-418	12,871	12,779	1%	-1%	3%	2%
Walk-Transit	-161	306	-13	132	-3%	13%	0%	1%
PNR-Transit	0	0	0	0	0%	0%	0%	0%
KNR-Transit	-75	51	72	48	-14%	8%	5%	2%
Premium Transit	-162	-306	-625	-1,093	-24%	-54%	-52%	-44%
Total	0	0	0	0	0%	0%	0%	0%

Table 21d. Tour Mode Choice by Auto Ownership – Final Adjustments – School Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers
Drive Alone		BASE	BASE
Shared2	BASE	0.756	-0.763
Shared3+	-0.701	1.417	-0.413
Walk	-0.998	0.186	-3.553
Bike	-999.000	-4.537	-6.009
Walk-Transit	2.607	2.743	-1.341
PNR-Transit	-999.000	-0.831	-0.613
KNR-Transit	1.241	1.250	-2.342
School Bus	-0.939	-0.552	-3.279

Table 22a. Tour Mode Choice by Auto Ownership – Observed Mode Shares Individual Non-Mandatory Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers	Total	Zero Auto	Autos < Workers	Autos >= Workers	Total
Drive Alone	0	35,006	839,290	874,296	0%	30%	42%	40%
Shared2	22,231	41,285	539,990	603,507	27%	35%	27%	28%
Shared3+	12,014	28,019	514,079	554,111	15%	24%	26%	25%
Walk	29,698	7,763	71,210	108,671	36%	7%	4%	5%
Bike	1,473	481	9,458	11,413	2%	0%	0%	1%
Walk All Transit	14,076	2,611	4,091	20,779	17%	2%	0%	1%
Walk Premium Only	1,673	449	851	2,972	2%	0%	0%	0%
PNR All Transit	0	87	130	217	0%	0%	0%	0%
PNR Premium Only	0	259	889	1,148	0%	0%	0%	0%
KNR All Transit	1,314	398	800	2,512	2%	0%	0%	0%
KNR Premium Only	347	492	674	1,514	0%	0%	0%	0%
School Bus	0	0	0	0	0%	0%	0%	0%
Walk-Transit	15,749	3,060	4,942	23,751	90%	71%	66%	82%
PNR-Transit	0	346	1,019	1,365	0%	8%	14%	5%
KNR-Transit	1,660	890	1,474	4,025	10%	21%	20%	14%
Premium Transit	2,020	1,200	2,414	5,634	12%	28%	32%	19%
Total	82,826	116,851	1,981,462	2,181,139	100%	100%	100%	100%

Table 22b. Tour Mode Choice by Auto Ownership – Estimated Mode Shares Individual Non-Mandatory Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers	Total	Zero Auto	Autos < Workers	Autos >= Workers	Total
Drive Alone	0	35,508	844,584	880,092	0%	30%	43%	40%
Shared2	22,263	40,499	535,582	598,344	27%	35%	27%	27%
Shared3+	12,331	27,672	512,570	552,573	15%	24%	26%	25%
Walk	29,758	8,118	71,928	109,804	36%	7%	4%	5%
Bike	1,667	488	9,377	11,532	2%	0%	0%	1%
Walk All Transit	12,539	2,746	4,131	19,416	15%	2%	0%	1%
Walk Premium Only	2,532	685	949	4,166	3%	1%	0%	0%
PNR All Transit	0	60	195	255	0%	0%	0%	0%
PNR Premium Only	0	293	871	1,164	0%	0%	0%	0%
KNR All Transit	1,385	600	988	2,973	2%	1%	0%	0%
KNR Premium Only	351	182	287	820	0%	0%	0%	0%
School Bus					0%	0%	0%	0%
Walk-Transit	15,071	3,431	5,080	23,582	18%	81%	80%	86%
PNR-Transit	0	353	1,066	1,419	0%	100%	100%	100%
KNR-Transit	1,736	782	1,275	3,793	2%	19%	20%	14%
Premium Transit	2,883	1,160	2,107	6,150	17%	28%	33%	22%
Total	82,826	116,851	1,981,462	2,181,139	100%	100%	100%	100%

Table 22c. Tour Mode Choice by Auto Ownership – Difference – Individual Non-Mandatory Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers	Total	Zero Auto	Autos < Workers	Autos >= Workers	Total
Drive Alone	0	502	5,294	5,796	0%	1%	1%	1%
Shared2	32	-786	-4,408	-5,163	0%	-2%	-1%	-1%
Shared3+	317	-347	-1,509	-1,538	3%	-1%	0%	0%
Walk	60	355	718	1,133	0%	5%	1%	1%
Bike	194	7	-81	119	13%	1%	-1%	1%
Walk All Transit	-1,537	135	40	-1,363	-11%	5%	1%	-7%
Walk Premium Only	859	236	98	1,194	51%	53%	12%	40%
PNR All Transit	0	-27	65	38	0%	-31%	50%	18%
PNR Premium Only	0	34	-18	16	0%	13%	-2%	1%
KNR All Transit	71	202	188	461	5%	51%	23%	18%
KNR Premium Only	4	-310	-387	-694	1%	-63%	-57%	-46%
School Bus	0	0	0	0	0%	0%	0%	0%
Walk-Transit	-678	371	138	-169	-4%	12%	3%	-1%
PNR-Transit	0	7	47	54	0%	2%	5%	4%
KNR-Transit	76	-108	-199	-232	5%	-12%	-14%	-6%
Premium Transit	863	-40	-307	516	43%	-3%	-13%	9%
Total	0	0	0	0	0%	0%	0%	0%

Table 22d. Tour Mode Choice by Auto Ownership – Final Adjustments – Individual Non-Mandatory Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers
Drive Alone		BASE	BASE
Shared2	BASE	0.447	-0.605
Shared3+	-0.354	0.221	-0.631
Walk	4.389	2.715	0.974
Bike	-1.146	-1.586	-2.708
Walk-Transit	6.877	5.203	1.192
PNR-Transit	-999.000	2.893	-0.844
KNR-Transit	3.419	2.907	-1.091
School Bus	--	--	--

Table 23a. Tour Mode Choice by Auto Ownership – Observed Mode Shares Joint Non-Mandatory Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers	Total	Zero Auto	Autos < Workers	Autos >= Workers	Total
Drive Alone	0	0	0	0	0%	0%	0%	0%
Shared2	1,444	21,939	435,645	459,028	9%	38%	49%	48%
Shared3+	5,753	29,157	431,467	466,378	35%	50%	49%	48%
Walk	7,477	6,798	17,611	31,885	45%	12%	2%	3%
Bike	0	0	2,342	2,342	0%	0%	0%	0%
Walk All Transit	1,559	289	453	2,301	9%	0%	0%	0%
Walk Premium Only	219	59	111	389	1%	0%	0%	0%
PNR All Transit	0	10	14	24	0%	0%	0%	0%
PNR Premium Only	0	29	98	127	0%	0%	0%	0%
KNR All Transit	162	49	98	309	1%	0%	0%	0%
KNR Premium Only	43	61	83	186	0%	0%	0%	0%
School Bus	0	0	0	0	0%	0%	0%	0%
Walk-Transit	1,778	348	564	2,690	90%	70%	66%	81%
PNR-Transit	0	38	113	151	0%	8%	13%	5%
KNR-Transit	204	110	181	495	10%	22%	21%	15%
Premium Transit	262	148	293	702	13%	30%	34%	21%
Total	16,656	58,390	887,923	962,969	100%	100%	100%	100%

Table 23b. Tour Mode Choice by Auto Ownership – Estimated Mode Shares Joint Non-Mandatory Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers	Total	Zero Auto	Autos < Workers	Autos >= Workers	Total
Drive Alone					0%	0%	0%	0%
Shared2	1,626	23,210	437,172	462,008	10%	40%	49%	48%
Shared3+	5,530	27,768	430,427	463,725	33%	48%	48%	48%
Walk	7,483	6,785	17,467	31,735	45%	12%	2%	3%
Bike	0	0	2,000	2,000	0%	0%	0%	0%
Walk All Transit	1,447	391	490	2,328	9%	1%	0%	0%
Walk Premium Only	323	129	87	539	2%	0%	0%	0%
PNR All Transit	0	0	33	33	0%	0%	0%	0%
PNR Premium Only	0	3	113	116	0%	0%	0%	0%
KNR All Transit	157	73	126	356	1%	0%	0%	0%
KNR Premium Only	90	31	8	129	1%	0%	0%	0%
School Bus					0%	0%	0%	0%
Walk-Transit	1,770	520	577	2,867	88%	83%	67%	82%
PNR-Transit	0	3	146	149	0%	0%	17%	4%
KNR-Transit	247	104	134	485	12%	17%	16%	14%
Premium Transit	413	163	208	784	20%	26%	29%	23%
Total	16,656	58,390	887,923	962,969	100%	100%	100%	100%

Table 23c. Tour Mode Choice by Auto Ownership – Difference – Joint Non-Mandatory Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers	Total	Zero Auto	Autos < Workers	Autos >= Workers	Total
Drive Alone	0	0	0	0	0%	0%	0%	0%
Shared2	182	1,271	1,527	2,980	13%	6%	0%	1%
Shared3+	-223	-1,389	-1,040	-2,653	-4%	-5%	0%	-1%
Walk	6	-13	-144	-150	0%	0%	-1%	0%
Bike	0	0	-342	-342	0%	0%	-15%	-15%
Walk All Transit	-112	102	37	27	-7%	35%	8%	1%
Walk Premium Only	104	70	-24	150	48%	120%	-22%	39%
PNR All Transit	0	-10	19	9	0%	-100%	130%	37%
PNR Premium Only	0	-26	15	-11	0%	-90%	15%	-9%
KNR All Transit	-5	24	28	47	-3%	49%	28%	15%
KNR Premium Only	47	-30	-75	-57	111%	-49%	-90%	-31%
School Bus	0	0	0	0	0%	0%	0%	0%
Walk-Transit	-8	172	13	177	0%	49%	2%	7%
PNR-Transit	0	-35	33	-2	0%	-92%	29%	-1%
KNR-Transit	43	-6	-47	-10	21%	-5%	-26%	-2%
Premium Transit	151	15	-85	82	58%	10%	-29%	12%
Total	0	0	0	0	0%	0%	0%	0%

Table 23d. Tour Mode Choice by Auto Ownership – Final Adjustments – Joint Non-Mandatory Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers
Drive Alone		BASE	BASE
Shared2	BASE	-0.493	0.831
Shared3+	1.241	-1.522	0.386
Walk	7.434	1.941	1.548
Bike	-999.000	-999.000	-2.276
Walk-Transit	8.159	2.706	1.628
PNR-Transit	-999.000	-0.077	0.147
KNR-Transit	5.593	1.220	-0.320
School Bus	--	--	--

Table 24a. Tour Mode Choice by Auto Ownership – Observed Mode Shares At-Work Sub-Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers	Total	Zero Auto	Autos < Workers	Autos >= Workers	Total
Drive Alone	0	18,060	401,230	419,291	0%	35%	65%	62%
Shared2	3,819	12,744	94,921	111,484	40%	24%	15%	17%
Shared3+	0	1,985	59,282	61,267	0%	4%	10%	9%
Walk	4,909	15,553	56,600	77,062	52%	30%	9%	11%
Bike	0	3,417	138	3,555	0%	7%	0%	1%
Walk All Transit	469	296	223	987	5%	1%	0%	0%
Walk Premium Only	252	281	1,011	1,544	3%	1%	0%	0%
PNR All Transit	0	0	0	0	0%	0%	0%	0%
PNR Premium Only	0	0	0	0	0%	0%	0%	0%
KNR All Transit	0	0	0	0	0%	0%	0%	0%
KNR Premium Only	0	0	0	0	0%	0%	0%	0%
School Bus	0	0	0	0	0%	0%	0%	0%
Walk-Transit	721	577	1,233	2,530	100%	100%	100%	100%
PNR-Transit	0	0	0	0	0%	0%	0%	0%
KNR-Transit	0	0	0	0	0%	0%	0%	0%
Premium Transit	252	281	1,011	1,544	35%	49%	82%	61%
Total	9,448	52,337	613,403	675,188	100%	100%	100%	100%

Table 24b. Tour Mode Choice by Auto Ownership – Estimated Mode Shares At-Work Sub-Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers	Total	Zero Auto	Autos < Workers	Autos >= Workers	Total
Drive Alone	0	18,235	401,175	419,410	0%	35%	65%	62%
Shared2	3,671	12,547	93,750	109,968	39%	24%	15%	16%
Shared3+	0	1,885	60,876	62,761	0%	4%	10%	9%
Walk	4,984	15,757	56,130	76,871	53%	30%	9%	11%
Bike	0	3,288	131	3,419	0%	6%	0%	1%
Walk All Transit	612	425	750	1,787	6%	1%	0%	0%
Walk Premium Only	181	200	591	972	2%	0%	0%	0%
PNR All Transit					0%	0%	0%	0%
PNR Premium Only					0%	0%	0%	0%
KNR All Transit					0%	0%	0%	0%
KNR Premium Only					0%	0%	0%	0%
School Bus					0%	0%	0%	0%
Walk-Transit	793	625	1,341	2,759	100%	100%	100%	100%
PNR-Transit	0	0	0	0	0%	0%	0%	0%
KNR-Transit	0	0	0	0	0%	0%	0%	0%
Premium Transit	181	200	591	972	23%	32%	44%	35%
Total	9,448	52,337	613,403	675,188	100%	100%	100%	100%

Table 24c. Tour Mode Choice by Auto Ownership – Difference – At-Work Sub-Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers	Total	Zero Auto	Autos < Workers	Autos >= Workers	Total
Drive Alone	0	175	-55	119	0%	1%	0%	0%
Shared2	-148	-197	-1,171	-1,516	-4%	-2%	-1%	-1%
Shared3+	0	-100	1,594	1,494	0%	-5%	3%	2%
Walk	75	204	-470	-191	2%	1%	-1%	0%
Bike	0	-129	-7	-136	0%	-4%	-5%	-4%
Walk All Transit	144	130	528	801	31%	44%	237%	81%
Walk Premium Only	-71	-81	-420	-572	-28%	-29%	-42%	-37%
PNR All Transit	0	0	0	0	0%	0%	0%	0%
PNR Premium Only	0	0	0	0	0%	0%	0%	0%
KNR All Transit	0	0	0	0	0%	0%	0%	0%
KNR Premium Only	0	0	0	0	0%	0%	0%	0%
School Bus	0	0	0	0	0%	0%	0%	0%
Walk-Transit	73	49	108	229	10%	8%	9%	9%
PNR-Transit	0	0	0	0	0%	0%	0%	0%
KNR-Transit	0	0	0	0	0%	0%	0%	0%
Premium Transit	-71	-81	-420	-572	-28%	-29%	-42%	-37%
Total	0	0	0	0	0%	0%	0%	0%

Table 24d. Tour Mode Choice by Auto Ownership – Final Adjustments – At-Work Sub-Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers
Drive Alone		BASE	BASE
Shared2		-1.331	-1.930
Shared3+	-999.000	-2.484	-2.194
Walk	5.444	2.603	-0.382
Bike	-999.000	-1.262	-6.827
Walk-Transit	4.982	1.775	-0.902
PNR-Transit	--	--	--
KNR-Transit	--	--	--
School Bus	--	--	--

Table 25a. Tour Mode Choice by Auto Ownership – Observed Mode Shares All Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers	Total	Zero Auto	Autos < Workers	Autos >= Workers	Total
Drive Alone	0	126,274	2,435,171	2,561,445	0%	27%	41%	38%
Shared2	46,751	132,374	1,457,094	1,636,219	22%	28%	24%	24%
Shared3+	24,023	92,514	1,361,039	1,477,575	11%	20%	23%	22%
Walk	49,025	36,476	169,861	255,361	23%	8%	3%	4%
Bike	2,441	6,003	26,351	34,796	1%	1%	0%	1%
Walk All Transit	45,334	14,786	17,097	77,217	21%	3%	0%	1%
Walk Premium Only	5,751	3,561	6,310	15,623	3%	1%	0%	0%
PNR All Transit	0	650	1,457	2,106	0%	0%	0%	0%
PNR Premium Only	0	4,421	19,741	24,161	0%	1%	0%	0%
KNR All Transit	4,161	3,008	3,853	11,021	2%	1%	0%	0%
KNR Premium Only	1,599	3,416	4,918	9,933	1%	1%	0%	0%
School Bus	32,772	41,468	508,628	582,868	15%	9%	8%	9%
Walk-Transit	51,085	18,347	23,408	92,839	90%	61%	44%	66%
PNR-Transit	0	5,070	21,197	26,267	0%	17%	40%	19%
KNR-Transit	5,760	6,424	8,771	20,955	10%	22%	16%	15%
Premium Transit	7,350	11,398	30,969	49,717	13%	38%	58%	35%
Total	211,856	464,950	6,011,519	6,688,325	100%	100%	100%	100%

Table 25b. Tour Mode Choice by Auto Ownership – Estimated Mode Shares All Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers	Total	Zero Auto	Autos < Workers	Autos >= Workers	Total
Drive Alone	0	126,608	2,437,442	2,564,050	0%	27%	41%	38%
Shared2	46,194	133,230	1,450,227	1,629,651	22%	29%	24%	24%
Shared3+	23,900	90,566	1,353,287	1,467,753	11%	19%	23%	22%
Walk	49,077	36,885	169,651	255,613	23%	8%	3%	4%
Bike	2,848	5,702	26,071	34,621	1%	1%	0%	1%
Walk All Transit	43,464	16,190	18,139	77,793	21%	3%	0%	1%
Walk Premium Only	7,179	3,310	5,209	15,698	3%	1%	0%	0%
PNR All Transit	0	1,132	1,800	2,932	0%	0%	0%	0%
PNR Premium Only	0	3,935	19,607	23,542	0%	1%	0%	0%
KNR All Transit	3,563	3,141	4,114	10,818	2%	1%	0%	0%
KNR Premium Only	2,533	3,201	4,473	10,207	1%	1%	0%	0%
School Bus	33,098	41,050	521,499	595,647	16%	9%	9%	9%
Walk-Transit	50,643	19,500	23,348	93,491	89%	63%	44%	66%
PNR-Transit	0	5,067	21,407	26,474	0%	16%	40%	19%
KNR-Transit	6,096	6,342	8,587	21,025	11%	21%	16%	15%
Premium Transit	9,712	10,446	29,289	49,447	17%	40%	92%	43%
Total	211,856	464,950	6,011,519	6,688,325	100%	100%	100%	100%

Table 25c. Tour Mode Choice by Auto Ownership – Difference – All Tours

Mode	Zero Auto	Autos < Workers	Autos >= Workers	Total	Zero Auto	Autos < Workers	Autos >= Workers	Total
Drive Alone	0	334	2,271	2,605	0%	0%	0%	0%
Shared2	-557	856	-6,867	-6,568	-1%	1%	0%	0%
Shared3+	-123	-1,948	-7,752	-9,822	-1%	-2%	-1%	-1%
Walk	52	409	-210	252	0%	1%	0%	0%
Bike	407	-301	-280	-175	17%	-5%	-1%	-1%
Walk All Transit	-1,870	1,405	1,042	576	-4%	9%	6%	1%
Walk Premium Only	1,428	-251	-1,101	75	25%	-7%	-17%	0%
PNR All Transit	0	483	344	826	0%	74%	24%	39%
PNR Premium Only	0	-486	-134	-619	0%	-11%	-1%	-3%
KNR All Transit	-598	133	261	-203	-14%	4%	7%	-2%
KNR Premium Only	934	-215	-445	274	58%	-6%	-9%	3%
School Bus	326	-418	12,871	12,779	1%	-1%	3%	2%
Walk-Transit	-442	1,153	-60	652	-1%	6%	0%	1%
PNR-Transit	0	-3	210	207	0%	0%	1%	1%
KNR-Transit	336	-82	-184	70	6%	-1%	-2%	0%
Premium Transit	2,362	-952	-1,680	-270	32%	-8%	-5%	-1%
Total	0	0	0	0	0%	0%	0%	0%

Trip Mode Choice Model

The trip mode choice model determines the mode used by the individual at the trip level. This uses a "mode-switching" framework. In essence, it computes the probability of a trip mode being chosen conditional on the tour mode. This model was calibrated to ensure the trip mode shares match by tour purpose and tour mode.

Similar to the tour mode choice model the calibration targets for the trip mode choice model uses both the 2011 Regional Travel Survey and the 2010 Transit On-Board Survey. The approach to create the trip mode choice calibration targets is similar to those already described above under tour mode choice. Note that if there were no household survey transit trips observed for a specific mode, symmetry (no mode switching) was assumed.

The base alternative for calibrating the trip mode choice model was as follows:

- For drive-alone tours, the base alternative was the drive alone trip mode
- For shared-ride 2 tours, the base alternative was shared-ride two-person trip mode
- For shared-ride 3+ person tours, the base alternative was the shared-ride three-plus trip mode
- For walk tours – no mode switching is allowed
- For walk-transit tours, the base alternative was the walk-transit trip mode
- PNR and KNR assumes symmetry – hence no constants were applied.

Trip Mode Choice Results

Table 26 through **Table 31** presents the trip mode calibration results for the tour purposes in this sequence: Work tours, University tours, School Tours, Individual non-mandatory tours, Joint non-mandatory tours and At-work subtours. For each tour purpose the following tables are documented:

Table a: Presents the trip mode choice calibration targets in terms of total trips.

Table b: Presents the trip mode choice target trip mode shares.

Table c: Presents the trip mode choice model results in terms of total trips.

Table d: Presents the trip mode choice model results mode shares.

Table e: Presents the difference between the model and the target number of trips.

Table f: Presents the difference in the percentage shares between the model and the observed data.

Table g: Presents the final adjustment factors applied to the model by tour mode and trip mode

Table 26a. Trip Mode Choice by Tour Purpose and Tour Mode – Observed Trip Mode Summary: Work Tours

	Trip Mode													Transit Totals		
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	Wlk-Trn	PNR	
SOV	3,393,892	-	-	-	-	-	-	-	-	-	-	-	3,393,892	-	-	
SR2	403,109	491,223	-	7,540	-	-	-	-	-	-	-	-	901,872	-	-	
SR3+	168,908	67,470	181,692	2,235	-	-	-	-	-	-	-	-	420,305	-	-	
Walk	-	-	-	31,107	-	-	-	-	-	-	-	-	31,107	-	-	
Bike	-	-	-	1,031	24,535	-	-	-	-	-	-	-	25,566	-	-	
Walk-Transit	-	8,522	1,605	23,213	-	68,712	13,362	-	-	-	-	-	115,414	82,074	-	
PNR-Transit	-	-	-	-	-	-	-	3,056	35,678	-	-	-	38,734	-	38,734	
KNR-Transit	-	-	-	-	-	-	-	-	-	9,723	11,214	-	20,937	-	-	2
Sch Bus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	3,965,909	567,215	183,297	65,126	24,535	68,712	13,362	3,056	35,678	9,723	11,214	-	4,947,827	82,074	38,734	2

Table 26b. Trip Mode Choice by Tour Purpose and Tour Mode – Observed Trip Mode Shares: Work Tours

	Trip Mode													Transit Totals		
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	Wlk-Trn	PNR	KNR
SOV	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
SR2	45%	54%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
SR3+	40%	16%	43%	1%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Bike	0%	0%	0%	4%	96%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk-Transit	0%	7%	1%	20%	0%	60%	12%	0%	0%	0%	0%	0%	100%	71%	0%	0%
PNR-Transit	0%	0%	0%	0%	0%	0%	0%	8%	92%	0%	0%	0%	100%	0%	100%	0%
KNR-Transit	0%	0%	0%	0%	0%	0%	0%	0%	0%	46%	54%	0%	100%	0%	0%	100%
Sch Bus	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total	80%	11%	4%	1%	0%	1%	0%	0%	1%	0%	0%	0%	100%	2%	1%	0%

Table 26c. Trip Mode Choice by Tour Purpose and Tour Mode – Estimated Trip Mode Summary: Work Tours

	Trip Mode												
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total
SOV	3,393,892	-	-	-	-	-	-	-	-	-	-	-	3,393,892
SR2	402,927	491,403	-	7,542	-	-	-	-	-	-	-	-	901,872
SR3+	168,446	67,818	181,740	2,301	-	-	-	-	-	-	-	-	420,305
Walk	-	-	-	31,107	-	-	-	-	-	-	-	-	31,107
Bike	-	-	-	980	24,586	-	-	-	-	-	-	-	25,566
Walk-Transit	-	8,667	1,543	23,854	-	62,079	19,271	-	-	-	-	-	115,414
PNR-Transit	-	-	-	-	-	-	-	2,986	38,892	-	-	-	41,878
KNR-Transit	-	-	-	-	-	-	-	-	-	10,721	11,115	-	21,836
Sch Bus	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	3,965,265	567,888	183,283	65,784	24,586	62,079	19,271	2,986	38,892	10,721	11,115	-	4,951,870

Table 26d. Trip Mode Choice by Tour Purpose and Tour Mode – Estimated Trip Mode Shares: Work Tours

	Trip Mode													Transit Totals		
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	Wlk-Trn	PNR	KNR
SOV	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
SR2	45%	54%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
SR3+	40%	16%	43%	1%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Bike	0%	0%	0%	4%	96%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk-Transit	0%	8%	1%	21%	0%	54%	17%	0%	0%	0%	0%	0%	100%	70%	0%	0%
PNR-Transit	0%	0%	0%	0%	0%	0%	0%	7%	93%	0%	0%	0%	100%	0%	100%	0%
KNR-Transit	0%	0%	0%	0%	0%	0%	0%	0%	0%	49%	51%	0%	100%	0%	0%	100%
Sch Bus	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%

	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	Wlk-Trn	PNR	KNR
Total	80%	11%	4%	1%	0%	1%	0%	0%	1%	0%	0%	0%	100%	2%	1%	0%

Table 26e. Trip Mode Choice by Tour Purpose and Tour Mode – Difference in number of trips: Work Tours

	Trip Mode												
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total
SOV	-	-	-	-	-	-	-	-	-	-	-	-	-
SR2	(182)	180	-	2	-	-	-	-	-	-	-	-	-
SR3+	(462)	348	48	66	-	-	-	-	-	-	-	-	-
Walk	-	-	-	-	-	-	-	-	-	-	-	-	-
Bike	-	-	-	(51)	51	-	-	-	-	-	-	-	-
Walk-Transit	-	145	(62)	641	-	(6,633)	5,909	-	-	-	-	-	-
PNR-Transit	-	-	-	-	-	-	-	(70)	3,214	-	-	-	3,144
KNR-Transit	-	-	-	-	-	-	-	-	-	998	(99)	-	899
Sch Bus	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	(644)	673	(14)	658	51	(6,633)	5,909	(70)	3,214	998	(99)	-	4,043

Table 26f. Trip Mode Choice by Tour Purpose and Tour Mode – Difference in shares: Work Tours

	Trip Mode													Transit Totals		
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	Wlk-Trn	PNR	KNR
SOV	0.0%	-	-	-	-	-	-	-	-	-	-	-	0.0%	-	-	-
SR2	0.0%	0.0%	-	0.0%	-	-	-	-	-	-	-	-	0.0%	-	-	-
SR3+	-0.3%	0.5%	0.0%	2.9%	-	-	-	-	-	-	-	-	0.0%	-	-	-
Walk	-	-	-	0.0%	-	-	-	-	-	-	-	-	0.0%	-	-	-
Bike	-	-	-	-4.9%	0.2%	-	-	-	-	-	-	-	0.0%	-	-	-
Walk-Transit	-	1.7%	-3.9%	2.8%	-	-9.7%	44.2%	-	-	-	-	-	0.0%	-0.9%	-	-
PNR-Transit	-	-	-	-	-	-	-	-2.3%	9.0%	-	-	-	8.1%	-	8.1%	-
KNR-Transit	-	-	-	-	-	-	-	-	-	10.3%	-0.9%	-	4.3%	-	-	4.3%
Sch Bus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-

Total	0.0%	0.1%	0.0%	1.0%	0.2%	-9.7%	44.2%	-2.3%	9.0%	10.3%	-0.9%	-	0.1%	-0.9%	8.1%	4.3%

Table 26g. Trip Mode Choice by Tour Purpose and Tour Mode – Final Adjustments: Work Tours

Tour Mode	Trip Mode			
	Drive Alone	Shared2	Shared3+	Walk
Drive Alone	BASE	--	--	--
Shared2	-0.0578	BASE		-1.5203
Shared3+	0.0007	-0.5886	BASE	-1.8014
Walk				BASE
Bike				-1.2280
Walk All Transit		-5.5462	-6.5751	-1.3623

Table 27a. Trip Mode Choice by Tour Purpose and Tour Mode – Observed Trip Mode Summary: University Tours

	Trip Mode												
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total
SOV	117,463	-	-	-	-	-	-	-	-	-	-	-	117,4
SR2	8,355	24,743	-	1,292	-	-	-	-	-	-	-	-	34,3
SR3+	5,086	2,484	7,481	-	-	-	-	-	-	-	-	-	15,0
Walk	-	-	-	2,402	-	-	-	-	-	-	-	-	2,4
Bike	-	-	-	-	5,457	-	-	-	-	-	-	-	5,4
Walk-Transit	-	1,875	96	3,251	-	17,333	5,001	-	-	-	-	-	27,5
PNR-Transit	-	-	-	-	-	-	-	428	7,636	-	-	-	8,0
KNR-Transit	-	-	-	-	-	-	-	-	-	3,397	3,394	-	6,7
Sch Bus	-	-	-	-	-	-	-	-	-	-	-	-	
Total	130,904	29,102	7,578	6,945	5,457	17,333	5,001	428	7,636	3,397	3,394	-	217,1

Table 27b. Trip Mode Choice by Tour Purpose and Tour Mode – Observed Trip Mode Shares: University Tours

	Trip Mode													Transit Totals		
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	Wlk-Trn	PNR	KNR
SOV	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
SR2	24%	72%	0%	4%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
SR3+	34%	17%	50%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Bike	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk-Transit	0%	7%	0%	12%	0%	63%	18%	0%	0%	0%	0%	0%	100%	81%	0%	0%
PNR-Transit	0%	0%	0%	0%	0%	0%	0%	5%	95%	0%	0%	0%	100%	0%	100%	0%
KNR-Transit	0%	0%	0%	0%	0%	0%	0%	0%	0%	50%	50%	0%	100%	0%	0%	100%
Sch Bus	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total	60%	13%	3%	3%	3%	8%	2%	0%	4%	2%	2%	0%	100%	10%	4%	3%

Table 27c. Trip Mode Choice by Tour Purpose and Tour Mode – Estimated Trip Mode Summary: University Tours

	Trip Mode												
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total
SOV	117,463	-	-	-	-	-	-	-	-	-	-	-	117,463
SR2	8,532	24,791	-	1,067	-	-	-	-	-	-	-	-	34,390
SR3+	5,044	2,542	7,422	43	-	-	-	-	-	-	-	-	15,051
Walk	-	-	-	2,402	-	-	-	-	-	-	-	-	2,402
Bike	-	-	-	31	5,426	-	-	-	-	-	-	-	5,457
Walk-Transit	-	2,025	99	3,305	-	19,866	2,245	-	-	-	-	-	27,540
PNR-Transit	-	-	-	-	-	-	-	2,751	5,183	-	-	-	7,934
KNR-Transit	-	-	-	-	-	-	-	-	-	1,877	4,545	-	6,422
Sch Bus	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	131,039	29,358	7,521	6,848	5,426	19,866	2,245	2,751	5,183	1,877	4,545	-	216,659

Table 27d. Trip Mode Choice by Tour Purpose and Tour Mode – Estimated Trip Mode Shares: University Tours

	Trip Mode													Transit Totals		
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	Wlk-Trn	PNR	KNR
SOV	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
SR2	25%	72%	0%	3%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
SR3+	34%	17%	49%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Bike	0%	0%	0%	1%	99%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk-Transit	0%	7%	0%	12%	0%	72%	8%	0%	0%	0%	0%	0%	100%	80%	0%	0%
PNR-Transit	0%	0%	0%	0%	0%	0%	0%	35%	65%	0%	0%	0%	100%	0%	100%	0%
KNR-Transit	0%	0%	0%	0%	0%	0%	0%	0%	0%	29%	71%	0%	100%	0%	0%	100%
Sch Bus	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total	60%	14%	3%	3%	3%	9%	1%	1%	2%	1%	2%	0%	100%	10%	4%	3%

Table 27e. Trip Mode Choice by Tour Purpose and Tour Mode – Difference in number of trips: University Tours

	Trip Mode												
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total
SOV	-	-	-	-	-	-	-	-	-	-	-	-	-
SR2	177	48	-	(225)	-	-	-	-	-	-	-	-	-
SR3+	(42)	58	(59)	43	-	-	-	-	-	-	-	-	-
Walk	-	-	-	-	-	-	-	-	-	-	-	-	-
Bike	-	-	-	31	(31)	-	-	-	-	-	-	-	-
Walk-Transit	-	150	3	54	-	2,533	(2,756)	-	-	-	-	-	(16)
PNR-Transit	-	-	-	-	-	-	-	2,323	(2,453)	-	-	-	(130)
KNR-Transit	-	-	-	-	-	-	-	-	-	(1,520)	1,151	-	(369)
Sch Bus	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	135	256	(57)	(97)	(31)	2,533	(2,756)	2,323	(2,453)	(1,520)	1,151	-	(515)

Table 27f. Trip Mode Choice by Tour Purpose and Tour Mode – Difference in shares: University Tours

	Trip Mode													Transit Totals		
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	Wlk-Trn	PNR	KNR
SOV	0.0%	-	-	-	-	-	-	-	-	-	-	-	0.0%	-	-	-
SR2	2.1%	0.2%	-	-17.4%	-	-	-	-	-	-	-	-	0.0%	-	-	-
SR3+	-0.8%	2.3%	-0.8%	-	-	-	-	-	-	-	-	-	0.0%	-	-	-
Walk	-	-	-	0.0%	-	-	-	-	-	-	-	-	0.0%	-	-	-
Bike	-	-	-	-	-0.6%	-	-	-	-	-	-	-	0.0%	-	-	-
Walk-Transit	-	8.0%	2.6%	1.7%	-	14.6%	-55.1%	-	-	-	-	-	-0.1%	-1.0%	-	-
PNR-Transit	-	-	-	-	-	-	-	542.8%	-32.1%	-	-	-	-1.6%	-	-1.6%	-
KNR-Transit	-	-	-	-	-	-	-	-	-	-44.7%	33.9%	-	-5.4%	-	-	-5.4%
Sch Bus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	0.1%	0.9%	-0.7%	-1.4%	-0.6%	14.6%	-55.1%	542.8%	-32.1%	-44.7%	33.9%	-	-0.2%	-1.0%	-1.6%	-5.4%

Table 27g. Trip Mode Choice by Tour Purpose and Tour Mode – Final Adjustments: University Tours

Tour Mode	Trip Mode			
	Drive Alone	Shared2	Shared3+	Walk
Drive Alone	BASE	--	--	--
Shared2	-0.5822	BASE		0.6433
Shared3+	-0.2187	-0.6595	BASE	-1.6708
Walk				BASE
Bike				-1.1243
Walk All Transit		-7.0963	-8.8593	-2.2281

Table 28a. Trip Mode Choice by Tour Purpose and Tour Mode – Observed Trip Mode Summary: School Tours

	Trip Mode												
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total
SOV	80,441	-	-	-	-	-	-	-	-	-	-	-	80
SR2	19,887	364,007	-	7,518	-	-	-	-	-	-	-	-	391
SR3+	7,936	144,448	535,721	15,951	-	-	-	-	-	-	-	-	704
Walk	-	-	-	64,266	-	-	-	-	-	-	-	-	64
Bike	-	-	-	483	11,800	-	-	-	-	-	-	-	12
Walk-Transit	-	6,290	4,850	5,976	-	16,880	1,921	-	-	-	-	-	35
PNR-Transit	-	-	-	-	-	-	-	246	2,458	-	-	-	2
KNR-Transit	-	-	-	-	-	-	-	-	-	3,282	1,859	-	5
Sch Bus	-	79,135	99,032	50,160	-	-	-	-	-	-	-	962,967	1,191
Total	108,264	593,880	639,604	144,354	11,800	16,880	1,921	246	2,458	3,282	1,859	962,967	2,487

Table 28b. Trip Mode Choice by Tour Purpose and Tour Mode – Observed Trip Mode Shares: School Tours

	Trip Mode													Transit Totals		
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	Wlk-Trn	PNR	KNR
SOV	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
SR2	5%	93%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
SR3+	1%	21%	76%	2%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Bike	0%	0%	0%	4%	96%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk-Transit	0%	18%	14%	17%	0%	47%	5%	0%	0%	0%	0%	0%	100%	52%	0%	0%
PNR-Transit	0%	0%	0%	0%	0%	0%	0%	9%	91%	0%	0%	0%	100%	0%	100%	0%
KNR-Transit	0%	0%	0%	0%	0%	0%	0%	0%	0%	64%	36%	0%	100%	0%	0%	100%
Sch Bus	0%	7%	8%	4%	0%	0%	0%	0%	0%	0%	0%	81%	100%	0%	0%	0%
Total	4%	24%	26%	6%	0%	1%	0%	0%	0%	0%	0%	39%	100%	1%	0%	0%

Table 28c. Trip Mode Choice by Tour Purpose and Tour Mode – Estimated Trip Mode Summary: School Tours

Tour Mode	Trip Mode SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total
SOV	80,441	-	-	-	-	-	-	-	-	-	-	-	80,441
SR2	18,928	364,371	-	8,113	-	-	-	-	-	-	-	-	391,412
SR3+	7,886	144,673	532,689	18,809	-	-	-	-	-	-	-	-	704,057
Walk	-	-	-	64,266	-	-	-	-	-	-	-	-	64,266
Bike	-	-	-	448	11,835	-	-	-	-	-	-	-	12,283
Walk-Transit	-	5,654	4,518	7,251	-	15,777	1,600	-	-	-	-	-	34,800
PNR-Transit	-	-	-	-	-	-	-	-	-	-	-	-	-
KNR-Transit	-	-	-	-	-	-	-	-	-	4,052	1,184	-	5,236
Sch Bus	-	78,273	96,715	51,132	-	-	-	-	-	-	-	965,174	1,191,294
Total	107,255	592,971	633,922	150,019	11,835	15,777	1,600	-	-	4,052	1,184	965,174	2,483,789

Table 28d. Trip Mode Choice by Tour Purpose and Tour Mode – Estimated Trip Mode Shares: School Tours

Tour Mode	Trip Mode SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	Transit Totals Wlk-Trn	PNR	KNR
SOV	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
SR2	5%	93%	0%	2%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
SR3+	1%	21%	76%	3%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Bike	0%	0%	0%	4%	96%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk-Transit	0%	16%	13%	21%	0%	45%	5%	0%	0%	0%	0%	0%	100%	50%	0%	0%
PNR-Transit	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
KNR-Transit	0%	0%	0%	0%	0%	0%	0%	0%	0%	77%	23%	0%	100%	0%	0%	100%
Sch Bus	0%	7%	8%	4%	0%	0%	0%	0%	0%	0%	0%	81%	100%	0%	0%	0%
Total	4%	24%	26%	6%	0%	1%	0%	0%	0%	0%	0%	39%	100%	1%	0%	0%

Table 28e. Trip Mode Choice by Tour Purpose and Tour Mode – Difference in number of trips: School Tours

Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Tota
	Trip Mode												
SOV	-	-	-	-	-	-	-	-	-	-	-	-	
SR2	(959)	364	-	595	-	-	-	-	-	-	-	-	
SR3+	(50)	225	(3,032)	2,858	-	-	-	-	-	-	-	-	
Walk	-	-	-	-	-	-	-	-	-	-	-	-	
Bike	-	-	-	(35)	35	-	-	-	-	-	-	-	
Walk-Transit	-	(636)	(332)	1,275	-	(1,103)	(321)	-	-	-	-	-	(1,
PNR-Transit	-	-	-	-	-	-	-	(246)	(2,458)	-	-	-	(2,
KNR-Transit	-	-	-	-	-	-	-	-	-	770	(675)	-	
Sch Bus	-	(862)	(2,317)	972	-	-	-	-	-	-	-	2,207	
Total	(1,009)	(909)	(5,682)	5,665	35	(1,103)	(321)	(246)	(2,458)	770	(675)	2,207	(3,

Table 28f. Trip Mode Choice by Tour Purpose and Tour Mode – Difference in shares: School Tours

	Trip Mode													Transit Totals		
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	Wlk-Trn	PNR	KNR
SOV	0.0%	-	-	-	-	-	-	-	-	-	-	-	0.0%	-	-	-
SR2	-4.8%	0.1%	-	7.9%	-	-	-	-	-	-	-	-	0.0%	-	-	-
SR3+	-0.6%	0.2%	-0.6%	17.9%	-	-	-	-	-	-	-	-	0.0%	-	-	-
Walk	-	-	-	0.0%	-	-	-	-	-	-	-	-	0.0%	-	-	-
Bike	-	-	-	-7.3%	0.3%	-	-	-	-	-	-	-	0.0%	-	-	-
Walk-Transit	-	-10.1%	-6.9%	21.3%	-	-6.5%	-16.7%	-	-	-	-	-	-3.1%	-7.6%	-	-
PNR-Transit	-	-	-	-	-	-	-	-100.0%	-100.0%	-	-	-	-100.0%	-	-100.0%	-
KNR-Transit	-	-	-	-	-	-	-	-	-	23.5%	-36.3%	-	1.8%	-	-	1.8%
Sch Bus	-	-1.1%	-2.3%	1.9%	-	-	-	-	-	-	-	0.2%	0.0%	-	-	-
Total	-0.9%	-0.2%	-0.9%	3.9%	0.3%	-6.5%	-16.7%	-100.0%	-100.0%	23.5%	-36.3%	0.2%	-0.1%	-7.6%	-100.0%	1.8%

Table 28g. Trip Mode Choice by Tour Purpose and Tour Mode – Final Adjustments: School Tours

Tour Mode	Trip Mode			
	Drive Alone	Shared2	Shared3+	Walk
Drive Alone	BASE	--	--	--
Shared2	-0.9526	BASE		-2.1215
Shared3+	-1.7980	-0.7826	BASE	-1.7543
Walk				BASE
Bike				-0.8027
Walk All Transit		-2.4172	-2.5440	-0.4381
School Bus		1.6783	1.8071	2.7595

Table 29a. Trip Mode Choice by Tour Purpose and Tour Mode – Observed Trip Mode Summary: Individual Non-Mandatory Tours

	Trip Mode												
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total
SOV	2,413,304	-	-	-	-	-	-	-	-	-	-	-	2,413,3
SR2	580,089	988,604	716	10,293	-	-	-	-	-	-	-	-	1,579,7
SR3+	218,930	320,459	905,265	12,249	-	-	-	-	-	-	-	-	1,456,9
Walk	-	-	-	262,958	-	-	-	-	-	-	-	-	262,9
Bike	-	-	-	1,641	26,536	-	-	-	-	-	-	-	28,1
Walk-Transit	-	4,326	1,912	11,591	-	41,558	5,404	-	-	-	-	-	64,7
PNR-Transit	-	-	-	-	-	-	-	434	2,296	-	-	-	2,7
KNR-Transit	-	-	-	-	-	-	-	-	-	5,579	3,363	-	8,9
Sch Bus	-	-	-	-	-	-	-	-	-	-	-	-	
Total	3,212,322	1,313,389	907,893	298,732	26,536	41,558	5,404	434	2,296	5,579	3,363	-	5,817,5

Table 29b. Trip Mode Choice by Tour Purpose and Tour Mode – Observed Trip Mode Shares: Individual Non-Mandatory Tours

	Trip Mode													Transit Totals		
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	Wlk-Trn	PNR	KNR
SOV	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
SR2	37%	63%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
SR3+	15%	22%	62%	1%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Bike	0%	0%	0%	6%	94%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk-Transit	0%	7%	3%	18%	0%	64%	8%	0%	0%	0%	0%	0%	100%	72%	0%	0%
PNR-Transit	0%	0%	0%	0%	0%	0%	0%	16%	84%	0%	0%	0%	100%	0%	100%	0%
KNR-Transit	0%	0%	0%	0%	0%	0%	0%	0%	0%	62%	38%	0%	100%	0%	0%	100%
Sch Bus	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total	55%	23%	16%	5%	0%	1%	0%	0%	0%	0%	0%	0%	100%	1%	0%	0%

Table 29c. Trip Mode Choice by Tour Purpose and Tour Mode – Estimated Trip Mode Summary: Individual Non-Mandatory Tours

	Trip Mode												
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total
SOV	2,413,304	-	-	-	-	-	-	-	-	-	-	-	2,413,304
SR2	581,503	987,572	-	10,626	-	-	-	-	-	-	-	-	1,579,701
SR3+	218,105	318,896	907,534	12,368	-	-	-	-	-	-	-	-	1,456,903
Walk	-	-	-	262,958	-	-	-	-	-	-	-	-	262,958
Bike	-	-	-	1,770	26,407	-	-	-	-	-	-	-	28,177
Walk-Transit	-	4,506	1,652	11,875	-	39,224	7,533	-	-	-	-	-	64,790
PNR-Transit	-	-	-	-	-	-	-	536	2,302	-	-	-	2,838
KNR-Transit	-	-	-	-	-	-	-	-	-	5,886	1,700	-	7,586
Sch Bus	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	3,212,912	1,310,974	909,186	299,597	26,407	39,224	7,533	536	2,302	5,886	1,700	-	5,816,257

Table 29d. Trip Mode Choice by Tour Purpose and Tour Mode – Estimated Trip Mode Shares: Individual Non-Mandatory Tours

	Trip Mode													Transit Totals		
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	Wlk-Trn	PNR	KNR
SOV	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
SR2	37%	63%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
SR3+	15%	22%	62%	1%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Bike	0%	0%	0%	6%	94%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk-Transit	0%	7%	3%	18%	0%	61%	12%	0%	0%	0%	0%	0%	100%	72%	0%	0%
PNR-Transit	0%	0%	0%	0%	0%	0%	0%	19%	81%	0%	0%	0%	100%	0%	100%	0%
KNR-Transit	0%	0%	0%	0%	0%	0%	0%	0%	0%	78%	22%	0%	100%	0%	0%	100%
Sch Bus	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total	55%	23%	16%	5%	0%	1%	0%	0%	0%	0%	0%	0%	100%	1%	0%	0%

Table 29e. Trip Mode Choice by Tour Purpose and Tour Mode – Difference in number of trips: Individual Non-Mandatory Tours

Tour Mode	Trip Mode SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total
SOV	-	-	-	-	-	-	-	-	-	-	-	-	-
SR2	1,414	(1,032)	(716)	333	-	-	-	-	-	-	-	-	-
SR3+	(825)	(1,563)	2,269	119	-	-	-	-	-	-	-	-	-
Walk	-	-	-	-	-	-	-	-	-	-	-	-	-
Bike	-	-	-	129	(129)	-	-	-	-	-	-	-	-
Walk-Transit	-	180	(260)	284	-	(2,334)	2,129	-	-	-	-	-	-
PNR-Transit	-	-	-	-	-	-	-	102	6	-	-	-	108
KNR-Transit	-	-	-	-	-	-	-	-	-	307	(1,663)	-	(1,356)
Sch Bus	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	590	(2,415)	1,293	865	(129)	(2,334)	2,129	102	6	307	(1,663)	-	(1,248)

Table 29f. Trip Mode Choice by Tour Purpose and Tour Mode – Difference in shares: Individual Non-Mandatory Tours

	Trip Mode													Transit Totals		
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	Wlk-Trn	PNR	KNR
SOV	0.0%	-	-	-	-	-	-	-	-	-	-	-	0.0%	-	-	-
SR2	0.2%	-0.1%	-100.0%	3.2%	-	-	-	-	-	-	-	-	0.0%	-	-	-
SR3+	-0.4%	-0.5%	0.3%	1.0%	-	-	-	-	-	-	-	-	0.0%	-	-	-
Walk	-	-	-	0.0%	-	-	-	-	-	-	-	-	0.0%	-	-	-
Bike	-	-	-	7.9%	-0.5%	-	-	-	-	-	-	-	0.0%	-	-	-
Walk-Transit	-	4.2%	-13.6%	2.5%	-	-5.6%	39.4%	-	-	-	-	-	0.0%	-0.4%	-	-
PNR-Transit	-	-	-	-	-	-	-	23.5%	0.3%	-	-	-	4.0%	-	4.0%	-
KNR-Transit	-	-	-	-	-	-	-	-	-	5.5%	-49.4%	-	-15.2%	-	-	-15.2%
Sch Bus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	0.0%	-0.2%	0.1%	0.3%	-0.5%	-5.6%	39.4%	23.5%	0.3%	5.5%	-49.4%	-	0.0%	-0.4%	4.0%	-15.2%

Table 29g. Trip Mode Choice by Tour Purpose and Tour Mode – Final Adjustments: Individual Non-Mandatory Tours

Tour Mode	Trip Mode			
	Drive Alone	Shared2	Shared3+	Walk
Drive Alone	BASE	--	--	--
Shared2	0.0371	BASE		-2.3821
Shared3+	-0.6228	-0.6281	BASE	-2.1263
Walk				BASE
Bike				0.3082
Walk All Transit		-6.3755	-6.6714	-2.9896
Walk Prem Transit		-3.4087	-5.0571	-0.4980

Table 30a. Trip Mode Choice by Tour Purpose and Tour Mode – Observed Trip Mode Summary: Joint Non-Mandatory Tours

Tour Mode	Trip Mode: SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total
SOV	-	-	-	-	-	-	-	-	-	-	-	-	
SR2	-	1,267,162	-	5,158	-	-	-	-	-	-	-	-	1,272,32
SR3+	-	76,157	1,196,762	12,373	-	-	-	-	-	-	-	-	1,285,29
Walk	-	-	-	78,586	-	-	-	-	-	-	-	-	78,58
Bike	-	-	-	-	4,858	-	-	-	-	-	-	-	4,85
Walk-Transit	-	506	-	1,480	-	4,601	598	-	-	-	-	-	7,18
PNR-Transit	-	-	-	-	-	-	-	48	254	-	-	-	30
KNR-Transit	-	-	-	-	-	-	-	-	-	618	372	-	99
Sch Bus	-	-	-	-	-	-	-	-	-	-	-	-	
Total	-	1,343,826	1,196,762	97,597	4,858	4,601	598	48	254	618	372	-	2,649,53

Table 30b. Trip Mode Choice by Tour Purpose and Tour Mode – Observed Trip Mode Shares: Joint Non-Mandatory Tours

Tour Mode	Trip Mode: SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	Transit Totals: Wlk-Trn	PNR	KNR
SOV	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
SR2	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
SR3+	0%	6%	93%	1%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Bike	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk-Transit	0%	7%	0%	21%	0%	64%	8%	0%	0%	0%	0%	0%	100%	72%	0%	0%
PNR-Transit	0%	0%	0%	0%	0%	0%	0%	16%	84%	0%	0%	0%	100%	0%	100%	0%
KNR-Transit	0%	0%	0%	0%	0%	0%	0%	0%	0%	62%	38%	0%	100%	0%	0%	100%
Sch Bus	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total	0%	51%	45%	4%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%

Table 30c. Trip Mode Choice by Tour Purpose and Tour Mode – Estimated Trip Mode Summary: Joint Non-Mandatory Tours

	Trip Mode													
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	W
SOV	-	-	-	-	-	-	-	-	-	-	-	-	-	
SR2	-	1,267,076	-	5,244	-	-	-	-	-	-	-	-	1,272,320	
SR3+	-	103,148	1,169,918	12,226	-	-	-	-	-	-	-	-	1,285,292	
Walk	-	-	-	78,586	-	-	-	-	-	-	-	-	78,586	
Bike	-	-	-	9	4,849	-	-	-	-	-	-	-	4,858	
Walk-Transit	-	462	121	1,913	-	4,385	1,389	-	-	-	-	-	8,270	
PNR-Transit	-	-	-	-	-	-	-	71	227	-	-	-	298	
KNR-Transit	-	-	-	-	-	-	-	-	-	693	277	-	970	
Sch Bus	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	-	1,370,686	1,170,039	97,978	4,849	4,385	1,389	71	227	693	277	-	2,650,594	

Table 30d. Trip Mode Choice by Tour Purpose and Tour Mode – Estimated Trip Mode Shares: Joint Non-Mandatory Tours

	Trip Mode													Transit Totals		
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	Wlk-Trn	PNR	KNR
SOV	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
SR2	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
SR3+	0%	8%	91%	1%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Bike	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk-Transit	0%	6%	1%	23%	0%	53%	17%	0%	0%	0%	0%	0%	100%	70%	0%	0%
PNR-Transit	0%	0%	0%	0%	0%	0%	0%	24%	76%	0%	0%	0%	100%	0%	100%	0%
KNR-Transit	0%	0%	0%	0%	0%	0%	0%	0%	0%	71%	29%	0%	100%	0%	0%	100%
Sch Bus	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total	0%	52%	44%	4%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%

Table 30e. Trip Mode Choice by Tour Purpose and Tour Mode – Difference in number of trips: Joint Non-Mandatory Tours

	Trip Mode												
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total
SOV	-	-	-	-	-	-	-	-	-	-	-	-	-
SR2	-	(86)	-	86	-	-	-	-	-	-	-	-	-
SR3+	-	26,991	(26,844)	(147)	-	-	-	-	-	-	-	-	-
Walk	-	-	-	-	-	-	-	-	-	-	-	-	-
Bike	-	-	-	9	(9)	-	-	-	-	-	-	-	-
Walk-Transit	-	(44)	121	433	-	(216)	791	-	-	-	-	-	1,084
PNR-Transit	-	-	-	-	-	-	-	23	(27)	-	-	-	(4)
KNR-Transit	-	-	-	-	-	-	-	-	-	75	(95)	-	(20)
Sch Bus	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	-	26,860	(26,723)	381	(9)	(216)	791	23	(27)	75	(95)	-	1,059

Table 30f. Trip Mode Choice by Tour Purpose and Tour Mode – Difference in shares: Joint Non-Mandatory Tours

	Trip Mode													Transit Totals		
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	Wlk-Trn	PNR	KNR
SOV	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
SR2	-	0.0%	-	1.7%	-	-	-	-	-	-	-	-	0.0%	-	-	-
SR3+	-	35.4%	-2.2%	-1.2%	-	-	-	-	-	-	-	-	0.0%	-	-	-
Walk	-	-	-	0.0%	-	-	-	-	-	-	-	-	0.0%	-	-	-
Bike	-	-	-	-	-0.2%	-	-	-	-	-	-	-	0.0%	-	-	-
Walk-Transit	-	-8.7%	-	29.2%	-	-4.7%	132.1%	-	-	-	-	-	15.1%	11.0%	-	-
PNR-Transit	-	-	-	-	-	-	-	47.8%	-10.7%	-	-	-	-1.4%	-	-1.4%	-
KNR-Transit	-	-	-	-	-	-	-	-	-	12.2%	-25.6%	-	-2.0%	-	-	-2.0%
Sch Bus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	-	2.0%	-2.2%	0.4%	-0.2%	-4.7%	132.1%	47.8%	-10.7%	12.2%	-25.6%	-	0.0%	11.0%	-1.4%	-2.0%

Table 30g. Trip Mode Choice by Tour Purpose and Tour Mode – Final Adjustments: Joint Non-Mandatory Tours

Tour Mode	Trip Mode			
	Drive Alone	Shared2	Shared3+	Walk
Shared2	-0.0011	BASE		-1.9496
Shared3+	0.1350	1.6003	BASE	-2.0082
Walk				BASE
Bike				-2.1393
Walk All Transit		-6.3354	-7.0769	-1.8638

Table 31a. Trip Mode Choice by Tour Purpose and Tour Mode – Observed Trip Mode Summary: At Work Sub-Tours

	Trip Mode												
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total
SOV	971,717	-	-	-	-	-	-	-	-	-	-	-	971,717
SR2	39,842	213,348	-	1,756	-	-	-	-	-	-	-	-	254,946
SR3+	1,871	6,728	136,934	-	-	-	-	-	-	-	-	-	145,534
Walk	-	-	-	192,093	-	-	-	-	-	-	-	-	192,093
Bike	-	-	-	-	8,565	-	-	-	-	-	-	-	8,565
Walk-Transit	-	-	-	2,319	-	1,973	3,087	-	-	-	-	-	7,379
PNR-Transit	-	-	-	-	-	-	-	-	-	-	-	-	-
KNR-Transit	-	-	-	-	-	-	-	-	-	-	-	-	-
Sch Bus	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	1,013,430	220,076	136,934	196,168	8,565	1,973	3,087	-	-	-	-	-	1,580,234

Table 31b. Trip Mode Choice by Tour Purpose and Tour Mode – Observed Trip Mode Shares: At Work Sub-Tours

	Trip Mode													Transit Totals		
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	Wlk-Trn	PNR	KNR
SOV	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
SR2	16%	84%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
SR3+	1%	5%	94%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Bike	0%	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk-Transit	0%	0%	0%	31%	0%	27%	42%	0%	0%	0%	0%	0%	100%	69%	0%	0%
PNR-Transit	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
KNR-Transit	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Sch Bus	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total	64%	14%	9%	12%	1%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%

Table 31c. Trip Mode Choice by Tour Purpose and Tour Mode – Estimated Trip Mode Summary: At Work Sub-Tours

Tour Mode	Trip Mode: SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	Wlk-
SOV	971,717	-	-	-	-	-	-	-	-	-	-	-	971,717	
SR2	40,120	212,855	-	1,971	-	-	-	-	-	-	-	-	254,946	
SR3+	1,794	6,527	133,025	4,188	-	-	-	-	-	-	-	-	145,534	
Walk	-	-	-	192,093	-	-	-	-	-	-	-	-	192,093	
Bike	-	-	-	166	8,399	-	-	-	-	-	-	-	8,565	
Walk-Transit	-	19	212	2,078	-	3,387	1,486	-	-	-	-	-	7,182	
PNR-Transit	-	-	-	-	-	-	-	-	-	-	-	-	-	
KNR-Transit	-	-	-	-	-	-	-	-	-	-	-	-	-	
Sch Bus	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	1,013,631	219,401	133,237	200,496	8,399	3,387	1,486	-	-	-	-	-	1,580,037	

Table 31d. Trip Mode Choice by Tour Purpose and Tour Mode – Estimated Trip Mode Shares: At Work Sub-Tours

Tour Mode	Trip Mode: SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	Transit Totals: Wlk-Trn	PNR	KNR
SOV	100%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
SR2	16%	83%	0%	1%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
SR3+	1%	4%	91%	3%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk	0%	0%	0%	100%	0%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Bike	0%	0%	0%	2%	98%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%
Walk-Transit	0%	0%	3%	29%	0%	47%	21%	0%	0%	0%	0%	0%	100%	68%	0%	0%
PNR-Transit	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
KNR-Transit	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Sch Bus	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%	0%
Total	64%	14%	8%	13%	1%	0%	0%	0%	0%	0%	0%	0%	100%	0%	0%	0%

Table 31e. Trip Mode Choice by Tour Purpose and Tour Mode – Difference in number of trips: At Work Sub-Tours

	Trip Mode													
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	W
SOV	-	-	-	-	-	-	-	-	-	-	-	-	-	
SR2	278	(493)	-	215	-	-	-	-	-	-	-	-	-	
SR3+	(77)	(201)	(3,909)	4,188	-	-	-	-	-	-	-	-	-	
Walk	-	-	-	-	-	-	-	-	-	-	-	-	-	
Bike	-	-	-	166	(166)	-	-	-	-	-	-	-	-	
Walk-Transit	-	19	212	(241)	-	1,414	(1,601)	-	-	-	-	-	(197)	
PNR-Transit	-	-	-	-	-	-	-	-	-	-	-	-	-	
KNR-Transit	-	-	-	-	-	-	-	-	-	-	-	-	-	
Sch Bus	-	-	-	-	-	-	-	-	-	-	-	-	-	
Total	201	(675)	(3,697)	4,328	(166)	1,414	(1,601)	-	-	-	-	-	(197)	

Table 31f. Trip Mode Choice by Tour Purpose and Tour Mode – Difference in shares: At Work Sub-Tours

	Trip Mode													Transit Totals		
Tour Mode	SOV	SR2	SR3+	Walk	Bike	Wlk All	Wlk Pre	PNR All	PNR Pre	KNR All	KNR Pre	Sch Bus	Total	Wlk-Trn	PNR	KNR
SOV	0.0%	-	-	-	-	-	-	-	-	-	-	-	0.0%	-	-	-
SR2	0.7%	-0.2%	-	12.3%	-	-	-	-	-	-	-	-	0.0%	-	-	-
SR3+	-4.1%	-3.0%	-2.9%	-	-	-	-	-	-	-	-	-	0.0%	-	-	-
Walk	-	-	-	0.0%	-	-	-	-	-	-	-	-	0.0%	-	-	-
Bike	-	-	-	-	-1.9%	-	-	-	-	-	-	-	0.0%	-	-	-
Walk-Transit	-	-	-	-10.4%	-	71.7%	-51.9%	-	-	-	-	-	-2.7%	-3.7%	-	-
PNR-Transit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
KNR-Transit	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sch Bus	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Total	0.0%	-0.3%	-2.7%	2.2%	-1.9%	71.7%	-51.9%	-	-	-	-	-	0.0%	-3.7%	-	-

Table 31g. Trip Mode Choice by Tour Purpose and Tour Mode – Final Adjustments: At Work Sub-Tours

Tour Mode	Trip Mode			
	Drive Alone	Shared2	Shared3+	Walk
Drive Alone	BASE	--	--	--
Shared2	-0.9706	BASE		-2.8690
Shared3+	-2.5828	-1.8179	BASE	-1.4940
Walk				BASE
Bike				-0.4432
Walk All Transit		-8.8685	-6.6100	-2.4358
Walk Prem Transit		-5.9017	-4.9957	0.0558

Stop Duration Model

The stop duration model allocates the total time on a tour (as predicted by the time-of-day choice model) into duration for each stop on the tour. The model operates in two stages. The first stage splits the total tour duration into the three tour legs defined as: inbound leg (the portion of the tour starting from home till the stop before the primary destination), main leg (the portion of the tour starting from the stop before the primary destination and the stop after the primary destination), and outbound leg (the portion of the tour comprising of first stop after the primary destination to home). This model is applied only to those tours that has at-least one stop in either direction. The second stage operates on the inbound and the outbound leg allocating the leg time into the different stops on that leg. This model kicks in only if there are more than one stop on the leg – otherwise the solution is trivial. For an extensive treatment of this model please refer to the stop duration model estimation documentation.

Both stages of the model required calibration. This is a duration model and hence calibrating this model was similar to how the tour time-of-day model was calibrated. The Stage 1 model calibration is discussed first followed by the Stage 2 models.

Stage 1 Model Calibration

The stage 1 model was calibrated to ensure the following:

1. The distributions of the main leg duration matched the observed durations for each tour purpose.
2. The distributions of the outbound and inbound leg durations matched that of the observed by number of stops on the leg.

This approach was adopted as it seemed more intuitive that the tour purpose would determine the duration of activity at the primary destination (i.e. the main leg duration) and the remaining time would get distributed to different stops based on how busy the rest of the schedule would be – number of stops on leg would act as a proxy for this. The calibration involved introducing duration specific constants by tour mode such that the peaks of the distributions would be accurately captured. The constants for each iteration was added to the previous constant. **Figure 33** through **Figure 42** shows the distributions of leg durations by tour purpose. We are matching the observed distributions for all the tour purposes really well. Remember that the durations of inbound and outbound leg were calibrated by number of stops on tour – the final distributions of these resemble the observed distributions for most of the tour purposes. However, for some there still seems to be some residual variance that needs to be explained/calibrated on using another aspect.

Figure 33: Tour Leg durations for Work Tours

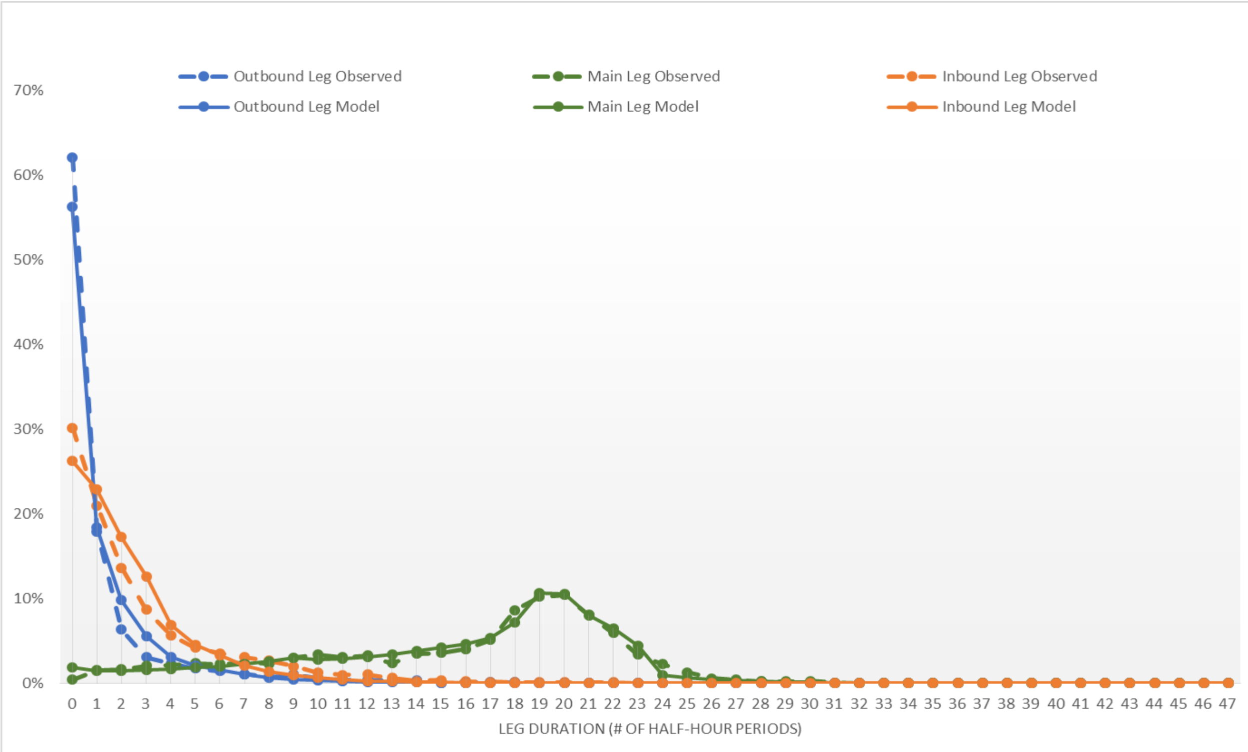


Figure 34: Tour Leg durations for University Tours

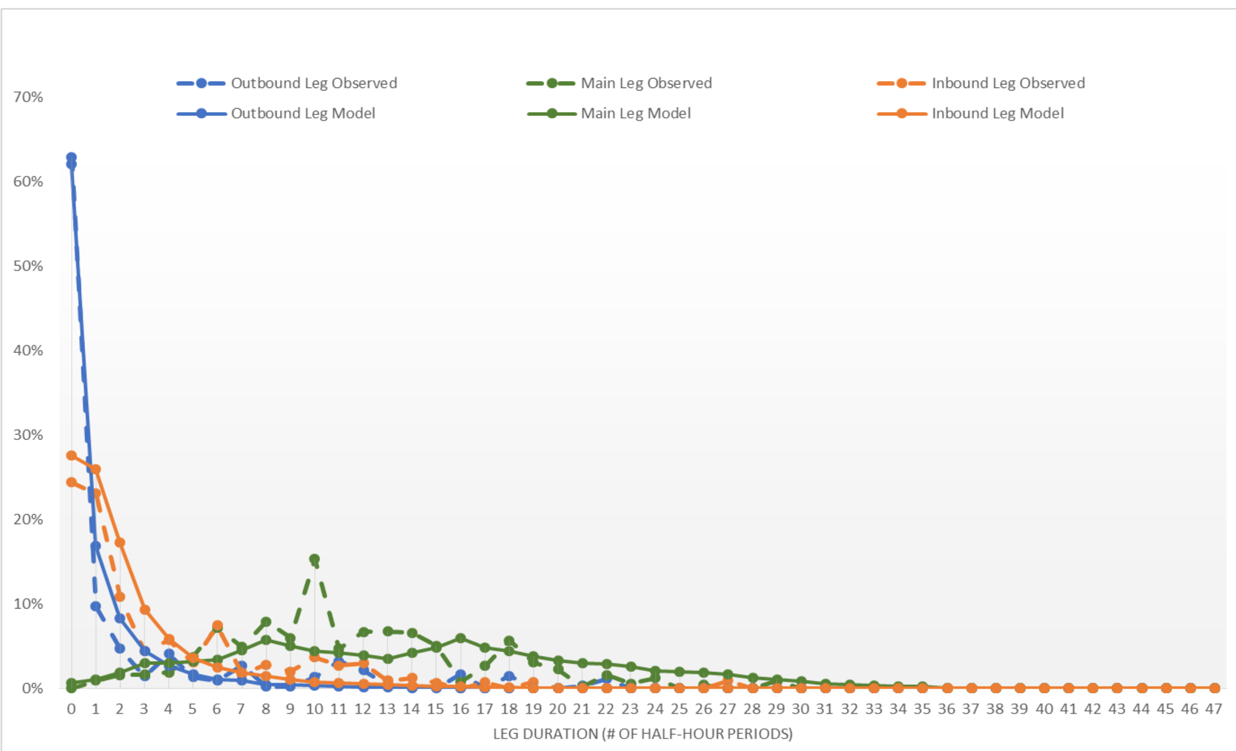


Figure 35: Tour Leg durations for School Tours

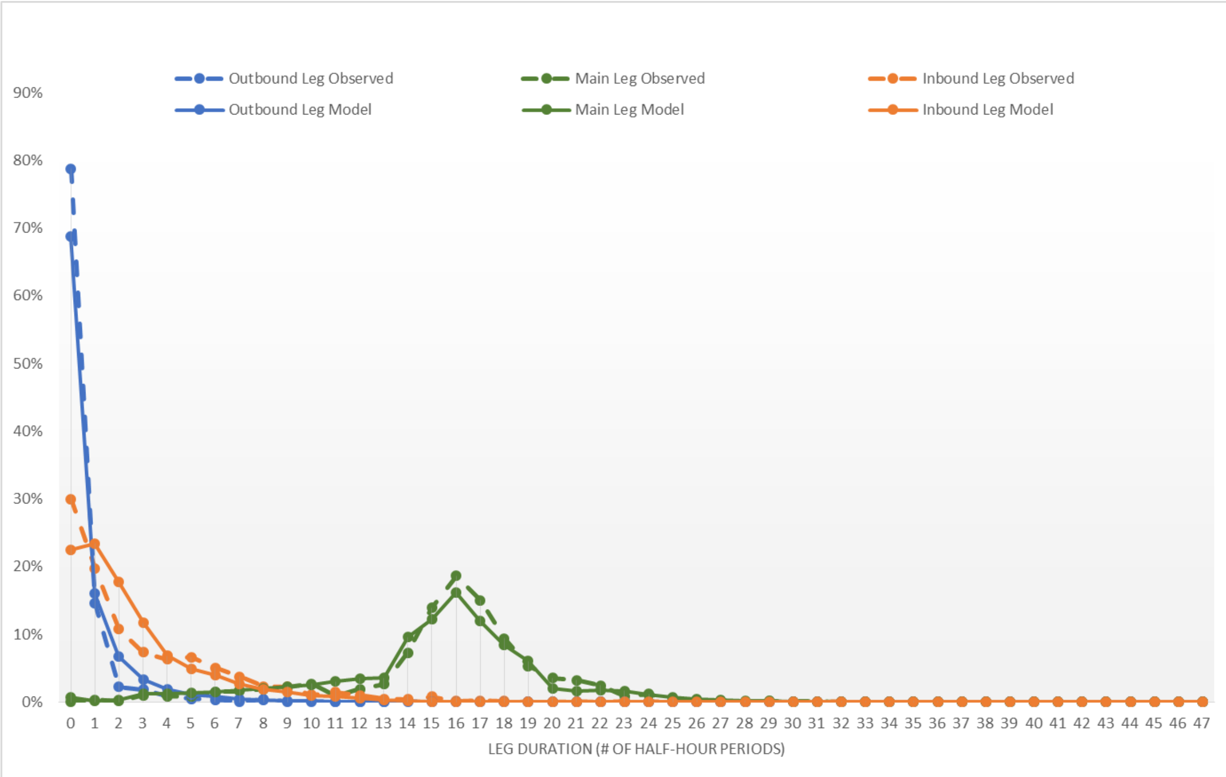


Figure 36: Tour Leg durations for Escort Tours

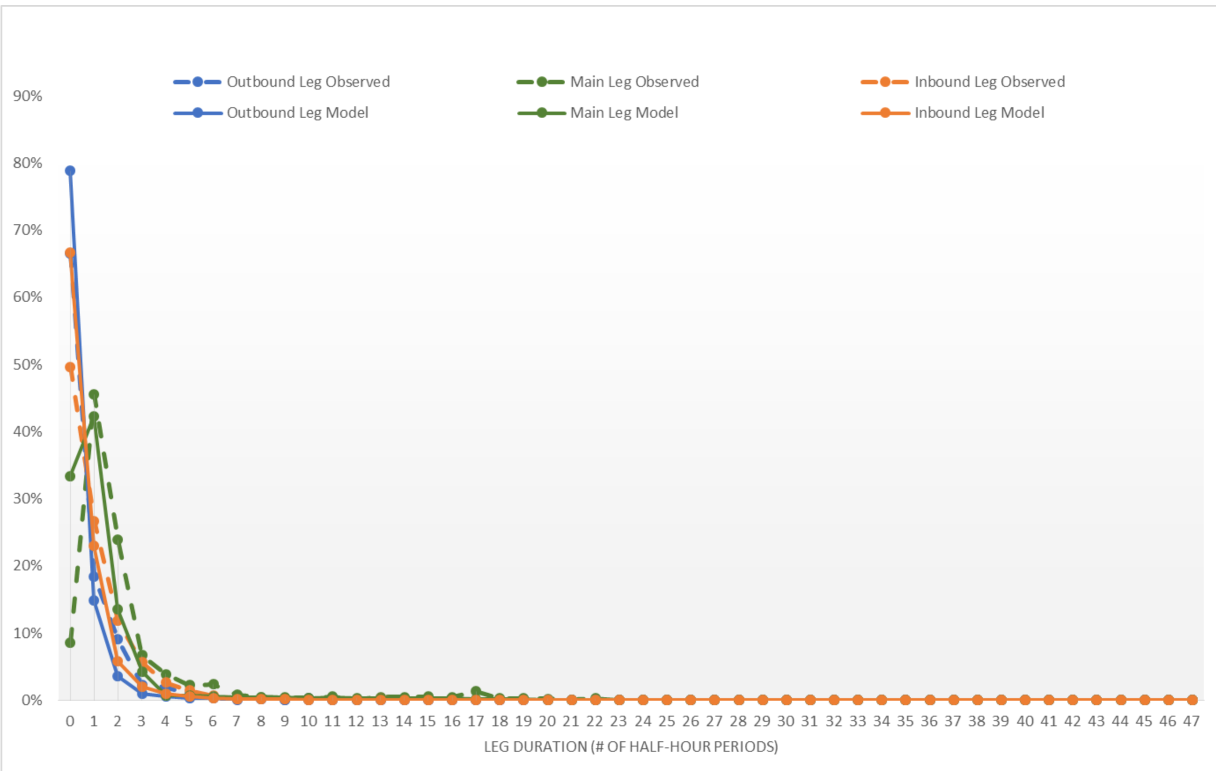


Figure 37: Tour Leg durations for Maintenance Tours

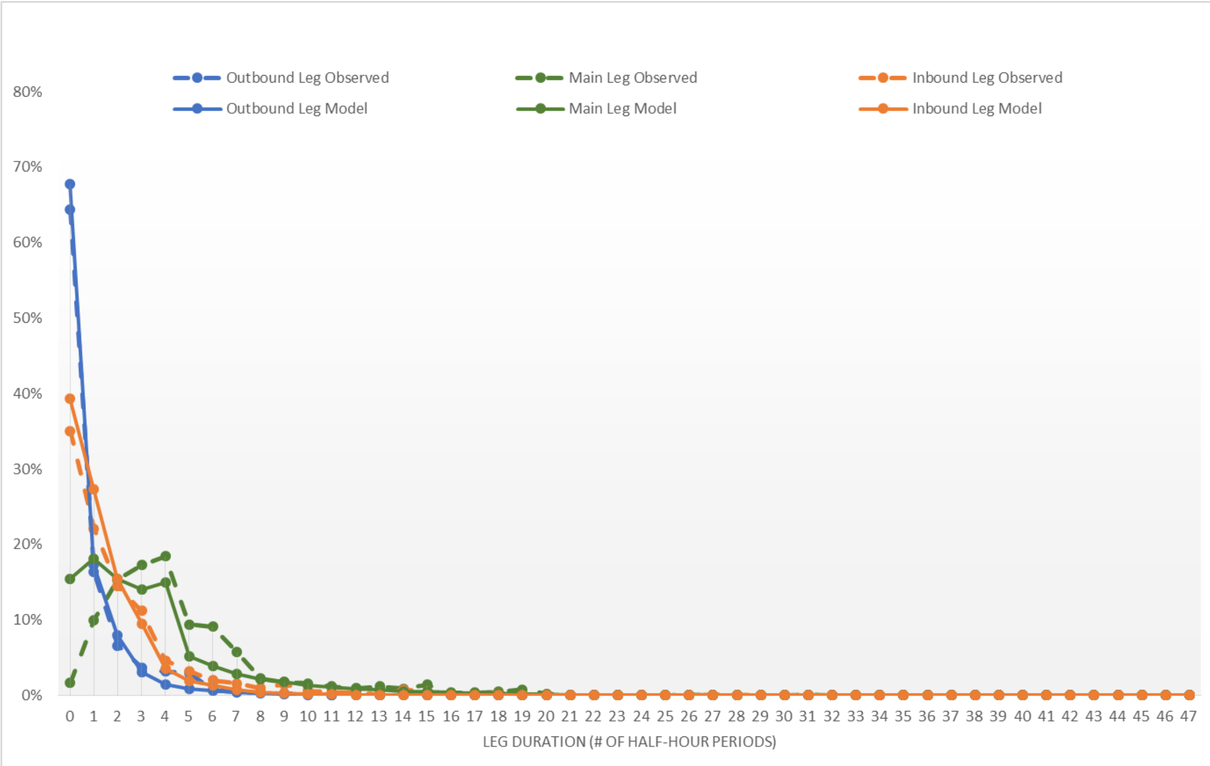


Figure 38: Tour Leg durations for Shopping Tours

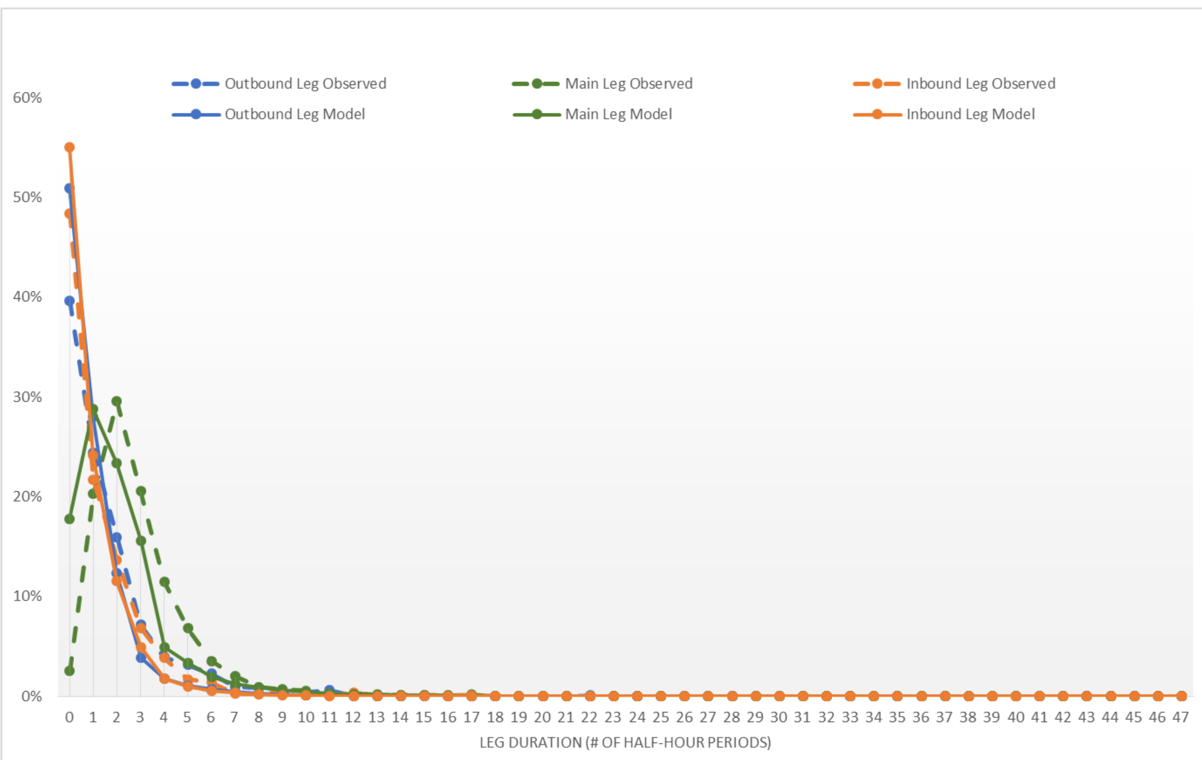


Figure 39: Tour Leg durations for Eatout Tours

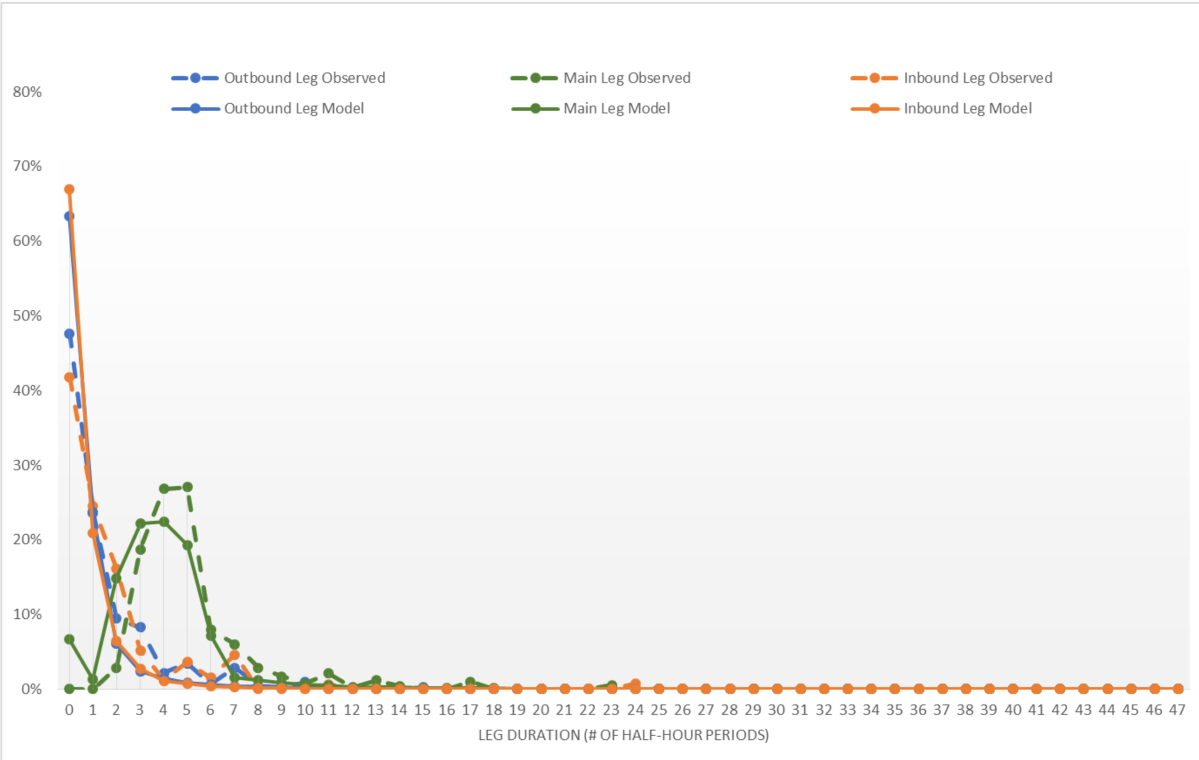


Figure 40: Tour Leg durations for Social Tours

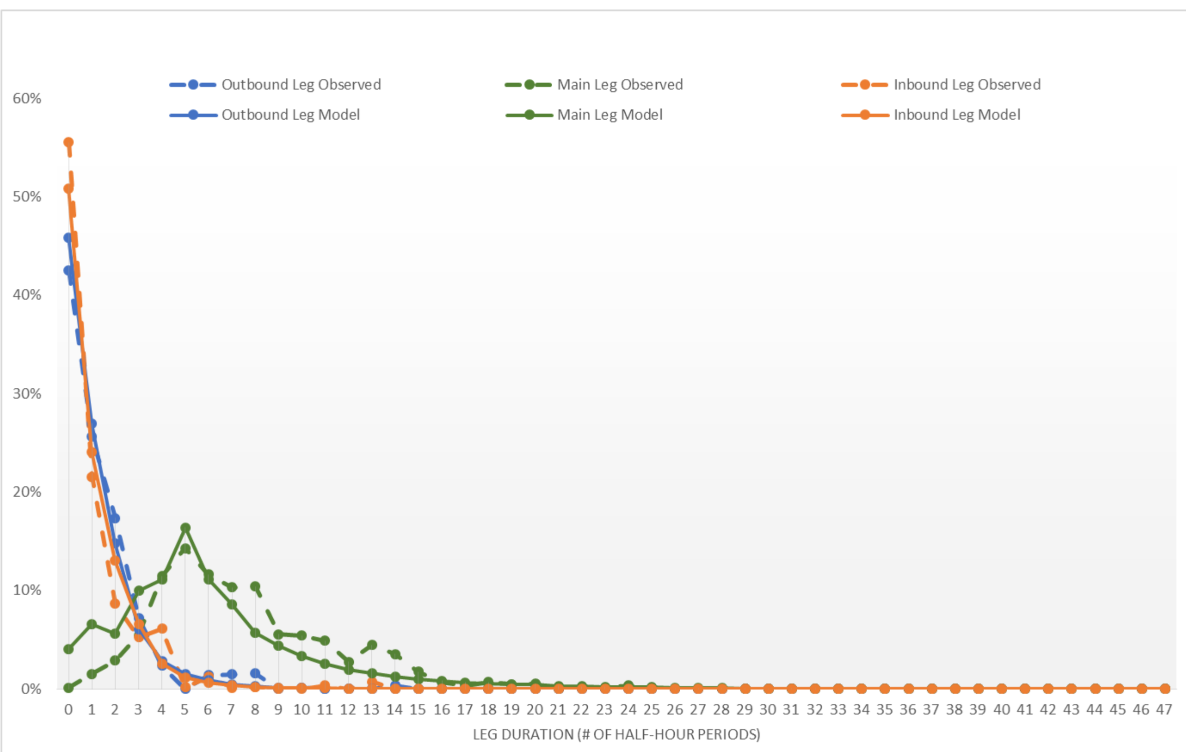


Figure 41: Tour Leg durations for Discretionary Tours

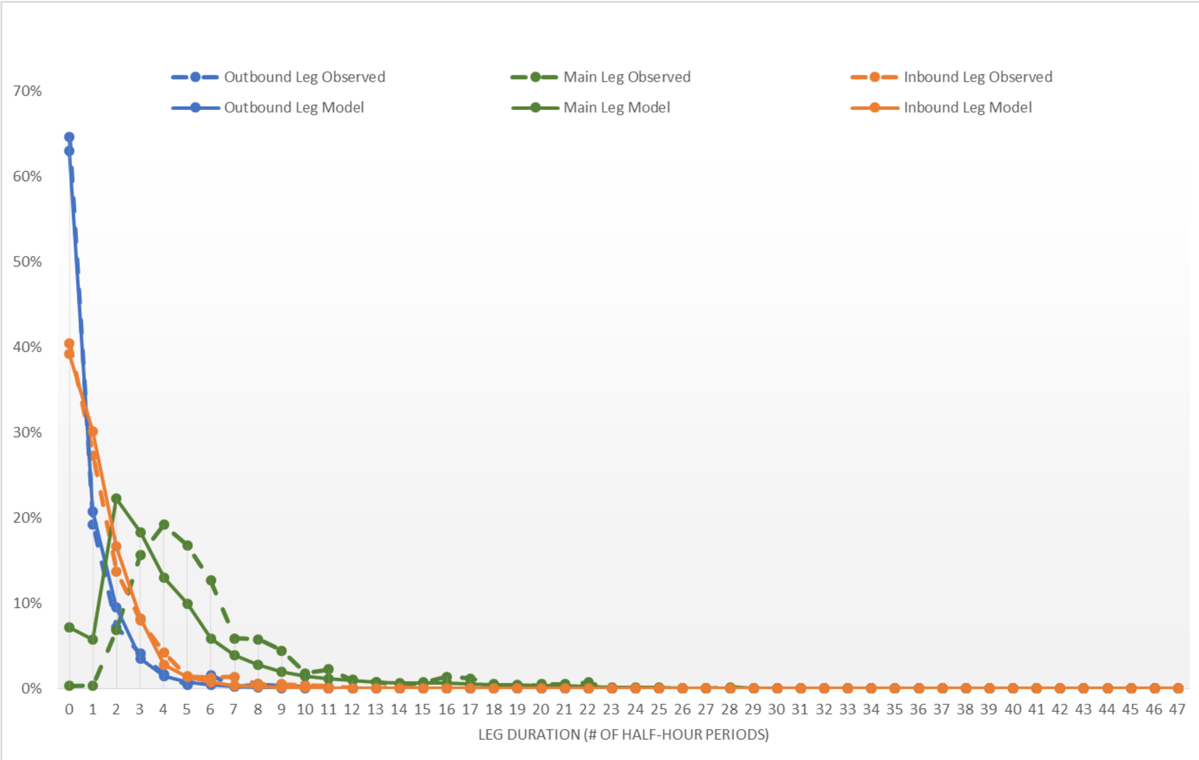


Figure 42: Tour Leg durations for At-work Sub-Tours

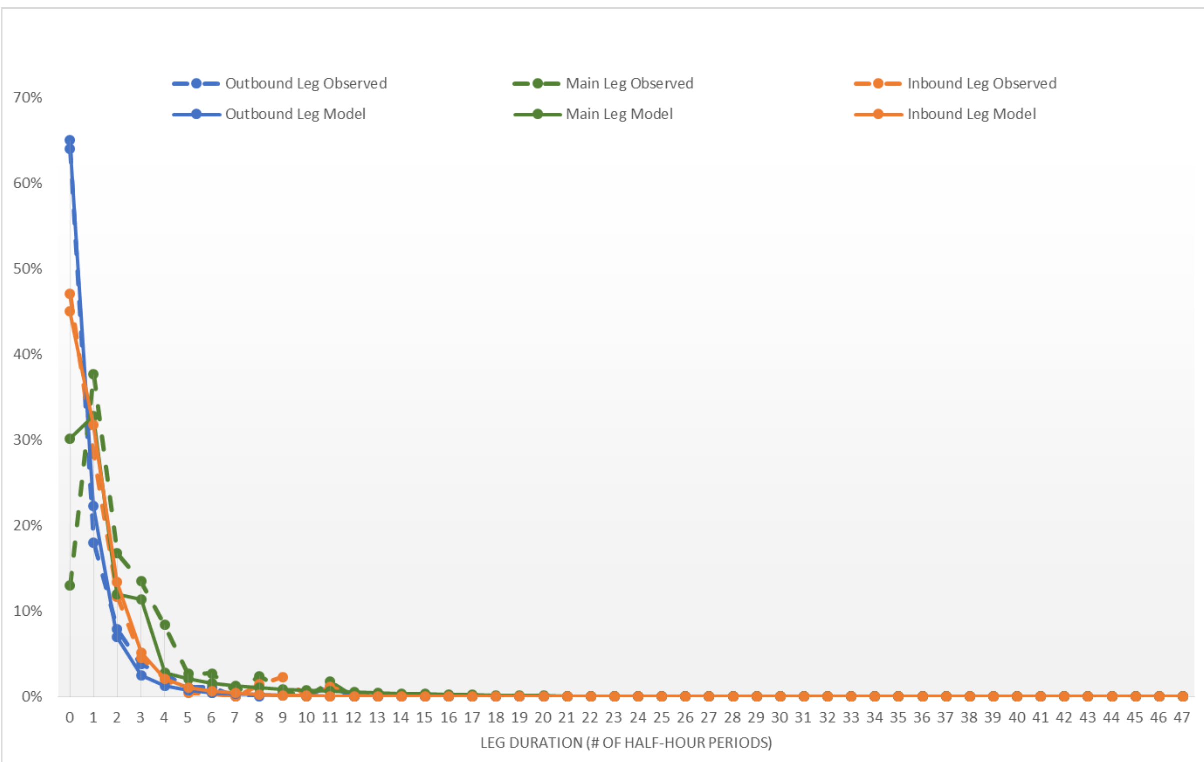


Figure 43 through **Figure 45** shows the calibration results for the inbound and outbound leg based on the number of stops on tours. We are matching the observed distributions closely for one and two stops on the leg of the tour. Please note how the difference between the observed and predicted is more for a higher number of stops on tours – this is so because the total number of tours with 2 and 3 stops on tours are a small portion of the entire tour set. This makes it difficult to accurately match these distributions. However, the final distributions shown here are reasonably close in terms of the total stops (in absolute terms).

Figure 43: Inbound and Outbound Leg durations for legs with one stop

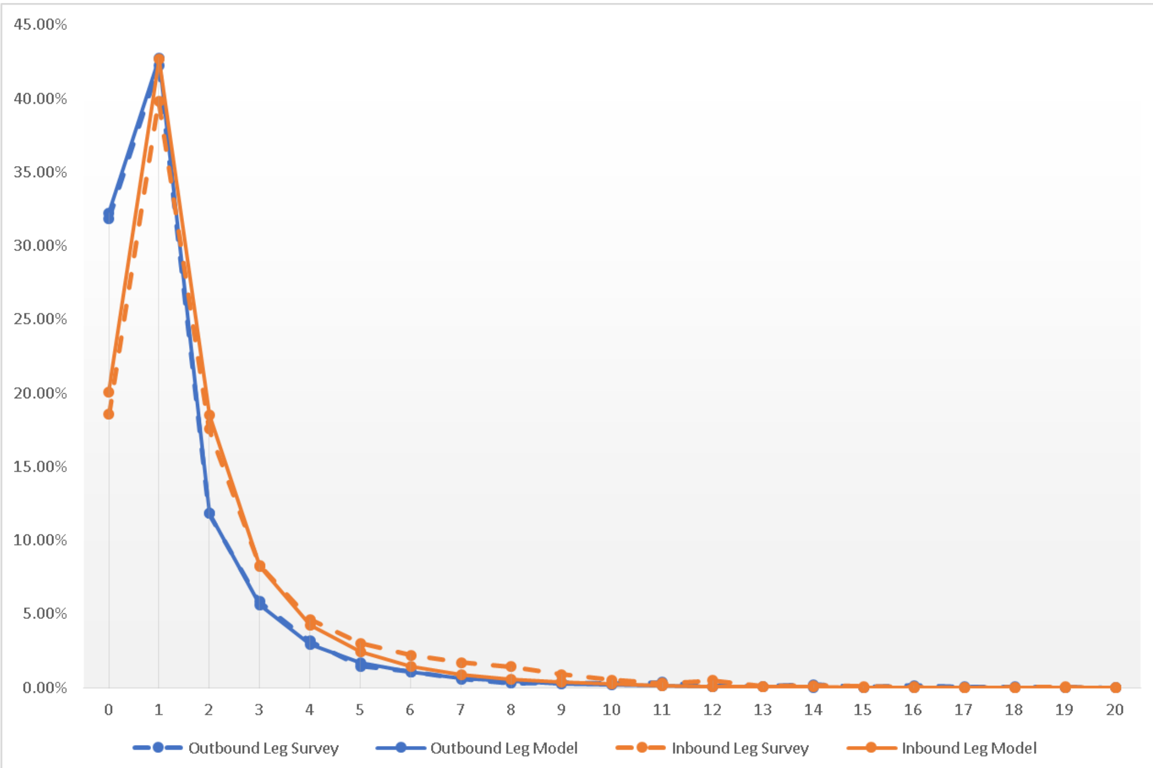


Figure 44: Inbound and Outbound Leg durations for legs with two stops

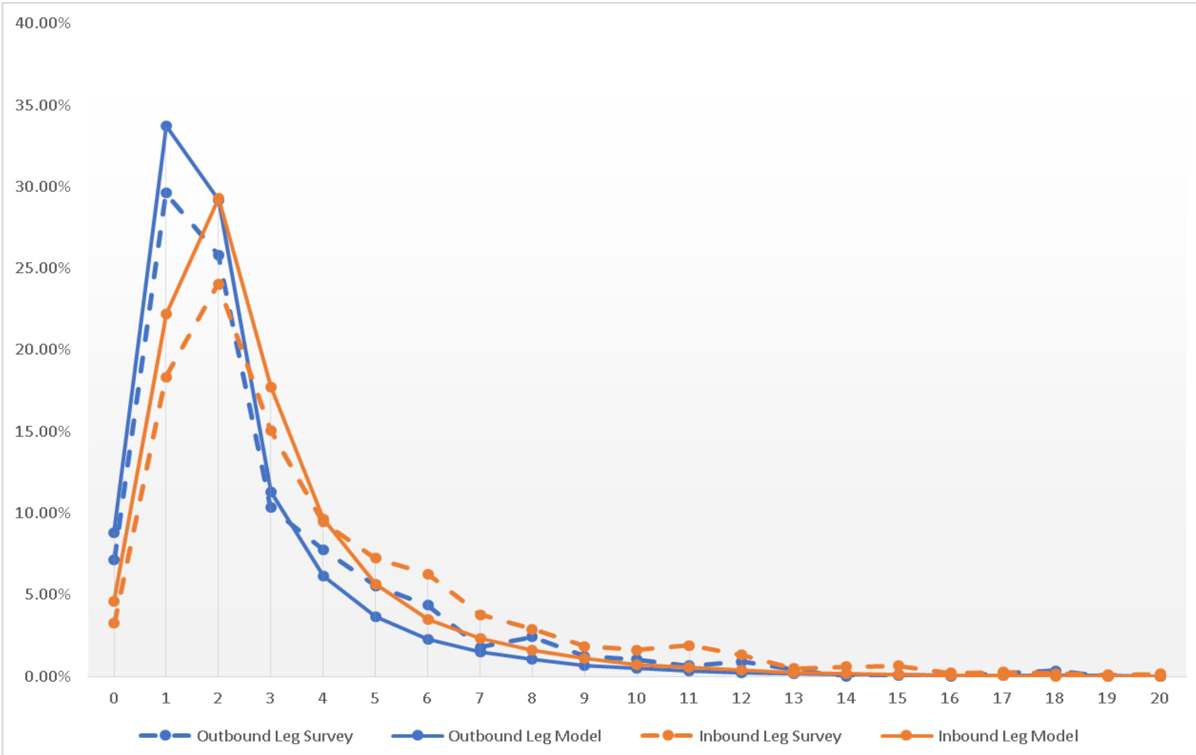


Figure 45: Inbound and Outbound Leg durations for legs with three stops

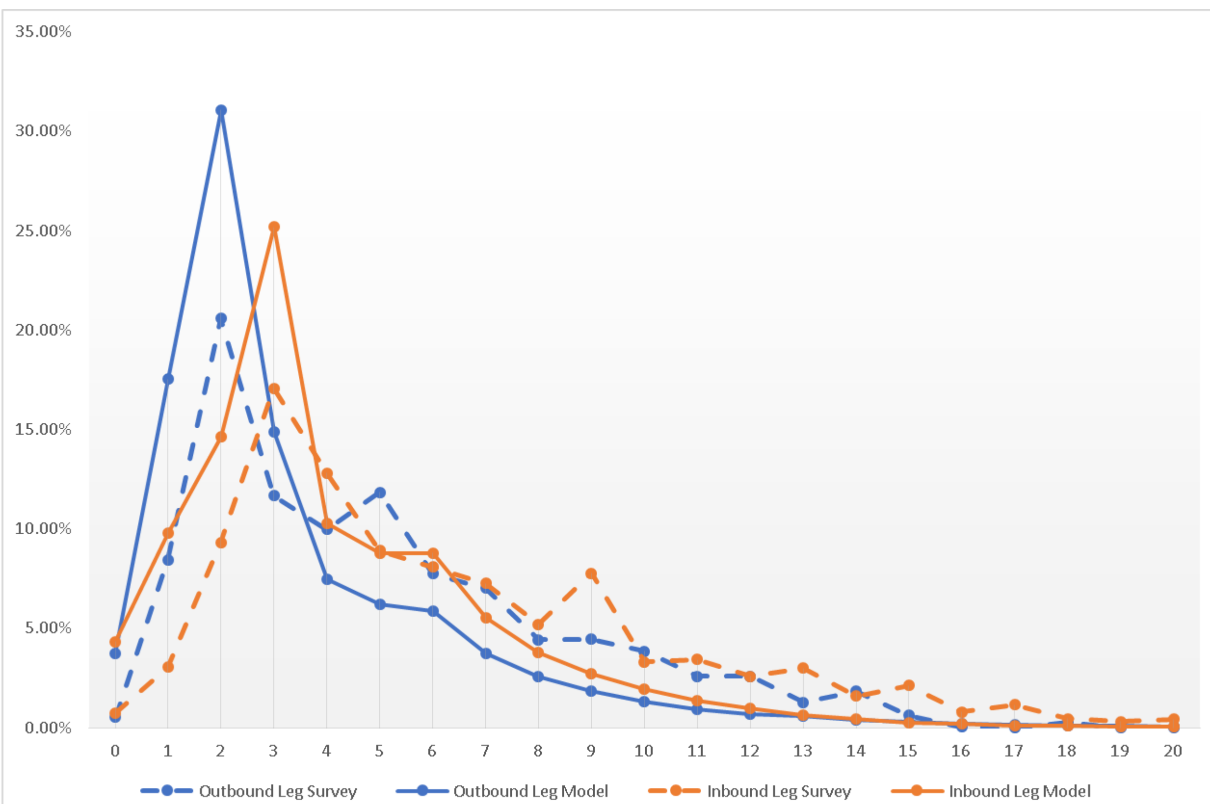


Table 32a: Final adjustments applied to the main leg duration by tour purpose for Stage 1 Model

Duration	Work	University	School	Escort	Maintenance	Shopping	Eatout	Social	Discretionary	At-Work
0				-2.8173	-3.3465	-2.0645	-100.0000	-5.9111		-1.9880
1				-0.3590	-1.5110	-1.0205	-100.0000	-2.9703		0.1619
2				1.2018	-0.4784	-0.0582	-6.8372	-1.5087		0.3350
3				1.6866	0.0637	0.5533	-0.3319			1.0155
4					0.4645		0.8709			
5							1.2215			
6							1.0655			
16			0.3565							
17			0.5677							
18			0.8005							
19	0.5253		0.7861							
20	0.7719									
21	1.0697									
22	1.2412									
23	1.1888									

Table 32b: Final adjustments applied to inbound and outbound leg durations by number of stops on leg for Stage 1 Model

Duration	Number of Stops					
	1		2		3	
	Outbound	Inbound	Outbound	Inbound	Outbound	Inbound
0	-0.7230	-1.9271	-4.8542	-6.9343	-15.0544	-14.2534
1	0.7921	0.2919	-0.1810	-1.3259	-4.8071	-8.0557
2			0.9673	0.4794	-0.1279	-2.1513
3			0.4671	0.4743	0.3056	0.3781

Stage 2 Model Calibration

The Stage 2 models were calibrated by the leg direction and stop purpose. Alternative specific constants were computed for each iteration as logarithm of observed by predicted for the duration which needed adjustment. Again, the adjustments are cumulated over the iterations. The final distributions are shown below in **Figure 46** through **Figure 53**.

Figure 46: Stop duration by tour leg and stop purpose – Work Stop

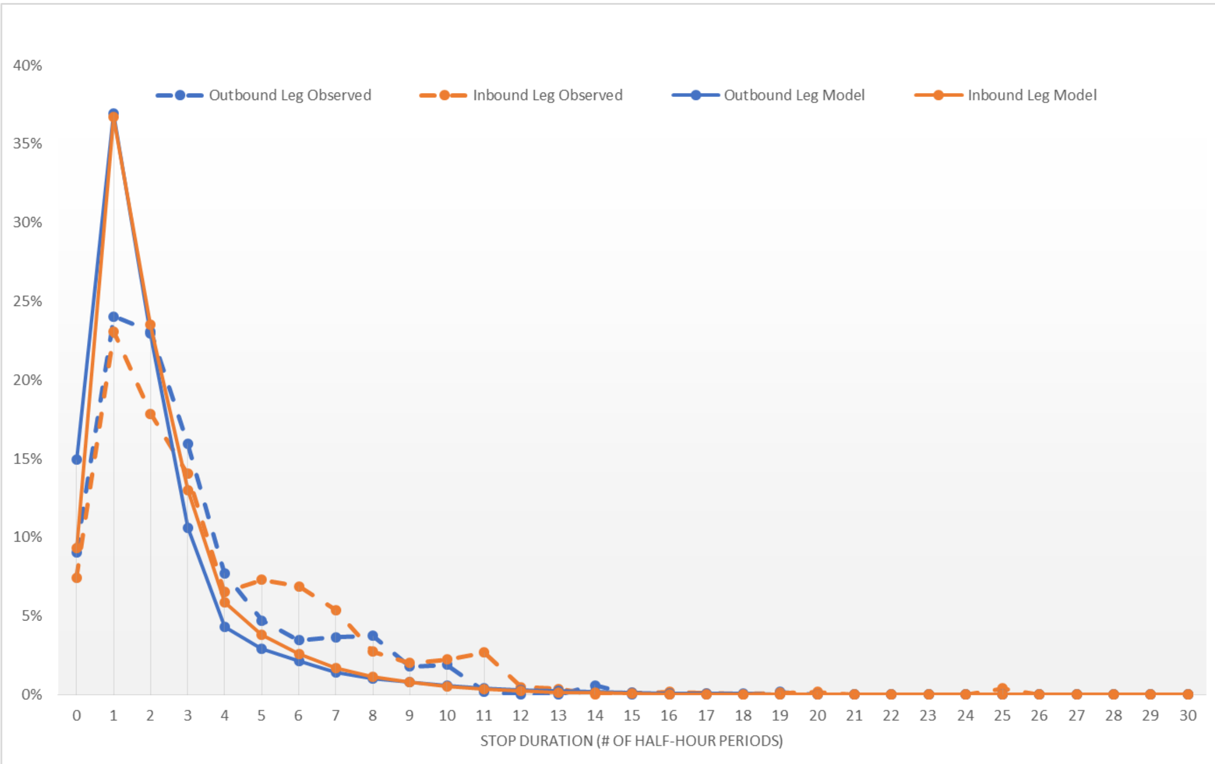


Figure 47: Stop duration by tour leg and stop purpose – School and University Stop

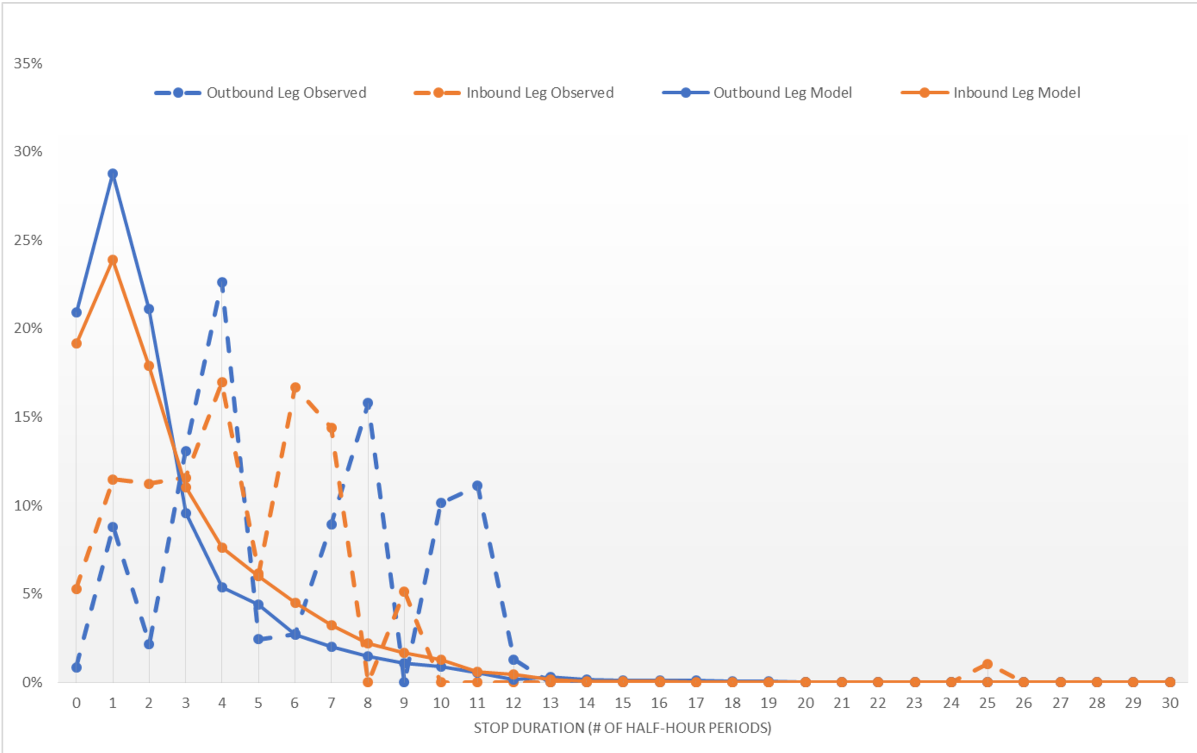


Figure 48: Stop duration by tour leg and stop purpose – Escort Stop

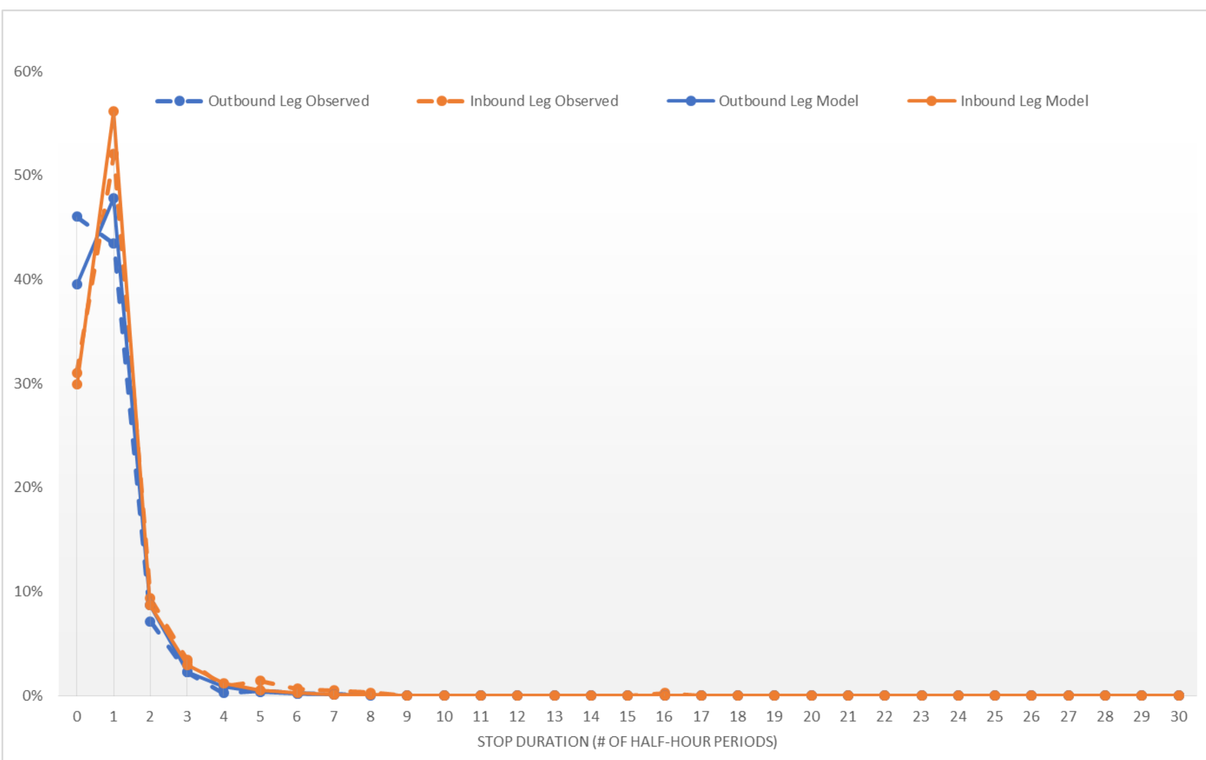


Figure 49: Stop duration by tour leg and stop purpose – Maintenance Stop

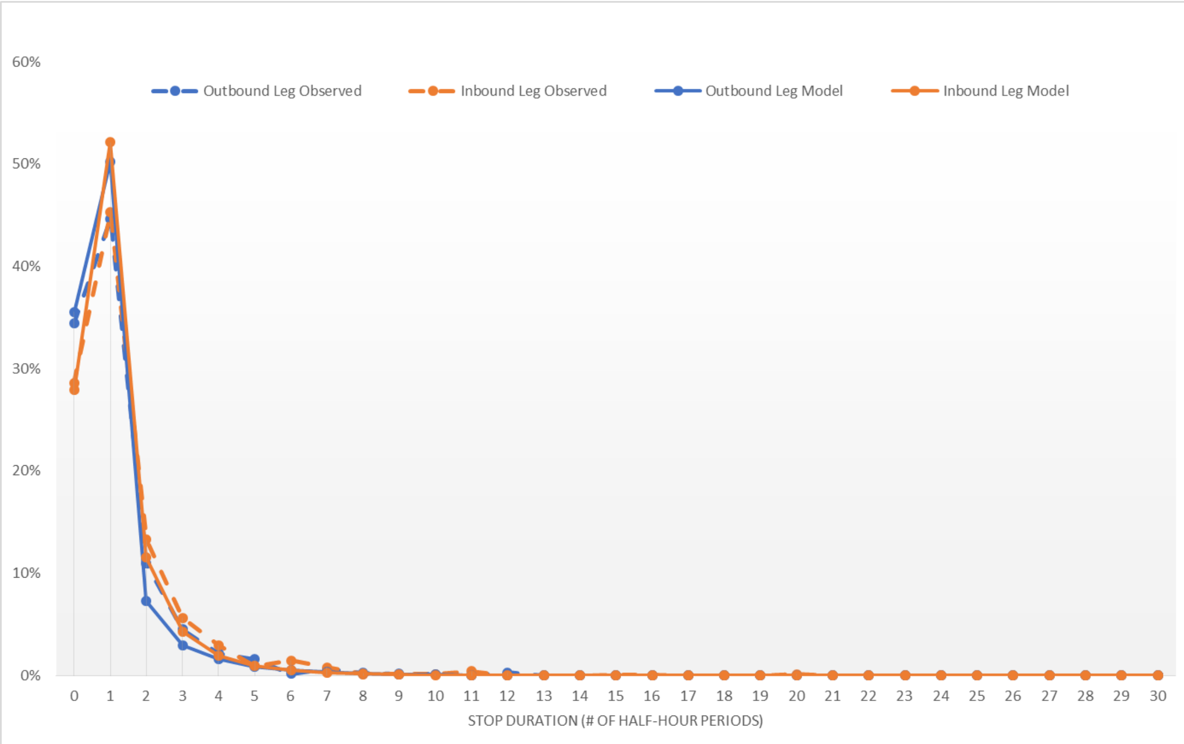


Figure 50: Stop duration by tour leg and stop purpose – Shopping Stop

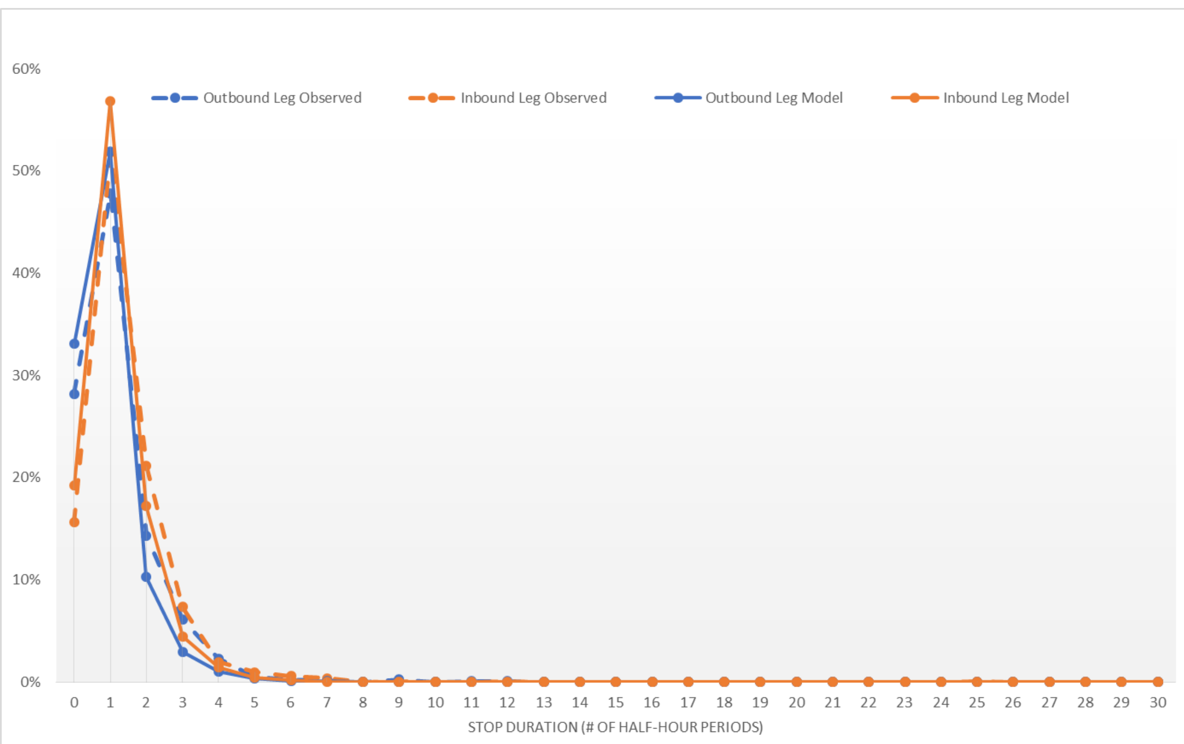


Figure 51: Stop duration by tour leg and stop purpose – Eatout Stop

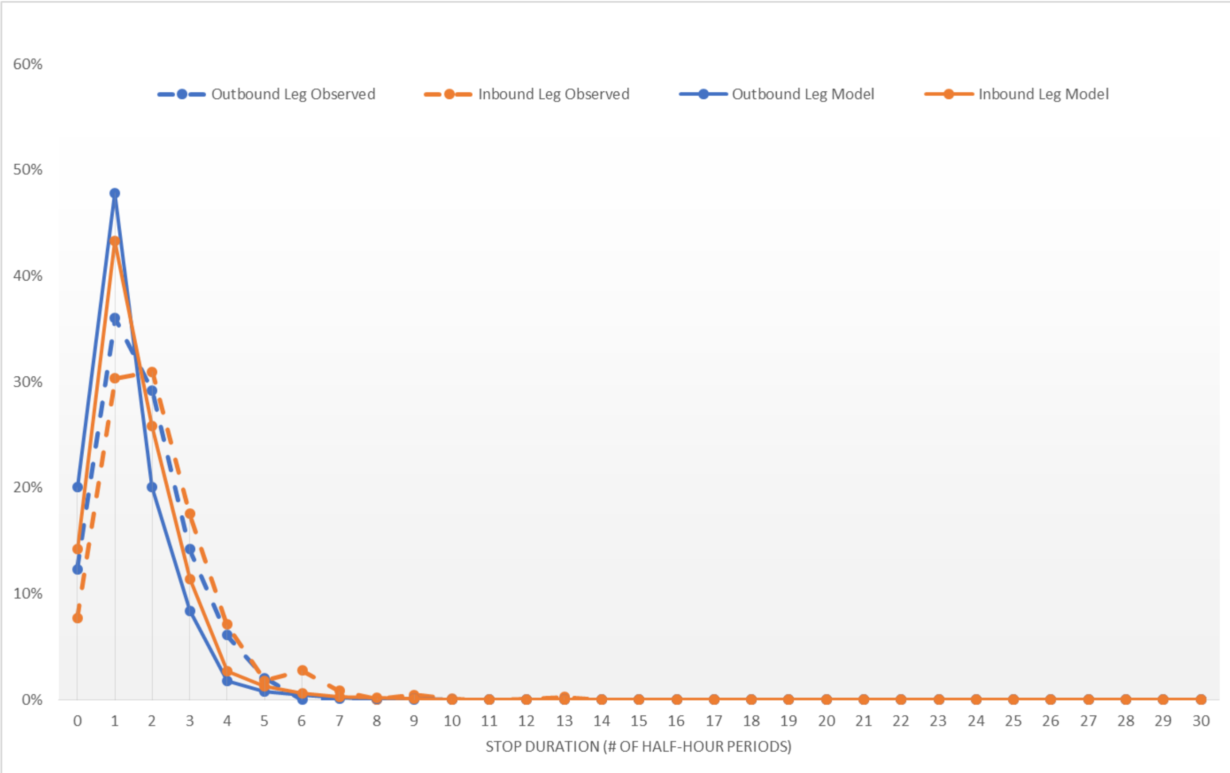


Figure 52: Stop duration by tour leg and stop purpose – Social Stop

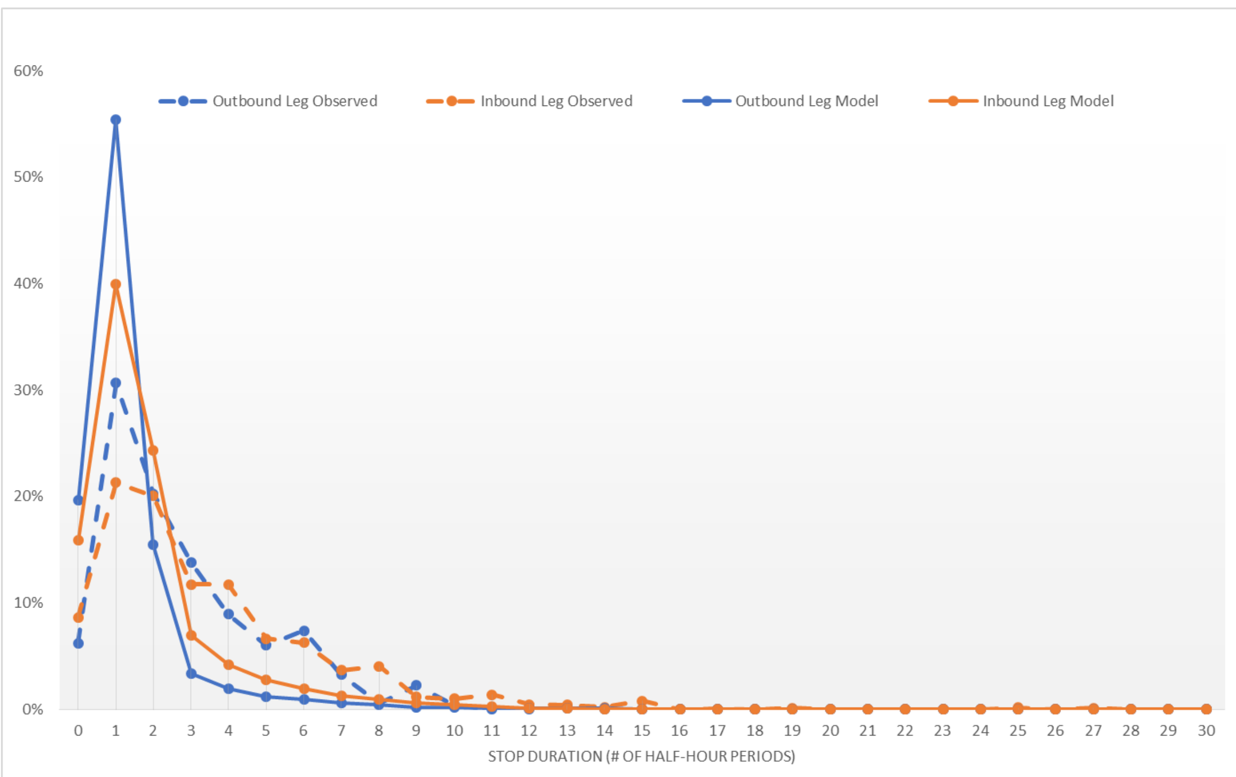


Figure 53: Stop duration by tour leg and stop purpose – Discretionary Stop

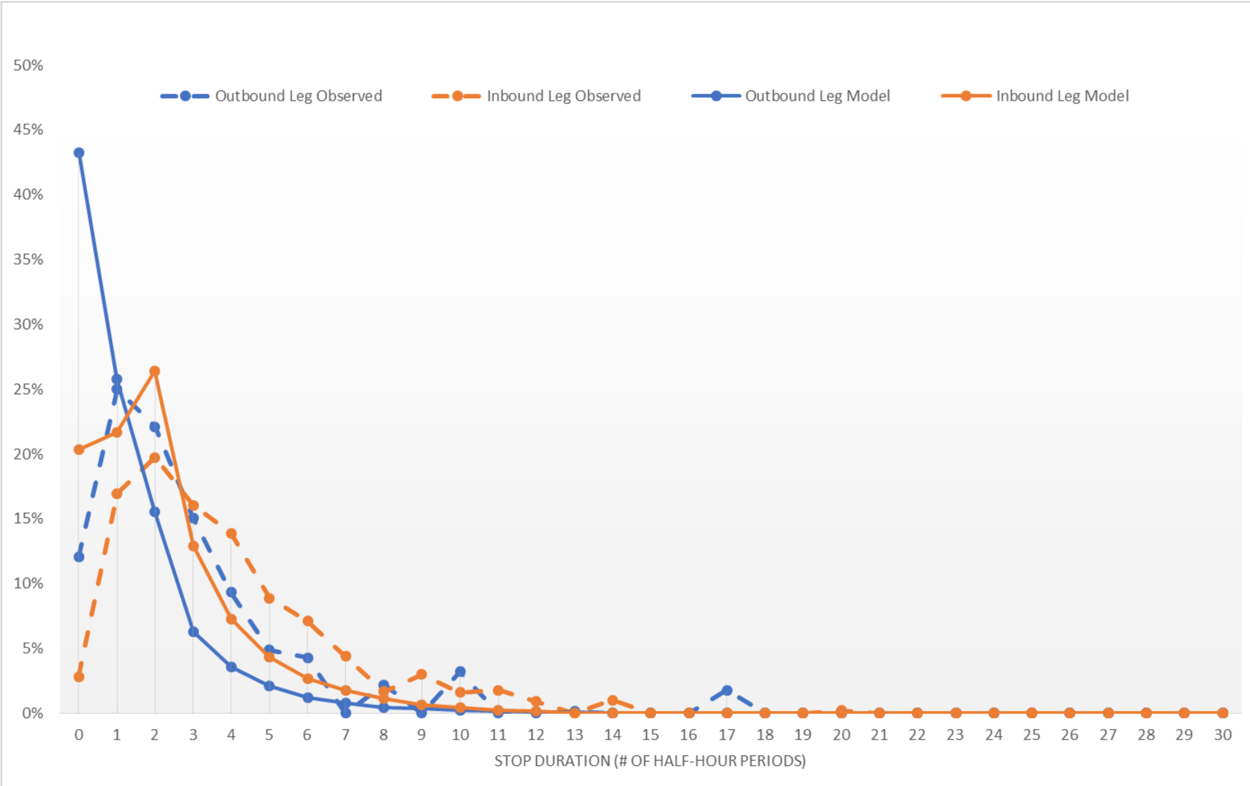


Table 33: Final adjustments applied to inbound and outbound leg durations by stop purpose for Stage 2 Model

	Work		University/School		Escort		Maintenance		Shopping		Eatout		Social		Discretionary	
Duration	O/B	I/B	O/B	I/B	O/B	I/B	O/B	I/B	O/B	I/B	O/B	I/B	O/B	I/B	O/B	I/B
0	-1.268	-1.293			-0.372	-0.732	-0.628	-0.692	-0.755	-1.187	-1.323	-1.644	-2.225	-1.607		
1	0.324	0.325			0.876	1.094	1.025	0.911	0.912	0.944	0.621	0.500	0.676	0.318		
2	0.280	0.110							-0.002	0.118	0.353	0.313	0.492	0.424		
3	0.456	0.319									0.680	0.625				

External Model

The External Travel Model forecasts trips for passenger cars and commercial vehicles. The model produces trips for internal-external and external-external movements. The initial External and Truck Models were developed based on a survey conducted by ARC in 1994-1995 at 30 sites on the periphery of the 13-county travel model study area. The roads were selected so that the survey sites captured nearly all of the high volume facilities where traffic enters and exits the region. Based on the data the following External Travel sub-models were developed.

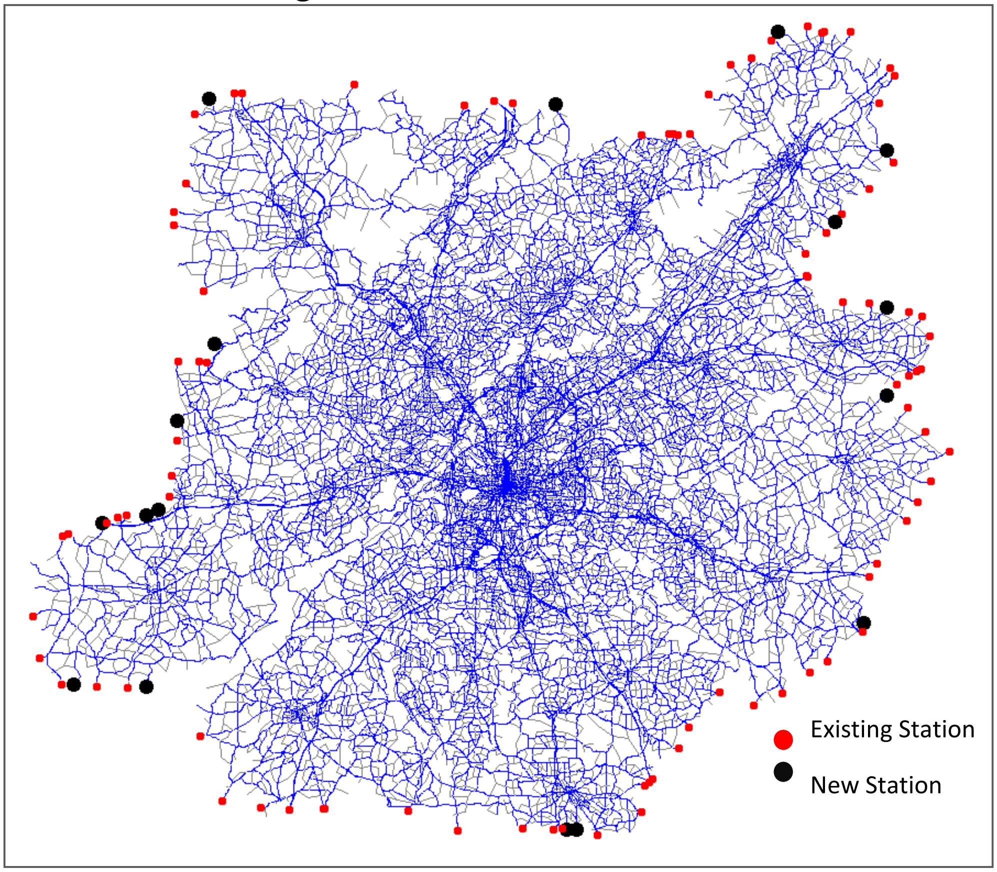
- External-External Passenger Car
- Internal-External
- Work Trips by Interstate Facilities
- Non-Work Trips by Interstate Facilities
- Work Trips by Non-Interstate Facilities
- Non-Work Trips by Non-Interstate Facilities

A new survey has not yet been conducted with the expansion of the modeling area to 20 counties due to time and budget constraints. With no survey available at the new model boundaries, the models developed from the previous survey were used. However, several modifications have been made to the external models since the expansion to 20 counties and are as follows:

- Commercial vehicle/truck model
- Use of 2010 average weekday traffic counts
- Transitioning to new conflated network (more internal zones and external stations)
- Use of GDOT vehicle classification counts
- Comparisons to GDOT statewide travel model
- Modifying the passenger car work trip equations based on 5-year ACS worker flows and AirSage County Commute Data

The new zone geographies required more highway network detail particularly in the outer counties. In some cases, the road facilities added extended to the external boundary. Some of these facilities had extremely low volumes and were not designated as external stations. The final cutoff to be an external station was an AADT of at least 500 vehicles. The external stations increased to 108 and are numbered from 5874 to 5981. The external station locations are provided in Figure 54 with the new stations shown with black dots. A detailed description of the survey results and initial model design is contained in the Transportation Solutions for A New Century – Appendix IV-V Model Documentation for the 2025 RTP, March 2000.

Figure 54 External Stations



The external input file contains a record for each external station and provides much of the information that the external model uses in application including the following:

- N = station number
- NAME = road name
- FIPS = county FIPs of count station
- EXTCNTSTA = count station number used for counts
- LANES = number of lanes
- EXTFLAG = external county grouping
- INTFLAG = interstate vs. non-interstate designation
- AADT2000 = year 2000 AADT
- AADT2005 = year 2005 AADT
- AADT2010 = year 2010 AADT
- AWDT2000 = year 2000 AWDT
- AWDT2005 = year 2005 AWDT
- AWDT2010 = year 2010 AWDT
- PCINTWK = percentage of interstate passenger car IE work trips
- PCINTNW = percentage of interstate passenger car IE non-work trips
- PCNINTW = percentage of non-interstate passenger car IE work trips
- PCNINTN = percentage of non-interstate passenger car IE non-work trips

- CAREE = percentage of passenger car EE trips
- COMIE = percentage of commercial vehicle IE trips
- COMEE = percentage of commercial vehicle EE trips
- MTKIE = percentage of medium duty truck IE trips
- MTKEE = percentage of medium duty truck EE trips
- HTKIE = percentage of heavy duty truck IE trips
- HTKEE = percentage of heavy duty truck EE trips

An example of the external station input file with some columns hidden is provided in Table 34.

Table 34 External Station Input File Example

A	B	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X
N	NAME	EXTFLAG	INTFLAG	AADT2000	AADT2005	AADT2010	AWDT2000	AWDT2005	AWDT2010	PCINTWK	PCINTNW	PCNINTW	PCNINTN	CAREE	COMIE	COMEE	MTKIE	MTKEE	HTKIE	HTKEE
5874	SR 113	7	0	9229	7890	7100	9840	8412	7570	0.0000	0.0000	0.3520	0.3519	0.0864	0.0941	0.0055	0.0551	0.0000	0.0462	0.0089
5875	Chulio Rd/Euhar	1	0	1122	1350	1430	1198	1440	1526	0.0000	0.0000	0.4207	0.4207	0.0000	0.1081	0.0000	0.0446	0.0000	0.0052	0.0000
5876	SR 20/US 411	1	0	18660	17290	16790	19892	18432	17900	0.0000	0.0000	0.3675	0.3675	0.0422	0.1002	0.0025	0.0411	0.0045	0.0546	0.0198
5877	SR 293	1	0	1400	1780	1630	1494	1898	1738	0.0000	0.0000	0.3717	0.3711	0.0213	0.1249	0.0023	0.0771	0.0000	0.0316	0.0000
5878	SR 140	1	0	9420	11450	10670	10042	12206	11376	0.0000	0.0000	0.3309	0.3309	0.0585	0.0953	0.0044	0.0900	0.0000	0.0861	0.0040
5879	Lancaster Rd	1	0	500	550	608	534	588	650	0.0000	0.0000	0.4138	0.4123	0.0000	0.1200	0.0000	0.0492	0.0000	0.0062	0.0000
5880	US 41	1	0	8160	8840	8600	8700	9424	9168	0.0000	0.0000	0.3733	0.3731	0.0201	0.1130	0.0028	0.0577	0.0000	0.0587	0.0013
5881	I-75	1	1	53129	61780	57990	53290	61966	58164	0.2551	0.2551	0.0000	0.0000	0.2022	0.0074	0.0003	0.0424	0.0108	0.0848	0.1420

The update of this file used information from the GDOT state-wide model, GDOT vehicle classification counts, ACS and AirSage data. Prior to running the state-wide model, an attribute was coded on links in the input highway network at a location near the ARC external locations. After running the state-wide model, a separate assignment process was used to extract vehicle trips that crossed one or more of these flagged links. The available output of the process included IE and EE trips for passenger cars, trucks, and commercial vehicles.

The first step in updating the input file was to establish the appropriate percentages by vehicle class at each station. The approach taken was to set the % truck (heavy and medium combined) and the % commercial vehicle and then compute the % passenger car (100% - % truck - % com). GDOT performs vehicle classification counts at numerous locations throughout the state and the information is available through GDOT's website[4]. Currently, the truck data for the permanent count stations is stored a bit differently than the portable count stations. GDOT prepares reports for their automated traffic recorders (ATR or permanent count stations) that include truck percentages by location. Currently, this information is stored in PDF format that can also be found on GDOT's website[5].

Using the GDOT count data, it was possible to determine the percent trucks by single unit (medium duty) and combination unit (heavy duty) for 73 external stations. For the remaining stations, the percentages were asserted using professional judgment after reviewing the current ARC input and results from the state-wide model extraction process. An example of the GDOT count data is provided in Figure 55. A map of the 73 locations is provided in Figure 56. In most cases, the count locations were in close proximity to the external stations; however, there are some instances (particularly for the permanent count stations) where the closest data point was several miles from the station.

[4] http://geocounts.com/gdot/

[5] https://www.dot.ga.gov/informationcenter/statistics/trafficdata/Pages/default.aspx

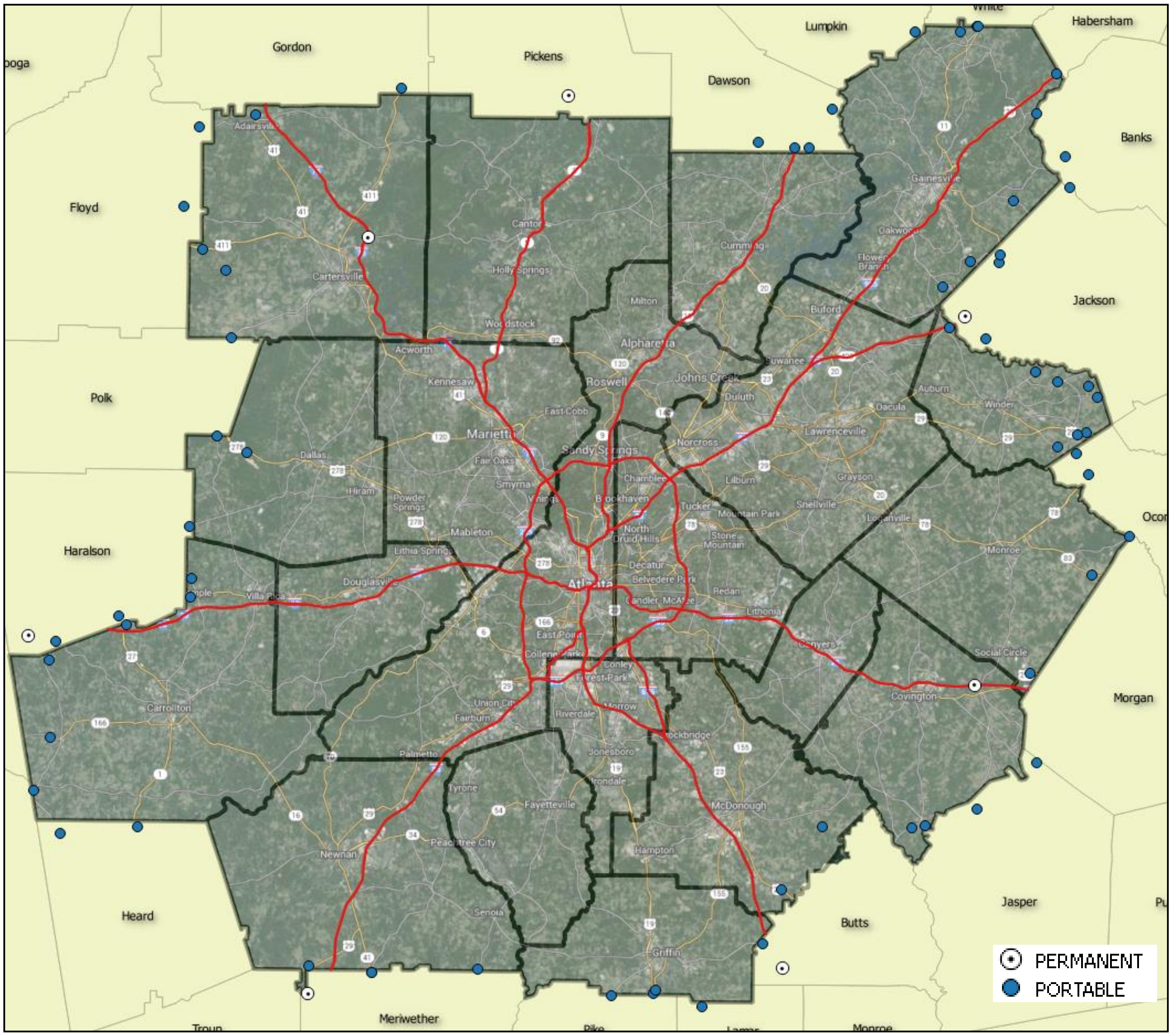
After determining the truck percentages (medium and heavy combined), the commercial vehicle shares were reviewed. Generally, the state-wide model showed fewer external trips than the ARC model. Since the ARC model commercial vehicle splits were based on count data that ARC collected as part of an update to the truck models in 2006-2007, the existing ARC percentages were deemed more appropriate and used directly. The passenger car percentage was then computed as 100% - (% commercial vehicle + % truck) for each station.

Figure 55 GDOT Vehicle Classification Count Data Example

Class By Hour
Direction: All Directions

Class	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	Vol	Trucks	CU	% Tr	% CU	Graphic
Monday Aug 31, 2009																					
14:00 PM	0	153	53	1	6	1	1	5	5	0	0	0	0	0	0	225	19	10	8.4	52.6	
15:00 PM	2	183	83	5	13	1	1	4	1	1	0	0	0	0	0	294	26	6	8.8	23.1	
16:00 PM	4	199	95	5	15	0	2	1	5	0	1	0	0	0	0	327	29	7	8.9	24.1	
17:00 PM	2	214	97	1	18	2	0	7	2	1	0	0	0	0	0	344	31	10	9.0	32.3	
18:00 PM	2	175	71	1	15	2	0	3	3	0	0	0	0	0	0	272	24	6	8.8	25.0	
19:00 PM	4	115	43	0	11	1	0	0	0	0	0	0	0	0	0	174	12	0	6.9		
20:00 PM	0	75	37	0	3	1	0	2	0	0	0	0	0	0	0	118	6	2	5.1	33.3	
21:00 PM	1	70	24	0	6	0	0	2	2	0	0	0	0	0	0	105	10	4	9.5	40.0	
22:00 PM	2	30	9	0	1	1	0	0	0	0	0	0	0	0	0	43	2	0	4.7		
23:00 PM	0	28	7	0	1	0	0	0	0	0	0	0	0	0	0	36	1	0	2.8		
Daily Total	17	1242	519	13	89	9	4	24	18	2	1	0	0	0	0	1938	160	45	8.3	28.1	
Tuesday Sep 01, 2009																					
00:00 AM	1	23	6	0	0	0	0	2	0	0	0	0	0	0	0	32	2	2	6.2	100.0	
01:00 AM	0	7	3	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0			
02:00 AM	0	7	1	0	0	1	0	1	1	0	0	0	0	0	0	11	3	2	27.3	66.7	
03:00 AM	0	14	6	1	1	1	0	0	3	0	0	0	0	0	0	26	6	3	23.1	50.0	
04:00 AM	1	26	15	0	1	2	1	0	1	0	0	0	0	0	0	47	5	1	10.6	20.0	
05:00 AM	1	95	57	1	8	2	1	4	3	0	0	0	0	0	0	172	19	7	11.0	36.8	
06:00 AM	2	148	83	0	18	2	1	5	3	0	0	0	0	0	0	262	29	8	11.1	27.6	
07:00 AM	5	200	93	6	20	4	0	5	1	1	0	0	0	0	0	335	37	7	11.0	18.9	
08:00 AM	2	106	61	3	11	6	0	7	3	0	0	0	0	0	0	199	30	10	15.1	33.3	
09:00 AM	4	121	40	2	14	2	0	3	3	0	0	0	0	0	0	189	24	6	12.7	25.0	
10:00 AM	5	97	53	1	11	5	0	4	8	0	0	0	0	0	0	184	29	12	15.8	41.4	
11:00 AM	2	103	55	2	11	4	0	5	4	0	0	0	0	0	0	186	26	9	14.0	34.6	
12:00 PM	1	110	58	2	11	6	0	3	4	0	0	0	0	0	0	195	26	7	13.3	26.9	
13:00 PM	1	131	71	2	18	1	0	3	4	0	0	0	0	0	0	231	28	7	12.1	25.0	
14:00 PM	3	152	51	3	10	4	0	4	1	0	0	0	0	0	0	228	22	5	9.6	22.7	
15:00 PM	2	180	71	4	16	2	1	3	3	0	0	0	0	0	0	282	29	6	10.3	20.7	
16:00 PM	0	198	79	4	22	0	0	4	4	0	0	0	0	0	0	311	34	8	10.9	23.5	
17:00 PM	1	251	101	0	16	1	0	3	1	0	0	0	0	0	0	**374**	21	4	5.6	19.0	
18:00 PM	1	173	67	0	13	1	0	6	1	0	0	0	0	0	0	262	21	7	8.0	33.3	
19:00 PM	2	136	65	1	11	1	0	2	0	0	0	0	0	0	0	218	15	2	6.9	13.3	
20:00 PM	1	77	31	0	6	1	0	1	2	0	0	0	0	0	0	119	10	3	8.4	30.0	
21:00 PM	1	64	13	0	5	0	0	1	1	0	0	0	0	0	0	85	7	2	8.2	28.6	
22:00 PM	0	32	8	0	2	2	0	0	1	0	0	0	0	0	0	45	5	1	11.1	20.0	
23:00 PM	1	33	12	0	0	2	0	0	1	0	0	0	0	0	0	49	3	1	6.1	33.3	
Daily Total	37	3726	1619	45	314	59	8	90	71	3	1	0	0	0	0	4052	431	120	10.6	27.8	
Wednesday Sep 02, 2009																					
00:00 AM	1	11	4	0	2	1	0	0	0	0	0	0	0	0	0	19	3	0	15.8		
01:00 AM	0	7	1	0	1	0	0	0	0	0	0	0	0	0	0	9	1	0	11.1		
02:00 AM	0	13	3	0	0	0	0	0	0	0	0	0	0	0	0	16	0	0			
03:00 AM	1	18	2	0	0	1	0	0	0	0	0	0	0	0	0	22	1	0	4.5		
04:00 AM	1	26	18	0	3	2	0	0	0	0	0	0	0	0	0	50	5	0	10.0		
05:00 AM	1	92	49	0	7	1	0	3	3	0	0	0	0	0	0	156	14	6	9.0	42.9	
06:00 AM	1	153	81	0	18	0	0	5	1	0	0	0	0	0	0	259	24	6	9.3	25.0	
07:00 AM	4	172	84	6	23	1	2	12	4	0	0	0	0	0	1	309	**48**	16	15.5	33.3	
08:00 AM	2	131	59	2	10	1	2	5	6	1	0	0	0	0	0	219	27	12	12.3	44.4	
09:00 AM	2	99	48	3	10	2	0	8	8	1	0	0	0	0	0	181	32	17	17.7	53.1	
10:00 AM	5	114	38	2	2	6	1	2	2	0	0	0	0	0	0	172	15	4	8.7	26.7	
11:00 AM	6	111	40	0	7	4	0	2	3	0	0	0	0	0	0	173	16	5	9.2	31.2	
12:00 PM	4	124	49	5	12	5	1	9	10	1	0	0	0	0	0	220	43	20	19.5	46.5	
13:00 PM	6	134	58	3	11	3	0	10	3	0	0	0	0	0	0	228	30	13	13.2	43.3	
Overall Total	88	4931	2153	66	420	86	14	146	111	6	1	0	0	0	1	8023	850	264	10.6	31.1	
Pct. (%)	1.1	61	27	0.8	5.2	1.1	0.2	1.8	1.4	0.1	0.0	0.0	0.0	0.0	0.0						

Figure 56 GDOT Vehicle Classification Count Locations



After the percentages by vehicle class were set, it was possible to start splitting the vehicle classes into IE vs. EE. The extracted data from the state-wide model and ARC's existing assumptions were used to perform these splits. The state-wide model included coverage of 88 out the 108 ARC stations and the IE/EE splits were compared against the current ARC model assumptions for all of these stations. In most cases, the final percentage used for the splits was an average of the existing ARC data and the state-wide model. However, professional judgement was used in some locations if there were extremely large discrepancies between the two sources. An example of the IE and EE splits for passenger cars is provided in Table 35.

Table 35 Passenger Car IE versus EE Example

N	NAME	ARC DATA		STATEWIDE 2010		FINAL	
		IE	EE	IE	EE	IE	EE
5874	SR 113	95%	5%	83%	17%	89%	11%
5875	Chulio Rd/Euhar	95%	5%	-	-	100%	0%
5876	SR 20/US 411	95%	5%	94%	6%	95%	5%
5877	SR 293	95%	5%	100%	0%	97%	3%
5878	SR 140	95%	5%	89%	11%	92%	8%
5879	Lancaster Rd	100%	0%	-	-	100%	0%

The final update to the input file was the passenger car percentage split of work versus non-work trips. The previous input used a 43% work and 57% non-work split for all stations. To check these splits, both the 5-year (2006-2010) ACS CTPP data[6] and a beta version of AirSage commute data were used. The beta version of the AirSage data was made available to a number of users in late 2014 and will be made available for public use in early 2015 (January 12, 2015). AirSage provided permission to use the beta version of the data for this analysis. In both data sources, it was possible to extract county-to-county work flows/trips for the ARC region and counties surrounding ARC. As the ACS represents home and work location, the flows in the data are one-directional. However, the model trips represent both directions of travel (home-to-work and work-to-home); therefore, the total ACS trip ends were multiplied by two to be consistent. The two data sources were averaged to tabulate a target total for the IE/EI work trip ends. As shown in Table 36, the target number of work trips for the region is approximately 268,000. Using the revised estimates from the input file, the total base year IE/EI passenger cars are about 540,000 which indicate the overall share of work trips is about 50% (268000 / 540000). This share was applied in the new input table for all external stations.

Table 36 AirSage and ACS External Work Trip Ends

COUNTY	NUMBER	AIRSAGE			ACS CTPP DATA				Avg
		IE	EI	TOTAL	IE	EI	TOTAL	TOTAL TRIPS	
Fulton	1	16,895	26,810	43,705	2,923	15,264	18,187	36,374	40,040

[6] http://ctpp.transportation.org/Pages/5-Year-Data.aspx

DeKalb	2	10,591	9,823	20,414	2,516	4,737	7,253	14,506	17,460
Cobb	3	8,409	11,623	20,032	3,219	6,577	9,796	19,592	19,812
Gwinnett	4	15,690	14,382	30,072	6,040	8,585	14,625	29,250	29,661
Rockdale	5	1,260	1,077	2,337	669	1,433	2,102	4,204	3,271
Henry	6	4,566	4,768	9,334	2,309	3,907	6,216	12,432	10,883
Clayton	7	3,483	2,499	5,982	1,309	3,517	4,826	9,652	7,817
Fayette	8	1,351	2,202	3,553	685	1,925	2,610	5,220	4,387
Douglas	9	1,036	831	1,867	859	1,108	1,967	3,934	2,901
Cherokee	10	4,178	4,861	9,039	2,270	3,770	6,040	12,080	10,560
Coweta	11	3,007	3,743	6,750	1,994	3,548	5,542	11,084	8,917
Forsyth	12	3,488	5,422	8,910	1,883	5,096	6,979	13,958	11,434
Paulding	13	2,226	1,616	3,842	1,310	1,239	2,549	5,098	4,470
Bartow	14	6,632	5,520	12,152	4,398	6,191	10,589	21,178	16,665
Carroll	15	3,288	3,371	6,659	3,632	5,913	9,545	19,090	12,875
Spalding	16	3,781	4,839	8,620	1,905	6,389	8,294	16,588	12,604
Newton	17	3,214	2,384	5,598	1,204	2,488	3,692	7,384	6,491
Walton	18	4,220	2,156	6,376	2,550	1,744	4,294	8,588	7,482
Barrow	19	5,880	3,249	9,129	4,302	2,707	7,009	14,018	11,574
Hall	20	10,264	10,436	20,700	5,398	12,982	18,380	36,760	28,730
Total		**113,459**	**121,612**	**235,071**	**51,375**	**99,120**	**150,495**	**300,990**	**268,031**

A summary of the differences by vehicle type and IE/EE is provided in Table 37. For passenger cars, the largest difference is the split between work and non-work previously discussed. While the percentage difference of the EE trips for commercial vehicles increased substantially, the overall EE trip increase was relative low (1,600). The increase in EE medium duty truck trips is similar in showing a 31% increase but this translates into only 780 more trips. For heavy duty trucks, the number of IE trips increased by 9% while the number of EE trips decreased by 28% which resulted in an overall decrease of heavy truck trips at the external stations compared to the existing percentages. The decrease in heavy duty trucks as compared to the existing percentages is primarily a function of the changes at the interstate stations. At each of these externals, the percentages were updated using GDOT's permanent count station data. This resulted in lower overall truck percentages with the exception of I-20 west which remained the same. It also resulted in a higher share of medium duty trucks as compared to heavy duty trucks at all the interstate externals excluding I-20 west. The comparison of the truck percentages for these interstates is provided in the Table 38

Table 37 External Input Summary Comparison

Vehicle Type	Purpose	Original	Revised	Difference	% Difference
Passenger Car	IE Work	229,576	270,505	40,929	18%
	IE Non-Work	299,842	270,450	-29,392	-10%

	EE	95,063	97,398	2,335	2%
	Sub-total	***624,481***	***638,353***	***13,872***	***2%***
Commercial Vehicle	IE	53,893	52,276	-1,617	-3%
	EE	1,160	2,778	1,618	139%
	Sub-total	***55,053***	***55,054***	***1***	***0%***
Medium Duty	IE	40,014	35,861	-4,153	-10%
	EE	2,516	3,294	778	31%
	Sub-total	***42,530***	***39,155***	***-3,375***	***-8%***
Heavy Duty	IE	39,636	43,256	3,620	9%
	EE	49,749	35,630	-14,119	-28%
	Sub-total	***89,385***	***78,886***	***-10,499***	***-12%***

Table 38 Interstate Truck Comparison

		Existing Model			**Revised Model**			**Difference**		
N	**NAME**	**% Truck**	**MTK Share**	**HTK Share**	**% Truck**	**MTK Share**	**HTK Share**	**% Truck**	**MTK Share**	**HTK Share**
5881	I-75 North	34%	2%	98%	28%	19%	81%	-6%	17%	-17%
5911	I-85 North	28%	11%	89%	22%	17%	83%	-6%	6%	-6%
5931	I-20 East	23%	19%	81%	19%	27%	73%	-4%	8%	-8%
5941	I-75 South	25%	7%	93%	21%	15%	85%	-4%	8%	-8%
5955	I-85 South	22%	17%	83%	18%	20%	80%	-4%	3%	-3%
5969	I-20 West	33%	15%	85%	33%	13%	87%	0%	-2%	2%

The trip generation component of the ARC external model uses the external station data as productions with the attractions occurring in the internal zones (subsequently balanced to the productions). The focus in this effort was to review the passenger car work trip generation model and compare that against the available ACS and AirSage commute data. As both data sources provide county level information, the model IE work trips were aggregated to counties as well. The summary provided in Table 39 includes the existing model and the existing model formulation but with the updated external inputs. The existing model underestimates total external work trips by 48,000 trips with a significant portion of this underestimation occurring in Fulton County. By modifying the external station passenger car work shares, the existing model formulation predicts the right magnitude of work trips, but there are still instances where the model isn't matching the observed data very well (Fulton, DeKalb, Cobb). Scatterplots for both the existing model and the existing model with updated inputs are provided in Figure 57 and Figure 58. The low coefficient of determination (R-squared) illustrated in the plots is further indication that the existing model formulation has some deficiencies in predicting the location of external work trips within the region.

Table 39 Existing Model County Level IE/EI Work Trips

County	**Target**	**Existing Model**	**Existing Model w/ Updated Inputs**
Fulton	40,040	17,514	21,619
DeKalb	17,460	6,068	7,491

Cobb	19,812	8,638	10,653
Gwinnett	29,661	33,545	41,372
Rockdale	3,271	4,427	5,451
Henry	10,883	12,797	15,766
Clayton	7,817	4,325	5,336
Fayette	4,387	3,531	4,317
Douglas	2,901	3,633	4,439
Cherokee	10,560	9,747	11,996
Coweta	8,917	9,010	11,070
Forsyth	11,434	14,971	18,384
Paulding	4,470	2,934	3,569
Bartow	16,665	9,682	11,813
Carroll	12,875	15,367	18,730
Spalding	12,604	12,508	15,137
Newton	6,491	9,034	11,071
Walton	7,482	5,358	6,516
Barrow	11,574	10,790	13,233
Hall	28,730	26,567	32,324
Total	**268,031**	**220,446**	**270,287**

Figure 57 Existing Model Scatterplot

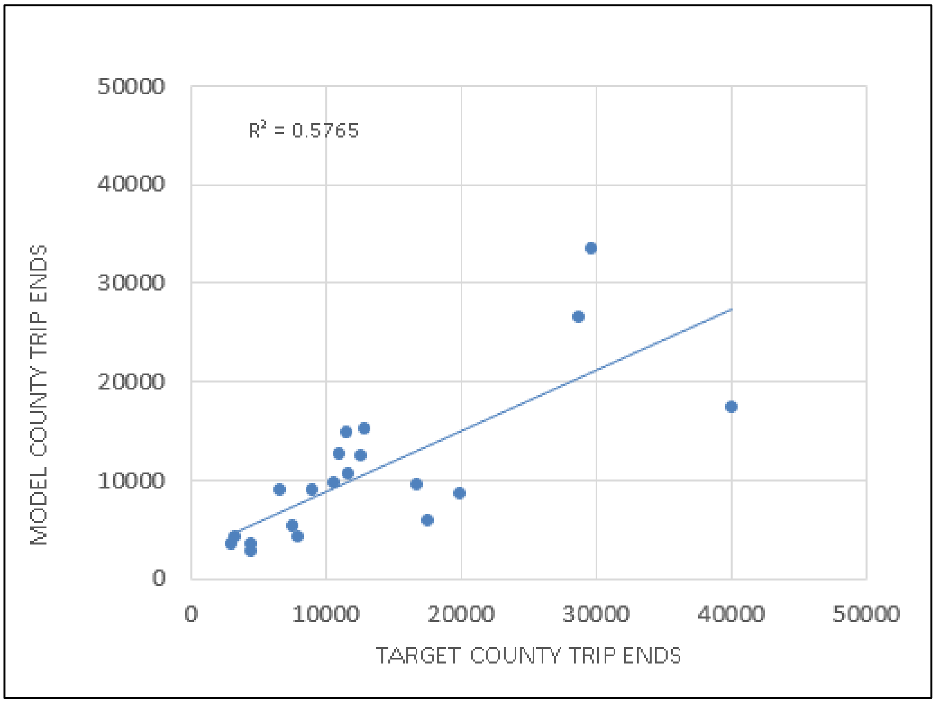
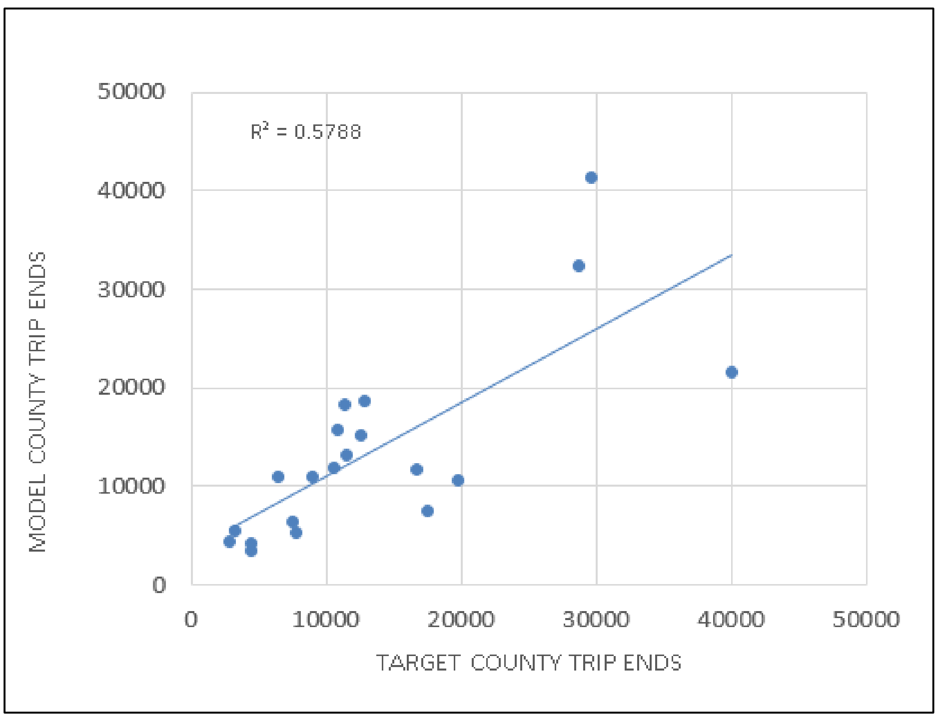


Figure 58 Existing Model Updated Inputs Scatterplot



The magnitude of IE/EI trips at the TAZ level is not only highly dependent on the development within the zone, but also on the proximity of the TAZ to the external boundary. For example, consider two zones with similar socioeconomic characteristics (number of jobs and households).

If one of the zones is 5 minutes from an external station and the other is 60 minutes, it is probable that the closest zone generates more IE/EI travel than the other zone. Therefore, when determining the magnitude of IE/EI trips for TAZs inside the region, the proximity to an external station needs to be part of the trip generation process. The ARC model uses the TAZ proximity to external stations as part of the trip attraction equations. The manner in which it is currently applied is that the travel time to the closest external station is skimmed and then a friction factor is applied in the equation based on the travel time to the station. The attraction equation is then scaled by 10^{-6} due to the large values of the friction factors. The friction factors decrease as the travel time increases making farther away TAZs less attractive. An example of the interstate work trip friction factors is provided in Figure 59. Rather than use friction factors, the following exponential equation was introduced:

Attraction factor = (travel time to nearest external station)$^{-1.5}$

The equation essentially has the same effect as the friction factors (TAZ attractiveness decreases as travel time increases) but it is more transparent in how it is applied and adjusting the parameter in testing is straightforward. Currently the model applies a different set of friction factors to interstates and non-interstates for work trips, but the update applied the same equation to both facility types. The revised factors are shown graphically in Figure 60. The revised equation results in a steeper decline as travel time increases when compared against the existing friction factors. As no data is currently available for the non-work trip purposes, no updates to the non-work model were applied at this time.

Figure 59 Existing Model Friction Factor Plot

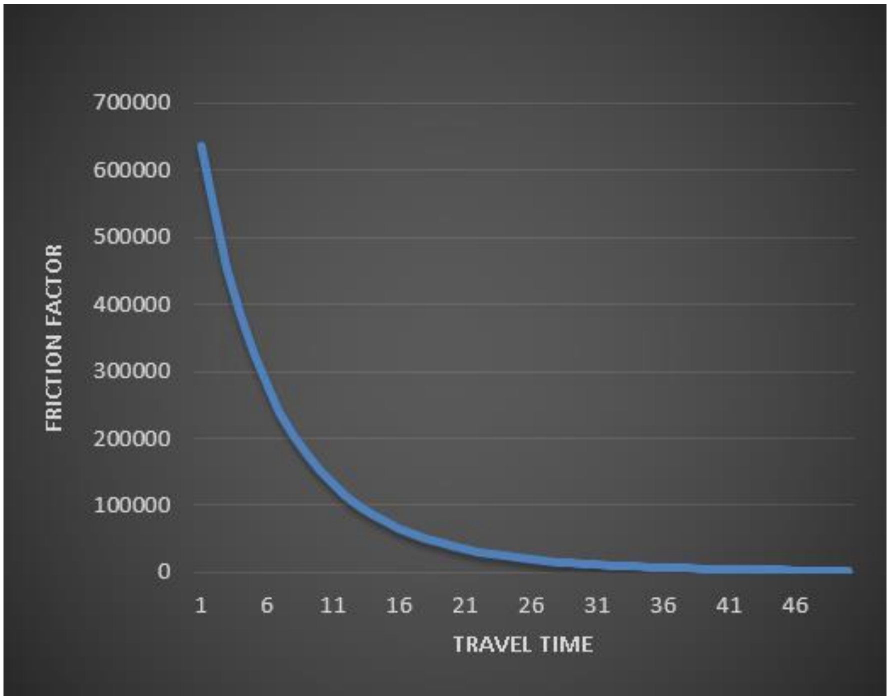
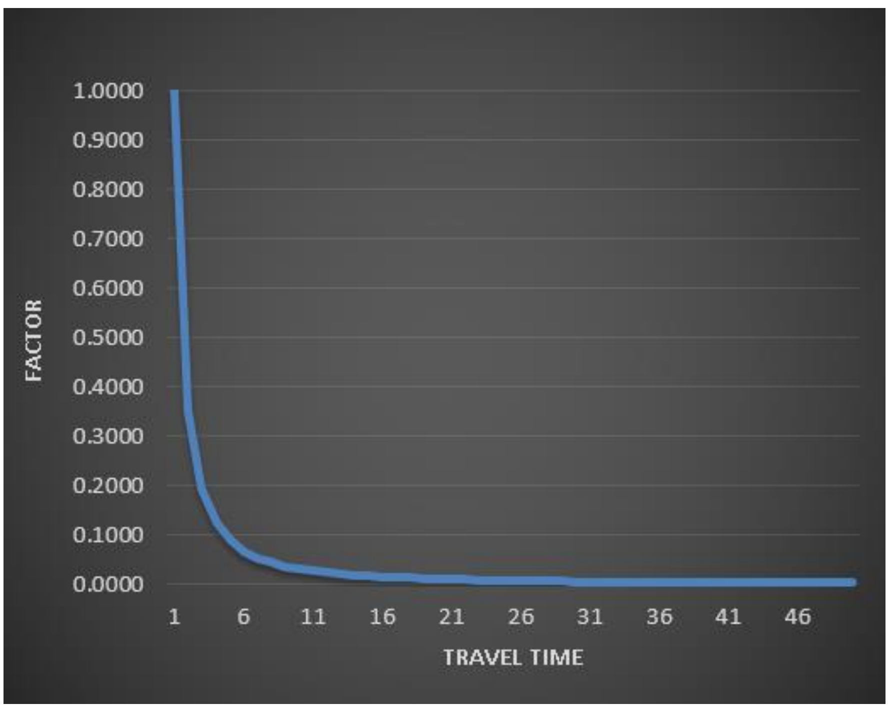


Figure 60 Modified Equation Plot



For work trips, the attraction equations also include coefficients multiplied by different employment types. The formulation of the existing model is provided in Figure 61 with a[1] representing the work trips at interstate external stations and a[3] representing work trips at non-interstate external stations. For interstate trips, the current equation uses total TAZ employment and wholesale employment while the non-interstate equation uses total employment, manufacturing, and wholesale employment. The coefficients are as follows:

- Interstate: total employment * 0.4268 + wholesale employment * 11.8344
- Non-interstate: total employment * 1.1111 + wholesale * 4.1048 + manufacturing * 4.6220

Figure 61 Existing Trip Attraction Cube Script

```
; Get "F factors".  Look these up as a function of the time to the
;  nearest external station, stratified by congested vs. free flow and the
;  station type.
  fIC = ffac(1,nearIC)
  fIF = ffac(2,nearIF)
  fNC = ffac(3,nearNC)
  fNF = ffac(4,nearNF)

; Calculate initial attractions; these are defined at internal zones
  a[1] = fIC * (totemp * coefA(1,1) + whole * coefA(2,1)) * 0.000001
  a[2] = fIF * (totemp * coefA(1,2) + hh    * coefA(2,2)) * 0.000001
  a[3] = fNC * (totemp * coefA(1,3) + manuf * coefA(2,3) + whole * coefA(3,3)) * 0.000001
  a[4] = fNF * (totemp * coefA(1,4) + hh    * coefA(2,4)) * 0.000001
```

The ACS and AirSage data are available at county level which makes estimating appropriate variables difficult due to the large aggregation. Rather than trying to use different employment types as variables, a simpler approach was taken which uses total employment. Also, some of the external work trips consist of residents that live in the ARC region but work outside the region. For this reason, the number of households was also tested in the revised formulation. The external work trip attraction equation for both interstate and non-interstate now includes the revised closest external station factor, total employment and the number of households. The coefficients for the exponential, total employment, and the number of households were iteratively adjusted until the model predicted reasonable results compared to the observed. The final application used the following formulation and coefficients:

- TAZ Attraction = (travel time to closest external)-1.5 * (total employment * 2 + households * 0.5)

As the ARC region includes significantly more employment than the surrounding counties, the number of people living outside the region but working inside the region (EI) is higher than the number of people living inside the region but working outside the region (IE). Consequently, the higher weight on total employment is both logical and expected. The results of the updated model are provided in Table 40 and show a more accurate representation compared to the observed work trip ends by county. The data is also shown graphically in Figure 62 and resulted in a significantly higher coefficient of determination (0.87) versus the current model (0.57). The final formulation of the Cube script is provided in Figure 63 (note that interstate and non-interstate use the same equation but with different travel times).

Table 40 Updated Model County Level IE/EI Work Trips

County	Target	Updated Model
Fulton	40,040	42,961
DeKalb	17,460	18,850
Cobb	19,812	20,418
Gwinnett	29,661	36,954
Rockdale	3,271	4,831
Henry	10,883	12,679
Clayton	7,817	9,797
Fayette	4,387	4,419
Douglas	2,901	5,405
Cherokee	10,560	10,280
Coweta	8,917	9,093
Forsyth	11,434	14,707
Paulding	4,470	4,427
Bartow	16,665	9,127
Carroll	12,875	13,419
Spalding	12,604	11,120
Newton	6,491	7,443
Walton	7,482	5,105
Barrow	11,574	9,982
Hall	28,730	19,467
Total	**268,031**	**270,484**

Figure 62 Updated Model Scatterplots

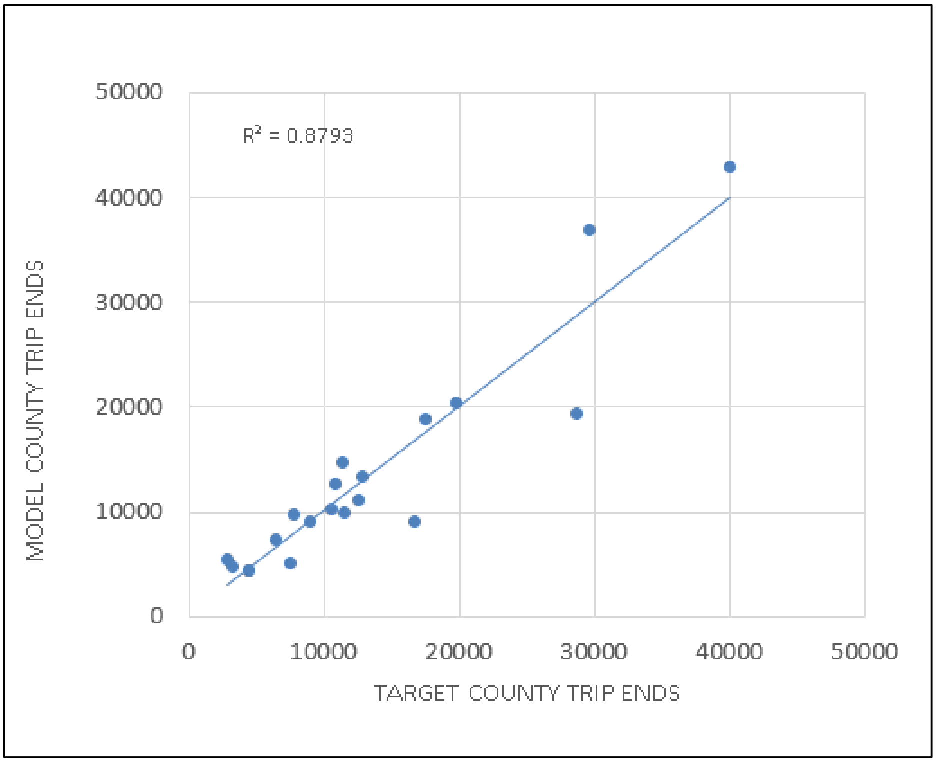


Figure 63 Updated Trip Attraction Cube Script

```
a[1] = max(nearIC,1)^-1.5 * (totemp * 2 + hh * 0.5)
a[2] = fIF * (totemp * coefA(1,2) + hh    * coefA(2,2)) * 0.000001
a[3] = max(nearNC,1)^-1.5 * (totemp * 2 + hh * 0.5)
a[4] = fNF * (totemp * coefA(1,4) + hh    * coefA(2,4)) * 0.000001
```

The resulting TAZ work trip ends were joined to ARC's zone shapefile for both the current model and the updated model and were used to create the two maps provided in Figure 64 and Figure 65. The maps represent the relative density of work trip ends at the TAZ level with the shade of blue becoming lighter as the density of trips decrease. The figures illustrate how the changes to the model have affected the location of work trips. As expected, the updated model resulted in higher densities around some of the major employment centers in the region including Downtown Atlanta, Midtown, Buckhead, CDC/Emory area, Cumberland/Galleria area, HJIA area, and Perimeter Center area. Given the amount of employment in these activity centers and proximity to interstates, the updated model appears to be predicting logical travel patterns.

Figure 64 Existing Model Work Trip End Density

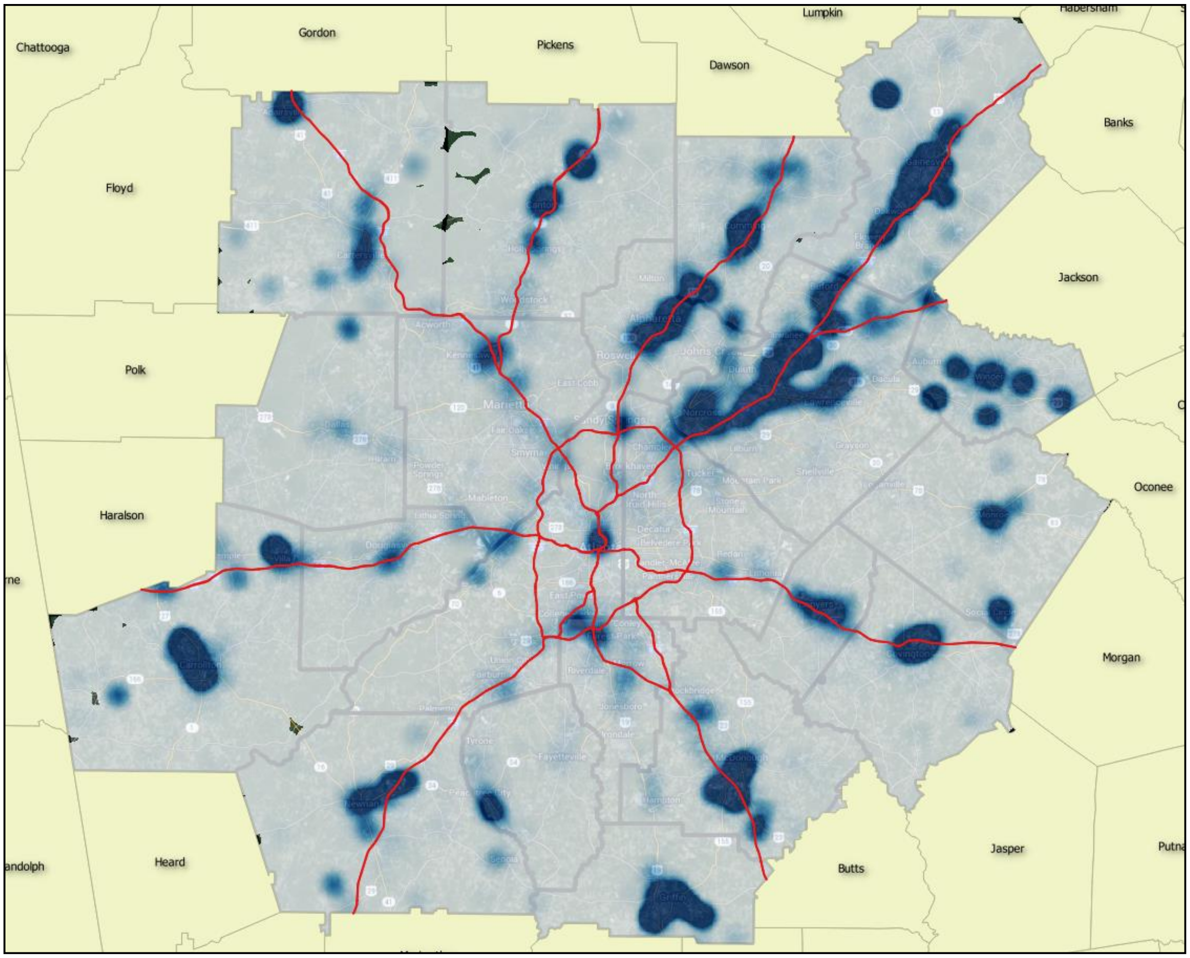
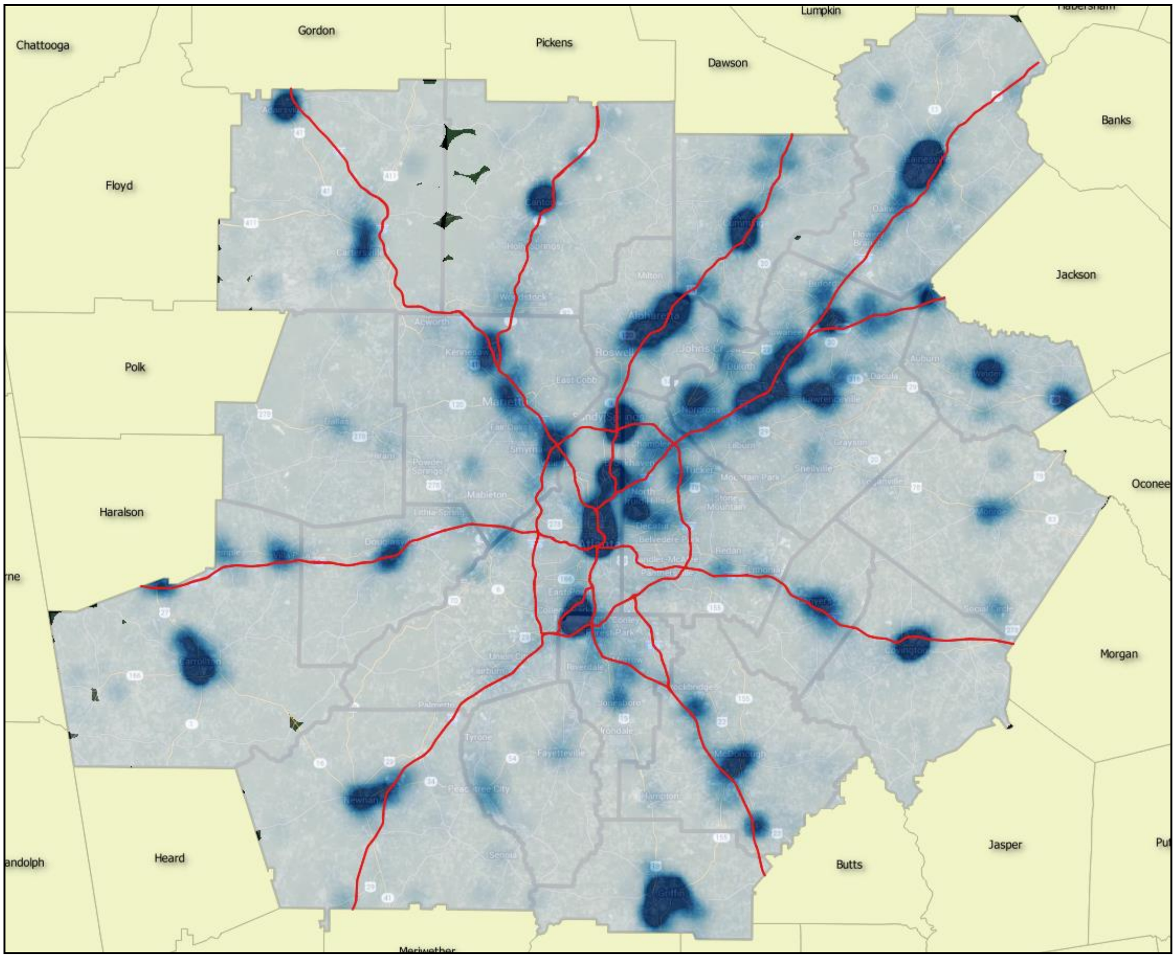


Figure 65 Updated Model Work Trip End Density

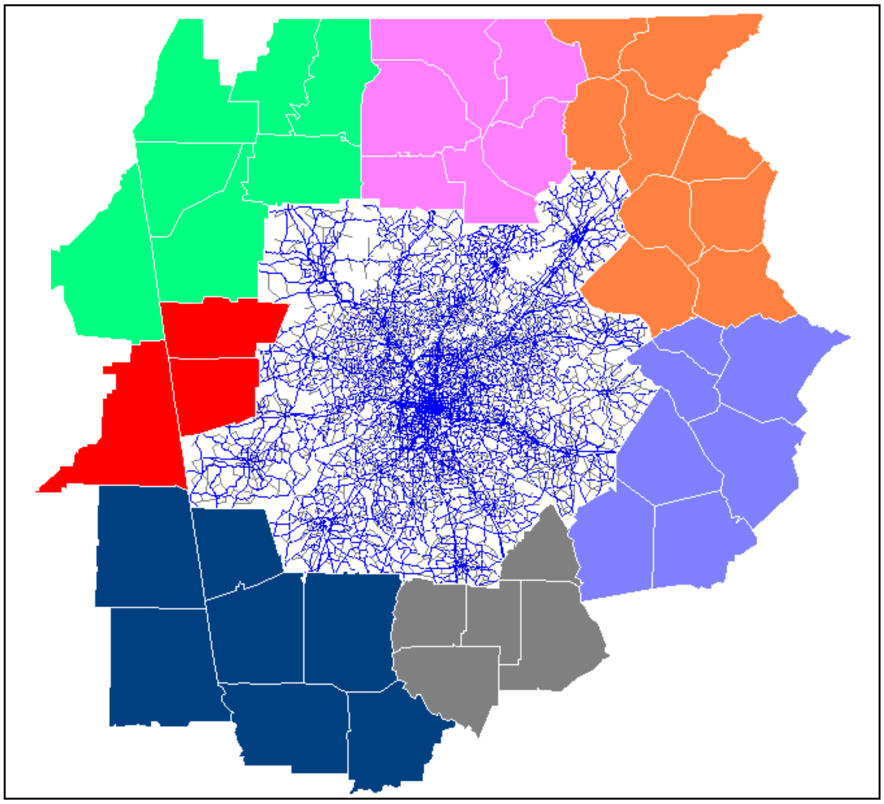


The ARC uses travel sheds from each external station along with population data in counties adjacent to the model boundary, population and employment data for the internal zones, and base year external traffic volume to predict future year external station forecasts. The travel shed for an external station consists of all zones within 45 minutes of the station. These sheds are built within the model script. For counties surrounding the model boundary, population forecasts were obtained from the Governor's Office of Planning and Budget in Georgia. These county population totals are grouped together to form large areas that influence a number of external stations. The groupings are provided in Figure 66. The internal zone population and employment are based on the input file zone data and the script uses the zones within previously mentioned travel shed to associate with each external station. Base year 2010 traffic counts were obtained from GDOT. The formula used for each external station forecast is below:

- Fut_int = future year internal zone travel shed population & employment
- Fut_ext = future year external county travel shed population
- Bas_int = year 2010 internal zone travel shed population & employment
- Bas_ext = year 2010 external county travel shed population

Forecast volume = 2010 AWDT * (1.2)*(fut_int + fut_ext) / (bas_int + bas_ext)

Figure 66 External County Groupings



Forecasts of population for the external counties were based on the 2012 projections of population by Georgia's Office of Planning Budget (OPB). Population was interpolated and extrapolated for other planning years as needed. There are four external counties in Alabama (highlighted in grey in Table 41). The 2000 population data came from the 2000 Census while the 2010 projections came from the US Census Bureau and Center for Business and Economic Research at the University of Alabama. The final populations are provided in Table 41.

Table 41 Forecasted Population for External Counties

N	COUNTY	POP00	POP05	POP10	POP15	POP20	POP25	POP30	POP40
5982	BANKS	14422	15926	18395	20009	21701	23475	25270	28983
5983	BUTTS	19522	23447	23655	25803	27987	30238	32548	36349

5984	CHAMBERS	35567	35961	34215	33345	32457	31491	30456	28317
5985	CHATTOOGA	25470	26977	26015	26719	27263	27666	27894	28625
5986	CHEROKEE	24525	26423	25989	26756	27356	27725	27883	27771
5987	CLARKE	101489	102662	116714	124904	134371	144570	155127	172546
5988	CLEBURNE	14123	14766	14972	15354	15634	15817	15907	15950
5989	DAWSON	15999	20121	22330	24644	27029	29507	32022	37297
5990	FANNIN	19798	22817	23682	24850	26348	28190	30361	33203
5991	FLOYD	90565	92727	96317	99147	101600	103731	105454	111356
5992	FRANKLIN	20285	22034	22084	22590	23024	23383	23685	24912
5993	GILMER	23456	26610	28292	29697	30946	32016	32900	36595
5994	GORDON	44104	49182	55186	59196	63371	67681	72031	81708
5995	GREENE	14406	16200	15994	16584	17049	17404	17687	18851
5996	HABERSHAM	35902	40296	43041	45856	48705	51629	54623	60810
5997	HARALSON	25690	27848	28780	30170	31494	32734	33817	36660
5998	HARRIS	23695	26671	32024	34841	37763	40806	43831	51093
5999	HEARD	11012	11770	11834	12421	13008	13575	14071	15020
6000	JACKSON	41589	50065	60485	66734	73438	80793	88837	104590
6001	JASPER	11426	13097	13900	14857	15799	16715	17592	19704
6002	LAMAR	15912	17298	18317	19902	21565	23326	25123	27873
6003	LUMPKIN	21016	24005	29966	33748	38075	42831	47966	56553
6004	MADISON	25730	27437	28120	29110	29809	30286	30536	32612
6005	MERIWETHER	22534	22867	21992	22304	22386	22258	21977	21886
6006	MONROE	21757	23200	26424	27596	28690	29665	30474	34213
6007	MORGAN	15457	17889	17868	18464	18941	19329	19604	21149
6008	MURRAY	36506	40865	39628	41484	43093	44487	45589	48443
6009	OCONEE	26225	29148	32808	36207	39777	43673	47833	54532
6010	OGLETHORPE	12635	13802	14899	15833	16708	17530	18295	20358
6011	PICKENS	22983	29263	29431	31055	32523	33829	34966	39181
6012	PIKE	13688	15663	17869	19523	21267	23170	25165	28914
6013	POLK	38127	40634	41475	43393	45099	46715	48256	51631
6014	PUTNAM	18812	19810	21218	22304	23237	24067	24871	27172
6015	RABUN	15050	15990	16276	16792	17201	17535	17762	18828
6016	RANDOLPH	22380	23600	22913	23185	23405	23555	23611	23524
6017	STEPHENS	25435	26192	26175	27078	27905	28604	29161	30388
6018	TALBOT	6498	7227	6865	6777	6602	6359	6046	6026
6019	TOWNS	9319	10493	10471	11173	11874	12470	13008	14191
6020	TROUP	58779	61342	67044	71486	75950	80616	85482	94308
6021	UNION	17289	19439	21356	22500	23570	24458	25219	28412
6022	UPSON	27597	28030	27153	27239	27144	26825	26329	26077
6023	WALKER	61053	64010	68756	70952	72878	74489	75717	82028
6024	WHITE	19944	24282	27144	29117	31057	32994	34841	40273
6025	WHITFIELD	83525	89564	102599	109225	116186	123691	131572	148406

Air Passenger Model

Specialized travel demand models are commonly developed for unique markets like non-employee travel to and from airports. The previous version of the ARC Airport Passenger Model was based on an airport passenger survey conducted at the Hartsfield-Jackson Atlanta International Airport (HJAIA) in 2000. The model development team led by ARC updated the model in the second half of 2013 based on a more recent (2009) airport passenger survey and other data sources. The 2013 airport passenger model update utilized the following key data sources:

- 2009 Atlanta airport peak week survey data and report7
- Airport Master Plan – aviation activity forecasts report8
- 2009-2010 MARTA on-board survey

Key insights on the air passenger travel from these data sources are listed below:

- More recent data suggests a significant drop in the overall airport enplanements at HJAIA compared to the enplanements used in the previous version of ARC airport passenger model.
- More than 69 percent of the annual enplanements at HJAIA in 2009 were transferring passengers.
- Approximately 41 percent of all the trips are business related whereas the remaining 59 percent are pleasure related.
- Approximately 55 percent of all the trips are made by residents in the Atlanta region and 45 percent by non-residents.
- The average parking duration at HJAIA is different for business (3 days) and pleasure trips (5 days).
- The average parking cost per day at HJAIA is also different for business ($13 per day) and pleasure trips ($10 per day).
- Residents in the Atlanta region primarily started their trips from a private residence. 93 percent of the business resident trips and 97 percent of the pleasure resident trips originated at a private residence.
- The starting location of the non-residents depended on the trip purpose. 85 percent of the business non-resident trips originated at a non-private residence like a work place or hotel/motel, whereas 67 percent of the pleasure non-resident trips originated from a private residence.
- Approximately 54 percent of the passengers using MARTA to reach the airport travel during the off-peak period. Further, trips at the airport stations had a 38/21/41 walk/park-ride/drop-off access mode split.

The updated airport passenger model is largely similar to the previous model in terms of trip purpose segmentation and mode choice nesting structure. Both versions follow industry standards in airport passenger demand modeling. The key enhancements to the model are listed below.

- The previous model was based on data from 2000 airport passenger survey data. Some of the input parameters like percentage of connecting passengers, parking costs etc.

[7] Hartsfield-Jackson Atlanta International Airport, 2009 Peak Week Survey Results prepared by Hartsfield Planning Collaborative in December 2009

[8] Hartsfield-Jackson Atlanta International Airport, Airport Master Plan: Aviation Activity Forecasts prepared for City of Atlanta, Department of Aviation (prepared by Ricondo & Associates, Inc, in October 2012)

have changed since then. To reflect these changes, the model development team used the findings from the 2009 airport passenger survey data to:

  - Update the various input parameters in the model
  - Improve and recalibrate the passenger trip distribution process
  - Split the auto-occupancy and parking rates by various trip purposes

- The team used the findings from the 2009-2010 MARTA on-board survey data to improve the method by which the regional model distributes the estimated airport passenger transit trips. Further, to be consistent with ARC's main mode choice model, the drive-access to MARTA trips is split into park-and-ride access and kiss-and-ride access transit trips.
- The updated airport passenger model will also be incorporated in the ARC activity-based model which is currently under development. Hence, to be consistent, the updated model utilizes the auto and transit travel time and cost impedances (skims) from the latest available version (October 2013) of the ARC activity-based model.

Airport Enplanements

Based on the 2012 Atlanta Airport Master Plan report, the annual enplanement numbers used in the previous version of the model were significantly higher for both 2010 and future year conditions. The annual enplanement data used in this model now reflects the updated values mentioned in the report. Table 42 provides a summary of the enplanement used in the updated model.

Table 42 Model Enplanements

Year	Previous Model Enplanements	Updated Model Enplanements
2000	40,022,900	40,022,900
2005	46,503,900	43,020,532
2010	58,978,700	45,816,397
2015	69,187,400	49,416,900
2020	78,000,000	52,278,697
2025	90,812,800	55,608,661
2030	100,000,000	59,347,102
2040	120,424,100	67,768,584

The 2010 annual enplanement is 22% lower compared to what was used in the previous model. This is because the base year in the previous model was 2000 and the 2010 enplanement was a forecast. Due to the recent economic downturn, the actual growth in enplanement between 2000 and 2010 didn't match the forecasted growth. After accounting for transferring passengers, this lower enplanement translates to approximately 56,000 fewer daily trips to and from the airport. Similarly, the 2040 enplanement is 44% lower compared to what was previously used, resulting in approximately 160,000 fewer trips to and from the airport. These are significant changes to the model inputs. Hence, any previous traffic volume or transit ridership forecasts developed for 2040 may be different if the updated model is used.

Updated Model Parameters

The model parameters in the updated model reflect the existing travel behavior observed in the airport passenger survey. The survey showed meaningful differences in the average parking cost at the airport and the auto occupancy rate by trip purpose. Table 43 below highlights the parameters in the updated model.

Table 43: Updated Model Parameters

Parameters	Units	Previous Model	Updated Model	Source	Comments
Percent of transferring (connecting) passengers	%	59.00%	69.70%	2012 Atlanta Airport Master Plan report	These passengers remain entirely within the airport concourses and do not utilize the surface transportation system.
Taxi flag drop fare	Cents	175	400	Taxi info	150 flag drop fee + 250 for the first 1/8th mile

Taxi fare	Cents/mile	175	200	from the airport website	
Transit PnR parking cost	Cents/day	100	500	MARTA website	
Average HJAIA parking duration of Business trips	Days	4	3		
Average HJAIA parking duration of Non-Business trips	Days	5	5		
Parking cost at HJAIA	Cents/day	800	Business – 1300 Non-Business – 1000	2009 Airport Passenger Survey	Overall average – 1150
Average auto occupancy, Dropped off	-	1.1	Business, Residents – 1.1 Business, Non-residents – 1.7 Non-Business, Residents – 2.2 Non-Business, Non-residents – 2.4		Overall average – 2.1
Average auto occupancy, Rental Car	-	1.1	Business, Non-residents – 1.7 Non-Business, Non-residents – 3.7		Overall average – 3
Average auto occupancy, Taxi (excluding the driver)	-	1.1	1.1	Previous Airport Passenger Model	Data not available from the 2009 survey

The airport passenger model is a three step process. This process is largely similar to the one used in the previous version of the model. These steps are:

1. Obtain total average daily enplanements. This data is available from external sources, mainly the Federal Aviation Administration (FAA) website or Airport Master Plan reports.
2. Allocate the daily enplanements to “ground side” trip ends. This allocation model primarily uses information on households and employment.
3. Estimate the mode used to travel between the airport and the “ground side” trip end. This model uses a nested logit model to develop these estimates.

The first step uses information from external sources and, in the model, can be specified by the user. The second step uses information from the normal transit demand models. The third step required a review of airport passenger models and the development of a nested logit mode choice model for the Atlanta region. In addition to developing the procedures and models to estimate airport passenger travel, Cube Voyager scripts were written to implement all three steps.

Step One: Estimating Total Airport Passengers

The initial step in estimating the airport passenger travel for the region is to estimate the average daily airport passengers to and from the airport. This estimate requires obtaining enplanements and the trip purpose of these enplanements. The team obtained the annual enplanement from the 2012 Atlanta Airport Master Plan report. For the year 2010, the Master Plan reported that the Hartsfield Airport had 45,816,397 annual enplanements. These enplanements include the transferring passengers as well. The Master Plan also reported that 69.70 percent of these enplanements were transferring passengers. Therefore, of the 45,816,397 annual passengers in 2010, approximately 13,882,368 actually leave the airport. The annual enplanements are then divided by 365 to get the average daily estimates. This results in 38,034 daily enplaning passengers. Finally, the daily enplanement number is multiplied by 2, resulting in a total of 76,068 total daily airport passengers to and from the airport. The assumption here is that for every enplaning passenger there is one deplaning passenger.

The next phase of this step is to estimate the “purpose” of the airport passenger. For this model, the purpose is defined in two ways; the type of airport passenger and the purpose of the trip. The type of airport passenger is either a resident or non-resident of the region. The purpose is either business or non-business/pleasure. Therefore this model has four purposes:

1. Residents on Business trips,
2. Non-residents on Business trips,
3. Residents on non-business/pleasure trips, and
4. Non-residents on non-business/pleasure trips.

Analysis of the survey data showed that the proportion of airport passengers for the HJAIA is as follows. These proportions of trips for the four purposes are within +/- 5% of those observed in the 2000 airport passenger survey.

1. Residents on Business – 20.86 percent of all airport passengers (7,934 trips)
2. Non-residents on Business – 19.79 percent of all airport passengers (7,527 trips)
3. Residents on non-business/pleasure – 33.73 percent of all airport passengers (12,829 trips)
4. Non-residents on non-business/pleasure – 25.62 percent of all airport passengers (9,744 trips)

These parameters need to be forecasted for future years. In the updated model, the enplanement forecasts presented in the Master Plan are used. They are presented in Table 42. Unless other surveys are taken, the percentage of transferring passengers and the split by purpose shown above are adequate for forecasting. The model uses the percentage of transferring passengers and split by purpose presented above for all years, but the user has the option to change these values.

Step Two: Allocating Ground Side Trip Ends

In this step, the total daily airport passengers estimated in step one are allocated to the ground side locations – either the homes of the residents or the offices, hotels, etc. of the non-residents. A review of the survey data and other studies indicated that the most appropriate allocation procedure would be to use the households by income level and total employment. The distribution process is similar to the previous version of the airport passenger model.

The survey data showed that most of the (over 93 percent) resident business trips had a non-airport end at a private residence. This means that there were very few people leaving from their place of business to go to the airport. These trip ends were compared to zip-code level data, including households by income level and employment by employment type. This comparison was performed using statistical measures, mainly regression. No significant equations, using different employment categories could be determined and the data showed that higher income households made more trips than lower incomes. Hence the regression analysis was constrained so that the trip rates were increasing with income. Though, it should be noted that these statistical relationships were not extremely significant. The possible reasons for this minor statistical relationships were: (1) the area of the measures for the non-airport end of the trip was zip code areas, of which there are only 168 in the region; (2) the employment categories were high level SIC categories which do not necessarily have any relationship to the income of the employee; (3) hotel and motel rooms or employment were not available; and (4) the survey was a sample which might have had, at the zip code level, a high degree of variability. But given the information from the survey and the analysis, a residential business trip generation model was developed. This model was an allocation model, since the total residential business trip are obtained in the first step of the model; that is the total residential business trips are 20.86 percent of total enplanements (7,934 trips). The trips from residences are then allocated to traffic analysis zones based on the number of households in the zone, by income group, with a weight assigned to each income group. Table 44 shows the equations used to estimate these trips ends with the coefficients of the equations adjusted so that the equations will estimate total 2010 airport passenger trips correctly. In the development of these models, the basic model under-estimated Fulton County (primarily the city of Atlanta) and over-estimated the outlying counties. To adjust for these errors, a set of K factors were developed. There were K factors associated with the four areas (Fulton, Cobb, DeKalb/Gwinnett and the outlying counties), on the equations for employment related trips and on the equations for household related trips (eight K factors in all). These K factors are shown on Table 45.

For the non-residential business trips, the survey data showed that 85 percent of the non-airport trip ends were employment related (2000 survey also indicated over 90 percent non-residential business trips with employment as the non-airport trip end with 55.15 percent being related to motels or hotels) and only 15 percent being related to private residences. Since the land use forecasts do not include any specific measures for hotels and motels (such as rooms), the non-residential business model was developed in the same manner as the residential business model. These trips were then allocated to the traffic analysis zones based on the total employment. Again Table 44 presents these equations.

For the non-business residential trips, the survey data showed that almost all the (over 97 percent) trips originated from a private residence. Therefore the model for the non-business residential trips was to allocate the trips based upon the number of households, by income level in the traffic analysis zone. The equations for these trips are shown on Table 44.

For the non-residential non-business trips, the survey data showed that 67 percent of the trip ends were private residence related and 33 percent were employment related. To handle this, the allocation model is split into two stages. The first stage separates the non-residential non-business trips into private residential based trips and into non-private residential based trips. This is a simple factoring procedure, with 67 percent of the trips being from residences (6,528 in 2010) and 33 being from businesses (3,215 in 2010). The private residence related trips were then allocated to the traffic analysis zones based on the households by income level and the non-private related trips were allocated to the traffic analysis zones based on the total employment.

Table 44: Equations to Allocate Airport Passenger Trip Ends to the Non-Airport End of the Trip

Equation to Allocate Residential Business Airport Passenger Trips from Residents

Number of Trips = 0.001032 * Low income households + 0.006525 * Medium Low Income Households + 0.008314* Medium High Income Households + 0.012414 * High Income Households

Equation to Allocate Non-Residential Business Airport Passenger Trips

Number of Trips = 0.008748 * Total Employment

Equation to Allocate Residential Non-Business Airport Passenger Trips

Number of Trips = 0.004218 * Low income households + 0.009454 * Medium Low Income Households + 0.015035 * Medium High Income Households + 0.018057 * High Income Households

Equation to Allocate Non-Residential Non-Business Airport Passenger Trips from Private Residences

Number of Trips = 0.001107 * Low income households + 0.002131 * Medium Low Income Households + 0.008232 * Medium High Income Households + 0.011870 * High Income Households

Equation to Allocate Non-Residential Non-Business Airport Passenger Trips from Non-Private Residences

Number of Trips = 0.005138 * Total Employment

Note: Income Groups (2010$): Low--$0~23,999; Medium Low--$24,000~59,999; Medium High--$60,000~118,999; High--$119,000~.

Table 45: Adjustment Factors for Employment and Households

Region	**Factor on Employment**	**Factor on Households**
Fulton County	1.28	1.48
DeKalb/Gwinett Counties	0.21	0.90

Cobb County	0.13	0.70
Other counties	0.10	0.62

The re-calibration of the distribution step using the new trip targets and the K-factors produce much better results of the distribution of the airport passenger trips. Table 46 compares the airport passenger trips from various counties for the four trip purposes. Overall the results replicate the existing conditions reasonably well.

Table 46: Distribution of Airport Passenger Trips from Various Counties to HJAIA

County	2009 Survey				Updated Model			
	Business, Residents	Business, Non-residents	Non-Business, Residents	Non-Business, Non-residents	Business, Residents	Business, Non-residents	Non-Business, Residents	Non-Business, Non-residents
Cobb	15%	3%	12%	5%	11%	4%	11%	9%
Fulton	32%	80%	29%	56%	33%	80%	33%	50%
DeKalb / Gwinnett	19%	12%	34%	21%	29%	11%	29%	22%
Other Counties	34%	5%	24%	18%	27%	5%	27%	19%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Step Three: Mode Choice Model

Since the airport passengers have a wide array of modal options, a relatively sophisticated approach to mode choice modeling was used. This was a nested logit model, with different structures and modal options for Resident and Non-resident airport passengers, as shown in Figure 1.

The survey data showed that the five predominant mode of access of the enplaning passenger are passengers driving their private car, being dropped off, using rental car, using taxi and riding MARTA train. Table 47 shows the breakdown of the various modes of access. In defining these modal access choices, hotel courtesy vehicle and commercial shuttle are treated similar to a rental car (no explanatory variable is used in the disutility equation of this access mode) and charter bus and limo are treated similar to a taxi.

The data suggested that the non-residents have three primary modal choices: being dropped off (or picked up) by someone in a private car, using a rental car, or using one of the non-private auto modes. Within the non-private auto mode, there are two choices: public transit (regularly scheduled service) and taxi. Similarly, residents of the Atlanta region have a different set of choices, involving one fewer mode at the top level (they are presumed to not be car renters). Within the Private Auto mode, they can be dropped off or can drive to the airport. Within the “Non-private auto" mode, they have the same Transit and Taxi options as Non-Residents. Throughout the model chain (Steps 1 through 3), the Non-resident trips are modeled with Airport as the production zone and one of the other zones in the region as the destination. The Resident trips, on the other hand, are modeled with Airport as the attraction zone and one of the other zones in the region as the production zone.

Table 47: Airport Passenger Mode of Access

Mode of Access	**Modeled Mode**	**Mode Share**
Dropped off	Dropped off	27.6%
Drive self	Drive self	36.3%
Rental car	Rental car	9.4%
MARTA	Transit	8.3%
Hotel courtesy vehicle	Rental car	4.0%
Commercial shuttle	Rental car	3.5%
Charter bus	Taxi	3.5%
Taxi	Taxi	2.9%
Limo/Exec sedan	Taxi	2.5%
Other	Dropped off	1.9%
C-TRAN	Taxi	0.2%
Total		**100%**

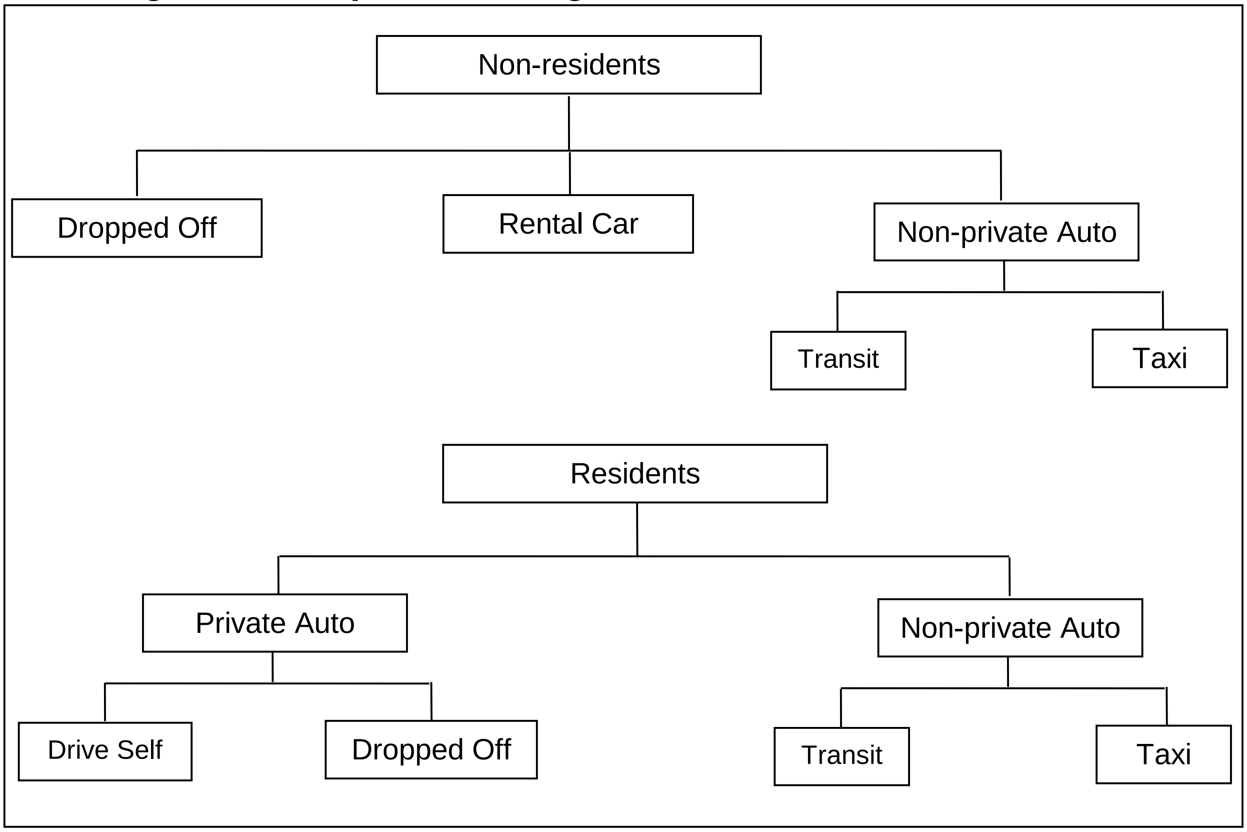
The model is a nested logit, as follows:

$p(m) = e^{U(m)}/\Sigma e^{U(m)}$

where:
p(m) = probability of choosing mode m
U(m) = disutility of mode m

The disutility equations for each mode and each model are shown in Table 48. The lower nest values are calculated first. For example, in the Non-resident model, the disutilities are calculated for Transit, Shuttle, and Taxi. The exponentials of these three disutilities are taken and then summed. The natural log of that sum is the "log sum" term that is used in the "top level" nest to compare the Non-private auto mode with Rental Car and Dropped Off. With this structure, trips that "leave" a mode, due to changes in cost and time, are more likely to go to other modes in the same nest, rather than modes on a different "level". The system coefficients (on time and cost) were obtained from other airport passenger models, mainly Washington and San Francisco's models.

Figure 67: Airport Passenger Mode Choice Model Structure



The mode choice model calculates trips in the Drive Self and Dropped Off private auto modes. The model does not do a separate calculation of auto occupancy, but uses a user-entered average occupancy, which for the calibration was as follows: Drive Self = 1.0, Dropped Off = 1.1 to 2.4 depending on the trip purpose (refer to Table 43 for detail), Rental Car = 1.7-3.7 depending on business or non-business trip (refer to Table 43 for detail) and Taxi = 1.1. In the case of Dropped Off trips, it is assumed that each airport passenger being dropped off generates two vehicle trips – one going and one coming. Therefore the 69,700 passenger trips, which used an automobile mode, generate approximately 61,300 vehicle trips to and from the airport on an average day.

The 2009-2010 ARC On-Board Transit Survey collected information regarding access mode and trip purpose of the transit trips made by airport passengers. This data was utilized to update the transit targets and calibrate by walk, park-and-ride and dropped off transit access modes. The MARTA survey also suggested that most of the airport passengers (54%) travel during the off-peak period. The survey also showed a 38/21/41 walk/PnR/KnR access mode split at the airport station. Hence, the drive-to-transit option available to Residents in the previous airport passenger mode choice model was split into PNR access and KNR access. Also, airport trips from the transit survey primarily used a premium transit mode. Hence, premium only transit skims were used as transit impedances into the airport passenger model.

The modal bias constants were developed using the airport passenger survey data set. In order to develop these modal bias constants a set of target mode shares (that is the observed mode shares) were required. The mode choice model was re-calibrated by iteratively changing the mode choice constants till reasonable representation of the trip purpose and access modes of the airport passenger trips were obtained. Additional constants were added for PnR and KnR access to get the access mode to transit splits right. The bias constants are shown at the bottom of Table 49. Table 50 shows these target mode shares and the mode shares estimated by the model, using the Atlanta specific modal constants. Table 51 shows the observed and estimated airport passenger trips on MARTA by various access modes. These figures indicate that the model replicates the target mode shares with a good degree of accuracy.

Table 48: Airport Passenger Mode Choice Disutility Equations

Business, Residents

U(Drive Self) = (–0.071 * HWYTIME – 0.00277 * (HWYCOST + PCOST) + biasDS)/0.3
U(Dropped Off) = (–0.071 * HWYTIME – 0.00277 * HWYCOST)/0.3
U(Transit) = (–0.093 * WALK – 0.107 * WAIT – 0.00277 * TRFARE – 0.053 * RUN + biasTR)/0.3

U(Taxi) = (–0.071 * HWYTIME – 0.00277 * TXFARE)/0.3
NonAuto logsum = $\ln(e^{U(Transit)}+e^{U(Taxi)})$
Auto logsum = $\ln(e^{U(Dropped\ Off)}+e^{U(Drive\ Self)})$
U(Non-private auto) = 0.3 * NonAuto logsum + biasNPA
U(Private Auto) = 0.3 * Auto logsum

Business, Non-residents

U(Dropped Off) = –0.068 * HWYTIME – 0.00256 * HWYCOST
U(Rental Car) = biasRC
U(Transit) = (–0.089 * WALK – 0.096 * WAIT – 0.00256 * TRFARE – 0.050 * RUN + biasTR)/0.3
U(Taxi) = (–0.068 * HWYTIME – 0.00256 * TXFARE)/0.3
NonAuto logsum = $\ln(e^{U(Transit)}+e^{U(Taxi)})$
U(Non-private auto) = 0.3 * NonAuto logsum + biasNPA

Non- Business Residents

U(Drive Self) = (–0.044 * HWYTIME – 0.002105 * (HWYCOST + PCOST) + biasDS)/0.3
U(Dropped Off) = (–0.044 * HWYTIME – 0.002105 * HWYCOST)/0.3
U(Transit) =(–0.051* WALK – 0.077 * WAIT – 0.002105 * TRFARE – 0.031 * RUN + biasTR)/0.3
U(Taxi) = (–0.044 * HWYTIME – 0.002105 * TXFARE)/0.3
NonAuto logsum = $\ln(e^{U(Transit)}+e^{U(Taxi)})$
Auto logsum = $\ln(e^{U(Dropped\ Off)}+e^{U(Drive\ Self)})$
U(Non-private auto) = 0.3 * NonAuto logsum + biasNPA
U(Private Auto) = 0.3 * Auto logsum

Non-business, Non-residents

U(Dropped Off) = –0.039 * HWYTIME – 0.001969 * HWYCOST
U(Rental Car) = biasRC
U(Transit) = (–0.045 *WALK–0.071* WAIT – 0.001969 * TRFARE – 0.029 * RUN + BiasTR)/0.3
U(Taxi) = (–0.039 * HWYTIME – 0.001969 * TXFARE)/0.3
NonAuto logsum = $\ln(e^{U(Transit)}+e^{U(Taxi)})$
U(Non-private auto) = 0.3 * NonAuto logsum + biasNPA

Where:

HWYTIME = off-peak travel time from the highway network (minutes)
HWYCOST = off-peak distance from the highway network * 8.74 cents/mile
PCOST = the observed average parking cost at HJAIA (cents) from the airport passenger survey, multiplied by the average duration of the trip in days (3 for Business, 5 for Non-business)
WALK = access + egress + sidewalk time from the off-peak transit network (minutes)
WAIT = initial wait + transfer wait time from the off-peak transit network (minutes)
RUN = total in-vehicle time from the off-peak transit network (minutes)
TRFARE = transit fare (cents)
TXFARE = taxi fare (cents); estimated, for 2010, as $4.00 plus $2.00 per mile

Note: Auto and taxi costs are not divided by average vehicle occupancy.
biasMM = bias coefficients (Table 49) by mode and purpose

Table 49: Bias Coefficients by mode and purpose

	TRIP MARKET			
Mode (MM)	**Business, Residents**	**Business, Non-Residents**	**Non-Business, Residents**	**Non-Business, Non-Residents**

Rental (RC)	NA	-2.917	NA	-2.154
Drive Self (DS)	5.706	NA	5.423	NA
Non-private auto nest (NPA)	4.341	9.164	3.665	3.252
Transit (TR) walk-access	-4.672	-6.250	-3.355	-3.851
Transit (TR) PnR-access	1.530	NA	2.440	NA
Transit (TR) KnR-access	-2.400	NA	-2.370	NA

NA – Not a choice for that market/purpose

Table 50: Observed and Estimated Airport Passenger Mode Shares

OBSERVED MODE SHARES					
Mode	**Business, Residents**	**Business, Non-Residents**	**Non-business, Residents**	**Non-business, Non-Residents**	**Total**

Dropped off	5.3%	2.6%	11.1%	10.6%	**29.5%**
Drive self	14.5%	0.0%	19.0%	0.0%	**33.5%**
Rental car	0.0%	6.9%	0.0%	12.7%	**19.6%**
Taxi	0.6%	5.8%	1.4%	1.2%	**9.0%**
Transit	0.4%	4.5%	2.2%	1.1%	**8.3%**
Total	**20.9%**	**19.8%**	**33.7%**	**25.6%**	**100.0%**
ESTIMATED MODE SHARES					
Mode	**Business, Residents**	**Business, Non-Residents**	**Non-business, Residents**	**Non-business, Non-Residents**	**Total**
Dropped off	5.28%	2.32%	11.21%	10.12%	**28.93%**
Drive self	14.57%	0.00%	19.14%	0.00%	**33.72%**
Rental car	0.00%	7.28%	0.00%	13.23%	**20.51%**
Taxi	0.63%	5.86%	1.45%	1.20%	**9.14%**
Transit	0.38%	4.34%	1.93%	1.06%	**7.70%**
Total	**20.86%**	**19.79%**	**33.73%**	**25.62%**	**100.00%**
PERCENT DIFFERENCE (ESTIMATED - OBSERVED)					
Mode	**Business, Residents**	**Business, Non-Residents**	**Non-business, Residents**	**Non-business, Non-Residents**	**Total**
Dropped off	-0.02%	-0.28%	0.11%	-0.48%	**-0.57%**
Drive self	0.07%	-	0.14%	-	**0.22%**
Rental car	-	0.38%	-	0.53%	**0.91%**
Taxi	0.03%	0.06%	0.05%	0.00%	**0.14%**
Transit	-0.02%	-0.16%	-0.27%	-0.04%	**-0.60%**
Total	**-0.04%**	**-0.01%**	**0.03%**	**0.02%**	**0.00%**

Table 51: Observed and Estimated Airport Passenger MARTA Trips

	Observed (2009-2010 MARTA On-board Survey)				Estimated			
Access Mode	**Business, Residents**	**Business, Non-residents**	**Non-Business, Residents**	**Non-Business, Non-residents**	**Business, Residents**	**Business, Non-residents**	**Non-Business, Residents**	**Non-Business, Non-residents**
Walk Access	128	3,453	635	859	117	3,298	563	810
PNR Access	71		348		41		230	
KNR Access	135		667		128		673	
Total Transit	**334**	**3,453**	**1,650**	**859**	**286**	**3,298**	**1,466**	**810**

Commercial Vehicle and Truck Models

This report documents the development of a regional truck and commercial trip forecasting models for the Atlanta Regional Commission (ARC). The truck model reported in this document is based on classification count data taken in 2005 and applying the model to a base year 2000. The truck model has not been updated as new classification counts are not available. The text in this section document the model as it is was built in 2005 with comparisons/summaries of the year 2000 model. In application, the model is applied to base year 2010 conditions.

The existing truck model was developed in the mid-1990's from survey data. Light-duty commercial trips were not explicitly modeled as a separate category, but were partially covered under what the existing model calls "Light Trucks". In this report, the "existing" truck model refers to the most recent ARC model version, completed in April 2005.

As used in this report, the term "truck model" actually refers to two separate models: one for heavy trucks and one for medium trucks. As defined here, these categories represent a change from the existing model. Segmentation of these two categories is based on the Federal Highway Administration's (FHWA) "F-13" classification scheme. "Heavy" trucks are defined as vehicles with either a single or multiple trailer combination (F8 – F13 in the FHWA scheme). "Medium" trucks include buses (FHWA's F4), vehicles with two axles and six tires (F5), and single-unit vehicle with three or four axles (F6, F7). The existing model uses a category called "light trucks". That terminology is no longer used, to avoid confusion with the more commonly used definition of "light trucks": pickups, vans, minivans, and sport-utility vehicles (SUVs). This change in truck categories from the existing model's weight-based definition was necessitated by the fact that the new model is more closely tied to count data, and truck counts are maintained by classification, using the FHWA scheme. Most truck counts use automatic counting equipment, which counts axles. The FHWA classification system is illustrated in Figure 68.

The light truck category is now replaced, more or less, by a new category of trips: "Commercial". This refers to those trips that are mainly business-oriented and are not personal transportation, but do not involve a medium or heavy truck, as described above. Light trucks, vans, and SUVs used for personal transportation are not included here. But the Commercial category does include passenger cars, light trucks, vans, and SUVs that are used for business purposes.

This is a new category of trip that has not been commonly recognized in regional travel demand models but which is currently becoming the focus of attention in several urban areas. It includes package delivery vehicles, postal vehicles, couriers, equipment repair and service technicians, craftsmen (carpenters, plumbers, etc.), government workers, taxis, police, fire, and rescue vehicles, and many other types of light-duty vehicles. Planners are beginning to realize that business-related travel is very poorly identified in home-interview surveys. In fact, the extreme difficulty in identifying such trips and surveying their travel patterns has doubtless kept many planners from including these trips in the modeling process.

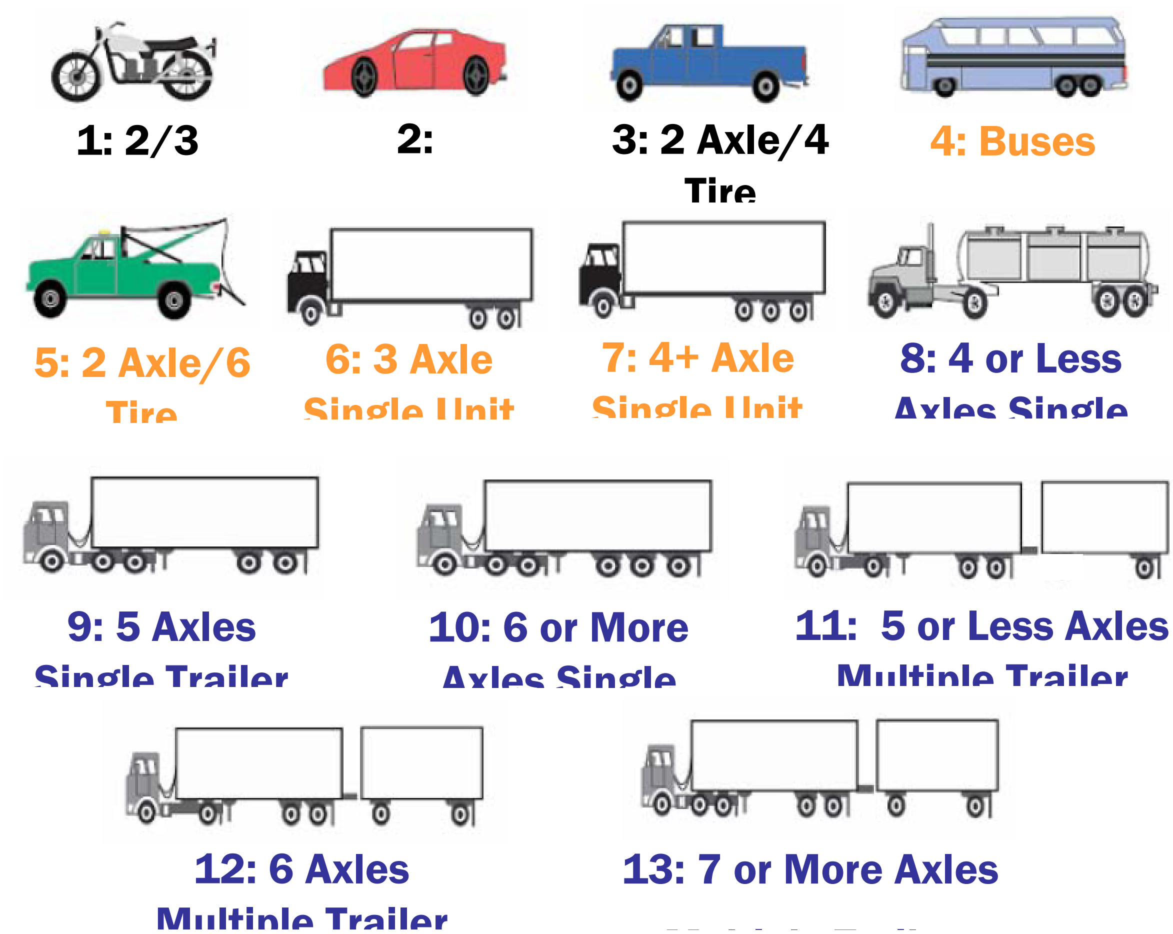
Simple observation of the traffic stream on any roadway will reveal the basic fact that Commercial trips represent a category of travel that is too large to ignore. Exclusion of these trips results in either underestimating traffic volumes, or (perhaps worse) implicitly incorporating their volume within some other category, most likely non-home-based personal travel. Since Commercial trips obviously have different travel characteristics than most personal travel, accounting for these trips in a separate category will improve the accuracy of the model.

Truck and commercial vehicle modeling has taken on more importance in recent years, for a couple of reasons. Perhaps the primary reason is that trucks contribute disproportionately to the region's mobile source emission inventory, especially for NOx and particulates. The need to meet increasingly stringent regional emission budgets has caused most planning agencies to examine every possible emission source in greater detail. Another reason is an increasing emphasis on goods movement and the role of the region's transportation system in facilitating goods movement, and by implication, the economy. Atlanta's role as a hub for goods movement throughout the southeastern U.S. makes this even more critical than in other cities.

A survey of truck travel was undertaken in the Atlanta area in 1996 and that was used to develop the existing truck model. However, that survey's coding of vehicle types was not sufficiently detailed to be used in this project. Instead, an innovative approach that addresses this problem in an indirect fashion was used. This new approach relies almost entirely on counts conducted throughout the region. The availability and relative accuracy of classification counts makes them a reliable and usable source of data for truck modeling. The new approach involves using these counts as a basis for synthesizing a truck trip table. That table is then used to "inform" the model, providing a more credible basis for adjusting the model's parameters. In addition, the method provides a systematic calibration adjustment that helps the model to achieve relatively high accuracy of assigned truck volumes on a link-by-link basis.

For Commercial travel, the same approach is used, except that classification count data is unavailable for this category of trips. Given the variety of vehicles in this group, automated count procedures have not yet been developed. Thus, these vehicles must be counted manually. The cost to perform enough counts for model development is prohibitive, so an alternate technique is used. A limited number of counts are collected and this data is used to synthesize other counts, enabling model development.

Figure 68 FHWA 13-Bin Vehicle Classification


1: 2/3
2:
3: 2 Axle/4
Tire
4: Buses
5: 2 Axle/6
Tire
6: 3 Axle
Single Unit
7: 4+ Axle
Single Unit
8: 4 or Less
Axles Single
9: 5 Axles
Single Trailer
10: 6 or More
Axles Single
11: 5 or Less Axles
Multiple Trailer
12: 6 Axles
Multiple Trailer
13: 7 or More Axles

Review of the State of the Art in Truck Modeling Issues

A brief review of the state of the art in truck trip modeling was conducted. Two recent reports greatly facilitated this effort: Travel Model Improvement Program's Quick Response Freight Manual and NCHRP Synthesis 298, Truck Trip Generation Data. These reports provide an excellent overview of current practice and key issues concerning truck trip modeling.

The first issue is: what is the context of the model? There are three levels of analysis detail: 1) national or statewide analyses of tax payments, pavement condition, or general rail vs. truck movement; 2) regional analyses concerned with link volumes, emissions, and corridor studies; and 3) local studies in which traffic engineers are looking at noise, geometrics, pavement, or loading facilities. These are very different kinds of analyses, calling for different kinds of models. Most of the focus of the literature is on regional truck models, and that is the level that this report is concerned with.

One of the most important issues is the definition of just what is a "truck". Models based on registration data use gross vehicle weight (GVW) definitions. Models based on classification counts use the number of axles as their criterion. These two definitions are not consistent with each other and create difficulties in comparing models and results. The selection of an appropriate definition also hinges on the purpose of the truck analysis: is it mainly for motor carrier/tax policy, pavement analysis, or emissions calculation?

Another key issue is the structure of the model. So-called "commodity-based" models attempt to analyze the flow of all goods from their source, through various transformations, and then on to the final consumer. This kind of analysis permits the explicit consideration of trade-offs among different freight modes (e.g., highway, air, rail, water). Many planners consider this the "ultimate" in freight modeling, but it is generally considered a goal that might be attained in the future, not something that is truly practical today. The alternative is a "vehicle-based" model, which simply estimates truck trips. This is the form taken by almost all operational truck trip models. The literature considers this to be a reasonable interim approach until such time as commodity-based models become more widely used and accepted.

The difficulty in conducting truck trip surveys is well known. One problem is that almost all regional travel models consider the basic unit of travel to be the "trip": a movement between an origin and a destination. For many trucks, however, the unit of travel is instead a "tour": a series of connected trips throughout the day. This not only complicates the survey itself, but it makes it extremely difficult to translate tour movements into the origin/destination trip approach taken by most models. An even more significant problem is simply one of participation. Trucking firms treat travel data as proprietary information and are not willing to have this information made available to the public (or their competitors). These firms are not accustomed to working with public planning agencies and often distrust or misunderstand the purpose of the surveys. Even when the trucking company is cooperative, truck drivers themselves usually view surveys as nothing more than an unwarranted and unnecessary intrusion on their workday. Thus, it should come as no surprise that reliable, usable data is rarely achieved in trucking surveys. A possible exception is that roadside intercept surveys, if conducted in a safe and efficient manner, can be very useful in obtaining data on truck trip movements that are external or completely through the region.

Those analysts lucky enough to obtain usable data on truck trips are being confronted with another obstacle: the measures of land use that are causally related to truck activity are generally not among the data items that are available at the traffic zone level, or are forecasted. As a result, in almost all cases, planners try to relate truck travel to the variables that are available. The outcome is usually a relatively crude model that relates truck trips to employment and population. The results are usually less than satisfactory, but are justified by noting that "trucks are only 5% of all trips". While this may be true in total, trucks do account for a higher share of traffic on the major roadways and heavy trucks also utilize a greater share of roadway capacity than their volumes indicate.

In summary, the state of the art in truck trip models is still in its infancy, but starting to improve. Substantial enhancements in these models will need to await the widespread acceptance and use of automated, non-intrusive data collection technology (perhaps GPS-based) and the development of traffic-zone-level data that is more closely related to goods movement. In recent years, more planning agencies are paying greater attention to these needs.

Factors Affecting Truck Forecasting

The above issues relate mainly to the development of a model which can adequately describe today's truck travel. Forecasting truck trips proves to be even more difficult than forecasting personal travel, for a number of reasons. Creating a model that accounts for all the factors that are likely to affect future truck travel would effectively require a crystal ball. One needs only to look at the last 10 years to understand some of these factors.

One of the most important phenomena to affect truck travel over the past two decades is the change in goods movement technology. Containerization has affected practically all aspects of goods movement, including ship, rail, and truck. Containerized freight movement now represents the majority of goods moved at all U.S. ports, for example. In a related development, trailer on flat car (TOFC) and container on flat car (COFC) have created tremendous opportunities for intermodal coordination and efficiency that did not exist until fairly recently.

Another similar development (also related to the above) is the sharp rise in freight labor productivity. Over the past 20 years, the number of truck trips per trucking industry employee has risen sharply. The nature of American industry has changed in recent years and improvements necessitated by international competition have practically revolutionized the freight industry. One example of this is just-in-time (JIT) delivery, in which industries reduce their warehousing space because they no longer stockpile materials used in production. These materials are delivered by suppliers on the day (sometimes at the hour) they are needed and they move directly from the loading dock onto the production line. JIT requires a veritable ballet of truck movements, organized and scheduled with great precision and timing. Obviously, it also increases the number of truck trips serving a manufacturing plant. This kind of operation barely existed ten years ago and now it is commonly used throughout the manufacturing sector, particularly for motor vehicle assembly.

As if recent changes in technology and productivity weren't drastic enough, the past decade has also seen major political changes that affect goods movement. The increase in the global nature of the U.S. economy, aided by actions such as the North American Free Trade Agreement (NAFTA), has had a profound effect on all forms of freight movement. One of the earliest impacts of NAFTA was a sharp increase in truck traffic across the borders with Canada and Mexico, as U.S. companies sought to improve their operations by using facilities in those countries.

Finally, the past few years have seen sharp up and down swings in the price of motor fuel. This has obviously had a major effect on the trucking industry and has provided other types of transport companies, especially railroads, with an opportunity to take market share away from trucks.

Many other external factors have been seen to strongly influence truck travel in recent years, including: deregulation, the shift in retail to "big box" stores, changes in truck weight and size limits, increased emphasis on truck safety, and more centralized warehousing and distribution.

The above commentary serves to highlight how difficult truck forecasting can be, especially in light of the limited resources typically devoted to it. Forecasting freight is certainly no less challenging (and probably more so) than forecasting personal travel. While there will doubtless continue to be changes in technology and productivity in the future, it is not feasible to incorporate them into the model or to estimate their impact at this time. This suggests a need to continually revisit and update any truck model at regular intervals.

Review of Other Truck Models

Other truck trip models from other urban areas were examined as part of this task. These include Washington, DC, Baltimore, New Orleans, Raleigh, NC, several Ohio cities, and Lehigh Valley, PA. Although these models represent a variety of different environments, a few typical practices can be identified:

- Trucks are often segmented into two groups: heavy and medium. "Medium" sometimes includes light-duty commercial vehicles, but an emerging practice is to use a separate model for commercial light trucks, vans, and automobiles.
- External trip ends have often been defined using an "off-model" procedure. An emerging practice is to estimate an external share based on the zone's distance to the cordon.
- Truck models are frequently based on very old survey data (e.g., 1960's).
- Truck generation models are relatively simple regression equations using population (or households) and employment by different types, with no constant term. The coefficient on population is smaller than that on employment.
- Zonal productions and attractions are set equal to each other.
- Special time of day or assignment procedures for trucks (e.g., to prevent trucks from using certain roadways) are rarely used.

Development of Truck Model

Approach

This study takes an innovative approach to the problem of estimating truck trips. The premise of this approach is that it is usually very difficult to obtain statistically valid survey data on truck movements, due to the diversity of truck travel, the difficulty of conducting the surveys, and the low survey response rates. Even when surveys have been properly conducted, as ARC did in 1996, they often have problems with the definition of vehicle types, geocoding, etc. that make them difficult to use for model calibration.

Thus, the traditional method of calibrating truck trip rates is often not workable. However, it should be possible to obtain relatively accurate counts of truck volumes by type on a number of roadway segments throughout the region. A number of researchers have addressed the problem of using count data to "work backwards" to obtain a zone-to-zone matrix of trips. The consultant has developed a way to do this, called adaptable assignment, which is quick, simple, and easily understood. If the current ARC model can be revised (or replaced with a model from the literature) such that the total estimated truck trips more closely match the truck counts, then the adaptable assignment process can be applied. This will produce a new truck trip table, whose differences from the initial table can be analyzed to identify where changes to the initial model are needed. This can be done separately for medium and heavy trucks.

This same approach has recently been used to develop truck trip models in Washington, Baltimore, and several cities in Ohio. A variation of this approach was also used to forecast truck trip volumes for the new travel model for the New York metropolitan area.

Starting Model

An important element of this approach is to start with an estimated trip table that is "in the ballpark". The decision was made to start with the existing model and modify it as needed for this project. The existing ARC model's definition of Heavy Trucks (HTK) is roughly equivalent to the new model's definition of Heavy Trucks and Medium Trucks (MTK). So the existing ARC HTK model was used, with the coefficients split 45% to MTK and 55% to HTK, which represents the ratio of the count totals for those vehicle types.

External trips were estimated as a share of the total trip ends in each zone, with that share declining as the zone's distance to the cordon increased. The external trip ends at the cordon stations by vehicle type were used as a control total.

Trips were distributed using off-peak highway skims with intrazonal and terminal times. F factors were borrowed from the QRFM report for I/I trips and from the MWCOG MTK External model for external trips.

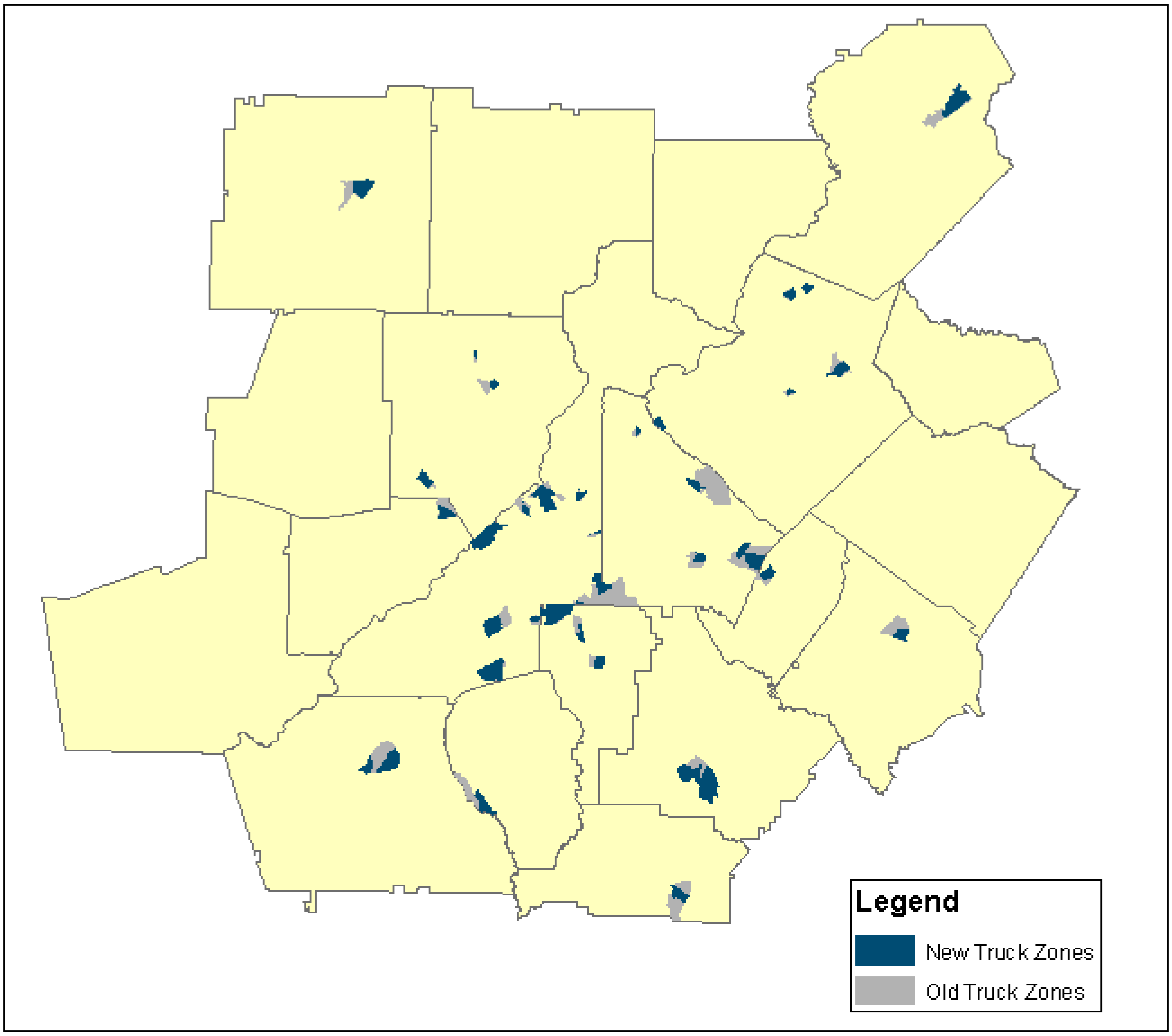
The MTK and HTK trip tables were assigned to the highway network using largely the same protocol as in the existing ARC model. The major difference was that passenger car equivalents (PCEs) were used in the volume/capacity calculation to reflect the greater influence of trucks on V/C. A PCE of 1.5 was used for MTK and 2.0 for HTK.

The resulting MTK and HTK link volumes were compared to the count data and adjustments were made to the starting model so as to better match these counts. Trip generation adjustment factors were incorporated by area type and the model was modified to reflect "truck zones".

Truck zones are areas in which there is strong reason to believe that the truck trip activity is higher than the standard trip rates would indicate. It was determined by the project team that the most important zones are few enough in number that they can be identified individually and classified in a way that allows the interim model to account for them. Although no data are available to specifically determine the increase in truck trips for such areas, a reasonable estimate can be made by those who know the region and confirmed or revised in the adaptable assignment process.

The main purpose of identifying truck zones is to highlight zones whose average truck trips per employee is likely to be higher than that of non-truck zones. This includes truck stops, warehouses, transfer terminals, and the like. ARC staff initially identified 46 such zones across the 20-county modeled area for the existing zone system (2027 internal). With the update to the zone geography, it was necessary to update the truck zone numbering. This was done by overlaying the two zone systems and flagging the appropriate truck zones in the new TAZ geography as shown in Figure 69. The new zone system is at a much finer detail than the old zone system; therefore, in some cases the truck zones represent a smaller geographic area which a more accurate representation of the truck facilities.

Figure 69 Truck Zones



Trip Generation

The starting truck trip generation model is shown in Table 51.

As applied to ARC's new 2000 zonal data, this model estimates 280,000 daily medium truck trips and 213,000 daily heavy truck trips. Of the medium truck trips, 243,000 are I/I and 37,000 are external. Of the heavy truck trips, 167,000 are I/I and 46,000 are external. As shown in Table 6.1, the trip rates, the area type adjustments, and the truck zone factors constitute the starting model. As the area type adjustments suggest, the truck trip rate per employee is higher in the less developed areas.

Table 51 Starting Truck Generation Model

MTK = (0.104 * INDEMP + 0.178 * RETEMP + 0.030 * OFFEMP + 0.058 * HH) * AT factor

HTK = (0.095 * INDEMP + 0.081 * RETEMP + 0.028 * OFFEMP + 0.053 * HH) * AT factor

INDEMP is Industrial Employment (Construction, Manufacturing, TCU, Wholesale)
RETEMP is Retail Employment
OFFEMP is Office Employment (FIRE, Government, Service)
HH is Households

Factor for area type:

Area Type	MTK	HTK
1	0.50	0.50
2	0.75	0.70
3	1.00	0.75
4	1.05	0.80
5	1.10	0.90
6	1.20	1.10
7	1.30	1.30

If a zone is a truck zone, multiply HTK trips by 3.

External Model

The method for estimating external truck trips assumes that the generation model estimates total trip ends, both I/I and external (which includes I/X and X/I). The external share of the total trip ends is then modeled as a function of the zone's distance to the model's cordon, along the highway network. Zones that are closer to the edge of the modeled region will generally have a higher share of external trips than other zones.

In addition, the external trip ends at the internal zones that are calculated in this manner are balanced to match the total external trip ends at the external stations. In this way, the external truck trip volumes at the cordon are conserved and are assumed to be the "correct" volumes.

The proposed external share model is shown in Figure 70 and Table 52. This calculation is performed for each internal zone. This model was adapted from a similar model calibrated from survey data for Berks County, PA and Baltimore, MD and has been adapted to other areas as well.

Figure 70 External Model

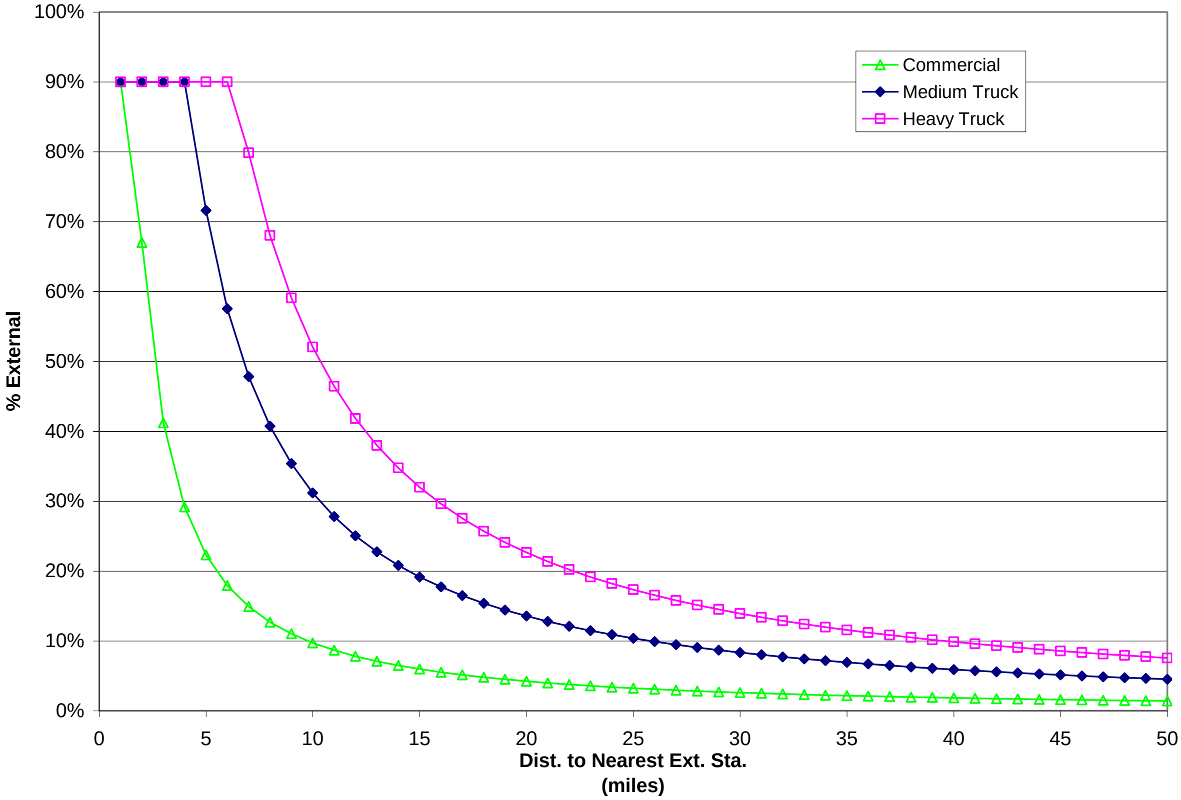


Table 52 External Truck Model

Percent External (MTK) = max(0.90, 4.94 * $D^{-1.2}$)
Percent External (HTK) = max(0.90, 8.25 * $D^{-1.2}$)
Where:
D = distance to nearest external station (via highway net), miles

Through Trips

At the external stations, the split of truck trips by type into external vs. through was estimated. This analysis was based on 2000 total weekday volumes posted on the network and a preliminary 2000 total through trip table provided by ARC. The percentage of total through trips by station was first calculated. It is estimated that medium trucks are less likely to make through trips than the general stream of traffic, since medium trucks are typically short-haul delivery vehicles. In contrast, heavy trucks should be more likely to make through trips, since they are frequently long-haul carriers.

In addition, the through trip percentage (through trips/total trips at cordon) logically varies by facility type. Freeways have by far the largest through trip percentage, because they are the major routes through the region. However, local roads typically have few, if any, through trips. Based on the relationships and assumptions described above, a look-up table was developed to estimate the external trip share (= 100% - through trip share) for each station, as shown in Table

53. Due to the importance of I-75 and I-85 to truck traffic, separate percentages were used for those roadways.

Table 53 External Shares by Road Type

Facility Type	MTK External %	HTK External %	COM External %	Description
1	80%	70%	93%	Interstate/freeway
11	90%	75%	95%	Expressway
12	90%	75%	95%	Principal arterial I
13	95%	80%	98%	Principal arterial II
15	100%	100%	100%	Minor arterial I
17	100%	100%	100%	Major Collector
18	100%	100%	100%	Minor Collector
I-75	80%	50%	93%	
I-85	85%	60%	93%	

Trip Distribution

The ARC truck survey suggested that the average trip length for MTK trips should be about 19.9 miles and for HTK trips 22.8 miles. This HTK figure seems very low, compared to the MTK figure and to other models, for which the HTK trip length is considerably higher than the MTK trip length. Thus, it was assumed that the HTK trip length should be in the range of 25-26 miles (especially given the expansion of the modeled area to 20 counties).

These were used as target values for the calibration of a new set of F (friction) factors for internal trips. For internal trips, the negative exponential function was used to define F factors. Its equation is as follows:

> $F = \alpha * e(\gamma t)$
> where:
> t = travel time, minutes
> α, γ = calibrated coefficients

Various coefficient values were tested, using the newly estimated trip ends, until coefficients were found that produced a trip table that had the target average trip lengths, for 2000.

For external trips, the negative exponential function did not produce reasonable looking average trip lengths. Thus, a power function was used:

> $F = \alpha * t\beta$
> where:
> t = travel time, minutes
> α, β = calibrated coefficients

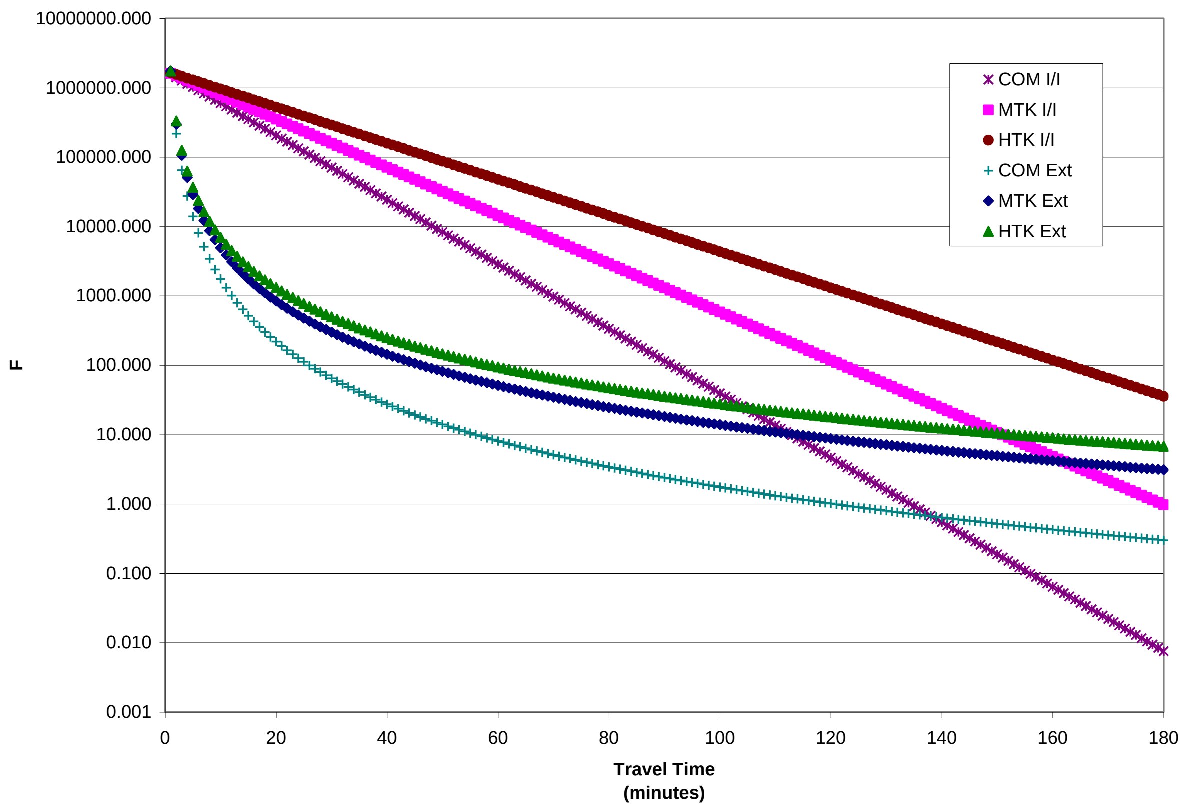
It should be noted that both the negative exponential and power functions are simply special cases of the gamma function, which is commonly used to define F factors: $F = \alpha * t\beta * e(\gamma t)$.

F factors were computed for travel times from 1 to 180 minutes. Table 54 shows the final F factor coefficients and Figure 71 shows the resulting F factor curves. The estimated trip lengths are 15.0 miles for MTK and 25.4 miles for HTK.

Table 54 Friction Factor Equation Coefficients

	α	β	γ
Commercial I/I	1,750,000		-0.107
Medium Truck I/I	1,750,000		-0.08
Heavy Truck I/I	1,750,000		-0.06
Commercial External	1,750,000	-3.00	
Medium Truck External	1,750,000	-2.55	
Heavy Truck External	1,750,000	-2.40	

Figure 71 Truck/Commercial F Factors



Through Trip Synthesis

For through (X/X) trips, the first step was to examine the 2000 total X/X daily vehicle trip table provided by ARC. This was found to be inadequate for describing truck X/X movements. Instead, the external station locations where X/X truck trips should be expected were examined. Then, by inspecting the external station geography and making assumptions about likely X/X patterns (as well as unlikely patterns), an "X/X pattern file" was developed. This was used to create a seed matrix, which was then Fratared to match the estimated number of daily X/X truck trip ends at each station, by truck type. The resulting tables were assigned to the network and the loading patterns examined to confirm that they represent a reasonable set of X/X truck volume patterns on the roadways. The final X/X 2000 daily truck totals are 1,694 MTK and 13,833 HTK. These volumes are not significant in the context of the entire model, but they become somewhat more important for analyses that focus on the major through roadways in the region. They also contribute disproportionately to truck VMT.

Time of Day

Since truck and commercial counts are not available by time of day, it is not possible to estimate a specific time of day model, or to validate it. Instead, the existing ARC truck time of day fractions and those of other similar truck models were reviewed. Although many other models use the same four time periods as the ARC model (AM peak, midday, PM peak, night), allowances must be made for the fact that some of these other models use slightly different definitions for the hours that make up those periods. From an examination of the various TOD fractions available, a set of fractions were devised that should be representative. In general, the proposed TOD fractions are lower in the midday and much higher in the nighttime hours than the existing ARC model. If a sufficient number of classification counts were available by time of day, it would be helpful to re-visit these fractions and derive values that more closely match the actual data.

Table 55 Time of Day Fractions

	ARC Model Time Periods			
	AM 6-10	MD 10a-3p	PM 3-7	NT 7p-6a
Commercial				
Existing BMC	25.1%	28.9%	29.4%	16.6%
ODOT	17.0%	39.2%	36.4%	7.4%
Existing ARC (I/I, Ext LTK)	30.7%	45.7%	17.4%	6.2%
Proposed	*23%*	*39%*	*27%*	*11%*
Medium Truck				
Existing BMC	27.3%	36.0%	22.9%	13.8%
Existing ARC (I/I, Ext HTK)	29.9%	49.1%	16.0%	5.1%
Proposed	*23%*	*39%*	*27%*	*11%*
Heavy Truck				
ODOT (MTK+HTK)	16.3%	35.8%	24.2%	23.7%
Existing BMC	22.5%	32.6%	18.3%	26.6%
Existing ARC (I/I, Ext HTK)	29.9%	49.1%	16.0%	5.1%
Proposed	*22%*	*34%*	*20%*	*24%*
Existing ARC EE Truck	21.9%	26.9%	28.5%	22.7%

Note:
BMC period definitions are: 6-10, 10a-3p, 3-7, 7p-6a
ODOT period definitions are: 6-9, 9a-2p, 2-6, 6p-6a

Assignment

The existing ARC model already incorporated several advanced features relating to the assignment of truck trips, including:

- separate assignments by time period
- coding of truck-prohibited links
- separate impedance calculation for trucks, incorporating tolls at a higher value of time than for passenger cars
- assigning trucks to their own path and maintaining the volumes separately on the output network
- separate loading of through trips

In addition, the assignment method included two untypical features: a special truck penalty on one particular link and a technique to assign some heavy trucks to a path that does not go inside the I-285 perimeter.

The only new feature that was added by this study was to incorporate “passenger car equivalents” (PCEs). This adjusts the volume/capacity calculation so as to represent the true impact of trucks on capacity. According to the Highway Capacity Manual and other sources, large trucks ”use up” more roadway capacity than other vehicles, due to their large size and slow acceleration. Thus, the accuracy of ARC’s capacity-restrained assignment should be improved if truck volumes could be temporarily factored upwards by a factor to represent their disproportional impact on the V/C calculation.

The question remains as to what PCE values to use. A review of the literature and discussions with other planners suggests that the PCE for heavy trucks is in the range of 2.0 – 4.0. Medium trucks perform more like passenger cars and should thus have a smaller PCE. The model project team recommends that values given in the 2000 Highway Capacity Manual of 1.5 and 2.0 should be used for medium and heavy trucks, respectively.

Validation

The interim model described above was applied to year 2000 conditions, using the input data for the new 20-county modeled area. The resulting daily assigned truck volumes were compared to the counts posted in the network, in total (sum of MTK+HTK).

The total error was +19% and the %RMSE was 89%. These do not indicate a high degree of accuracy, although they are clearly better than the existing model for 2000, which has a total error of -27% and a %RMSE of 117%. In any case, it is apparent that the starting model’s results can be improved upon.

The starting model provides a reasonable basis for the subsequent analysis. This model is then applied for 2000 to develop the truck trip tables to be used as the starting point for the adaptable assignment process. This is described in the next section.

Adaptable Assignment

Approach

The premise of adaptable assignment is that it is possible to systematically compare the traffic counts to the assigned volumes and then use that comparison to adjust the starting trip table for each O/D pair. The resulting O/D volumes will produce assignments that more closely match the counts. However, it is entirely possible that the adjustment for some O/D pairs will counteract the adjustment for other O/D pairs. Thus, the process must be iterated several times until a balance has been achieved and little additional assignment accuracy can be expected.

Having applied the adaptable assignment procedure to several different models, the consultant has discovered that its use is not a deterministic process. In particular, the "strength" of the adjustment and the appropriate number of iterations must be ascertained by trial and error. Typically, the iterations are increased until the improvement in accuracy between iterations is very small and the trip table changes stabilize.

In addition, the output trip table must be examined carefully to determine how it differs from the input trip table. Understanding these differences makes it possible to use them to develop adjustments to the starting model, so that its estimates will better reflect the count data.

Various tests of the adaptable assignment process were run to determine suitable values for its various parameters and options. The best results were achieved by using 10 iterations, with the adapted trip table being Fratared after the last iteration, so that the external station totals will match the counts. This analysis was initially conducted using daily volumes, in the interest of saving processing time. However, it was subsequently discovered that the analysis had to be conducted by time period, in order to achieve sufficiently accurate results.

Uses of the Calibration Adjustment

As noted above, the adaptable assignment process produces a new vehicle trip table. The difference between this table and the starting trip table is called the delta table. In effect, the delta table is an O/D matrix of calibration adjustments that, when added to the starting trip table, produce a table that matches the counts fairly closely. Analysis of this delta table can provide clues as to how to modify the starting model, so as to make it more accurate.

Specifically, the trip end summary of this delta table (separately for medium and heavy trucks) was examined. This was then compared to the land use data to see if there was a systematic employment- or household-based adjustment that would improve the model. The finding was that the adjustments were positive in the suburban and rural areas and negative in the downtown areas. This suggested that the trip rate factor on HHs should be increased and the factor on office employment should be decreased.

Next, the delta trip ends were cross-tabulated and compared to the starting model trip ends by truck zone and area type. This analysis indicated that the HTK trips should be increased in the "truck zones" and area type-based factors were necessary.

After several iterations of this analysis, some adjustments to the initial trip generation model to make it more suitable were developed. The revised model is the one shown in Table 56. In general, these adjustments reduce the number of trips in the more developed areas and increase the trips in the less developed areas. This is logical -- since the developed areas have more employees, it would make sense that the truck trip rate per employee might be less in those areas.

Although adaptable assignment helped identify a number of changes that make the initial model more accurate, the resulting accuracy is still not as good as one would like to see. One must recognize the limitations of all relatively simplistic regional travel models, which use fairly basic, available zone-level variables. It is the project team's experience that no travel forecasting model can replicate the millions of individual decisions that take place each day, so as to estimate link-level volumes that match the counts with a very high degree of accuracy. Traffic counts may be somewhat consistent from day to day, but they do include a certain degree of randomness that cannot be reproduced perfectly by a travel model that is limited to relatively simple inputs and relatively simple relationships. However, that observation does not invalidate the use of this model, or any regional travel model, for planning purposes.

As described above, adaptable assignment can be used to "inform" a model, to make it more accurate with respect to the counts. However, no matter how accurate the starting model becomes, the adaptable process will always create a non-zero delta table. This final delta table represents a set of calibration adjustments that are necessary in order to match the counts with a higher degree of accuracy.

This adjustment table becomes an integral part of the model. It is always added to the trip table output by the starting model, to become the final trip table for assignment purposes. The project team believes that this method of assignment calibration is superior to most other techniques and produces results that are not only more accurate in the base year, but more credible in the forecast years.

Table 6.6 presents the final delta trip tables for medium and heavy trucks, compressed to districts. The total delta (net difference) is about 24,000 trips for medium trucks and 3,400 trips for heavy trucks. The most desirable characteristic of a delta trip table is that it is small, relative to the starting table. For medium trucks, the total delta is 9% of the starting trip table; for heavy trucks, the delta is about 3%. Smaller fractions are better and these are quite acceptable. The second half of Table 6.6 shows the final truck trip tables, including the calibration adjustment.

As part of the update to the new zone system, the delta tables had to be renumbered. This was done by tagging the new zone centroids with the old zone numbers and acreage in a GIS based procedure. Percentages based on zonal acreage were computed to disaggregate the original O/D tables to the new zone system.

Table 56 Final Delta Trip Tables

Date: 4/13/2006
Time: 14:48

Atlanta Regional Commission Travel Model
2000 Commercial Vehicle Calibration Adjustment Table

Destination District

Origin District	1	2	3	4	5	6	7	8	9	10	11	Total
1 Fulton	77681	-9562	-9054	-8408	-217	-758	-385	348	-2463	-3347	-787	43048
2 DeKalb	-8429	43745	-5496	-5740	-150	-393	-189	-562	-939	-2494	-594	18759
3 Cobb	-7808	-5582	26127	-2371	-40	-1150	584	-264	1128	-1090	-438	9096
4 Gwinnett	-8343	-4328	-2504	11425	-1415	-288	-54	-365	-186	-395	-648	-7101
5 Hall	-248	-238	-66	-1690	23492	0	0	-260	-2	-20	550	21518
6 Cherokee	-848	-433	-1123	-352	5	8276	-146	455	-41	-61	166	5898
7 NW	-475	-213	963	-75	0	6	19272	-3	187	-70	655	20247
8 NE	348	-472	-399	-179	-197	473	-8	15459	-16	765	870	16644
9 SW	1554	-1087	-88	-182	-6	-31	60	-8	36249	169	751	37381
10 SE	-4441	-3177	-993	-44	-23	-68	-47	265	429	47262	127	39290
11 External	-978	-678	-583	-742	619	201	853	867	887	105	-199	352
Total	48013	17975	6784	-8358	22068	6268	19940	15932	35233	40824	453	205132

Date: 4/13/2006
Time: 14:48

Atlanta Regional Commission Travel Model
2000 Medium Truck Calibration Adjustment Table

Destination District

		1	2	3	4	5	6	7	8	9	10	11	Total
O	1 Fulton	4800	2488	869	954	23	-251	5	-1	-352	-826	-28	7681
r	2 DeKalb	-2708	-691	-948	100	129	-157	-58	-207	-405	-624	-124	-5693
i	3 Cobb	-1056	-2095	3126	-848	-4	-170	172	-92	486	-444	-224	-1149
g	4 Gwinnett	-232	-469	-1054	11437	586	-60	-28	79	-103	-237	23	9942
i	5 Hall	128	137	-6	994	1295	9	1	202	-1	-10	-93	2656
n	6 Cherokee	-280	-148	-21	-12	10	19	17	74	3	-42	7	-373
	7 NW	10	-116	1025	-35	1	4	1692	0	354	-31	281	3185
D	8 NE	-57	-259	-156	279	89	73	0	820	-12	27	309	1113
i	9 SW	-596	938	355	24	1	18	301	1	1569	-40	519	3090
s	10 SE	-1215	2490	-184	886	14	-29	-8	51	291	1125	421	3842
t	11 External	-456	-136	-190	64	-180	-2	309	411	270	236	-407	-81
	Total	-1662	2139	2816	13843	1964	-546	2403	1338	2100	-866	684	24213

Date: 4/13/2006
Time: 14:48

Atlanta Regional Commission Travel Model
2000 Heavy Truck Calibration Adjustment Table

Destination District

Origin District	1	2	3	4	5	6	7	8	9	10	11	Total
1 Fulton	-1482	-2378	-634	-1041	-43	-155	170	-152	1484	5246	517	1532
2 DeKalb	-2782	-961	-868	-625	-24	-98	13	-142	19	1066	132	-4270
3 Cobb	-1762	-1545	1063	253	11	-216	286	-48	974	1630	521	1167
4 Gwinnett	-1218	854	-473	-1492	-218	-114	-16	-223	30	-47	73	-2844
5 Hall	-72	-49	-28	-276	-1	-4	-2	-27	1	-31	270	-219
6 Cherokee	-451	-252	-319	-204	-1	58	77	12	24	-23	147	-932
7 NW	29	-102	403	25	-2	135	419	12	74	121	452	1566
8 NE	-273	-187	-166	-209	0	-24	2	148	-7	210	215	-291
9 SW	1514	188	889	-8	0	19	49	13	229	-138	259	3014
10 SE	1474	-161	743	-101	-30	-2	164	178	497	1112	915	4789
11 External	445	97	487	172	364	186	552	316	266	565	-3522	-72
Total	-4578	-4496	1097	-3506	56	-215	1714	87	3591	9711	-21	3440

Date: 4/13/2006
Time: 14:48

Atlanta Regional Commission Travel Model
2000 Commercial Vehicle Daily Trips
With Calibration Adjustment

Destination District

		1	2	3	4	5	6	7	8	9	10	11	Total
O	1 Fulton	181251	26963	23060	10024	395	3306	1031	5657	7198	16025	1735	276645
r	2 DeKalb	28235	104121	4746	17766	317	394	249	1178	1087	11893	1012	170998
i	3 Cobb	24344	4649	98976	2445	62	7111	7639	505	6057	1910	1405	155103
g	4 Gwinnett	10039	19267	2407	82052	2367	294	83	7425	223	3243	1869	129269
i	5 Hall	382	283	70	2445	45896	81	5	1591	10	28	2934	53725
n	6 Cherokee	3179	308	7104	211	81	19698	1232	1550	82	86	925	34456
	7 NW	964	212	8144	91	4	1407	37678	35	2419	101	2326	53381
D	8 NE	5678	1328	491	7578	1551	1561	27	34713	34	2937	3818	59716
i	9 SW	11672	1101	4981	238	5	76	2341	26	86876	7205	4015	118536
s	10 SE	14926	11594	2005	3723	31	93	130	2341	7066	117716	5078	164703
t	11 External	1400	875	1228	1728	2923	956	2493	3714	4072	4882	454	24725
	Total	282070	170701	153212	128301	53632	34977	52908	58735	115124	166026	25571	1241257

Date: 4/13/2006
Time: 14:48

Atlanta Regional Commission Travel Model
2000 Medium Truck Daily Trips
With Calibration Adjustment

Destination District

		1	2	3	4	5	6	7	8	9	10	11	Total
O	1 Fulton	28086	12059	10218	7035	486	989	687	1423	2715	4995	2072	70765
r	2 DeKalb	6951	11654	2522	6841	490	170	216	303	505	3525	1136	34313
i	3 Cobb	8206	1342	18723	1186	89	1726	2010	230	2170	990	1337	38009
g	4 Gwinnett	5780	6218	1093	26864	1792	211	67	1989	192	1175	2186	47567
i	5 Hall	477	419	69	2160	4994	51	4	583	16	36	1627	10436
n	6 Cherokee	847	134	1952	238	63	1556	361	332	108	45	590	6226
	7 NW	598	90	2785	70	10	361	4328	35	825	79	1423	10604
D	8 NE	1351	373	218	2138	461	309	25	2966	20	503	2232	10596
i	9 SW	2435	1918	1857	369	22	86	782	34	10377	1899	2929	22708
s	10 SE	4454	6750	1222	2457	78	66	103	502	2178	13747	3893	35450
t	11 External	1751	1236	1404	2347	1602	600	1483	2417	2795	3763	1279	20677
	Total	60936	42193	42063	51705	10087	6125	10066	10814	21901	30757	20704	307351

Date: 4/13/2006
Time: 14:48

Atlanta Regional Commission Travel Model
2000 Heavy Truck Daily Trips
With Calibration Adjustment

Destination District

		1	2	3	4	5	6	7	8	9	10	11	Total
O	1 Fulton	14221	4957	6303	3362	271	615	1087	736	4418	11239	3895	51104
r	2 DeKalb	4422	6735	1842	3832	172	104	359	387	1109	4906	2151	26019
i	3 Cobb	4954	1166	8935	2058	112	698	1564	166	2382	3238	2681	27954
g	4 Gwinnett	3153	5485	1251	5993	446	87	167	902	476	1421	3124	22505
i	5 Hall	230	237	67	440	1221	12	4	207	42	57	2438	4955
n	6 Cherokee	379	61	763	66	24	655	349	111	114	157	989	3668
	7 NW	679	166	1528	190	7	356	1522	35	375	307	2077	7242
D	8 NE	632	361	167	870	188	115	41	847	54	604	2601	6480
i	9 SW	4381	1158	2177	352	16	118	361	83	4383	1572	3690	18291
s	10 SE	7078	3705	2401	1401	43	140	430	536	2231	9026	5806	32797
t	11 External	3009	1686	2132	2518	2122	835	1873	2331	3147	4600	10021	34274
	Total	43138	25717	27566	21082	4622	3735	7757	6341	18731	37127	39473	235289

Note:

NW = Bartow, Paulding
NE = Forsyth, Barrow, Walton
SW = Douglas, Carroll, Coweta, Fayette
SE = Clayton, Spalding, Henry, Rockdale, Newton

It is also clear from these tables that the intra-district cells are mostly positive, while many of the inter-district cells are negative. This reflects the tendency of adaptable assignment to add more short trips than long trips. Mechanically, this is because adaptable assignment factors the starting trips to match the counts, and the majority of the trips from any zone tend to go to nearby zones. Thus, the process tends to magnify these short trips. The reduction in longer trips suggests that those trips are contributing disproportionately to the links that are initially overestimated.

The average trip length of both types of truck trips is reduced, when the delta table is included, as shown in Table 57. These slight drops in average trip length are typical and are of no great concern.

Table 57 Starting and Final Travel Times

	COM	MTK	HTK
Starting Trip Table	27.5	33.2	41.3
Final Trip Table	23.0	31.9	39.9
Percent Change	-16%	-4%	-3%

Note: figures are in minutes and include External and X/X trips.

It should also be noted that in the delta trip matrix, the individual cell values include fractional amounts of trips and in many cases are negative. Special care must be taken in forecasting to ensure that when these delta values are added to the model's initial estimates, that the resulting value does not become negative for any cell. Such values should be re-set to zero. Also, the delta tables include all matrix cells, including I/I, I/X, X/I, and X/X values. Both the starting model and the delta tables maintain trips separately by period: AM peak, midday, PM peak, and night.

As noted above, the medium and heavy truck delta tables now become an integral part of the truck model. They must always be added to the results of the model, in order to produce the final trip table.

Accuracy

As the final step in the development of the truck model, the truck delta tables were added to the tables from the starting model and the resulting tables were assigned to the ARC 2000 network. The assignment procedure was modified slightly from ARC's standard process, as mentioned above, so as to include truck PCEs.

The resulting assigned volumes were compared to the new medium and heavy truck counts, producing the reports shown in Tables 58 and 59. These reports tabulate the assignment error by facility type group (1=freeway, 2=arterial, 3=collector/local) and zonal area type (1-7).

The total error is +7% for medium trucks and +15% for heavy trucks, while the %RMSE values are 37% and 64%, respectively. This is a large improvement over the starting model alone and is substantially better than the current ARC model. For comparison, the combined MTK/HTK error of the new model is +14%, with a %RMSE of 49%. The current ARC model's total truck error is -27%, with a %RMSE of 117%.

There is little difference in the estimated/observed ratio, when stratified by the various fields shown in these reports. The %RMSE values tend to be better (lower) for the higher-type, higher-volume facilities, but this is to be expected. There is no discernable bias in the error by area type.

The project team believes that the adaptable assignment process is at least as valid as the count data. The result of this process is a model that both matches the counts and displays reasonable sensitivity to changes. The new model's coefficients and the inclusion of special factors for truck zones should produce more logical and defensible trip patterns. This is a major improvement in accuracy and credibility, compared to the existing truck model.

Table 58 Assignment Report: Medium Trucks

CROSSTAB ROW=_ftg COL=ATYPE VAR=_cnt (Count)

	1	2	3	4	5	6	7	1 7
1 - 1	2,037	15,269	14,491	15,935	83,108	20,490	14,531	165,861
2 - 2	0	4,745	27,981	15,421	47,171	13,330	12,761	121,409
3 - 3	171	4,626	2,924	1,910	4,694	237	1,010	15,572
1 - 3	2,208	24,640	45,396	33,266	134,973	34,057	28,302	302,842

CROSSTAB ROW=_ftg COL=ATYPE VAR=MTKvol (Assigned Volume)

	1	2	3	4	5	6	7	1 7
1 - 1	2,169	19,130	14,271	19,792	89,467	26,696	13,646	185,171
2 - 2	0	4,878	28,564	14,918	49,323	13,338	13,588	124,609
3 - 3	167	4,602	2,823	1,494	4,791	380	1,027	15,284
1 - 3	2,336	28,610	45,658	36,204	143,581	40,414	28,261	325,064

CROSSTAB ROW=_ftg COL=ATYPE VAR=_links (Number of Counted Links)

	1	2	3	4	5	6	7	1 7
1 - 1	6	17	17	28	61	26	10	165
2 - 2	0	7	48	24	137	47	76	339
3 - 3	1	10	10	13	38	4	6	82
1 - 3	7	34	75	65	236	77	92	586

CROSSTAB ROW=_ftg COL=ATYPE VAR=_bad ("Bad" Links)

	1	2	3	4	5	6	7	1 7
1 - 1	1	4	1	4	10	6	0	26
2 - 2	0	1	2	0	6	0	5	14
3 - 3	0	0	0	3	2	0	0	5
1 - 3	1	5	3	7	18	6	5	45

Note: "bad" links are those whose error lies above the FHWA error tolerance line

CROSSTAB ROW=_ftg COL=ATYPE VAR=_sqerr (Squared Error)

	1	2	3	4	5	6	7	1 7
1 - 1	40,244	1,612,779	467,556	2,767,979	6,157,083	6,918,312	944,841	18,908,794
2 - 2	0	27,363	654,473	170,081	793,558	19,350	265,425	1,930,250
3 - 3	16	2,096	3,247	52,572	9,863	7,569	1,871	77,234
1 - 3	40,260	1,642,238	1,125,276	2,990,632	6,960,504	6,945,231	1,212,137	20,916,278

CROSSTAB ROW=_ftg COL=ATYPE COMP=MTKvol/_cnt (Assigned/Count Ratio)

	1	2	3	4	5	6	7	1 7
1 - 1	1.06	1.25	0.98	1.24	1.08	1.30	0.94	1.12
2 - 2	0.00	1.03	1.02	0.97	1.05	1.00	1.06	1.03
3 - 3	0.98	0.99	0.97	0.78	1.02	1.60	1.02	0.98
1 - 3	1.06	1.16	1.01	1.09	1.06	1.19	1.00	1.07

CROSSTAB ROW=_ftg COL=ATYPE COMP=_bad/_links (Proportion of "Bad" Links)

	1	2	3	4	5	6	7	17
1 - 1	0.17	0.24	0.06	0.14	0.16	0.23	0.00	0.16
2 - 2	0.00	0.14	0.04	0.00	0.04	0.00	0.07	0.04
3 - 3	0.00	0.00	0.00	0.23	0.05	0.00	0.00	0.06
1 - 3	0.14	0.15	0.04	0.11	0.08	0.08	0.05	0.08

CROSSTAB ROW=_ftg COL=ATYPE COMP=sqrt(_sqerr/_links) (RMSE)

	1	2	3	4	5	6	7	17
1 - 1	81.9	308.0	165.8	314.4	317.7	515.8	307.4	338.5
2 - 2	0.0	62.5	116.8	84.2	76.1	20.3	59.1	75.5
3 - 3	4.0	14.5	18.0	63.6	16.1	43.5	17.7	30.7
1 - 3	75.8	219.8	122.5	214.5	171.7	300.3	114.8	188.9

CROSSTAB ROW=_ftg COL=ATYPE COMP=sqrt(_sqerr/_links)/(_cnt/_links) (% RMSE)

	1	2	3	4	5	6	7	17
1 - 1	0.24	0.34	0.19	0.55	0.23	0.65	0.21	0.34
2 - 2	0.00	0.09	0.20	0.13	0.22	0.07	0.35	0.21
3 - 3	0.02	0.03	0.06	0.43	0.13	0.73	0.10	0.16
1 - 3	0.24	0.30	0.20	0.42	0.30	0.68	0.37	0.37

Rows represent facility type groups: 1 = Freeway, 2 = Arterial, 3 = Collector/Local.
Columns represent ARC zonal area type codes.

Table 59 Assignment Report: Heavy Trucks

CROSSTAB ROW=_ftg COL=ATYPE VAR=_cnt (Count)

	1	2	3	4	5	6	7	17
1 - 1	2,572	27,239	11,873	41,349	127,165	56,050	55,346	321,594
2 - 2	0	409	3,580	2,632	13,219	4,678	5,585	30,103
3 - 3	0	158	568	248	1,734	59	113	2,880
1 - 3	2,572	27,806	16,021	44,229	142,118	60,787	61,044	354,577

CROSSTAB ROW=_ftg COL=ATYPE VAR=HTKvol (Assigned Volume)

	1	2	3	4	5	6	7	17
1 - 1	3,171	38,157	12,822	46,201	140,598	56,945	47,549	345,443
2 - 2	0	869	11,500	5,051	23,835	7,568	9,131	57,954
3 - 3	0	483	699	285	2,725	616	434	5,242
1 - 3	3,171	39,509	25,021	51,537	167,158	65,129	57,114	408,639

CROSSTAB ROW=_ftg COL=ATYPE VAR=_links (Number of Counted Links)

	1	2	3	4	5	6	7	17
1 - 1	6	15	17	28	62	27	10	165
2 - 2	0	7	42	24	105	45	57	280
3 - 3	0	6	9	9	17	2	4	47
1 - 3	6	28	68	61	184	74	71	492

CROSSTAB ROW=_ftg COL=ATYPE VAR=_bad ("Bad" Links)

	1	2	3	4	5	6	7	17
1 - 1	3	5	6	6	15	3	0	38
2 - 2	0	4	32	12	56	18	21	143
3 - 3	0	5	2	3	7	2	4	23
1 - 3	3	14	40	21	78	23	25	204

Note: "bad" links are those whose error lies above the FHWA error tolerance line

CROSSTAB ROW=_ftg COL=ATYPE VAR=_sqerr (Squared Error)

	1	2	3	4	5	6	7	17
1 - 1	360,169	21,557,822	893,513	20,496,056	29,277,211	8,702,615	12,319,771	93,607,157
2 - 2	0	63,790	4,213,560	710,111	3,313,530	806,062	1,482,914	10,589,967
3 - 3	0	22,431	17,837	4,241	173,843	156,865	27,543	402,760
1 - 3	360,169	21,644,043	5,124,910	21,210,408	32,764,584	9,665,542	13,830,228	104,599,884

CROSSTAB ROW=_ftg COL=ATYPE COMP=HTKvol/_cnt (Assigned/Count Ratio)

	1	2	3	4	5	6	7	17
1 - 1	1.23	1.40	1.08	1.12	1.11	1.02	0.86	1.07
2 - 2	0.00	2.12	3.21	1.92	1.80	1.62	1.63	1.93
3 - 3	0.00	3.06	1.23	1.15	1.57	10.44	3.84	1.82
1 - 3	1.23	1.42	1.56	1.17	1.18	1.07	0.94	1.15

CROSSTAB ROW=_ftg COL=ATYPE COMP=_bad/_links (Proportion of "Bad" Links)

	1	2	3	4	5	6	7	17
1 - 1	0.50	0.33	0.35	0.21	0.24	0.11	0.00	0.23
2 - 2	0.00	0.57	0.76	0.50	0.53	0.40	0.37	0.51
3 - 3	0.00	0.83	0.22	0.33	0.41	1.00	1.00	0.49
1 - 3	0.50	0.50	0.59	0.34	0.42	0.31	0.35	0.41

CROSSTAB ROW=_ftg COL=ATYPE COMP=sqrt(_sqerr/_links) (RMSE)

	1	2	3	4	5	6	7	17
1 - 1	245.0	1198.8	229.3	855.6	687.2	567.7	1109.9	753.2
2 - 2	0.0	95.5	316.7	172.0	177.6	133.8	161.3	194.5
3 - 3	0.0	61.1	44.5	21.7	101.1	280.1	83.0	92.6
1 - 3	245.0	879.2	274.5	589.7	422.0	361.4	441.4	461.1

CROSSTAB ROW=_ftg COL=ATYPE COMP=sqrt(_sqerr/_links)/(_cnt/_links) (% RMSE)

	1	2	3	4	5	6	7	17
1 - 1	0.57	0.66	0.33	0.58	0.34	0.27	0.20	0.39
2 - 2	0.00	1.63	3.72	1.57	1.41	1.29	1.65	1.81
3 - 3	0.00	2.32	0.71	0.79	0.99	9.49	2.94	1.51
1 - 3	0.57	0.89	1.17	0.81	0.55	0.44	0.51	0.64

Rows represent facility type groups: 1 = Freeway, 2 = Arterial, 3 = Collector/Local.
Columns represent ARC zonal area type codes.

Commercial Vehicle Trips

Development of the Commercial (COM) vehicle trip model proceeded in exactly the same fashion as for the truck models, except that instead of actual classification counts, synthesized counts were used, as described in detail in Appendix A. The starting trip generation model was borrowed from a similar model recently developed for the Washington, DC area (Metropolitan Washington COG). The starting F factors were taken as those of the existing ARC internal light truck model.

The same protocol described above was used. The starting model was applied and the resulting assigned link volumes compared to the synthesized counts. The generation model was then adjusted so as to better match the counts and the distribution model was adjusted so as to better match an average trip length of 14.9 miles, which represents the average light truck/commercial trip length from the ARC survey. As part of this effort, the trip rate was decreased on office employment and increased on HHs. Also, area type adjustment factors were developed that decreased the trip rate in urbanized areas and increased the trip rate in suburban/rural areas. Both adjustments mirrored those made to the MTK and HTK models.

The starting COM trip generation model is shown in Table 60. This model estimates 1,035,000 daily COM trips: 987,000 internal and 48,000 external. It should be noted that the COM total is more than twice the total of MTK plus HTK. Since COM trips are almost all passenger cars and light duty trucks, it is important from an emissions viewpoint to clearly separate them from MTK and HTK, and important from a mode choice perspective to clearly separate them from NHB trips.

Table 60 Starting COM Generation Model

COM = (0.230 * INDEMP + 0.407 * RETEMP + 0.125 * OFFEMP + 0.330 * HH) * factor

INDEMP is Industrial Employment
RETEMP is Retail Employment
OFFEMP is Office Employment
HH is Households

Factor for area type:

Area Type	COM
1	0.70
2	0.80
3	0.90
4	1.00
5	1.10
6	1.20
7	1.40

The external model uses the same form as for trucks, as shown in Table 61 and Figure 67.

Table 61 External COM Model

Percent External (COM) = max(0.90, 1.54 * D-1.2)

Where:
D = distance to nearest external station (via highway net), miles

Table 54 shows the F factor coefficients used for COM trips. As noted above, the existing ARC light truck F factors were used to start and were then adjusted to achieve more reasonable-looking trip patterns and average trip length. The final COM F factors are graphed in Figure 68.

The through trip methodology for COM trips was the same as for MTK and HTK. However, the COM X/X trips are much smaller in number: 662. COM trips are mainly local in nature and so a lot of external and through COM trips should not be expected.

COM trips are assigned in the same fashion as SOV trips – that is, they are all assumed to be single-occupant passenger cars and light trucks. The starting COM model was validated in the same manner as the MTK/HTK models. The assignment error was +27% and the %RMSE was 112%. As with the truck models, it is clear that these results can be improved upon.

The adaptable assignment procedure was applied to COM trips, producing a delta table. The sum of this table is about 205,000, which is 20% of the starting trip table's total. This is a higher percentage than is normally desirable, but various attempts to modify this figure proved unworkable (i.e., they ended up with higher overall errors). The delta table and final COM trip table are shown in Table 62.

As with the truck trips, the calibration adjustment process resulted in a shorter trip length. As Table 57 shows, the difference was more dramatic for COM trips than for the truck trips: -16%. This is typical of such analyses.

The time of day fractions assumed for COM trips are shown in Table 55.

The final assignment results for COM indicate an error of -1% and a %RMSE of 24%. These are both considerably better than the starting model and for the truck models. Table 62 presents the assignment accuracy report for COM trips.

Table 62 Assignment Report: Commercial Trips

CROSSTAB ROW=_ftg COL=ATYPE VAR=_cnt (Total Count)

	1	2	3	4	5	6	7	1 7
1 - 1	156,648	283,266	363,191	280,988	894,612	160,229	66,619	2,205,553
2 - 2	71,357	112,148	447,406	374,340	1,218,933	442,422	427,071	3,093,677
3 - 3	10,681	41,728	91,729	80,066	314,703	33,976	37,972	610,855
1 - 3	238,686	437,142	902,326	735,394	2,428,248	636,627	531,662	5,910,085

CROSSTAB ROW=_ftg COL=ATYPE VAR=COMvol (Assigned Volume)

	1	2	3	4	5	6	7	1 7
1 - 1	162,933	281,769	379,260	285,820	870,818	200,469	76,074	2,257,143
2 - 2	69,203	108,609	440,916	362,989	1,216,403	426,246	416,067	3,040,433
3 - 3	12,127	41,424	85,676	75,628	295,300	31,773	37,321	579,249
1 - 3	244,263	431,802	905,852	724,437	2,382,521	658,488	529,462	5,876,825

CROSSTAB ROW=_ftg COL=ATYPE VAR=_links (Number of Counted Links)

	1	2	3	4	5	6	7	1 7
1 - 1	21	42	66	65	194	77	46	511
2 - 2	53	85	366	334	1,373	597	921	3,729
3 - 3	32	72	178	193	613	74	112	1,274
1 - 3	106	199	610	592	2,180	748	1,079	5,514

CROSSTAB ROW=_ftg COL=ATYPE VAR=_bad (Number of "Bad" Links)

	1	2	3	4	5	6	7	1 7
1 - 1	0	0	3	0	0	8	0	11
2 - 2	1	7	10	9	53	28	48	156
3 - 3	3	3	21	38	70	7	9	151
1 - 3	4	10	34	47	123	43	57	318

Note: "bad" links are those whose error lies above the FHWA error tolerance line

CROSSTAB ROW=_ftg COL=ATYPE VAR=_sqerr (Squared Error)

	1	2	3	4	5	6	7	1 7
1 - 1	11,934,517	27,065,235	24,335,017	16,091,772	80,450,784	50,685,948	7,402,487	217,965,760
2 - 2	2,805,158	7,671,041	25,939,270	24,377,681	36,296,290	15,616,822	8,547,896	121,254,158
3 - 3	342,314	833,658	5,000,263	5,182,644	14,771,489	1,408,851	1,330,575	28,869,794
1 - 3	15,081,989	35,569,934	55,274,550	45,652,097	131,518,563	67,711,621	17,280,958	368,089,712

CROSSTAB ROW=_ftg COL=ATYPE COMP=COMvol/_cnt (Assigned/Count Ratio)

	1	2	3	4	5	6	7	1 7
1 - 1	1.04	0.99	1.04	1.02	0.97	1.25	1.14	1.02
2 - 2	0.97	0.97	0.99	0.97	1.00	0.96	0.97	0.98
3 - 3	1.14	0.99	0.93	0.94	0.94	0.94	0.98	0.95
1 - 3	1.02	0.99	1.00	0.99	0.98	1.03	1.00	0.99

CROSSTAB ROW=_ftg COL=ATYPE COMP=_bad/_links (Proportion of "Bad" Links)

	1	2	3	4	5	6	7	1 7
1 - 1	0.00	0.00	0.05	0.00	0.00	0.10	0.00	0.02
2 - 2	0.02	0.08	0.03	0.03	0.04	0.05	0.05	0.04
3 - 3	0.09	0.04	0.12	0.20	0.11	0.09	0.08	0.12
1 - 3	0.04	0.05	0.06	0.08	0.06	0.06	0.05	0.06

CROSSTAB ROW=_ftg COL=ATYPE COMP=sqrt(_sqerr/_links) (RMSE)

	1	2	3	4	5	6	7	17
1 - 1	753.9	802.8	607.2	497.6	644.0	811.3	401.2	653.1
2 - 2	230.1	300.4	266.2	270.2	162.6	161.7	96.3	180.3
3 - 3	103.4	107.6	167.6	163.9	155.2	138.0	109.0	150.5
1 - 3	377.2	422.8	301.0	277.7	245.6	300.9	126.6	258.4

CROSSTAB ROW=_ftg COL=ATYPE COMP=sqrt(_sqerr/_links)/(_cnt/_links) (%RMSE)

	1	2	3	4	5	6	7	17
1 - 1	0.10	0.12	0.11	0.12	0.14	0.39	0.28	0.15
2 - 2	0.17	0.23	0.22	0.24	0.18	0.22	0.21	0.22
3 - 3	0.31	0.19	0.33	0.40	0.30	0.30	0.32	0.31
1 - 3	0.17	0.19	0.20	0.22	0.22	0.35	0.26	0.24

Rows represent facility type groups: 1 = Freeway, 2 = Arterial, 3 = Collector/Local.
Columns represent ARC zonal area type codes.

Application

The new COM/MTK/HTK model is applied using a Cube/TP+ setup. This includes trip generation, trip distribution, time of day, and assignment steps. Trip generation uses the standard ARC land use file, which for 2000 was named NWTAZ00G.PRN and the standard ARC area type file, named ZNEDAT00.DAT. Three new zonal files are needed:

1. Forecast year external trips by external station and vehicle type. ASCII file with one record per station. First field is the station number. Next 3 fields are the COM cordon total, MTK cordon total, and HTK cordon total. Data can be in any columns, but there must be at least one space between each field on each record.
2. Distance to nearest external station. ASCII file with one record per internal zone and two fields per record. First field is the zone number, second field is the distance to the nearest external station in miles (via the highway network). Data can be in any columns, but there must be at least one space between each field on each record.
3. Zonal file identifying truck zones. Currently a DBF file with one record per internal zone and two fields: ZONE and FLAG. If FLAG is non-zero, it identifies the zone as a "truck zone", having a higher heavy truck trip rate per employee than other zones. During development, this file was named "Truck Zones.DBF".

Trip distribution uses a matrix file of off-peak highway times, which include intrazonal time and O and D terminal times, as in the existing ARC model. The F factors are stored in a file called FFACTORS.PRN. K factors are not used. Through trips are stored in a matrix file named CMHEE.TRP, with three tables: 1=COMEE, 2=MTKEE, 3=HTKEE. This file was developed for 2000. Forecast year versions would presumably be developed by Frataring the 2000 tables.

The time of day fractions are located in the TP+ setup. The calibration adjustment tables are stored in four files: DELTApp.TRP, where pp is the time of day (AM, MD, PM, NT). Each of those files contains 3 tables: 1=COM, 2=MTK, 3=HTK. These are matrix files that use the current 20-county zone system. If the zone system is changed, these files must be modified accordingly.

References

1. *Quick Response Freight Manual*, prepared by Cambridge Systematics for the Travel Model Improvement Program, September 1996
2. *Truck Trip Generation Data*, NCHRP Synthesis 298, prepared by Cambridge Systematics and Jack Faucett Associates for the Transportation Research Board, 2001
3. Allen, W.G., *Adaptable Assignment,* presented at the Sixth TRB Conference on the Application of Transportation Planning Methods, May 1997

List, G. and Turnquist, M., *Estimating Truck Travel Patterns in Urban Areas*, Transportation Research Record 1430, 1994

Highway Assignment Results

The highway assignment procedure used by the model is a standard equilibrium technique to assign vehicles trips to the transportation network. The assignment is done in Cube Voyager software using the bi-conjugate Frank-Wolfe algorithm. In application, the assignment parameters are currently set to a maximum of 200 iterations and assumed to be converged when the relative gap is less than 0.0005.

The highway assignments make use of a generalized cost function that includes time, toll, and distance which are converted to equivalent year 2010 dollars using a value of time (VOT) and auto operating costs. The passenger car VOT used in the model is $25 per hour and is based on the median hourly household income in the Atlanta region[9]. For commercial vehicles, the VOT is $36 per hour and is based on a literature review of truck VOT[10].

The operating cost for passenger cars is $0.1385 per mile based on a fuel cost of $2.77 per gallon and a fuel efficiency of 20 miles per gallon. The operating cost for commercial vehicles is $0.4933 per mile based on a fuel cost of $2.96 per gallon and a fuel efficiency of 6 miles per gallon. The fuel costs were obtained from the U.S. Energy Information Administration[11]. An example of the generalized cost function is as follows:

Cost = (time * VOT) + toll cost + (distance * operating cost)

Heavy duty trucks without an origin or destination inside the I-285 by-pass are prohibited from traveling roadways inside the by-pass. This is accomplished in the model by extracting the heavy duty truck trips that do not have a trip end within I-285 and using prohibition codes on links inside I-285. The assignments are multi-class and include the following classes:

1. SOV (non-toll)
2. HOV 2/car (non-toll)
3. HOV 3+/car (non-toll)
4. SOV (toll eligible)
5. HOV 2/car (toll eligible)
6. HOV 3+/car (toll eligible)
7. Commercial vehicle (toll eligible)
8. Medium duty truck (toll eligible)
9. Heavy duty truck: I-285 by-pass (toll eligible)
10. Heavy duty truck: remaining (toll eligible)

The model performs highway assignments for the following five time periods:

- Early AM: 3:00 AM to 6:00 AM
- AM Peak: 6:00 AM to 10:00 AM
- Midday: 10:00 AM to 3:00 PM

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[9] American Community Survey, 2008-2010. *http://www.census.gov/acs/www/*
[10] Allen, William and PBS&J. *Review of Existing Truck Model*. ARC 2010.
[11] U.S. Energy Information Administration. *http://www.eia.gov/dnav/pet/pet_pri_gnd_dcus_r1z_a.htm*

- PM Peak: 3:00 PM to 7:00 PM
- Late Evening / Night: 7:00 PM to 3:00 AM

Volume-delay functions (VDF curves) describe the rate at which delay is added to the travel time on a roadway segment as a function of the quantity of traffic being carried. Ratios of the assigned traffic volume versus the capacity (or the V/C ratio) are used to predict how travel times (and hence, delays) increase as roadway volumes build up to and beyond the capacity of the roadway. As part of the implementation of new VDF curves, the period level travel speeds were calibrated and validated using FHWA's National Performance Management Research Data Set (NPMRDS). The NPMRDS includes travel time data for individual Traffic Message Channels (TMC) and is available in 5 minute increments (EPOCHS) for every day of a chosen month. For the purposes of calibrating and validating the model, data from October 2013 was used.

To understand the data, a cursory review of individual TMC codes was performed by plotting the observed travel times (seconds) for each 5 minute EPOCH as showing in Figure 72. As shown in the figure by the circled observations, the data appears to include some default values that would skew the observed travel times. In this example, the reported upper limit travel times include numerous points approaching 12000 seconds. Because the values are so high and the exact number of seconds is repeated multiple times, these data points do not appear to be valid. Randomly selecting other individual TMC codes yielded similar patterns; therefore, it was necessary to filter these invalid observations from the data prior to using. An outlier detection algorithm was applied to the data in two stages:

Stage 1: Check for outliers within 5 minute EPOCH period

Stage 2: Check for outliers in the 4 broad model time periods

- AM, MD, PM, EA + EV (to get enough data points)

A rule was used to classify outliers that included computing the 25th and 75th percentile (Q25 and Q75 respectively) with data being considered valid if the point falls in between (Q25 – 1.5 * IQR) and (Q75 + 1.5 * IQR) where IQR is the interquartile range (Q75-Q25). A visual representation of this in application is provided in Figure 73 with one TMC link example of the filtered data provided in Figure 74. After the data had been filtered, travel times were averaged over the model time periods (EA, AM, MD, PM) and the TMC link distance was used to compute period level travel speeds. To join the data to the highway network, ARC staff coded the appropriate TMC code as a network attribute. The links identified with a TMC code are illustrated in Figure 75.

Figure 72 Example TMC Link

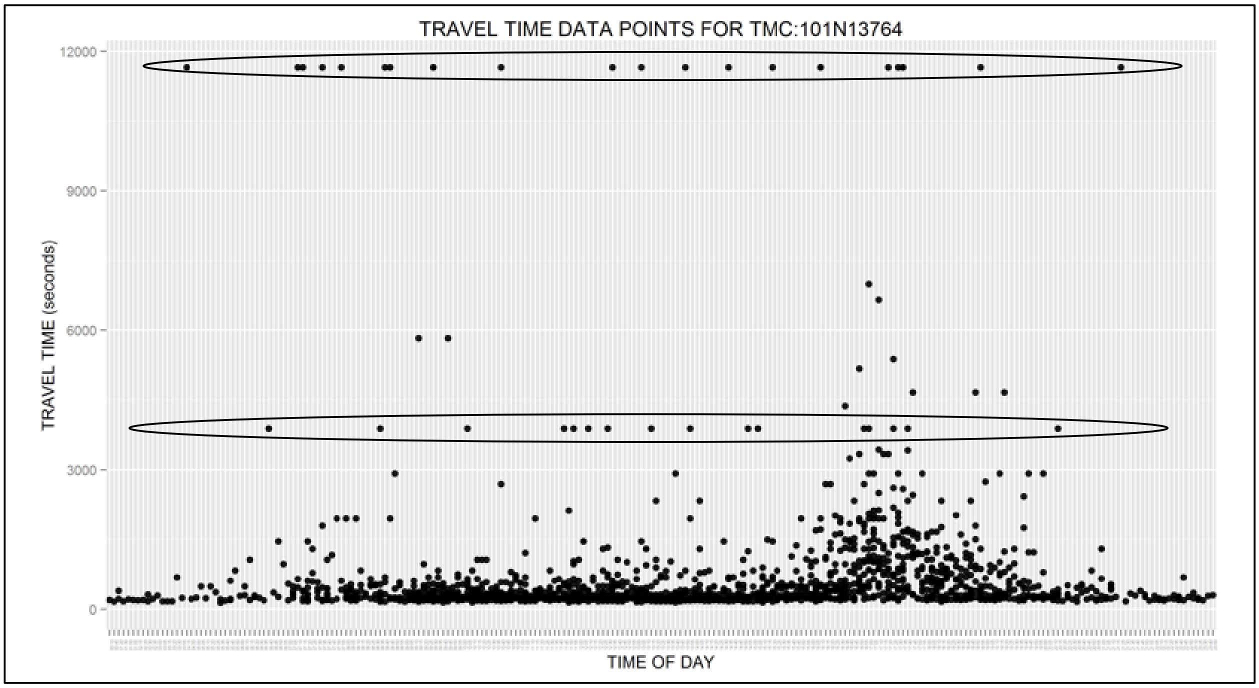


Figure 73 Identifying Outliers

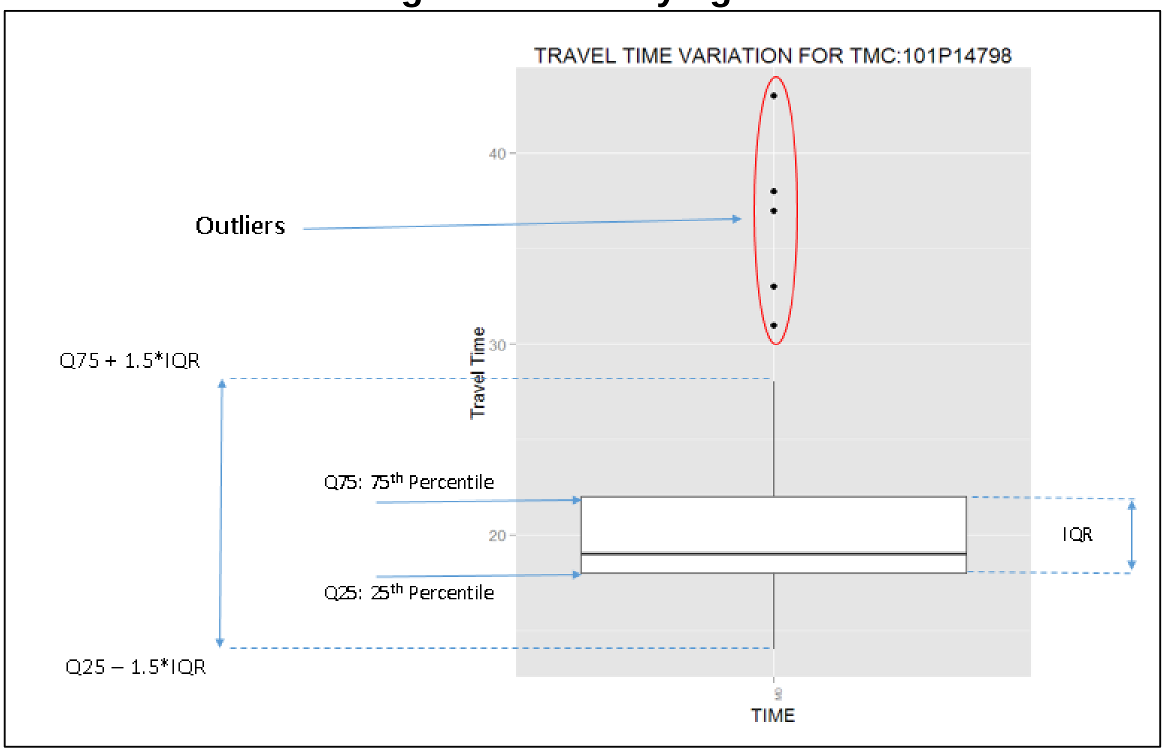


Figure 74 Example Filtered TMC Link

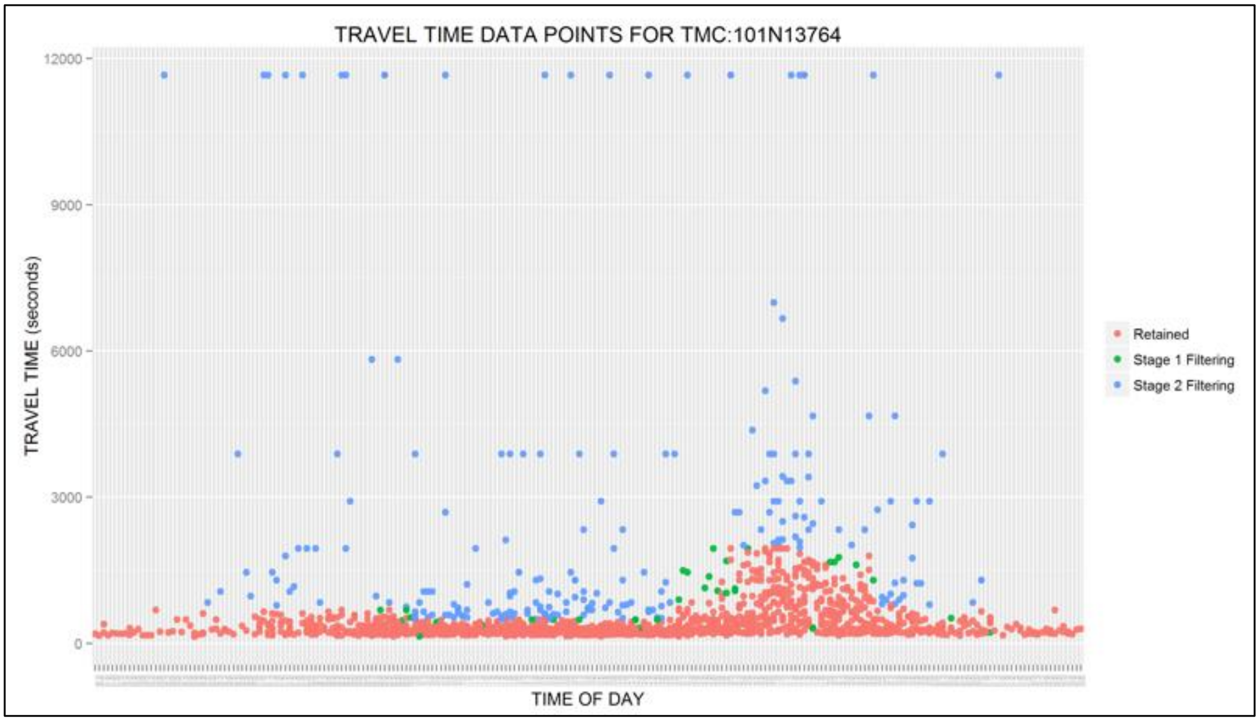


Figure 75 ARC Highway Network TMC Links

The initial model output comparisons to the NPMRDS revealed differences in free-flow speeds which resulted in speeds that did not match the observed data well. Several steps were taken to update the assumed model free-flow speeds:

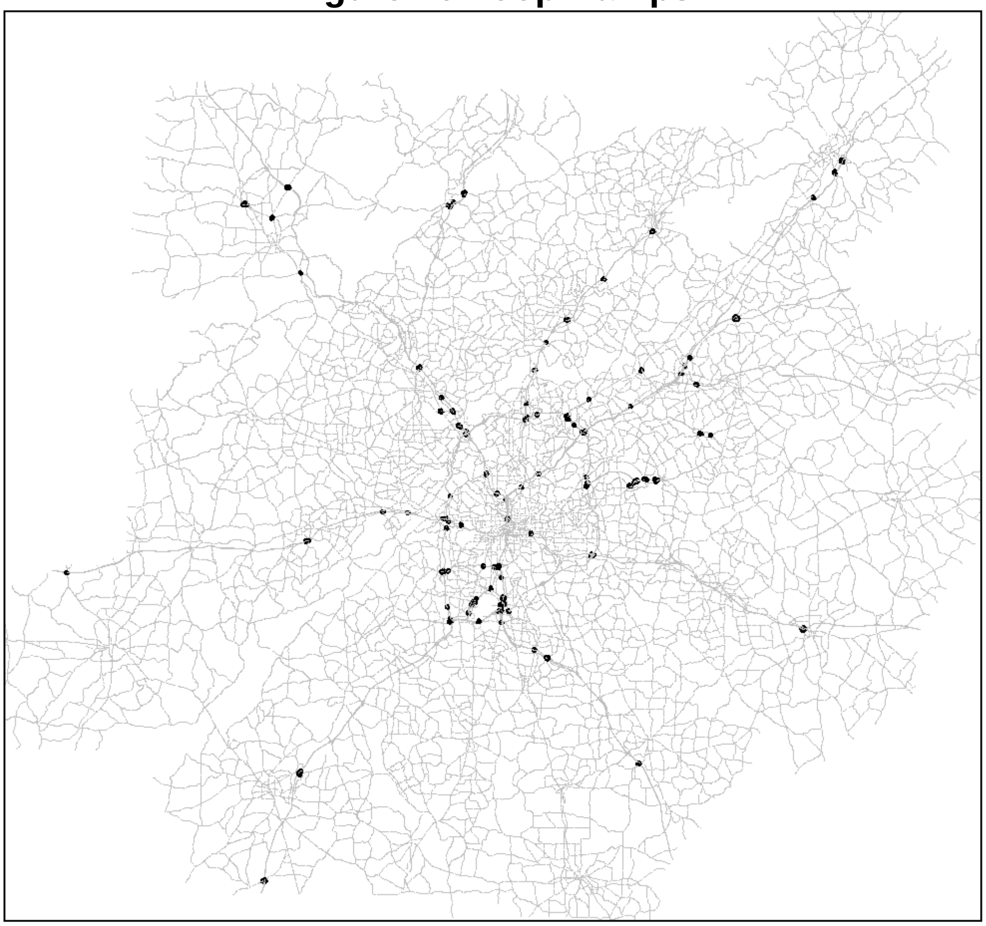
1. Computed the average NPMRDS early AM speeds by facility type and area type to develop new free-flow speed lookup table (shown in Table 63)
2. Identified loop ramps (network attribute) and set free-flow speed to 35 mph (Figure 76)
3. Principal arterial speeds varied by number of lanes for CBD area types
4. For links with observed speed data, free-flow speed is computed as the average of the observed early AM speed and the lookup table speed from step 1 above.

Table 63 Free-Flow Speed Lookup Table

NAME	FACTYPE	ATYPE1	ATYPE2	ATYPE3	ATYPE4	ATYPE5	ATYPE6	ATYPE7

centroid connector	0	7	11	11	11	11	14	14
interstate/freeway	1	62	63	63	63	64	65	66
expressway	2	43	46	49	52	55	58	61
parkway	3	43	46	49	52	55	58	61
freeway HOV (concurrent)	4	64	65	65	65	66	67	68
freeway HOV (barrier sep)	5	64	65	65	65	66	67	68
freeway truck only	6	62	63	63	63	64	65	66
system to system ramp	7	50	50	50	55	55	55	55
exit ramp	8	50	50	50	50	50	50	50
entrance ramp	9	50	50	50	50	50	50	50
principal arterial	10	23	26	31	35	41	48	53
minor arterial	11	21	26	29	33	38	43	48
arterial HOV	12	21	26	29	33	38	43	48
arterial truck only	13	21	26	29	33	38	43	48
collector	14	17	23	24	26	30	35	45

Figure 76 Loop Ramps



Hourly capacities were also updated during the assignment calibration and validation. The final level-of-service E capacities are provided in Table 64 below.

Table 64 LOS E Hourly Capacities

Name	Facility Type	ATYPE1 CBD	ATYPE2 Urban Commercial	ATYPE3 Urban Residential	ATYPE4 Suburban Commercial	ATYPE5 Suburban Residential	ATYPE6 Exurban	ATYPE7 Rural
centroid connector	0	10000	10000	10000	10000	10000	10000	10000
interstate/freeway	1	1900	1900	2000	2000	2050	2100	2100
expressway	2	1200	1200	1300	1350	1400	1450	1450
parkway	3	1150	1150	1250	1300	1350	1400	1400
freeway HOV (concurrent)	4	1900	1900	2000	2000	2050	2100	2100
freeway HOV (barrier sep)	5	1900	1900	2000	2000	2050	2100	2100
freeway truck only	6	1900	1900	2000	2000	2050	2100	2100
system to system ramp	7	1300	1400	1500	1600	1700	1700	1700
exit ramp	8	800	850	850	850	850	900	900
entrance ramp	9	900	900	950	950	1000	1050	1100
principal arterial	10	1000	1050	1100	1150	1200	1250	1300
minor arterial	11	900	900	950	1000	1000	1050	1100
arterial HOV	12	1000	1050	1100	1150	1200	1250	1300
arterial truck only	13	900	900	950	1000	1000	1050	1100
collector	14	750	800	800	850	850	900	900

Preliminary reviews of the observed and model estimated travel speeds also revealed the model had difficulty replicating interstate speeds near major system-to-system interchanges. This is due in large part to the fact that the user equilibrium assignment algorithm does not handle the operational issues that occur on these segments (weaving for example). As a means to improve the model's ability to replicate speeds in these locations, a network attribute (WEAVEFLAG=1) was coded to identify the interstate links adjacent to these major interchanges. Then, during the assignment process, these links are handled with a separate volume delay function. The identified links in the base year network are shown in Figure 77. The links were also subjected to a modification in total capacity based on the number of lanes using the following the equation when lanes > 4 and WEAVEFLAG =1:

Weave section link capacity = initial capacity * $0.98^{(LANES-1)}$

Example of the total link capacity for a 4 lane weave section and a 5 lane weave section:

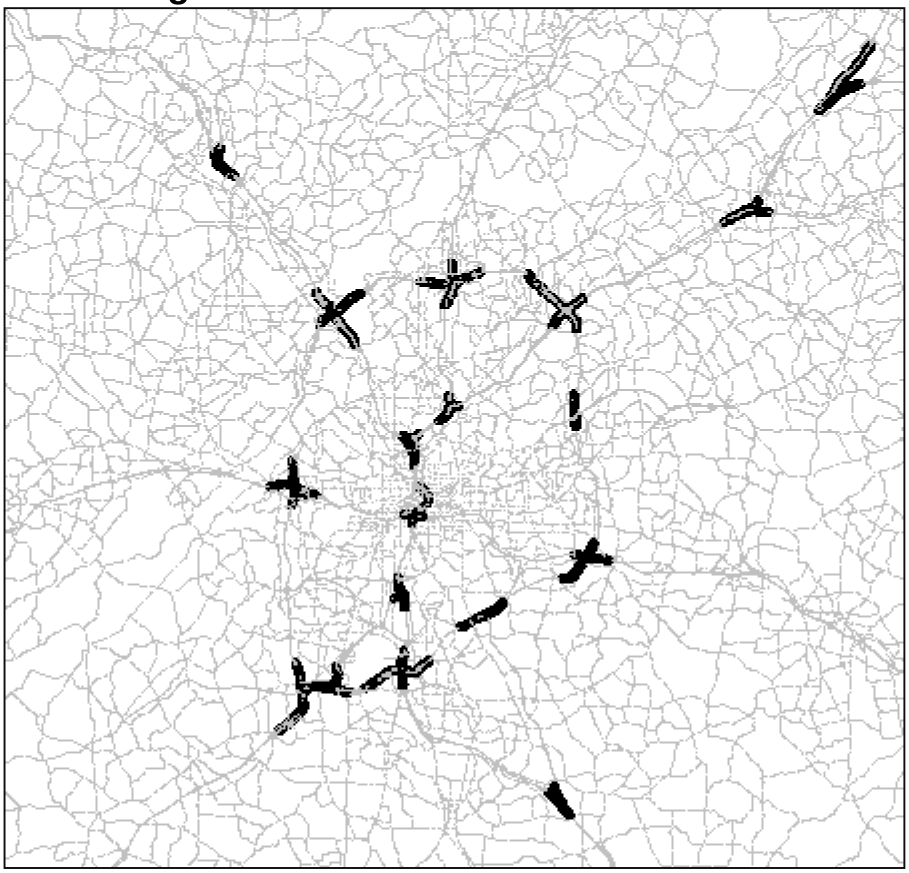
Hourly cap/lane	2000	2000
# lanes	4	5
Total Capacity	8000	10000
Capacity factor	1	0.98
Revised capacity	8000	9220

Period level capacity adjustments were made to reflect the peaking that occurs within the modeled time periods. These period level adjustments were based on the available GDOT hourly traffic count data and are as follows:

- EA = 1.66
- AM = 3.66

- MD = 4.70
- PM = 3.66
- EV = 3.91

Figure 77 Interstate Weave Sections



The new VDF curves are a modified version of the BPR function with coefficients that vary by facility type. Each facility type curve is segmented into two parts: one function when the V/C ratio is less than or equal to 1.0 and another for V/C ratios exceeding 1.0. Some of the functions include a separate term with an additional factor on the V/C ratio in order to lower the speeds slightly for lower V/C ratios. The formula for the VDF curves is as follows:

$Tc = T0 * (A * V/C + C * (V/C)^{B})$ if $V/C <= 1$

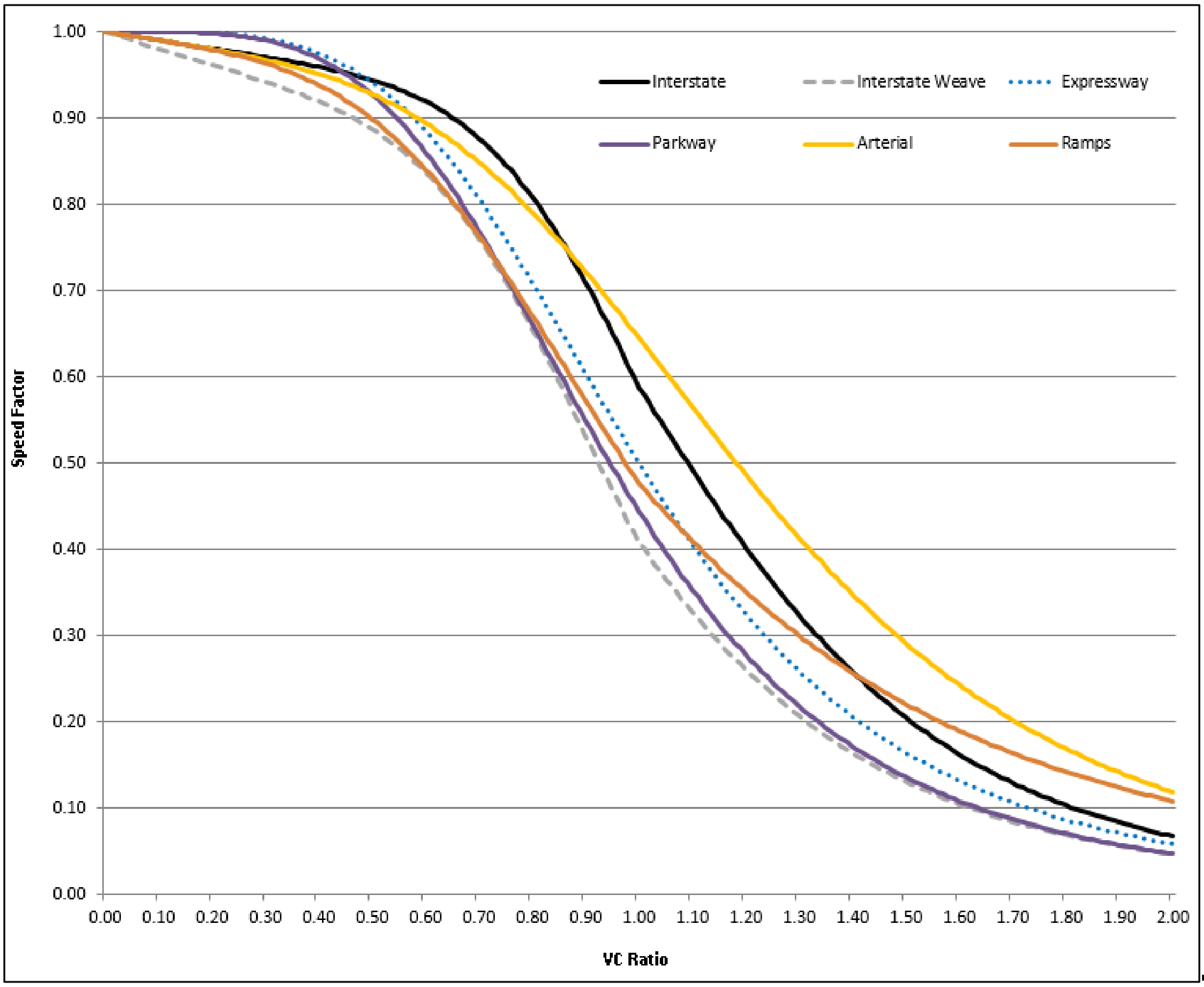
$Tc = T0 * (D * V/C + F * (V/C)^E)$ if $V/C > 1$
Where:
Tc = congested time
T0 = free-flow time
V/C = volume to capacity ratio
A, B, C, D, E, F = see VDF curve parameter Table 65

Graphical representations of the VDF curves by facility type are provided in Figure 78.

Table 65 VDF Curve Parameters

Facility Type	A	B	C	D	E	F
Freeway Basic	0.10	6.00	0.60	0.10	4.50	0.60
Freeway Weave	0.20	5.50	1.25	0.20	4.00	1.25
Expressway	0.00	4.00	1.00	0.00	3.00	1.00
Parkway	0.00	4.00	1.25	0.00	3.00	1.25
Ramp	0.10	4.00	1.00	0.10	3.00	1.00
Principal Arterial	0.10	4.00	0.45	0.10	4.00	0.45
Minor Arterial	0.10	4.00	0.45	0.10	4.00	0.45
Collector	0.10	4.00	0.45	0.10	4.00	0.45

Figure 78 VDF Curves: Freeway, Expressway, & Parkway



The highway assignments were calibrated / validated to match observed vehicle miles traveled (VMT), traffic counts (daily, by time period, screen-lines, etc.) and travel speeds. The initial observed VMT and traffic counts are based on average daily volumes which include weekends. Since the model represents an average weekday, the observed data was converted to average weekday as well. Daily VMT was summarized by functional classification and compared against GDOT HPMS data in Table 66. When viewing for all road types, the model underestimated VMT by approximately 17%. However, the model does not include the majority of local roads. To assess the model's representation of total VMT, a more appropriate comparison is for collector and above. The observed VMT for collectors and above is approximately 124 million as compared to 118 million estimated by the model (approximately 6% low).

Table 66 Estimated vs. Observed Year 2010 VMT (1000s)

FUNCTIONAL CLASSIFICATION	GDOT 2010 (AWDT)	MODEL 2010	PERCENT DIFFERENCE
Interstate	55,430	52,827	-4.70%
Principal Arterial	20,967	20,588	-1.81%
Minor Arterial	34,377	30,260	-11.98%
Collector	14,099	14,141	0.29%
Local	43,580	21,434	-50.82%
Total	168,453	139,249	-17.34%
Collector and above	124,873	117,815	-5.65%

The model highway network includes approximately 5400 links (one-directional counts) with daily traffic count data from GDOT. The estimated volumes were compared against the observed counts in several ways to ensure the validation results were acceptable by volume group, facility type, and area type at the regional level. The analysis included percent root mean square errors and volume to count ratios. The results are provided in Tables 67 through Table 69. The overall % RMSE of 33% and a volume to count ratio of 0.98 indicates the model is accurately assigning vehicle trips to the network. As expected, the model's accuracy improves as the observed volumes increase and on higher roadway classifications. The model is also generally more accurate in the more urban areas of the region which also tracks with the improved accuracy on higher volume facilities. However, the summary by area type demonstrates the model is replicating counts reasonably well across all area types in the region.

Table 67 Highway Validation Statistics by Volume Group

Volume Group	Observations	RMSE	%RMSE	Total Volume	Total Counts	Vol / Cnt Ratio
< 2500	926	1,391	99.0%	1,744,808	1,297,157	1.35
2500 - 4999	1,148	1,840	50.0%	4,507,075	4,249,983	1.06
5000 - 9999	1,439	2,696	38.0%	9,651,756	10,117,288	0.95
10000 - 24999	1,238	4,442	30.0%	16,971,619	18,486,962	0.92
25000 - 49999	182	6,501	18.0%	6,115,838	6,429,569	0.95
50000 - 74999	111	12,216	19.0%	6,282,256	7,082,456	0.89
75000 - 99999	108	13,811	16.0%	8,132,042	9,191,869	0.88
>= 100000	58	15,453	13.0%	6,380,446	7,094,626	0.90
Total	***5,210***	***4,365***	***36.0%***	***59,785,840***	***63,949,910***	***0.93***

Table 68 Highway Validation Statistics by Facility Type

Facility Type	Observations	RMSE	%RMSE	Total Volume	Total Counts	Vol / Cnt Ratio

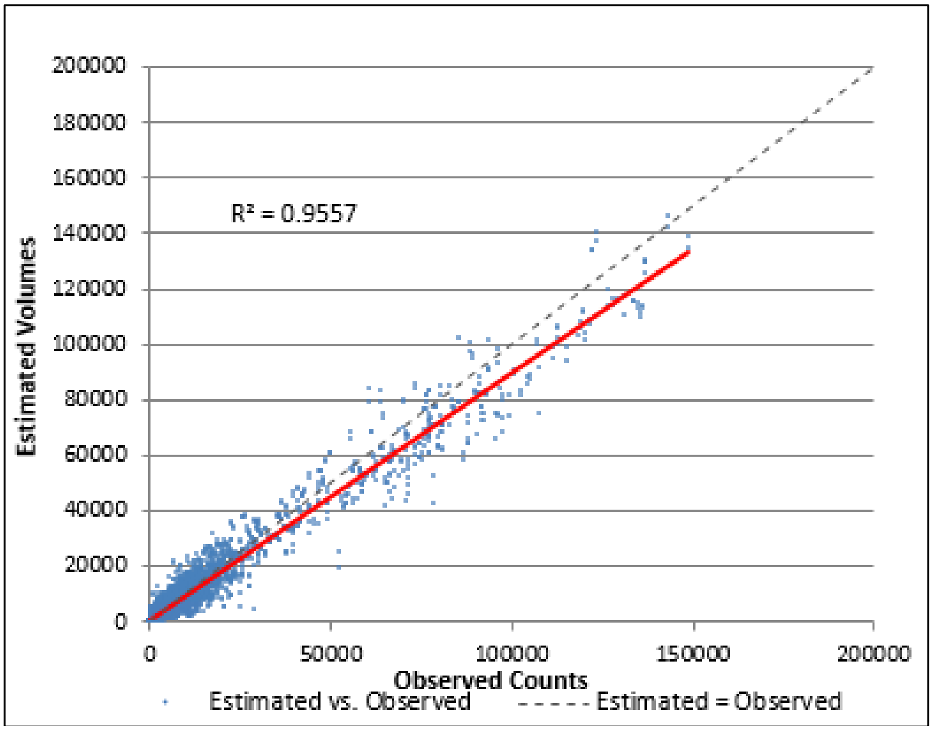
Interstate / Freeway	572	10,278	19.0%	27,920,141	30,990,824	0.90
Principal Arterial	1,094	4,385	31.0%	14,885,039	15,710,910	0.95
Minor Arterial	2,509	2,258	44.0%	13,219,278	12,907,131	1.02
Collector / Local	1,031	2,199	52.0%	3,757,848	4,329,619	0.87
Total	***5,210***	***4,365***	***36.0%***	***59,785,840***	***63,949,910***	***0.93***

Table 69 Highway Validation Statistics by Area Type

Area Type	Observations	RMSE	% RMSE	Total Volume	Total Counts	Vol / Cnt Ratio
Area Type 1 - CBD	130	6,186	27.0%	2,692,716	2,992,960	0.90
Area Type 2 – Urban Commercial	251	6,555	29.0%	4,826,654	5,658,068	0.85
Area Type 3 – Urban Residential	513	5,734	29.0%	8,952,032	10,023,945	0.89
Area Type 4 – Suburban Commercial	880	4,612	30.0%	12,636,634	13,668,184	0.92
Area Type 5 – Suburban Residential	2,115	4,470	37.0%	23,872,059	25,294,310	0.94
Area Type 6 - Exurban	657	2,155	38.0%	3,988,976	3,756,585	1.06
Area Type 7 - Rural	664	1,981	51.0%	2,816,769	2,555,858	1.10
Total	***5,210***	***4,365***	***36.0%***	***59,785,840***	***63,949,910***	***0.93***

The daily estimated volumes and observed counts were also summarized graphically using a scatterplot as provided in Figure 79. The scatterplot further illustrates the model's accuracy in replicating link level counts. The fitted line (bold red line) closely resembles the best fit 45 degree line (black dotted line) and the correlation coefficient is 0.958. While the % RMSE and correlation coefficient demonstrate the model is performing well at the regional level, the scatterplot also illustrates links where estimated volumes are much different than observed counts which are typical of all regional models. When performing detailed analysis of projects, it is important to be aware of the base year error and how that potentially affects the forecasts.

Figure 79 Daily Estimated Volumes vs. Observed Counts (0.956 Correlation Coefficient)



The highway networks also include hourly volumes from GDOT's Automated Traffic Recorders (ATRs). In the ARC model region, there were 85 ATR locations coded in the network. The data was summarized by time period in Table 70 and provided in scatterplots for each period in Figures 80 through 84. The percentage shares by time period were computed for the estimated and observed and show the model is matching the counts reasonably well. The scatterplots also illustrate the model accurately replicates the time period traffic with correlation coefficients all above 0.87. The correlation coefficients for the AM peak, midday, and PM peak periods were all above 0.94. It is important to note that the comparisons include truck trips and the truck time of day models were not revised in the model update.

Table 70 Time Period Highway Validation

Time Period	Total Volume	Volume % Share	Total Counts	Count % Share	Vol / Cnt Ratio
Early AM	294,279	4.6%	287,321	4.1%	1.02
AM Peak	1,668,398	25.9%	1,651,936	23.3%	1.01
Midday	1,656,669	25.7%	1,924,070	27.1%	0.86
PM Peak	1,800,366	28.0%	1,890,943	26.7%	0.95
Evening/Night	1,018,088	15.8%	1,334,122	18.8%	0.76
Total	***6,437,800***	***100.0%***	***7,088,392***	***100.0%***	***0.91***

Figure 80 Early AM Estimated Volumes vs. Observed Counts (0.875 Correlation Coefficient)

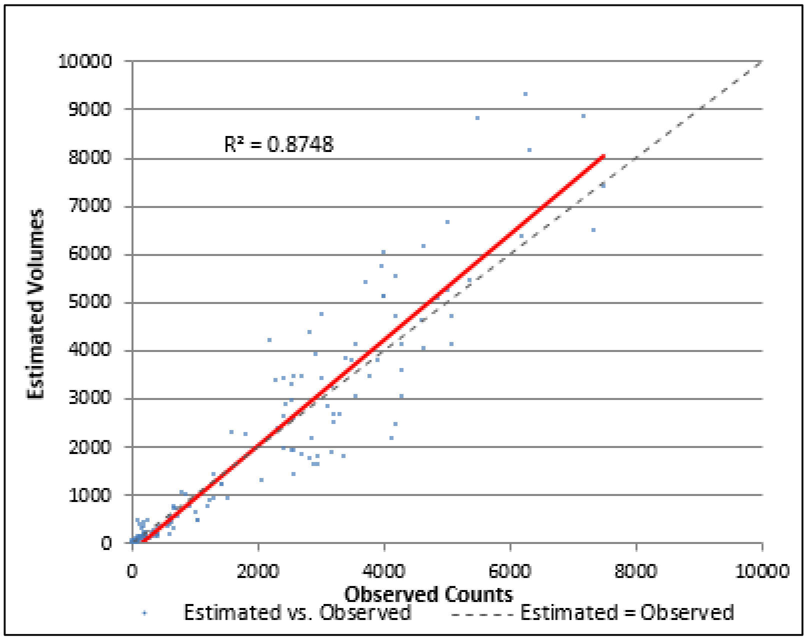


Figure 81 AM Peak Estimated Volumes vs. Observed Counts (0.950 Correlation Coefficient)

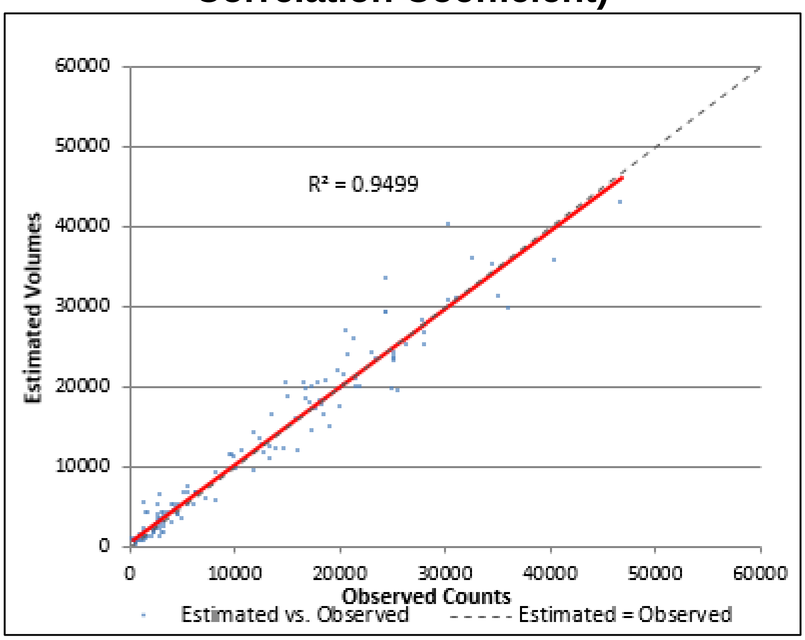


Figure 82 Midday Estimated Volumes vs. Observed Counts (0.964 Correlation Coefficient)

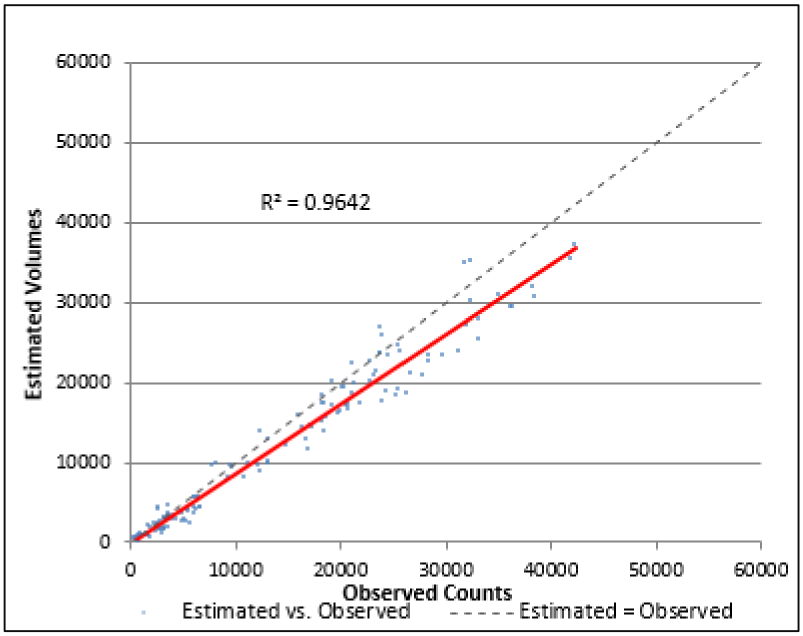


Figure 83 PM Peak Estimated Volumes vs. Observed Counts (0.973 Correlation Coefficient)

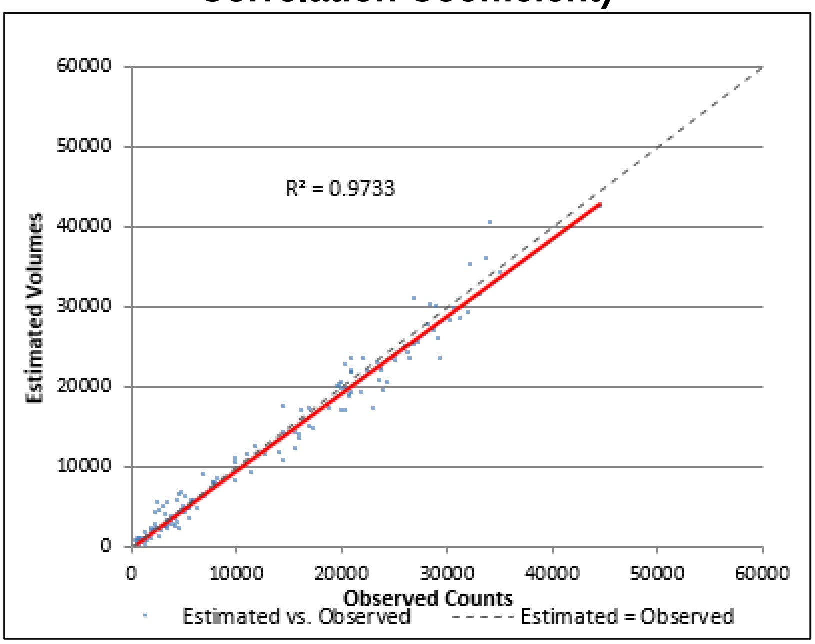
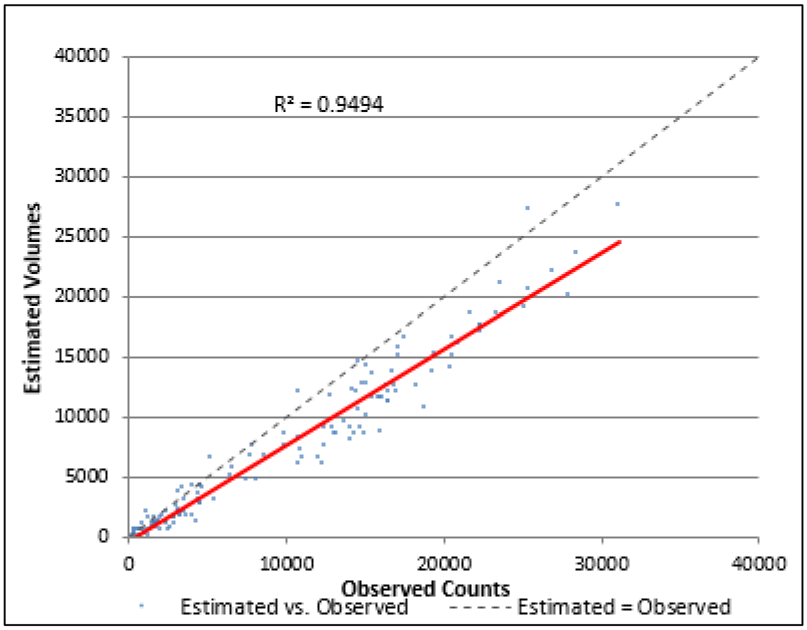


Figure 84 Evening / Night Estimated Volumes vs. Observed Counts (0.949 Correlation Coefficient)



The final validation measure for comparing estimated volumes to observed counts was through the use of screen-lines. A screen-line analysis typically includes the following types:

Cordon – A cordon forms an enclosed boundary, which is intended to determine the traffic flows entering and exiting the enclosed area. Cordons are often used to determine if traffic flows into and out of a Central Business District are being modeled accurately. An example of a cordon line used in the Atlanta model validation is the "Outside of I-285" screen-line.

Cutline – A cutline captures the flows through a major corridor. The "I-85 Corridor north of Norcross" is an example of a cutline. This cutline compares modeled volumes to observed counts on I-85 and other parallel facilities such as Peachtree Industrial Boulevard, Buford Highway, and Lawrenceville Highway.

Screen-line – a "true" screen-line captures all flows from one side of the region to the other. The "Chattahoochee River" screen-line does this by comparing all bridge crossing traffic counts with the modeled volumes.

The results from the 20 screen-lines in the ARC region are provided in Table 71. The analysis included a maximum desirable deviation standard[12]. The standards require higher levels of accuracy for higher volume corridors and lower levels of accuracy for lower volume corridors. Of the 20 screen-lines analyzed, only 4 were outside the desired standard (Outside I-285, Cen Atlanta N of I-20, I-85 Corridor N of Norcross, and I-985 S of Gainesville). A map of the screen-line locations is provided in Figure 85.

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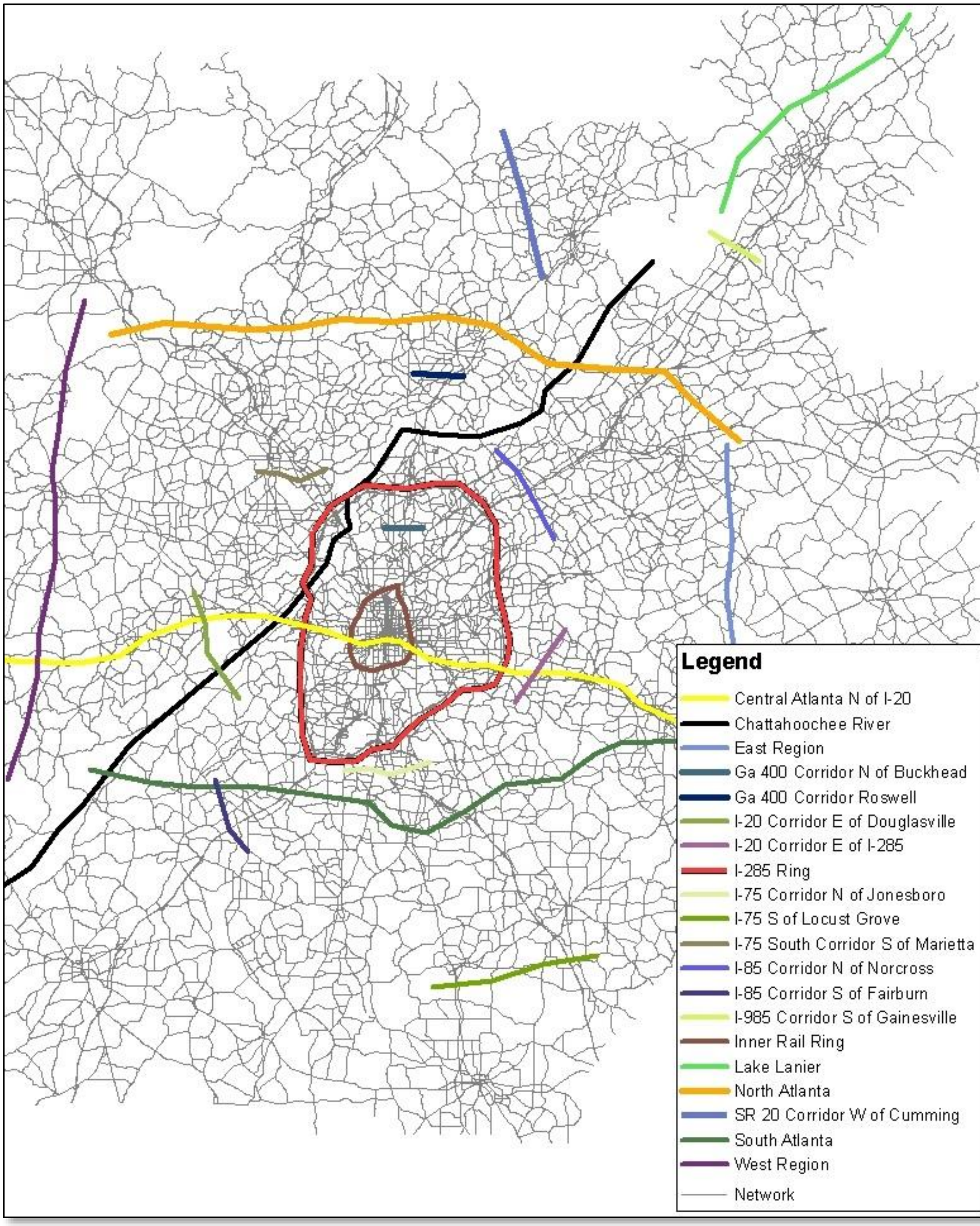
[12] Maximum Desirable Deviation standards for screen-lines and individual count locations are available in NCHRP 255 HIGHWAY TRAFFIC DATA FOR URBANIZED AREA PROJECT PLANNING AND DESIGN, Transportation Research Board, National Research Council.

Table 71 Screen-Line Summary

Screen-line	Volume	Count	Volume / Count Ratio	Percent Deviation	Max Desirable Deviation (+/-)
Chattahoochee River	1,323,394	1,244,714	1.06	6%	8%
Inner Rail Ring	1,298,462	1,338,262	0.97	-3%	8%
Outside I-285	2,287,909	2,552,558	0.90	-10%	6%
S Atlanta East/West	570,127	631,588	0.90	-10%	11%
N Atlanta East/West	771,751	762,426	1.01	1%	10%
Cen Atlanta N of I-20	917,874	1,017,532	0.90	-10%	9%
I-75 Corridor S of Marietta	391,723	412,284	0.95	-5%	13%
I-20 Corridor E of Douglasville	158,172	138,926	1.14	14%	20%
I-75 Corridor N of Jonesboro	283,777	302,338	0.94	-6%	15%
I-85 Corridor N of Norcross	384,292	472,870	0.81	-19%	12%
GA 400 Corridor N of Buckhead	144,885	170,944	0.85	-15%	18%
I-20 Corridor E of I-285	208,085	244,176	0.85	-15%	16%
GA 400 Corridor in Roswell	155,769	159,368	0.98	-2%	19%
SR 20 Corridor W of Cumming	33,458	30,106	1.11	11%	24%
I-85 Corridor S of Fairburn	121,055	109,430	1.11	11%	22%
Lake Lanier	88,191	80,622	1.09	9%	15%
I-985 S of Gainesville	115,719	92,455	1.25	25%	23%
West Region North/South	170,642	151,688	1.12	12%	19%
East Region North/South	113,964	131,068	0.87	-13%	20%
I-75 South of Locust Grove	122,750	139,586	0.88	-12%	20%
Total	***9,661,999***	***10,182,941***	***0.95***	***-5%***	***4%***

Figure 85 Screen-line Locations


Legend
Central Atlanta N of I-20
Chattahoochee River
East Region
Ga 400 Corridor N of Buckhead
Ga 400 Corridor Roswell
I-20 Corridor E of Douglasville
I-20 Corridor E of I-285
I-285 Ring
I-75 Corridor N of Jonesboro
I-75 S of Locust Grove
I-75 South Corridor S of Marietta
I-85 Corridor N of Norcross
I-85 Corridor S of Fairburn
I-985 Corridor S of Gainesville
Inner Rail Ring
Lake Lanier
North Atlanta
SR 20 Corridor W of Cumming
South Atlanta
West Region
Network

The model estimated speeds were validated against the observed NPMRDS speeds previously discussed. Generally, the model matches observed speeds well. The observed versus estimated speeds are provided by time period in Figure 86 through Figure 90.

Figure 86 EA Period Speeds

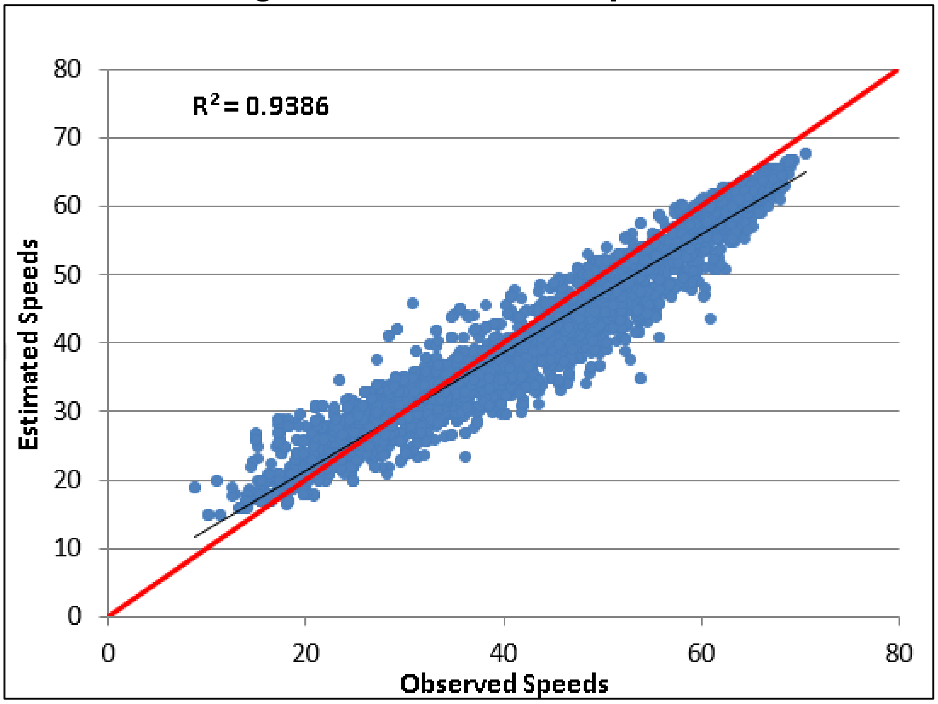


Figure 87 AM Period Speeds

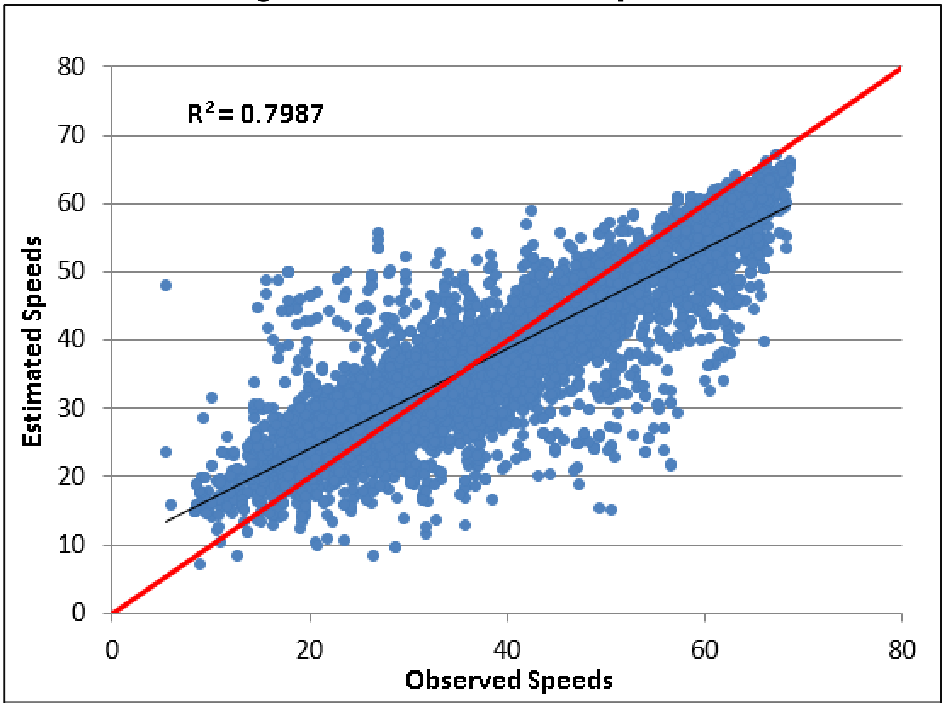


Figure 88 MD Period Speeds

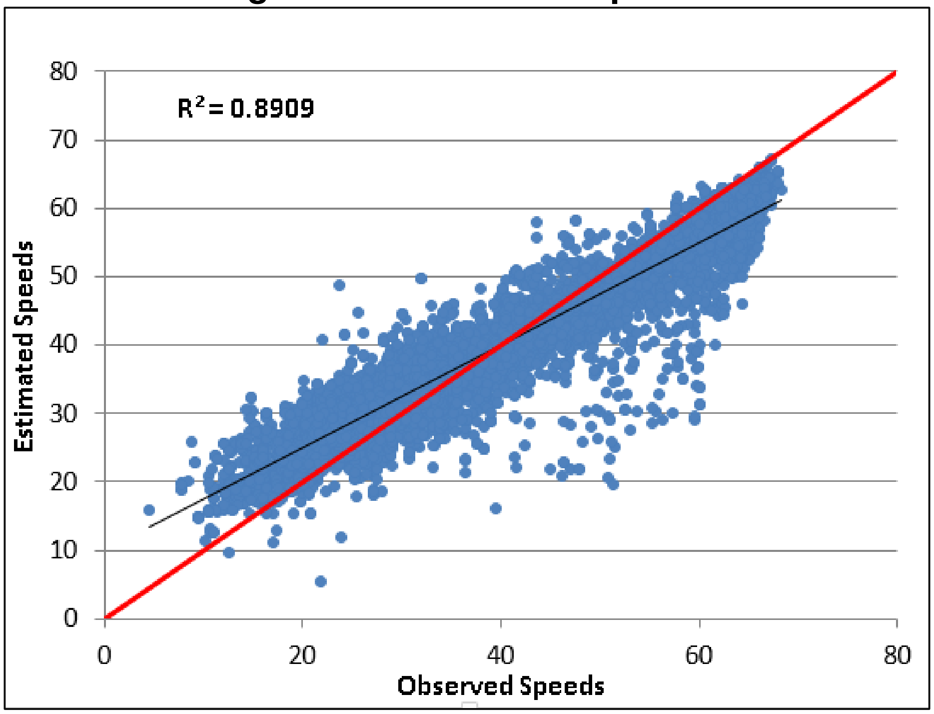


Figure 89 PM Period Speeds

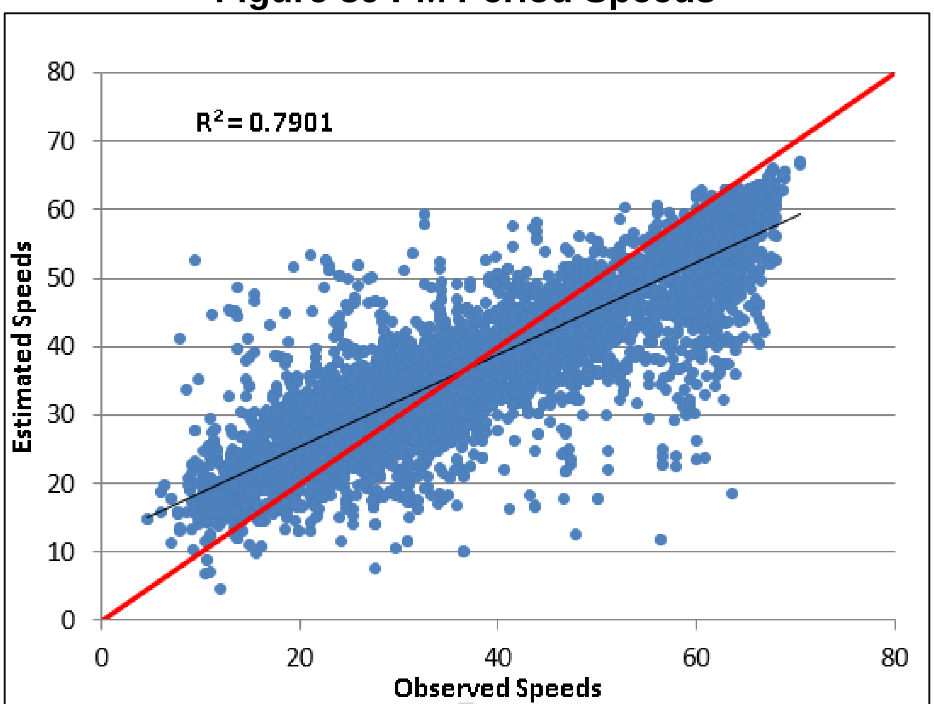
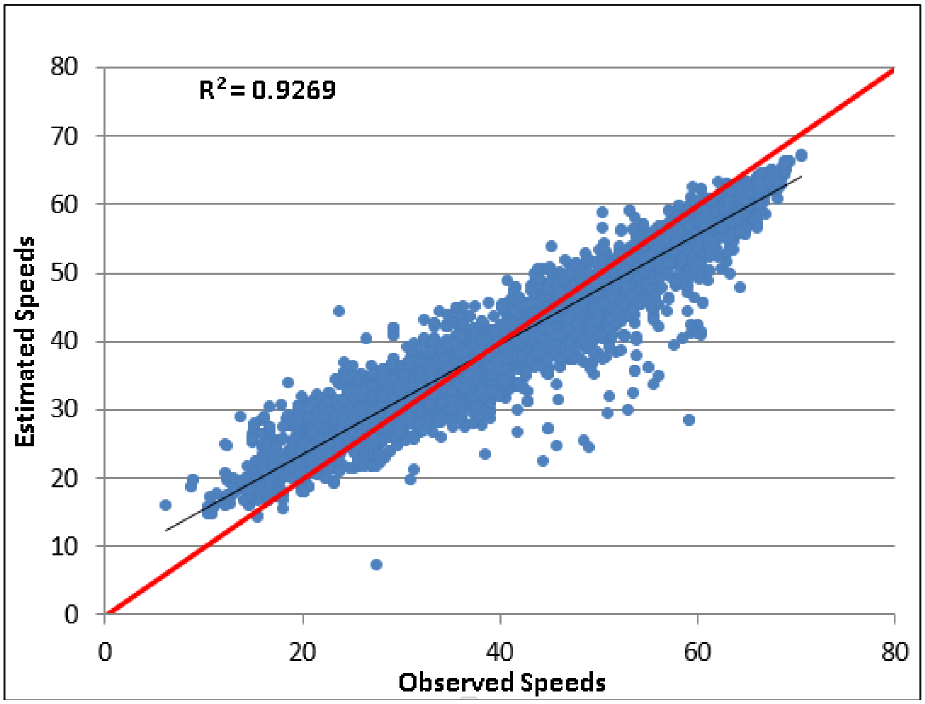


Figure 90 EV Period Speeds



Transit Assignment Results

The model uses a best path formulation for assigning transit trips to the network with the Cube Voyager Public Transport module. The transit assignments include 32 individual assignments specific to the five time periods plus the air passenger model, mode of access/egress, and line-haul modes. The summation of these assignments were tabulated and compared against observed boardings by operator, individual line, and MARTA rail station entries.

The boardings by operator (MARTA rail represents station entries) are provided in Table 72. As shown, the model is currently within 1% of matching MARTA rail ridership. The model tended to underestimate MARTA bus ridership and overestimate the suburban transit providers, primarily Cobb and Gwinnett.

The observed versus estimated bus boardings by line is shown graphically in Figure 91. Individual routes vary, but in general, the model is matching the observed data reasonably well and the correlation coefficient is 0.767.

MARTA rail station entries are provided in Table 73 and show the model is currently within 1% of the observed data. There is variation at individual stations, but the model matches the overall line volumes well. The model did overestimate the trunk line by 7,500 or 19%. However, the model underestimated entries at Five Points by almost 3,000. Five Points is reported separately as this is the major transfer station for MARTA's lines but is located in very close proximity to the other stations on the trunk line. The station entries are presented graphically in the scatterplot in Figure 92. The correlation coefficient is 0.923 and the fitted line (red line) matches well.

Table 72 Boardings by Operator

Operator	Observed	Modeled	Difference	% Difference
MARTA Rail	194,610	197,484	2,874	1%
MARTA Bus	208,393	154,506	-53,887	-26%
Clayton	8,303	8,347	44	1%
Cobb	14,909	18,053	3,144	21%
GRTA	8,381	5,989	-2,392	-29%
Gwinnett	6,905	9,639	2,734	40%
Cherokee	56	317	261	466%
Hall	303	982	679	224%
Total	441,860	395,317	-47,483	-11%

Figure 91 Estimated vs. Observed Bus Boardings (0.767 Correlation Coefficient)

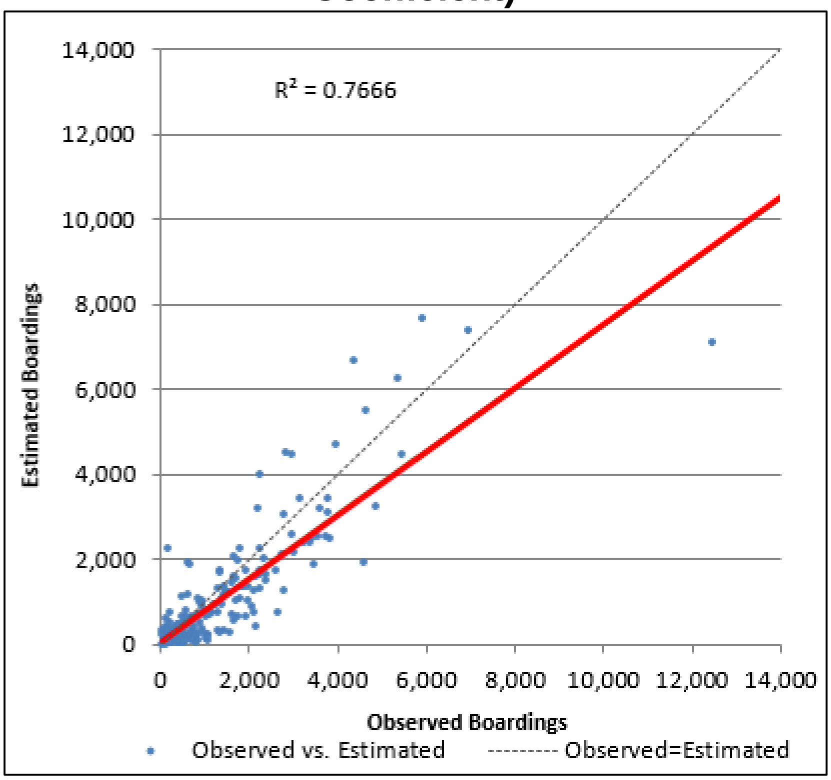
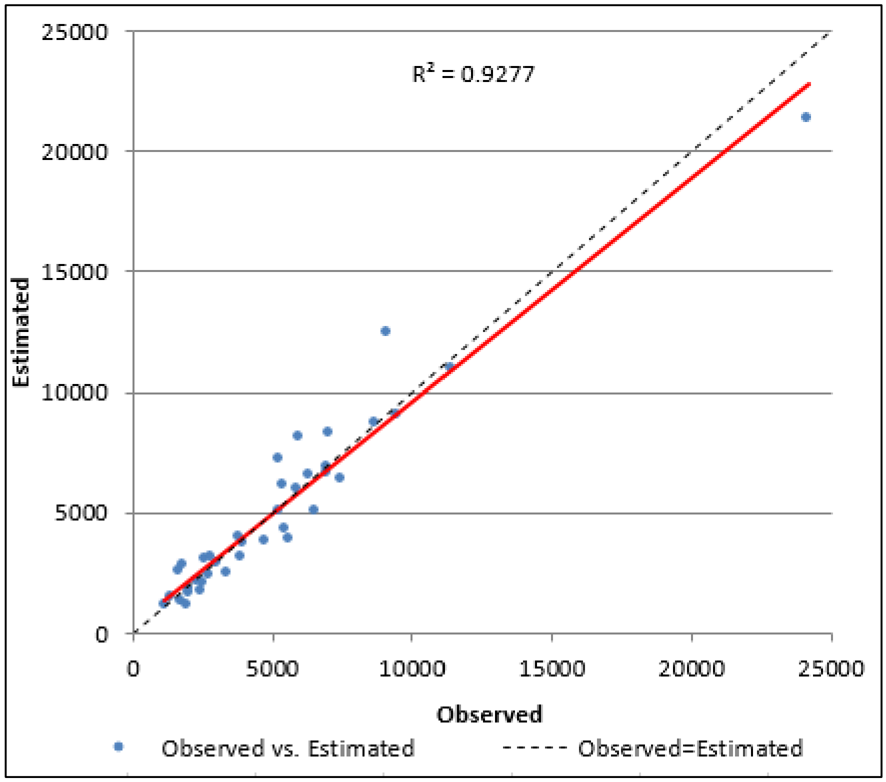


Table 73 MARTA Rail Station Entries

LINE	STATION	Observed	Model	Diff	% Diff
FIVE POINTS	Total	24,200	21,315	-2,885	-12%

EAST LINE	Georgia State	5,210	7,196	1,986	38%
	King Memorial	2,030	1,687	-343	-17%
	Inman Park	3,380	2,492	-888	-26%
	Candler Park	1,390	1,532	142	10%
	East Lake	1,150	1,160	10	1%
	Decatur	4,730	3,833	-897	-19%
	Avondale	5,590	3,874	-1,716	-31%
	Kensington	6,950	6,895	-55	-1%
	Indian Creek	5,860	6,007	147	3%
	Total	**36,290**	**34,676**	**-1,614**	**-4%**
WEST LINE	Dome/GWCC	2,500	2,109	-391	-16%
	Vine City	1,690	1,299	-391	-23%
	Ashby	2,310	2,149	-161	-7%
	West Lake	2,410	1,723	-687	-29%
	Holmes	6,960	6,646	-314	-5%
	Bankhead	1,940	1,148	-792	-41%
	Total	**17,810**	**15,075**	**-2,735**	**-15%**
NORTH EAST LINE	Lenox	3,940	3,706	-234	-6%
	Brookhaven	2,760	2,387	-373	-14%
	Chamblee	3,850	3,171	-679	-18%
	Doraville	5,400	6,181	781	14%
	Total	**15,950**	**15,445**	**-505**	**-3%**
NORTH LINE	Buckhead	2,620	3,033	413	16%
	Medical Center	1,830	2,839	1,009	55%
	Dunwoody	3,780	4,004	224	6%
	Sandy Springs	2,990	2,885	-105	-4%
	North Springs	6,530	5,050	-1,480	-23%
	Total	**17,750**	**17,812**	**62**	**0%**
TRUNK LINE	Peachtree Center	8,660	8,745	85	1%
	Civic Center	2,800	3,174	374	13%
	North Avenue	6,320	6,535	215	3%
	Midtown	5,960	8,176	2,216	37%
	Arts Center	7,040	8,264	1,224	17%
	Lindbergh	9,100	12,465	3,365	37%
	Total	**39,880**	**47,358**	**7,478**	**19%**
SOUTH LINE	Garnett	1,630	2,612	982	60%
	West End	7,470	6,429	-1,041	-14%
	Oakland City	5,450	4,342	-1,108	-20%
	Lakewood	2,040	1,848	-192	-9%
	East Point	5,250	5,085	-165	-3%
	College Park	9,500	9,073	-427	-4%
	Airport	11,390	10,969	-421	-4%
	Total	**42,730**	**40,358**	**-2,372**	**-6%**
MARTA Rail Total		**194,610**	**192,038**	**-2,572**	**-1%**

Figure 92 Estimated vs. Observed MARTA Rail Entries (0.928 Correlation Coefficient)



R² = 0.9277
Estimated
Observed
0
5000
10000
15000
20000
25000
Observed vs. Estimated
Observed=Estimated