

# **APPENDIX A. GREATER BOSTON TRANSPORT MODEL SPECIFICATION AND ESTIMATION**

This document includes a brief summary of the model specification and estimation results for the four-step transport model developed for Boston Metropolitan Area. The four-step model includes vehicle ownership model, trip generation, trip distribution, mode choice and traffic assignments. We mainly use 2010-11 Massachusetts Travel Survey (2010MTS) and 1991 Boston Travel Survey (1991BTS) for model estimation. Some model parameters come from CTPP (Census Journey-to-Work) data for 2010 and 1990.

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## **1 Vehicle Ownership Model**

The vehicle ownership model has a logit model structure. The choice set consists of 0, 1, 2, 3+ vehicles as alternatives. Predictors include household characteristics and built environment variables. Table 1–1 shows the different model specifications. The variable representing the household’s race (categorical variable for race composition in the household) is only available for 2010. We estimated models of different specifications for 1991 and 2010, including a specification directly implementable in a four-step model in Cube (MCube). Note that by sequentially adding sets of variables, the complexity increases. Table 1–2 and Table 1–3 show the coefficients estimates for 1991 and 2010. Table 1–4 lists the model estimates for the Cube model specification (MCube) separately, as it is a simplified version. Table 1–5 and Table 1–6 summarize the model fit for all specifications. More details can be found in Han (2015)’s Master Thesis.

**Table 1–1 Vehicle ownership model specifications**

Explanatory variables		M1 <sup>b</sup>	M2	M3	M4	M5	M6	M7	M Cube
<i>Socio-demographics</i>	Household size	✓	✓	✓	✓	✓	✓	✓	✓
	Number of workers	✓	✓	✓	✓	✓	✓	✓	✓
	Income level (6 levels)	✓	✓	✓	✓	✓	✓	✓	
	Income level (4-levels)								✓
	Number of children		✓	✓	✓	✓	✓	✓	
	Number of seniors		✓	✓	✓	✓	✓	✓	
	Race <sup>a</sup>							✓	
<i>Transit access</i>	Within 800m to subway	✓	✓	✓	✓	✓	✓	✓	✓
	Within 800 m to commuter rail	✓	✓	✓	✓	✓	✓	✓	✓
	Accessibility ratio: transit/auto			✓	✓	✓	✓	✓	✓
<i>Built environment</i>	Distance to CBD (km)				✓	✓	✓	✓	✓
	Distance to CBD squared				✓	✓	✓	✓	✓
	LN: Population density					✓	✓	✓	✓
	LN: Jobs/workers					✓	✓	✓	✓
	Road intersections per km						✓	✓	
	% of 4-way intersections						✓	✓	

a. Race in MTS is the racial category of the household. It consists of 7 categories: White Alone; Black or African American Alone; American Indian or Alaskan Native Alone; Asian Alone; Native Hawaiian, Pacific Islander Alone; Some Other Race Alone; and Two or More Races.

b.

Model 1: basic demographic characteristics and transit access.

Model 2: add number of children, and senior people

Model 3: add job accessibility measure (transit VS auto)

Model 4: add distance to CBD and squared distance to CBD

Model 5: add population density and job-worker ratio.

Model 6: add road intersection density and percentage of 4-way intersections

Model 7: add race (only for 2010)

Model Cube: a simplified model version implemented in a four-step model in Cube.

**Table 1–2 Vehicle ownership model estimation results for 1991 (BTS)**

	M1		M2		M3		M4		M5		M6							
	B	SE	B	SE	B	SE	B	SE	B	SE	B	SE						
1:(intercept)	0.936	0.163	***	0.639	0.208	**	0.722	0.210	***	-0.657	0.373	-0.117	0.514	-0.337	0.596			
2:(intercept)	-2.210	0.268	***	-2.411	0.301	***	-2.185	0.304	***	-4.576	0.471	***	-3.356	0.608	***	-3.606	0.719	***
3:(intercept)	-2.836	0.415	***	-3.429	0.449	***	-3.160	0.452	***	-5.992	0.626	***	-4.687	0.758	***	-4.661	0.926	***
1:Size: 2-pers	0.594	0.180	***	0.400	0.198	*	0.367	0.201		0.414	0.203	*	0.406	0.204	*	0.409	0.204	*
2:Size: 2-pers	2.638	0.234	***	2.536	0.249	***	2.523	0.253	***	2.599	0.257	***	2.571	0.258	***	2.572	0.258	***
3:Size: 2-pers	1.329	0.353	***	1.129	0.369	**	1.121	0.372	**	1.204	0.375	***	1.177	0.376	**	1.183	0.376	**
1:Size: 3-pers	1.296	0.328	***	1.426	0.380	***	1.349	0.382	***	1.363	0.386	***	1.340	0.391	***	1.358	0.392	***
2:Size: 3-pers	3.889	0.361	***	4.301	0.410	***	4.254	0.415	***	4.295	0.419	***	4.255	0.424	***	4.275	0.425	***
3:Size: 3-pers	3.694	0.437	***	4.205	0.484	***	4.165	0.488	***	4.205	0.492	***	4.166	0.497	***	4.188	0.497	***
1:Size: 4-pers	0.726	0.379		0.945	0.468	*	0.824	0.468		0.832	0.476		0.822	0.479		0.847	0.480	
2:Size: 4-pers	3.820	0.401	***	4.549	0.490	***	4.445	0.494	***	4.490	0.502	***	4.490	0.506	***	4.519	0.507	***
3:Size: 4-pers	3.346	0.475	***	4.457	0.559	***	4.357	0.562	***	4.405	0.570	***	4.413	0.573	***	4.441	0.574	***
1:Size: 5-pers+	1.652	0.583	**	1.866	0.665	**	1.739	0.695	*	1.772	0.696	*	1.707	0.691	*	1.729	0.691	*
2:Size: 5-pers+	4.308	0.600	***	5.168	0.684	***	5.037	0.714	***	5.126	0.717	***	5.047	0.712	***	5.075	0.713	***
3: Size: 5-pers+	3.864	0.653	***	5.308	0.738	***	5.196	0.767	***	5.287	0.769	***	5.210	0.766	***	5.239	0.766	***
1:Workers1	0.528	0.181	**	0.786	0.203	***	0.795	0.204	***	0.830	0.208	***	0.825	0.210	***	0.831	0.211	***
2:Workers1	0.862	0.230	***	1.057	0.254	***	1.051	0.257	***	1.112	0.263	***	1.118	0.265	***	1.127	0.266	***
3:Workers1	0.302	0.343		0.764	0.368	*	0.768	0.369	*	0.832	0.374	*	0.846	0.375	*	0.853	0.376	*
1:Workers2	-0.292	0.251		0.086	0.275		0.150	0.277		0.165	0.280		0.176	0.283		0.181	0.284	
2:Workers2	0.470	0.280		0.747	0.311	*	0.817	0.316	**	0.868	0.321	**	0.900	0.325	**	0.912	0.325	**
3:Workers2	0.471	0.376		1.129	0.413	**	1.206	0.417	**	1.264	0.421	**	1.305	0.424	**	1.314	0.424	**
1:Workers3+	-0.544	0.558		-0.419	0.559		-0.426	0.573		-0.362	0.571		-0.386	0.569		-0.387	0.569	
2:Workers3+	-0.327	0.572		-0.376	0.574		-0.437	0.591		-0.328	0.591		-0.343	0.589		-0.339	0.589	
3:Workers3+	1.729	0.617	**	1.908	0.630	**	1.848	0.645	**	1.972	0.647	**	1.968	0.645	**	1.967	0.645	**
1:INC35-50K	0.886	0.169	***	0.888	0.173	***	0.923	0.175	***	0.934	0.177	***	0.921	0.178	***	0.915	0.179	***

2:INC35-50K	1.682	0.228	***	1.670	0.230	***	1.741	0.234	***	1.784	0.238	***	1.739	0.240	***	1.733	0.240	***
3:INC35-50K	1.449	0.346	***	1.461	0.351	***	1.514	0.354	***	1.556	0.356	***	1.509	0.357	***	1.506	0.357	***
1:INC50-75K	1.672	0.232	***	1.700	0.235	***	1.747	0.239	***	1.765	0.240	***	1.754	0.242	***	1.735	0.243	***
2:INC50-75K	3.014	0.278	***	3.006	0.280	***	3.073	0.287	***	3.143	0.290	***	3.092	0.292	***	3.070	0.293	***
3:INC50-75K	2.842	0.376	***	2.846	0.382	***	2.889	0.387	***	2.960	0.389	***	2.904	0.390	***	2.886	0.390	***
1:INC75-100K	2.222	0.339	***	2.295	0.342	***	2.427	0.348	***	2.454	0.347	***	2.423	0.348	***	2.380	0.351	***
2:INC75-100K	4.011	0.373	***	4.051	0.376	***	4.274	0.386	***	4.343	0.387	***	4.247	0.388	***	4.195	0.391	***
3:INC75-100K	3.725	0.455	***	3.837	0.461	***	4.053	0.470	***	4.119	0.470	***	4.016	0.471	***	3.971	0.473	***
1:INC100-150K	2.191	0.570	***	2.227	0.571	***	2.406	0.584	***	2.385	0.581	***	2.417	0.583	***	2.415	0.583	***
2:INC100-150K	4.381	0.589	***	4.378	0.589	***	4.578	0.613	***	4.611	0.608	***	4.554	0.611	***	4.552	0.612	***
3:INC100-150K	4.369	0.652	***	4.366	0.657	***	4.534	0.679	***	4.566	0.675	***	4.497	0.677	***	4.493	0.678	***
1:INCMT150K	3.559	0.745	***	3.580	0.747	***	3.884	0.754	***	3.815	0.753	***	3.841	0.757	***	3.782	0.758	***
2:INCMT150K	5.587	0.762	***	5.568	0.763	***	5.978	0.779	***	5.934	0.776	***	5.850	0.781	***	5.781	0.782	***
3:INCMT150K	5.640	0.809	***	5.624	0.814	***	5.999	0.828	***	5.953	0.826	***	5.854	0.831	***	5.785	0.832	***
1:Child: 1				-0.310	0.359		-0.333	0.364		-0.332	0.374		-0.375	0.379		-0.392	0.380	
2:Child: 1				-0.882	0.371	*	-0.995	0.379	**	-1.009	0.389	**	-1.067	0.394	**	-1.087	0.395	**
3:Child: 1				-1.377	0.397	***	-1.504	0.405	***	-1.510	0.414	***	-1.570	0.418	***	-1.587	0.419	***
1:Child: 2+				-0.448	0.505		-0.414	0.510		-0.390	0.519		-0.367	0.517		-0.391	0.518	
2:Child: 2+				-1.141	0.509	*	-1.174	0.517	*	-1.209	0.527	*	-1.198	0.525	*	-1.229	0.526	*
3:Child: 2+				-1.956	0.529	***	-2.001	0.539	***	-2.046	0.547	***	-2.046	0.546	***	-2.073	0.547	***
1:Senior: 1				0.388	0.224		0.393	0.226		0.398	0.230		0.361	0.232		0.356	0.233	
2:Senior: 1				0.291	0.265		0.232	0.269		0.247	0.274		0.168	0.276		0.163	0.277	
3:Senior: 1				1.036	0.304	***	0.974	0.308	**	0.998	0.312	***	0.918	0.314	**	0.914	0.315	**
1:Senior: 2+				1.399	0.420	***	1.396	0.424	***	1.391	0.428	***	1.384	0.431	***	1.366	0.432	**
2:Senior: 2+				1.122	0.445	*	1.063	0.450	*	1.072	0.456	*	1.032	0.460	*	1.013	0.461	*
3:Senior: 2+				1.767	0.508	***	1.700	0.513	***	1.713	0.519	***	1.668	0.523	***	1.650	0.523	**
1:Subway	-2.042	0.155	***	-2.009	0.159	***	-1.222	0.239	***	-0.875	0.240	***	-0.804	0.242	***	-0.772	0.244	**
2:Subway	-3.293	0.190	***	-3.318	0.194	***	-1.325	0.286	***	-0.852	0.288	**	-0.774	0.290	**	-0.738	0.292	*
3:Subway	-3.671	0.270	***	-3.790	0.279	***	-1.610	0.384	***	-1.078	0.390	**	-0.994	0.392	*	-0.976	0.394	*
1:CommRail	-0.551	0.153	***	-0.528	0.154	***	-0.217	0.172		-0.347	0.174	*	-0.293	0.176		-0.297	0.176	

2:CommRail	-0.997	0.188	***	-0.970	0.189	***	-0.297	0.210	-0.490	0.213	*	-0.375	0.215	-0.384	0.215			
3:CommRail	-1.107	0.248	***	-1.109	0.251	***	-0.377	0.271	-0.582	0.274	*	-0.459	0.276	-0.459	0.277			
1:AccRatio							-0.111	0.025	***	-0.041	0.030		-0.011	0.032	-0.010	0.032		
2:AccRatio							-0.308	0.033	***	-0.164	0.038	***	-0.113	0.040	**	-0.115	0.040	**
3:AccRatio							-0.353	0.048	***	-0.171	0.054	**	-0.117	0.056	*	-0.117	0.056	*
1:DISTCBD (km)									0.113	0.028	***	0.098	0.031	***	0.106	0.032	***	***
2:DISTCBD (km)									0.171	0.030	***	0.132	0.033	***	0.140	0.035	***	***
3:DISTCBD (km)									0.199	0.034	***	0.157	0.038	***	0.161	0.040	***	***
1:DISTCBD_SQ									-0.002	0.000	***	-0.002	0.001	**	-0.002	0.001	**	**
2:DISTCBD_SQ									-0.002	0.001	***	-0.002	0.001	***	-0.002	0.001	***	***
3:DISTCBD_SQ									-0.003	0.001	***	-0.002	0.001	***	-0.003	0.001	***	***
1:LN(DENPOP)												-0.266	0.122	*	-0.313	0.137	*	*
2:LN(DENPOP)												-0.507	0.131	***	-0.566	0.154	***	***
3:LN(DENPOP)												-0.543	0.146	***	-0.536	0.186	**	**
1:LN(JWR)												-0.232	0.084	**	-0.240	0.085	**	**
2:LN(JWR)												-0.275	0.096	**	-0.285	0.097	**	**
3:LN(JWR)												-0.281	0.111	*	-0.286	0.113	*	*
1:inters. per km															0.021	0.040		
2:inters. per km															0.016	0.057		
3:inters. per km															-0.021	0.088		
1: % 4-way inters.															0.578	0.670		
2: % 4-way inters.															1.012	0.861		
3: % 4-way inters.															0.247	1.289		

Notes: *JWR*: job-worker ratio. *DENPOP*:  $1 \cdot 10^{-3}$  persons/square miles; *inters. per km*:  $1 \cdot 10^{-3}$  intersections per road kilometer. AccRatio: job accessibility by transit/auto\*100. Significance level: \*0.05; \*\*0.01; \*\*\*0.001.

**Table 1–3 Vehicle ownership model estimation results for 2010 (MTS)**

	M1		M2		M3		M4		M5						
	B	SE	B	SE	B	SE	B	SE	B	SE					
1:(intercept)	0.552	0.069	***	0.173	0.084	*	0.259	0.085	**	-0.801	0.183	***	0.726	0.250	**
2:(intercept)	-2.487	0.135	***	-2.979	0.152	***	-2.761	0.153	***	-5.819	0.268	***	-3.279	0.328	***
3:(intercept)	-3.896	0.221	***	-4.467	0.241	***	-4.169	0.242	***	-8.411	0.362	***	-5.286	0.414	***
1:Size: 2-pers	0.193	0.108		0.024	0.122		0.020	0.124		0.080	0.125		0.127	0.126	
2:Size: 2-pers	2.994	0.141	***	2.869	0.153	***	2.878	0.155	***	3.034	0.159	***	3.143	0.162	***
3:Size: 2-pers	2.662	0.199	***	2.617	0.210	***	2.622	0.212	***	2.815	0.216	***	2.957	0.219	***
1:Size: 3-pers	0.261	0.160		-0.179	0.231		-0.244	0.234		-0.189	0.239		-0.099	0.240	
2:Size: 3-pers	2.926	0.186	***	3.285	0.251	***	3.223	0.255	***	3.369	0.263	***	3.579	0.266	***
3:Size: 3-pers	3.206	0.233	***	4.179	0.290	***	4.122	0.294	***	4.301	0.302	***	4.563	0.306	***
1:Size: 4-pers	0.315	0.224		-0.548	0.386		-0.634	0.387		-0.550	0.390		-0.370	0.387	
2:Size: 4-pers	3.612	0.238	***	4.290	0.399	***	4.255	0.401	***	4.455	0.409	***	4.798	0.409	***
3:Size: 4-pers	3.376	0.278	***	5.661	0.429	***	5.636	0.432	***	5.876	0.441	***	6.284	0.443	***
1:Size: 5-pers+	0.013	0.283		-0.928	0.446	*	-1.005	0.446	*	-0.863	0.454		-0.678	0.454	
2:Size: 5-pers+	3.295	0.294	***	4.011	0.457	***	3.930	0.462	***	4.225	0.475	***	4.547	0.478	***
3: Size: 5-pers+	3.245	0.329	***	5.919	0.489	***	5.828	0.495	***	6.168	0.509	***	6.549	0.513	***
1:Workers1	0.312	0.094	***	0.576	0.100	***	0.608	0.101	***	0.631	0.102	***	0.640	0.104	***
2:Workers1	0.472	0.123	***	0.891	0.134	***	0.933	0.136	***	1.026	0.140	***	1.044	0.143	***
3:Workers1	0.608	0.168	***	0.968	0.182	***	1.032	0.184	***	1.146	0.188	***	1.174	0.191	***
1:Workers2	0.582	0.175	***	0.981	0.184	***	1.046	0.186	***	1.039	0.186	***	0.995	0.187	***
2:Workers2	1.300	0.187	***	1.782	0.200	***	1.890	0.203	***	2.009	0.207	***	1.991	0.209	***
3:Workers2	1.627	0.219	***	1.976	0.236	***	2.119	0.239	***	2.288	0.244	***	2.302	0.246	***
1:Workers3+	0.715	0.505		1.303	0.522	*	1.481	0.525	**	1.544	0.528	**	1.508	0.534	**
2:Workers3+	1.436	0.502	**	1.670	0.522	***	1.956	0.529	***	2.145	0.533	***	2.085	0.540	***
3:Workers3+	3.739	0.511	***	3.189	0.535	***	3.517	0.543	***	3.785	0.549	***	3.750	0.555	***
1:INC35-50K	1.377	0.133	***	1.336	0.135	***	1.319	0.136	***	1.336	0.137	***	1.250	0.139	***
2:INC35-50K	1.786	0.167	***	1.682	0.171	***	1.621	0.173	***	1.682	0.177	***	1.491	0.181	***

3:INC35-50K	1.773	0.225	***	1.694	0.233	***	1.601	0.235	***	1.696	0.240	***	1.446	0.243	***
1:INC50-75K	1.555	0.129	***	1.568	0.130	***	1.579	0.132	***	1.590	0.132	***	1.484	0.134	***
2:INC50-75K	2.458	0.155	***	2.463	0.158	***	2.460	0.160	***	2.537	0.163	***	2.305	0.166	***
3:INC50-75K	2.639	0.199	***	2.749	0.204	***	2.729	0.206	***	2.849	0.210	***	2.558	0.213	***
1:INC75-100K	1.870	0.170	***	1.883	0.171	***	1.964	0.174	***	1.949	0.173	***	1.876	0.176	***
2:INC75-100K	3.110	0.190	***	3.112	0.192	***	3.190	0.197	***	3.227	0.199	***	2.998	0.203	***
3:INC75-100K	3.315	0.227	***	3.451	0.231	***	3.508	0.236	***	3.595	0.239	***	3.274	0.243	***
1:INC100-150K	2.278	0.213	***	2.330	0.214	***	2.463	0.219	***	2.435	0.216	***	2.368	0.219	***
2:INC100-150K	3.802	0.227	***	3.880	0.229	***	4.024	0.235	***	4.066	0.235	***	3.822	0.239	***
3:INC100-150K	4.099	0.256	***	4.359	0.261	***	4.479	0.267	***	4.583	0.268	***	4.236	0.273	***
1:INCMT150K	2.349	0.240	***	2.374	0.240	***	2.617	0.248	***	2.537	0.244	***	2.484	0.248	***
2:INCMT150K	4.029	0.251	***	4.085	0.252	***	4.365	0.263	***	4.392	0.261	***	4.130	0.266	***
3:INCMT150K	4.560	0.277	***	4.819	0.281	***	5.079	0.292	***	5.232	0.291	***	4.823	0.297	***
1:Child: 1				0.328	0.207		0.359	0.210		0.356	0.215		0.297	0.216	
2:Child: 1				-0.684	0.218	**	-0.706	0.223	**	-0.733	0.229	***	-0.855	0.232	***
3:Child: 1				-1.486	0.230	***	-1.534	0.236	***	-1.582	0.242	***	-1.728	0.246	***
1:Child: 2+				0.962	0.347	**	0.984	0.347	**	0.999	0.352	**	0.908	0.350	**
2:Child: 2+				-0.709	0.357	*	-0.757	0.360	*	-0.821	0.369	*	-1.010	0.369	**
3:Child: 2+				-2.750	0.371	***	-2.815	0.375	***	-2.917	0.384	***	-3.154	0.385	***
1:Senior: 1				0.797	0.108	***	0.788	0.109	***	0.763	0.110	***	0.648	0.113	***
2:Senior: 1				0.854	0.147	***	0.851	0.148	***	0.896	0.151	***	0.717	0.153	***
3:Senior: 1				0.874	0.174	***	0.902	0.176	***	0.993	0.179	***	0.814	0.181	***
1:Senior: 2+				1.334	0.269	***	1.372	0.273	***	1.365	0.274	***	1.252	0.278	***
2:Senior: 2+				1.605	0.275	***	1.614	0.280	***	1.661	0.285	***	1.445	0.290	***
3:Senior: 2+				1.337	0.299	***	1.357	0.304	***	1.449	0.309	***	1.199	0.315	***
1:Subway	-1.364	0.089	***	-1.327	0.090	***	-0.614	0.132	***	-0.396	0.131	**	-0.300	0.131	*
2:Subway	-3.195	0.116	***	-3.189	0.117	***	-1.374	0.170	***	-0.855	0.170	***	-0.694	0.171	***
3:Subway	-3.955	0.157	***	-4.004	0.162	***	-1.475	0.218	***	-0.792	0.228	***	-0.586	0.230	*
1:CommRail	-0.526	0.096	***	-0.471	0.098	***	-0.233	0.104	*	-0.256	0.105	*	-0.168	0.105	
2:CommRail	-1.004	0.122	***	-0.956	0.124	***	-0.401	0.132	**	-0.438	0.134	***	-0.301	0.136	*
3:CommRail	-1.248	0.148	***	-1.226	0.152	***	-0.461	0.162	**	-0.452	0.165	**	-0.256	0.167	

1:AccRatio	-0.124	0.017	***	-0.061	0.019	***	-0.008	0.020	
2:AccRatio	-0.338	0.023	***	-0.143	0.026	***	-0.053	0.027	
3:AccRatio	-0.523	0.034	***	-0.206	0.037	***	-0.090	0.037	*
1:DISTCBD_KM				0.069	0.014	***	0.033	0.015	*
2:DISTCBD_KM				0.178	0.016	***	0.110	0.018	***
3:DISTCBD_KM				0.223	0.018	***	0.135	0.020	***
1:DISTCBD_SQ				-0.001	0.000	***	-0.001	0.000	*
2:DISTCBD_SQ				-0.002	0.000	***	-0.002	0.000	***
3:DISTCBD_SQ				-0.002	0.000	***	-0.002	0.000	***
1: LN(DENPOP)							-0.623	0.061	***
2: LN(DENPOP)							-1.010	0.072	***
3: LN(DENPOP)							-1.240	0.081	***
1: LN(JWR)							-0.230	0.053	***
2: LN(JWR)							-0.309	0.066	***
3: LN(JWR)							-0.325	0.076	***
1:inters_per_km									
2:inters_per_km									
3:inters_per_km									
1: % inters.4									
2: % inters.4									
3: % inters.4									
1:Black									
2:Black									
3:Black									
1:Asian									
2:Asian									
3:Asian									
1:Others									
2:Others									
3:Others									



Table 1-3 cont'd

	M6			M7		
	B	SE		B	SE	
1:(intercept)	0.894	0.308	**	0.928	0.256	***
2:(intercept)	-2.778	0.405	***	-3.05	0.334	***
3:(intercept)	-4.613	0.517	***	-5.024	0.419	***
1:Size: 2-pers	0.132	0.126		0.248	0.129	
2:Size: 2-pers	3.153	0.162	***	3.283	0.164	***
3:Size: 2-pers	2.966	0.219	***	3.103	0.221	***
1:Size: 3-pers	-0.1	0.24		0.049	0.243	
2:Size: 3-pers	3.579	0.266	***	3.751	0.27	***
3:Size: 3-pers	4.56	0.306	***	4.744	0.31	***
1:Size: 4-pers	-0.351	0.389		-0.23	0.392	
2:Size: 4-pers	4.829	0.41	***	4.99	0.415	***
3:Size: 4-pers	6.312	0.444	***	6.505	0.449	***
1:Size: 5-pers+	-0.676	0.454		-0.453	0.461	
2:Size: 5-pers+	4.563	0.479	***	4.841	0.488	***
3: Size: 5-pers+	6.56	0.514	***	6.88	0.522	***
1:Workers1	0.637	0.104	***	0.643	0.106	***
2:Workers1	1.043	0.143	***	1.056	0.144	***
3:Workers1	1.173	0.191	***	1.199	0.192	***
1:Workers2	0.992	0.187	***	0.956	0.189	***
2:Workers2	1.989	0.209	***	1.955	0.212	***
3:Workers2	2.301	0.246	***	2.27	0.248	***
1:Workers3+	1.503	0.533	**	1.536	0.536	**
2:Workers3+	2.079	0.539	***	2.131	0.544	***
3:Workers3+	3.747	0.555	***	3.793	0.559	***
1:INC35-50K	1.251	0.139	***	1.156	0.141	***
2:INC35-50K	1.482	0.181	***	1.375	0.183	***
3:INC35-50K	1.434	0.243	***	1.331	0.245	***
1:INC50-75K	1.489	0.134	***	1.38	0.135	***
2:INC50-75K	2.306	0.166	***	2.173	0.168	***
3:INC50-75K	2.555	0.214	***	2.429	0.215	***
1:INC75-100K	1.877	0.176	***	1.707	0.178	***
2:INC75-100K	2.984	0.203	***	2.786	0.205	***
3:INC75-100K	3.254	0.243	***	3.052	0.246	***
1:INC100-150K	2.372	0.22	***	2.167	0.222	***
2:INC100-150K	3.807	0.24	***	3.577	0.243	***
3:INC100-150K	4.212	0.273	***	3.981	0.276	***
1:INCMT150K	2.498	0.249	***	2.226	0.251	***
2:INCMT150K	4.129	0.267	***	3.816	0.269	***
3:INCMT150K	4.812	0.298	***	4.503	0.3	***
1:Child: 1	0.294	0.217		0.375	0.219	
2:Child: 1	-0.859	0.233	***	-0.764	0.236	***
3:Child: 1	-1.73	0.246	***	-1.624	0.249	***
1:Child: 2+	0.902	0.351	**	0.972	0.353	**
2:Child: 2+	-1.026	0.369	**	-0.973	0.373	**
3:Child: 2+	-3.168	0.386	***	-3.135	0.389	***
1:Senior: 1	0.643	0.113	***	0.618	0.114	***
2:Senior: 1	0.711	0.153	***	0.683	0.155	***

3:Senior: 1	0.81	0.181	***	0.777	0.182	***
1:Senior: 2+	1.24	0.278	***	1.199	0.285	***
2:Senior: 2+	1.426	0.29	***	1.371	0.298	***
3:Senior: 2+	1.177	0.315	***	1.118	0.322	***
1:Subway	-0.304	0.132	*	-0.354	0.133	**
2:Subway	-0.725	0.171	***	-0.758	0.173	***
3:Subway	-0.624	0.231	**	-0.645	0.232	**
1:CommRail	-0.165	0.106		-0.105	0.108	
2:CommRail	-0.282	0.136	*	-0.222	0.138	
3:CommRail	-0.229	0.168		-0.175	0.169	
1:AccRatio	-0.006	0.02		-0.014	0.02	
2:AccRatio	-0.047	0.027		-0.06	0.027	*
3:AccRatio	-0.082	0.038	*	-0.098	0.038	**
1:DISTCBD_KM	0.032	0.015	*	0.026	0.015	
2:DISTCBD_KM	0.107	0.018	***	0.104	0.018	***
3:DISTCBD_KM	0.13	0.02	***	0.127	0.02	***
1:DISTCBD_SQ	-0.001	0	*	0	0	
2:DISTCBD_SQ	-0.002	0	***	-0.002	0	***
3:DISTCBD_SQ	-0.002	0	***	-0.002	0	***
1:LN(DENPOP)	-0.578	0.076	***	-0.572	0.062	***
2:LN(DENPOP)	-0.871	0.094	***	-0.94	0.073	***
3:LN(DENPOP)	-1.06	0.11	***	-1.167	0.082	***
1:LN(JWR)	-0.213	0.056	***	-0.251	0.054	***
2:LN(JWR)	-0.263	0.07	***	-0.327	0.067	***
3:LN(JWR)	-0.273	0.079	***	-0.34	0.076	***
1:inters_per_km	-0.034	0.033				
2:inters_per_km	-0.075	0.045				
3:inters_per_km	-0.096	0.058				
1:% inters.4	-0.173	0.517				
2:% inters.4	-1.326	0.696				
3:% inters.4	-1.862	0.93	*			
1:Black				-0.682	0.136	***
2:Black				-0.928	0.208	***
3:Black				-1.402	0.334	***
1:Asian				-0.535	0.265	*
2:Asian				-0.929	0.306	**
3:Asian				-1.991	0.401	***
1:Others				-0.917	0.133	***
2:Others				-1.278	0.173	***
3:Others				-1.329	0.213	***

**Table 1–4 Vehicle ownership model for Cube model implementation (MCube)**

	1991		2010		
	B	S.E.	B	S.E.	
1:(intercept)	0.315	0.486	0.504	0.252	*
2:(intercept)	-3.005	0.573	-3.822	0.324	***
3:(intercept)	-3.966	0.706	-5.773	0.401	***
1:SIZE2-pers	0.530	0.185	0.944	0.116	***

2:SIZE2-pers	2.492	0.241	***	4.299	0.156	***
3:SIZE2-pers	1.133	0.362	**	4.154	0.212	***
1:SIZE3-pers	1.680	0.340	***	1.232	0.171	***
2:SIZE3-pers	4.637	0.377	***	4.574	0.205	***
3:SIZE3-pers	4.410	0.454	***	5.047	0.251	***
1:SIZE4-pers+	1.388	0.348	***	1.207	0.193	***
2:SIZE4-pers+	4.685	0.382	***	5.148	0.220	***
3:SIZE4-pers+	4.180	0.458	***	5.142	0.264	***
1:WORKERS1	0.614	0.186	***	0.329	0.100	**
2:WORKERS1	1.063	0.236	***	0.635	0.131	***
3:WORKERS1	0.498	0.342		0.830	0.175	***
1:WORKERS2	-0.170	0.256		0.655	0.175	***
2:WORKERS2	0.803	0.288	**	1.671	0.191	***
3:WORKERS2	0.796	0.376	*	2.116	0.224	***
1:WORKERS3+	-0.262	0.540		1.097	0.506	*
2:WORKERS3+	0.039	0.558		2.222	0.507	***
3:WORKERS3+	2.108	0.601	***	4.713	0.519	***
1:IncGrpMid-low	0.880	0.175	***	1.213	0.108	***
2:IncGrpMid-low	1.779	0.212	***	2.015	0.136	***
3:IncGrpMid-low	1.503	0.256	***	1.986	0.167	***
1:IncGrpMid-high	1.871	0.229	***	2.014	0.129	***
2:IncGrpMid-high	3.185	0.265	***	3.272	0.159	***
3:IncGrpMid-high	3.082	0.303	***	3.410	0.186	***
1:IncGrpHigh	2.727	0.397	***	2.589	0.172	***
2:IncGrpHigh	4.572	0.416	***	4.173	0.201	***
3:IncGrpHigh	4.615	0.444	***	4.543	0.224	***
1:Subway1	-0.850	0.238	***	-0.331	0.130	*
2:Subway1	-0.830	0.285	**	-0.742	0.168	***
3:Subway1	-0.995	0.383	**	-0.656	0.223	**
1:CommRail1	-0.325	0.172	.	-0.183	0.105	.
2:CommRail1	-0.437	0.210	*	-0.332	0.134	*
3:CommRail1	-0.498	0.270	.	-0.285	0.162	.
1:AccRatio	-0.00546	0.0310		0.00241	0.0200	
2:AccRatio	-0.0975	0.0393	*	-0.0398	0.0267	
3:AccRatio	-0.103	0.055	.	-0.0768	0.0364	*
1:DISTCBD_KM	0.0930	0.0305	**	0.0334	0.0154	*
2:DISTCBD_KM	0.126	0.0330	***	0.107	0.0177	***
3:DISTCBD_KM	0.152	0.0374	***	0.129	0.0196	***
1:DISTCBD_SQ	-0.00152	0.000510	**	-0.00054	0.000262	*
2:DISTCBD_SQ	-0.00201	0.000544	***	-0.00157	0.000292	***
3:DISTCBD_SQ	-0.00240	0.000605	***	-0.00173	0.000314	***
1:LN (DENPOP)	-0.309	0.121	*	-0.663	0.0616	***
2:LN (DENPOP)	-0.546	0.130	***	-1.053	0.0718	***

3:LN (DENPOP)	-0.566	0.144	***	-1.249	0.0794	***
1:LN (JWR)	-0.219	0.082	**	-0.239	0.0535	***
2:LN (JWR)	-0.254	0.093	**	-0.322	0.0658	***
3:LN (JWR)	-0.264	0.109	*	-0.343	0.0744	***

**Table 1–5 Summary of model estimation for 1991**

<b>1991</b>	<b>M1</b>	<b>M2</b>	<b>M3</b>	<b>M4</b>	<b>M5</b>	<b>M6</b>	<b>M7</b>	<b>Cube</b>
Null Log-Likelihood	-4357	-4357	-4357	-4357	-4357	-4357	n.a.	-4357
Final log-Likelihood	-2996	-2955	-2897	-2867	-2853	-2852	n.a.	-2915
Rho-square <sup>a</sup>	0.312	0.322	0.335	0.342	0.345	0.345	n.a.	0.331
Adjusted rho-square <sup>b</sup>	0.302	0.309	0.321	0.327	0.329	0.327	n.a.	0.319
Likelihood ratio <sup>c</sup>	2721	2804	2919	2980	3007	3009	n.a.	2883
Degree of freedom	45	57	60	66	72	78	n.a.	51

a.  $1 - (L(\beta)/L(0))$

b.  $1 - (L(\beta) - K)/L(0)$

c.  $-2 (L(0)-L(\beta))$

**Table 1–6 Summary of model estimation for 2010**

<b>2010</b>	<b>M1</b>	<b>M2</b>	<b>M3</b>	<b>M4</b>	<b>M5</b>	<b>M6</b>	<b>M7</b>	<b>Cube</b>
Null Log-Likelihood	-12380	-12380	-12380	-12380	-12380	-12380	-12380	-12380
Final Log-Likelihood	-8498	-8246	-8076	-7879	-7748	-7743	-7694	-8000
Rho-square	0.314	0.334	0.348	0.364	0.374	0.375	0.379	0.354
Adjusted rho-square	0.310	0.329	0.343	0.358	0.368	0.368	0.372	0.350
Likelihood ratio	7764	8268	8608	9004	9265	9274	9375	8761
Degree of freedom	45	57	60	66	72	78	81	51

## 2 Trip Generation Model

### 2.1 Household characterization

Cross-classification is a widely used approach for trip generation in the four-step model, due to its relative simplicity and ease of application using population data typically available from a census. We initially tried other trip generation model structures, including linear regression, Tobit, Poisson regression, negative binomial, and ordered logit models. But the forecast performances of these models turn out no better than the traditional cross-classification approach for the Boston data. So we proceeded with the cross-classification structure for the uncertainty analysis.

The classification approach divides households into categories based on their socioeconomic and demographic characteristics, with trip rates then computed for each category, and subsequently applied in the forecasts.

Household categories can be defined in various ways, the most common being size, number of workers, income and the number of motor vehicles. We choose three variations in characterizing households – size-worker-vehicle, size-worker-income, and size-worker-income-vehicle – and calculate trip rates for each approach. We then test if household characterization significantly affects trip generation forecasts, providing an example of uncertainty in model specification.

Table 2–1 shows the values for each categorical variable and the number of household categories for each characterization approach. Note that some categories have zero or too few observations in the surveys. We combine such small groups with their neighboring group to enlarge the sample size. After this consolidation, the “size-worker-vehicle” and “size-worker-income” categorizations have 22 and 50 categories respectively, with at least 10 observations from the surveys for each category. These two household characterizations are denoted as HH22 and HH50.

The most complex “size-worker-income-vehicle” characterization is dealt with differently. Originally it has 224 categories, many of which have fewer than 5 observations. Instead of consolidating them, we replace their trip rates with those from the upper-level group that the household belongs to. “Size-worker-income” – HH50 – is used as the upper-level backup. For example, household group P1W1I1C2 (P1: 1-person, W1: 1-worker, I1: low-income, and C2: 2-car) with fewer than 5 observations inherits the trip rates of its parent in the HH50, which is P1W1I1.

We define and assign the four income levels based on the survey’s original income categories and household size, since for households of different sizes, the four income levels should correspond to different income thresholds (Table 2–2). Table 2–3 shows the income level distribution for the 2010 CTPP population based on this definition.

**Table 2–1 Household characterization details**

<b>Household characteristics</b>		<b>Values</b>
Size (P)		1, 2, 3, 4+
Worker (W)		0, 1, 2, 3+
Income (I)		Low, mid-low, mid-high, high
Vehicles (C)		0, 1, 2, 3+
<b>Household characterization</b>		<b>Number of household categories</b>
Size-worker-vehicle (HH22)		22
Size-worker-income (HH50)		50
Size-worker-income-vehicle (HH224)		224

**Table 2–2 Household income level definitions (K: 1000 dollars in 2010)**

Income levels	1-person	2-person	3-person	4+person
Low	<15K	<35K	<50K	<50K
Mid-low	15K-35K	35K-75K	50K-100K	50K-100K
Mid-high	35K-75K	75K-150K	100K-150K	100K-150K
High	75K+	150K+	150K+	150K+

**Table 2–3 Four-level income level distribution for 2010 CTPP population**

P: persons										
W: workers	Low	Mid-Low	Mid-High	High	Total	Low	Mid-Low	Mid-High	High	Total
1P0W	106,632	73,840	37,858	11,295	229,625	46.4%	32.2%	16.5%	4.9%	100.0%
1P1W	17,532	50,007	114,167	73,748	255,454	6.9%	19.6%	44.7%	28.9%	100.0%
2P0W	58,727	39,714	18,439	5,589	122,469	48.0%	32.4%	15.1%	4.6%	100.0%
2P1W	36,163	65,149	50,748	21,250	173,310	20.9%	37.6%	29.3%	12.3%	100.0%
2P2W	10,620	52,983	112,577	57,630	233,810	4.5%	22.7%	48.1%	24.6%	100.0%
3P0W	17,540	4,448	1,372	869	24,229	72.4%	18.4%	5.7%	3.6%	100.0%
3P1W	31,464	29,625	13,763	11,323	86,175	36.5%	34.4%	16.0%	13.1%	100.0%
3P2W	13,825	37,770	33,443	31,939	116,977	11.8%	32.3%	28.6%	27.3%	100.0%
3P3W	3,247	13,035	15,735	14,605	46,622	7.0%	28.0%	33.8%	31.3%	100.0%
4P0W	14,740	3,680	1,057	1,132	20,609	71.5%	17.9%	5.1%	5.5%	100.0%
4P1W	28,872	33,598	23,106	27,586	113,162	25.5%	29.7%	20.4%	24.4%	100.0%
4P2W	17,644	54,060	48,644	52,768	173,116	10.2%	31.2%	28.1%	30.5%	100.0%
4P3W	2,944	16,578	20,098	18,345	57,965	5.1%	28.6%	34.7%	31.6%	100.0%
4P4W	1,179	7,100	11,214	15,085	34,578	3.4%	20.5%	32.4%	43.6%	100.0%
Total	361,129	481,587	502,221	343,164	1,688,101					

Data source: 2010 CTPP.

## 2.2 Trip rates by trip purposes

### *List of trip purposes*

HBW: home-based work
HBWR: home-based work-related
HBSC: home-based school
HBPUDO: home-based pick-up/drop-off
HBSH: home-based shopping
HBBPB: home-based bank/personal business
HBSO: home-based social
HBEAT: home-based eating
HBREC: home-based recreation
HBO: home-based other
NHBW: non-home-based work/work-related
NHBO: non-home-based other

### *HBW trips*

HBW trips are generated at the worker level. The 224 HH types are first split into 1120 HH types by 5 worker's earning groups. Doing this has two purposes: 1) allowing trip distribution step to have HBW trip inputs by earning; and 2) allowing variations in work-at-home rates by earning. HBW trips for HH type  $i$  ( $i$  from 1 to 1120) is:

$$HBW[i] = \text{Number of workers}[i] * (1 - \text{workAtHome}[i]) * TR\_HBW$$

Note that work-at-home rate (Table 2–4) is from CTPP data. It varies across worker's earning categories. HBW trips per worker ( $TR\_HBW$ ) is calculated from 2010MTS and 1991BTS. It is the number of HBW or HBWR trips per worker who actually travels to work on the travel survey day.

HBW trip attraction is computed based on jobs by earning in each TAZ. The attractions are matched to the trip production for each earning category.

Major changes in HBW generation include:

- Worker-level generation (vs. HH level generation)
- Including percentage of working at home, which varies by earning
- Having considered work-at-home rate variations across earning groups, we assume the same HBW trips per worker for every worker. This is debatable, because HBW trip rate also reflects trip-chaining behavior: higher value means less trip chaining during commute. This can vary across HH type. We use the same rate here for simplicity, assuming the difference in HBW trip production across HH types is fully captured by the different work-at-home ratios.
- Disaggregated HBW trip outputs according to worker's earning level.



**Table 2–4 Work-at-home rates by worker earning group**

<b>Input parameters</b>	<b>1990</b>	<b>2010</b>
Work-at-home rate	0.0231	0.0404
Earn 1	0.042	0.049
Earn 2	0.0142	0.0291
Earn 3	0.012	0.0295
Earn 4	0.0149	0.0417
Earn 5	0.024	0.0586
HBW trips per worker	1.52	1.317

*Other trip purposes*

For other purposes, trips are generated at the HH level and computed from travel surveys in 1990 and 2010. Trip rates vary across the HH types. Attractions are based on three types of jobs: retail, service and the others. Total attractions are matched to the total productions.

**3 Gravity model calibration for trip distribution**

Gravity model with friction factors is used for trip distribution. Friction factors are calibrated based on matching the observed travel time distribution with the predicted travel time distribution.

For HBW trips, we disaggregate trip distribution by 5 workers’ earning categories, and by choice (with car) and captive (no car) riders. It means that the trip productions and attractions are by earning group; and that the travel time distribution is earning-specific. The calibrated friction factors for HBW trips are shown in Table 3–1 and Table 3–2. Note that we cannot do a similar calibration for 1990, since the disaggregated data is not available in CTPP1990. For 1990, we calibrate the overall HBW friction factors instead of by earning group. For other trip purposes, the friction factors are calibrated for choice and captive riders using travel surveys.

**3.1 2010 trip distribution calibration**

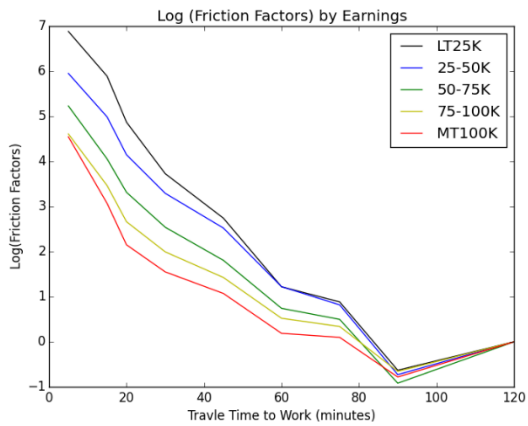
**Table 3–1 Friction factors for HBW CHO riders in 2010**

Time	Earn1	Earn2	Earn3	Earn4	Earn5
5	974.40	384.14	186.74	100.41	94.16
15	360.96	146.37	57.65	31.92	21.51
20	130.31	63.27	27.52	14.33	8.59

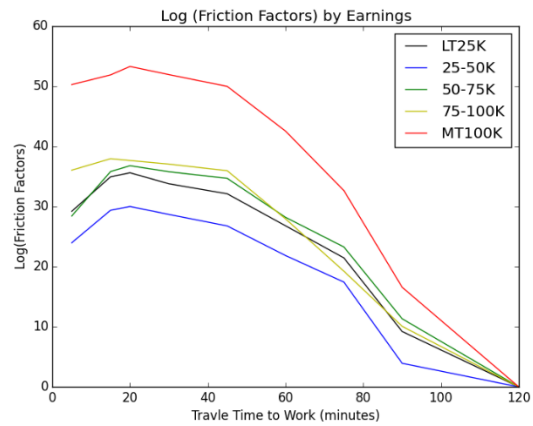
30	41.56	26.90	12.68	7.35	4.71
45	15.52	12.46	6.09	4.16	2.92
60	3.39	3.40	2.10	1.69	1.21
75	2.42	2.27	1.65	1.41	1.10
90	0.53	0.48	0.40	0.52	0.46
120	1	1	1	1	1

**Table 3–2 Friction factors for HBW CAP riders in 2010**

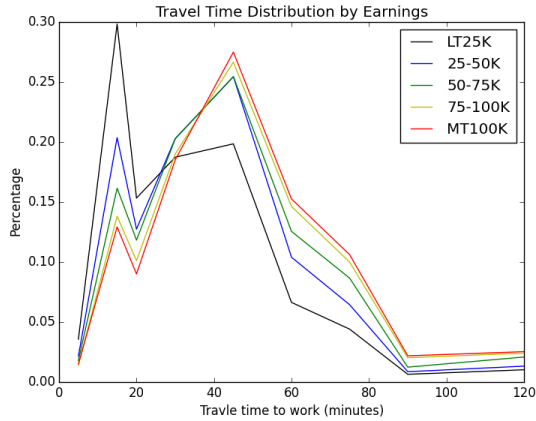
	Earn1	Earn2	Earn3	Earn4	Earn5
5	2286.0	685.4	170.5	3267.4	2274.9
15	713214.8	153660.9	277894.6	22047.5	11443.2
20	1398099.3	287412.6	734317.2	16321.0	46477.0
30	224351.2	76571.7	270251.0	8997.1	11998.7
45	42405.6	11326.9	89762.9	3001.6	1703.2
60	207.2	82.3	137.9	1.0	1.0
75	1	1	1	0	0
90	0	0	0	0	0
120	0	0	0	0	0



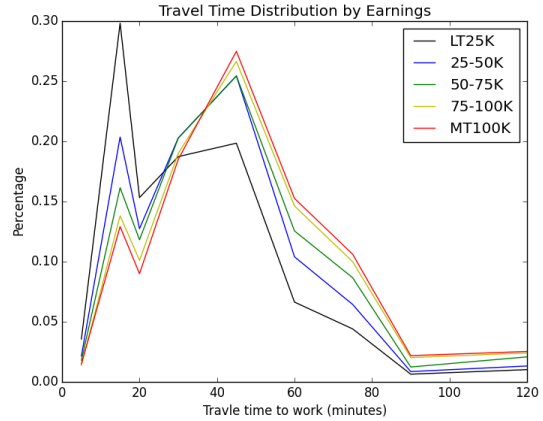
**Log FF for HBW CHO**



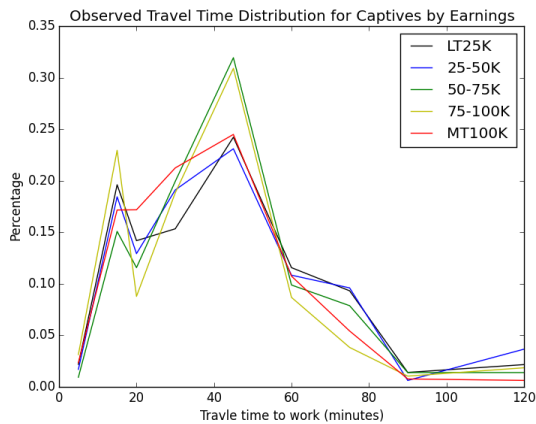
**Log FF for HBW CAP**



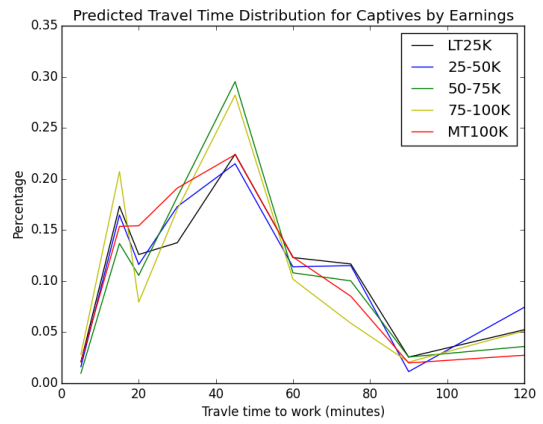
Observed HBW TLD for **Choice**



Predicted HBW TLD for **Choice**



Observed HBW TLD for **Captives**



Predicted HBW TLD for **Captives**

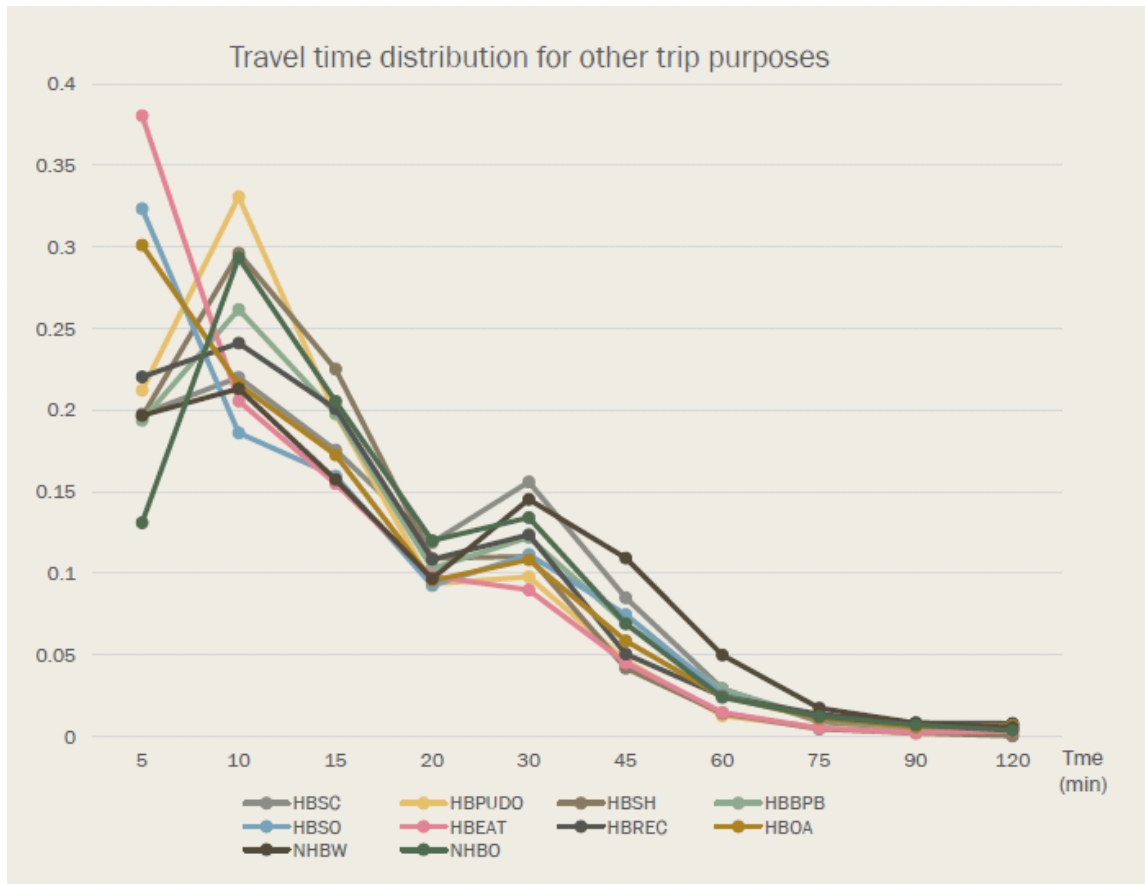
**Figure 3-1 Friction factors and travel time distribution for choice and captive travelers in 2010.**

**Table 3-3 Friction factors for other trip purposes for CHOICE in 2010**

Time (min)	HBSC	HBPUDO	HBSH	HBBPB	HBSO	HBEAT	HBREC	HBO	NHBW	NHBO
5	44454.1	212927.9	809458.4	13586.0	36905.5	188842.7	15278.0	1.42E+24	15332.2	18193.1
10	3933.4	32743.5	116697.9	1991.2	1495.2	5666.8	1561.0	228.0	1842.2	5204.8
15	851.7	4655.7	21852.9	393.9	328.7	972.2	329.4	71.1	359.2	932.0
20	285.2	1046.1	5203.8	99.2	92.0	287.3	85.1	17.9	110.4	266.3
30	92.4	267.2	1274.2	27.6	26.1	59.8	22.5	6.9	41.5	71.6
45	16.3	40.0	154.5	4.7	5.2	8.4	2.8	2.3	10.4	11.7
60	3.3	6.3	33.8	1.2	1.1	1.5	0.8	0.9	3.1	2.5
75	0.9	2.4	9.9	0.5	0.5	0.5	0.5	0.7	1.2	1.3
90	0.5	1.0	5.6	0.4	0.6	0.4	0.6	0.3	0.9	1.2
120	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

**Table 3–4 Friction factors for other trip purposes for CAPTIVE in 2010**

Time (min)	HBSC	HBPUDO	HBSH	HBBPB	HBSO	HBEAT	HBREC	HBO	HBOA	NHBW	NHBO
5	4813.0	11755.9	45226.5	1762.3	3491.9	8808.6	2016.4	78379.6	469.0	2593.9	2219.4
10	54441.8	666260.3	1879908.4	33801.9	8593.6	19158.1	18538.7	28.0	55036.9	14020.4	124446.9
15	5656.6	20855.5	127967.1	3626.5	1964.3	3562.6	2783.1	563.4	5115.0	2246.7	9250.1
20	2024.4	4647.5	26674.6	943.4	677.6	1391.4	810.0	350.7	1246.3	840.0	2565.7
30	827.2	1545.0	7303.0	355.2	275.9	427.1	297.8	221.0	409.6	418.2	840.0
45	182.5	319.8	1086.2	85.6	79.4	92.3	52.2	73.6	89.3	136.6	176.5
60	35.4	46.7	236.2	20.0	14.9	16.2	13.7	22.0	22.1	33.5	35.3
75	5.1	10.2	48.0	4.1	3.6	3.3	4.2	9.9	5.3	7.0	9.7
90	1.4	2.6	17.0	1.4	2.1	1.2	2.1	1.8	2.0	2.8	4.3
120	1	1	1	1	1	1	1	1	1	1	1

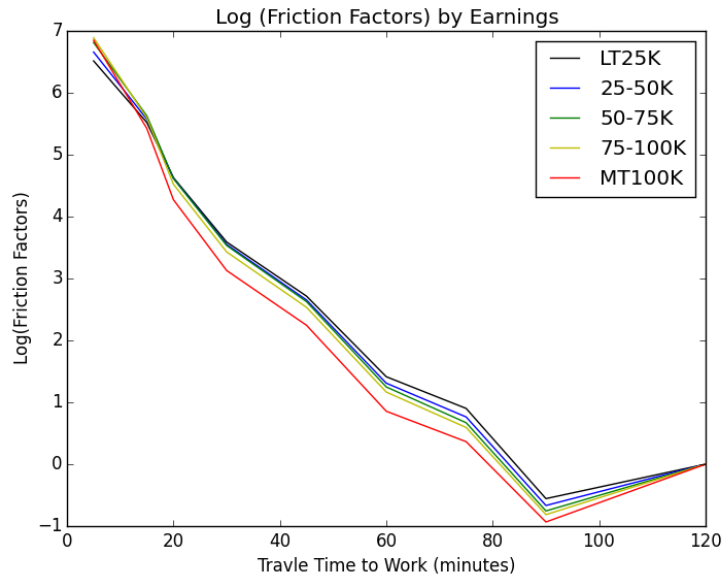


**Figure 3-2 Observed travel time distribution for other purposes in 2010.**

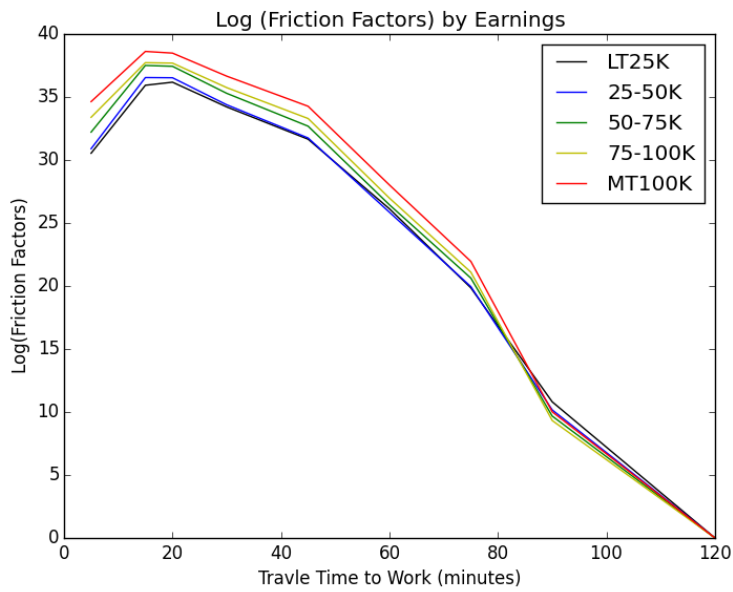
### 3.2 1990 trip distribution calibration

**Table 3–5 Observed HBW Travel Time Distribution for All Workers in 1990**

Journey to work travel time	Percentage
5	3.0%
15	25.7%
20	14.9%
30	19.4%
45	22.0%
60	8.7%
75	4.7%
90	0.7%
120	1.0%

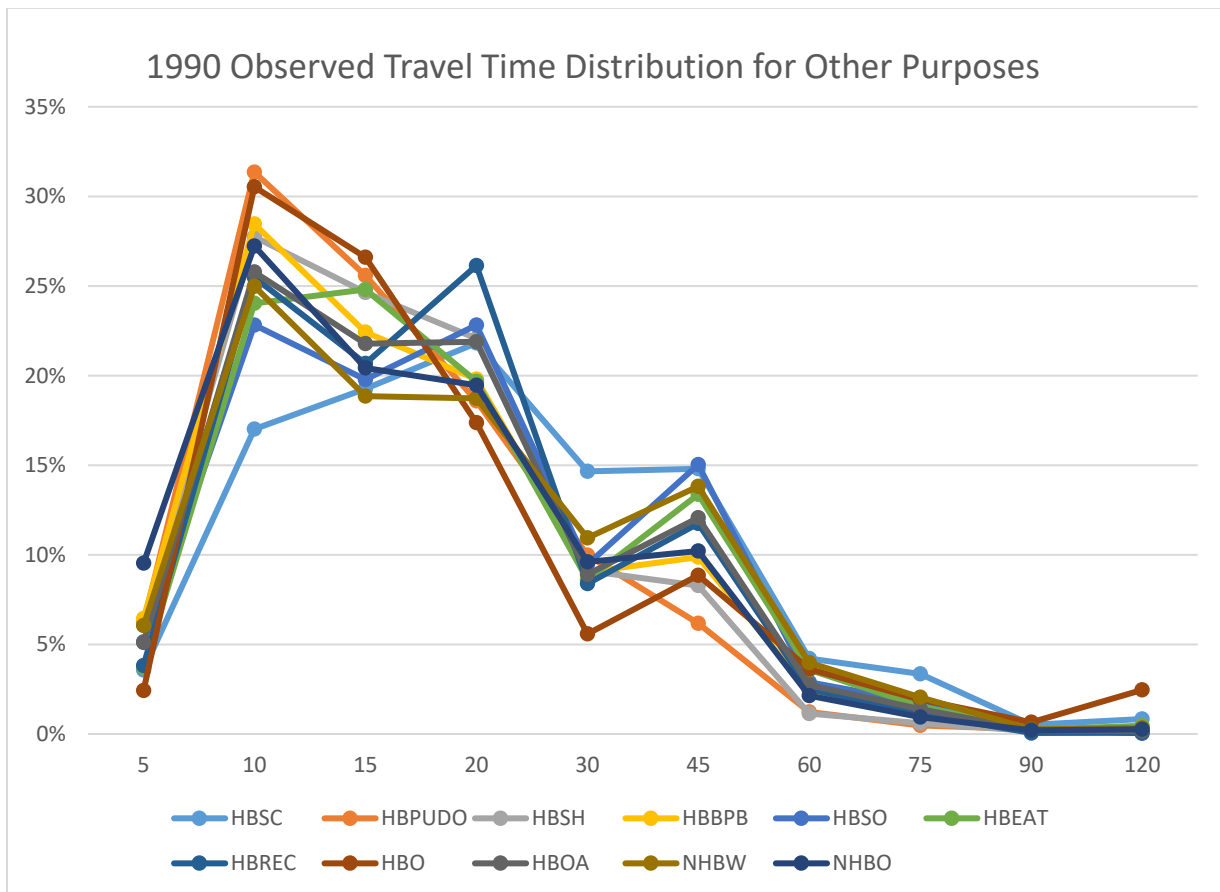


**Figure 3-3 1990 Log of Friction Factors by Earning Groups for HBW Choice riders**



**Figure 3-4 1990 Log of Friction Factors by Earning Groups for HBW Captive riders**

*Other purposes*



**Figure 3-5 Observed Travel time distribution for other purposes in 1990.**

**Table 3–6 1990 Friction Factors for Other Trip Purposes for Choice**

	HBSC	HBPUDO	HBSH	HBBPB	HBSO	HBEAT	HBREC	HBO	HBOA	NHBW	NHBO
5	1115.5	19623.1	19664.6	15721.6	45760.0	1844.6	14141.3	212.5	8618.0	5030.1	12904.1
10	908.1	20561.3	15816.5	14306.5	41611.4	2767.3	21202.7	636.5	9269.2	3859.4	5939.8
15	331.8	4815.1	4111.3	3377.3	11176.0	871.4	5072.5	168.7	2367.3	840.7	1290.1
20	200.2	1737.7	1897.2	1500.3	6623.7	347.6	3238.0	55.2	1204.6	424.1	618.6
30	34.8	233.6	189.3	165.3	672.2	37.1	247.6	4.3	118.6	62.5	75.5
45	12.1	46.8	54.9	57.2	344.2	18.9	108.7	2.2	51.3	26.4	25.8
60	2.2	5.7	4.5	8.5	40.7	3.1	13.9	0.6	7.1	4.9	3.4
75	1.8	2.0	1.7	4.3	24.6	1.4	6.2	0.3	3.6	2.5	1.4
90	0.4	1.4	0.6	1.2	6.4	0.3	0.5	0.2	0.8	0.5	0.5
120	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

**Table 3–7 1990 FF for Other Trip Purposes for Captives**

	HBSC	HBPUDO	HBSH	HBBPB	HBSO	HBEAT	HBREC	HBO	HBOA	NHBW	NHBO
5	180.7	1810.2	1070.3	2266.0	6982.1	256.8	1717.7	21.1	1227.5	904.2	1783.4
10	12041.8	666481.4	402618.3	481106.8	712505.3	58229.8	424564.8	68444.1	212776.2	42222.4	124453.4
15	4980.5	52019.0	38347.5	43400.5	114908.6	11454.9	54908.7	4942.4	27751.6	6264.5	12498.9
20	3238.6	16554.5	15947.4	19820.4	82693.2	4615.2	44073.1	1088.9	15824.9	4042.9	6843.0
30	505.4	1844.2	1009.6	1926.6	7643.0	436.3	2655.3	56.3	1356.1	600.4	779.5
45	190.8	456.6	343.1	881.3	5239.5	290.4	1591.4	36.9	781.3	335.1	350.0
60	30.8	52.2	28.3	123.5	554.0	44.7	189.1	9.5	100.0	51.6	40.5
75	13.8	11.5	9.8	36.4	195.3	11.1	49.9	3.0	29.5	16.1	10.4
90	1.4	4.6	2.0	4.6	23.9	1.2	1.8	0.7	3.2	1.6	1.7
120	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0

## 4 Mode choice models

Mode choice uses the multinomial logit model structure. The choice set consists of five alternatives: single-occupant vehicle (SOV), walk (WALK), walk-access-transit (WAT), drive-access-transit (DAT), and auto-passenger (APAX). The models are estimated using 2010 MTS and 1990 BTS. The travel impedance metrics are from Cube model skims.

### 4.1 2010 model estimation

**Table 4–1 HBW Mode Choice Model Estimation**

Name	Value	Std err	t-test	p-value	Robust Std err	Robust t-test	p-value
ASC_APAX	-3.49	0.334	-10.45	0.00	0.309	-11.29	0.00
ASC_DAT	-4.38	0.589	-7.44	0.00	0.620	-7.07	0.00
ASC_SOV	-1.20	0.294	-4.06	0.00	0.291	-4.10	0.00
ASC_WALK	0.00	fixed					
ASC_WAT	0.162	0.408	0.40	0.69	* 0.397	0.41	0.68 *
B_APAX_COST_INC	-0.00272	0.0647	-0.04	0.97	* 0.0699	-0.04	0.97 *
B_CAP_APAX	-0.844	0.323	-2.61	0.01	0.343	-2.46	0.01
B_DAT_ACCEGG	-0.0417	0.0106	-3.92	0.00	0.0106	-3.93	0.00
B_D_CBD_DAT	3.46	0.337	10.28	0.00	0.359	9.64	0.00
B_D_CBD_WAT	0.939	0.161	5.81	0.00	0.162	5.78	0.00
B_D_JOB DEN10K_SOV	-0.0371	0.00387	-9.59	0.00	0.00433	-8.57	0.00
B_HHSIZ_APAX	0.248	0.0458	5.41	0.00	0.0422	5.87	0.00
B_O_CBD_APAX	-0.487	0.278	-1.75	0.08	* 0.284	-1.71	0.09 *
B_O_CBD_SOV	-0.978	0.221	-4.42	0.00	0.219	-4.47	0.00
B_O_CBD_WAT	-0.793	0.243	-3.27	0.00	0.240	-3.31	0.00
B_O_POPDEN10K_WAT	0.188	0.0571	3.29	0.00	0.0579	3.24	0.00
B_PT_FARES_DIST	-1.03	0.170	-6.10	0.00	0.181	-5.72	0.00
B_PT_IVTT_DIST	-0.140	0.0338	-4.14	0.00	0.0317	-4.42	0.00
B_PT_IVTT_DIST_HIGHINC	-0.0718	0.0352	-2.04	0.04	0.0345	-2.08	0.04
B_PT_IVTT_DIST_MIDHIGHINC	-0.0599	0.0343	-1.75	0.08	* 0.0328	-1.83	0.07 *
B_PT_IVTT_DIST_MIDLOWINC	-0.0154	0.0342	-0.45	0.65	* 0.0338	-0.46	0.65 *
B_PT_WAITT	-0.0241	0.0110	-2.19	0.03	0.0106	-2.27	0.02
B_SOV_COST_INC	-0.0594	0.0531	-1.12	0.26	* 0.0546	-1.09	0.28 *
B_TERMJ_APAX	-0.151	0.0512	-2.96	0.00	0.0533	-2.84	0.00
B_TERMJ_SOV	-0.187	0.0408	-4.60	0.00	0.0416	-4.50	0.00
B_VEHPWRK_DAT	1.50	0.155	9.70	0.00	0.193	7.77	0.00
B_VEHPWRK_SOV	1.59	0.117	13.56	0.00	0.166	9.61	0.00
B_WALK_TT	-0.0785	0.00712	-11.02	0.00	0.00714	-10.99	0.00
B_WAT_WALKT	-0.0518	0.00782	-6.62	0.00	0.00796	-6.51	0.00

Adjusted rho-square: 0.623



**Table 4–2 HBSHOP Mode Choice Logit Model Estimation**

Name	Value	Std err	t-test	p-value		Robust Std err	Robust t-test	p-value	
ASC_APAX	-2.34	0.383	-6.11	0.00		0.368	-6.36	0.00	
ASC_DAT	-4.13	0.741	-5.57	0.00		0.637	-6.48	0.00	
ASC_SOV	-0.836	0.373	-2.24	0.02		0.372	-2.25	0.02	
ASC_WALK	0.00	fixed							
ASC_WAT	-1.50	0.696	-2.15	0.03		0.770	-1.95	0.05	*
B_APAX_COST_INC	-0.220	0.216	-1.02	0.31	*	0.230	-0.96	0.34	*
B_CAP_APAX	-0.700	0.344	-2.04	0.04		0.353	-1.99	0.05	
B_CAP_WAT	1.96	0.427	4.60	0.00		0.442	4.45	0.00	
B_DDENSITY10K_APAX	-0.374	0.121	-3.10	0.00		0.124	-3.02	0.00	
B_DDENSITY10K_PT	0.489	0.128	3.82	0.00		0.127	3.84	0.00	
B_DDENSITY10K_SOV	-0.247	0.0989	-2.50	0.01		0.0951	-2.60	0.01	
B_D_CBD_APAX	-0.642	0.274	-2.34	0.02		0.272	-2.36	0.02	
B_D_CBD_SOV	-0.900	0.239	-3.77	0.00		0.236	-3.80	0.00	
B_HHSIZ_APAX	0.325	0.0441	7.37	0.00		0.0445	7.31	0.00	
B_INCOME_WAT	-0.128	0.0400	-3.20	0.00		0.0488	-2.62	0.01	
B_PT_FARES_DIST	-1.65	0.341	-4.84	0.00		0.354	-4.67	0.00	
B_PT_WAITT	-0.112	0.0366	-3.05	0.00		0.0340	-3.29	0.00	
B_PT_XFERWT	-0.0240	0.0336	-0.71	0.48	*	0.0359	-0.67	0.50	*
B_SOV_COST_INC	-0.396	0.212	-1.87	0.06	*	0.222	-1.79	0.07	*
B_VEPPER_SOV	1.04	0.175	5.95	0.00		0.197	5.27	0.00	
B_WALK_TT	-0.0863	0.0103	-8.40	0.00		0.00991	-8.70	0.00	

Adjusted rho-square: 0.474

**Table 4–3 HBO Mode Choice Logit Model Estimation**

Name	Value	Std err	t-test	p-value		Robust Std err	Robust t-test	p-value	
ASC_APAX	-2.23	0.262	-8.52	0.00		0.276	-8.07	0.00	
ASC_DAT	-1.04	0.856	-1.22	0.22	*	0.677	-1.54	0.12	*
ASC_SOV	-1.31	0.210	-6.22	0.00		0.204	-6.42	0.00	
ASC_WALK	0.00	fixed							
ASC_WAT	-0.851	0.387	-2.20	0.03		0.431	-1.97	0.05	
B_APAX_COST_INC	-0.0228	0.0648	-0.35	0.73	*	0.0786	-0.29	0.77	*
B_CAP_APAX	-0.889	0.234	-3.80	0.00		0.239	-3.72	0.00	
B_CAP_WAT	1.91	0.204	9.38	0.00		0.199	9.62	0.00	
B_DAT_ACCEGG	-0.107	0.0244	-4.40	0.00		0.0188	-5.72	0.00	
B_DDENSITY10K_APAX	-0.227	0.0535	-4.25	0.00		0.0517	-4.40	0.00	
B_DDENSITY10K_PT	0.212	0.0543	3.92	0.00		0.0536	3.97	0.00	
B_DDENSITY10K_SOV	-0.215	0.0508	-4.24	0.00		0.0500	-4.31	0.00	
B_D_CBD_APAX	-0.700	0.126	-5.54	0.00		0.129	-5.41	0.00	
B_D_CBD_SOV	-0.612	0.121	-5.06	0.00		0.126	-4.86	0.00	
B_HHSIZ_APAX	0.173	0.0397	4.36	0.00		0.0446	3.88	0.00	
B_HHVEH_APAX	0.533	0.0945	5.64	0.00		0.0998	5.34	0.00	
B_HHVEH_SOV	0.400	0.0749	5.34	0.00		0.0787	5.09	0.00	
B_PT_FARES_DIST	-1.18	0.150	-7.87	0.00		0.165	-7.16	0.00	
B_PT_IVTT_DIST	-0.0913	0.0276	-3.31	0.00		0.0310	-2.94	0.00	
B_PT_IVTT_DIST_HIGHINC	-0.150	0.0390	-3.84	0.00		0.0383	-3.92	0.00	
B_PT_IVTT_DIST_MIDHIGHINC	-0.0691	0.0305	-2.27	0.02		0.0306	-2.26	0.02	
B_PT_IVTT_DIST_MIDLOWINC	-0.0478	0.0264	-1.81	0.07	*	0.0261	-1.83	0.07	*
B_PT_WAITT	-0.0728	0.0163	-4.47	0.00		0.0157	-4.63	0.00	
B_PT_XFERWT	-0.0416	0.0179	-2.32	0.02		0.0210	-1.98	0.05	
B_SOV_COST_INC	-0.114	0.0644	-1.76	0.08	*	0.0770	-1.47	0.14	*
B_TERM_J_SOV	-0.0562	0.0214	-2.63	0.01		0.0217	-2.58	0.01	
B_VEPPER_APAX	-1.07	0.261	-4.10	0.00		0.291	-3.68	0.00	
B_VEPPER_DAT	1.06	0.475	2.22	0.03		0.392	2.69	0.01	
B_VEPPER_SOV	0.537	0.166	3.24	0.00		0.168	3.20	0.00	
B_WALK_TT	-0.0931	0.00482	-19.30	0.00		0.00466	-19.96	0.00	
B_WAT_WALKT	-0.0432	0.0104	-4.15	0.00		0.0110	-3.94	0.00	

Adjusted rho-square: 0.441

**Table 4–4 NHBW Mode Choice Logit Model Estimation**

Name	Value	Std err	t-test	p-value		Robust Std err	Robust t-test	p-value	
ASC_APAX	-3.86	0.225	-17.11	0.00		0.227	-17.01	0.00	
ASC_DAT	-2.06	0.794	-2.59	0.01		0.729	-2.82	0.00	
ASC_SOV	-1.23	0.248	-4.97	0.00		0.248	-4.96	0.00	
ASC_WALK	0.00	fixed							
ASC_WAT	-1.42	0.410	-3.46	0.00		0.430	-3.30	0.00	
B_APAX_COST_INC	-0.417	0.147	-2.84	0.00		0.162	-2.58	0.01	
B_DAT_ACCEGG	-0.0941	0.0209	-4.50	0.00		0.0205	-4.59	0.00	
B_DDENSITY10K_APAX	-0.247	0.0638	-3.87	0.00		0.0676	-3.65	0.00	
B_DDENSITY10K_PT	0.136	0.0425	3.19	0.00		0.0423	3.20	0.00	
B_DDENSITY10K_SOV	-0.0668	0.0404	-1.65	0.10	*	0.0411	-1.62	0.10	*
B_D_CBD_PT	0.397	0.194	2.04	0.04		0.195	2.04	0.04	
B_D_CBD_SOV	-0.542	0.143	-3.79	0.00		0.142	-3.83	0.00	
B_ODENSITY10K_APAX	-0.286	0.0589	-4.87	0.00		0.0719	-3.98	0.00	
B_ODENSITY10K_SOV	-0.176	0.0350	-5.03	0.00		0.0488	-3.61	0.00	
B_PT_FARES_DIST	-1.02	0.141	-7.23	0.00		0.161	-6.33	0.00	
B_PT_IVTT_DIST	-0.0864	0.0415	-2.08	0.04		0.0546	-1.58	0.11	*
B_PT_IVTT_DIST_HIGHINC	-0.166	0.0456	-3.64	0.00		0.0515	-3.22	0.00	
B_PT_IVTT_DIST_MIDHIGHINC	-0.0939	0.0422	-2.23	0.03		0.0491	-1.91	0.06	*
B_PT_IVTT_DIST_MIDLOWINC	-0.119	0.0446	-2.66	0.01		0.0513	-2.31	0.02	
B_PT_WAITT	-0.0702	0.0196	-3.58	0.00		0.0171	-4.11	0.00	
B_PT_XFERWT	-0.0256	0.0177	-1.44	0.15	*	0.0180	-1.42	0.15	*
B_SOV_COST_INC	-0.178	0.0917	-1.94	0.05	*	0.0653	-2.73	0.01	
B_TERM_I_SOV	-0.244	0.0571	-4.28	0.00		0.0586	-4.16	0.00	
B_TERM_J_SOV	-0.163	0.0388	-4.21	0.00		0.0393	-4.16	0.00	
B_VEHPWRK_DAT	0.742	0.292	2.54	0.01		0.229	3.25	0.00	
B_VEHPWRK_SOV	0.704	0.0921	7.65	0.00		0.102	6.87	0.00	
B_WALK_TT	-0.139	0.00722	-19.30	0.00		0.00725	-19.22	0.00	
B_WAT_WALKT	-0.0687	0.0124	-5.55	0.00		0.0122	-5.64	0.00	

Adjusted rho-square: 0.677

**Table 4–5 NHBO Mode Choice Logit Model Estimation**

Name	Value	Std err	t-test	p-value		Robust Std err	Robust t-test	p-value	
ASC_APAX	-0.733	0.257	-2.86	0.00		0.252	-2.91	0.00	
ASC_DAT	-3.96	0.368	-10.76	0.00		0.352	-11.22	0.00	
ASC_SOV	-0.0934	0.223	-0.42	0.68	*	0.214	-0.44	0.66	*
ASC_WALK	0.00	fixed							
ASC_WAT	-0.115	0.416	-0.28	0.78	*	0.697	-0.17	0.87	*
B_APAX_COST_INC	-0.0131	0.0746	-0.18	0.86	*	0.0937	-0.14	0.89	*
B_CAP_APAX	-2.17	0.219	-9.93	0.00		0.223	-9.74	0.00	
B_DDENSITY10K_APAX	-0.295	0.0463	-6.38	0.00		0.0460	-6.42	0.00	
B_DDENSITY10K_SOV	-0.234	0.0407	-5.76	0.00		0.0411	-5.71	0.00	
B_D_CBD_PT	0.622	0.167	3.72	0.00		0.172	3.62	0.00	
B_HHSIZ_APAX	0.275	0.0215	12.83	0.00		0.0216	12.75	0.00	
B_ODENSITY10K_APAX	-0.301	0.0447	-6.75	0.00		0.0445	-6.78	0.00	
B_ODENSITY10K_SOV	-0.278	0.0399	-6.98	0.00		0.0399	-6.97	0.00	
B_PT_FARES_DIST	-0.847	0.129	-6.54	0.00		0.253	-3.34	0.00	
B_PT_IVTT_DIST	-0.0583	0.0272	-2.14	0.03		0.0328	-1.78	0.08	*
B_PT_IVTT_DIST_HIGHINC	-0.127	0.0388	-3.27	0.00		0.0381	-3.33	0.00	
B_PT_IVTT_DIST_MIDHIGHINC	-0.134	0.0350	-3.83	0.00		0.0334	-4.01	0.00	
B_PT_IVTT_DIST_MIDLOWINC	-0.0945	0.0293	-3.22	0.00		0.0268	-3.53	0.00	
B_PT_WAITT	-0.0649	0.0210	-3.09	0.00		0.0194	-3.35	0.00	
B_PT_XFERWT	-0.0306	0.0196	-1.56	0.12	*	0.0218	-1.40	0.16	*
B_SOV_COST_INC	-0.0502	0.0746	-0.67	0.50	*	0.0943	-0.53	0.59	*
B_TERM_J_APAX	-0.183	0.0376	-4.87	0.00		0.0379	-4.84	0.00	
B_TERM_J_SOV	-0.206	0.0361	-5.71	0.00		0.0360	-5.72	0.00	
B_VEHPPER_APAX	-0.757	0.189	-4.00	0.00		0.197	-3.85	0.00	
B_VEHPPER_SOV	0.853	0.168	5.09	0.00		0.169	5.05	0.00	
B_VEHPPER_WAT	-1.13	0.246	-4.57	0.00		0.289	-3.90	0.00	
B_WALK_TT	-0.0978	0.00546	-17.89	0.00		0.00510	-19.16	0.00	
B_WAT_WALKT	-0.0643	0.0124	-5.20	0.00		0.0157	-4.09	0.00	

Adjusted rho-square: 0.450

**Table 4–6 Value of Time by Household Income Groups in 2010**

Income groups	Low	Mid-Low	Mid-High	High
HBW	8.2	9.1	11.6	12.3
HBSHOP	NA	NA	NA	NA
HBO	4.6	7.1	8.2	12.3
NHBW	5.1	12.1	10.6	14.8
NHBO	4.1	10.8	13.6	13.1

## 4.2 1990 model estimation

Table 4–7 HBW Mode Choice Model Estimation for 1990

Name	Value	Std err	t-test	p-value		Robust Std err	Robust t-test	p-value	
ASC_APAX	-0.979	0.341	-2.87	0.00		0.331	-2.96	0.00	
ASC_DAT	-3.50	0.832	-4.20	0.00		0.816	-4.28	0.00	
ASC_SOV	0.369	0.330	1.12	0.26	*	0.326	1.13	0.26	*
ASC_WALK	0.00	fixed							
ASC_WAT	1.48	0.502	2.94	0.00		0.522	2.83	0.00	
B_APAX_COST_INC	-0.0615	0.183	-0.34	0.74	*	0.178	-0.35	0.73	*
B_CAP_APAX	-2.72	0.465	-5.86	0.00		0.505	-5.40	0.00	
B_CAP_SOV	-2.73	0.414	-6.59	0.00		0.375	-7.28	0.00	
B_D_CBD_DAT	2.58	0.734	3.51	0.00		0.739	3.49	0.00	
B_D_JOB DEN10K_APAX	-0.0574	0.0109	-5.24	0.00		0.0120	-4.79	0.00	
B_D_JOB DEN10K_SOV	-0.0893	0.00822	-10.86	0.00		0.00985	-9.07	0.00	
B_D_POPDEN10K_SOV	-0.188	0.0452	-4.17	0.00		0.0449	-4.20	0.00	
B_HHSIZ_APAX	0.0755	0.0353	2.14	0.03		0.0329	2.29	0.02	
B_O_CBD_SOV	-0.551	0.182	-3.03	0.00		0.167	-3.30	0.00	
B_PT_FARES_DIST	-1.40	0.193	-7.26	0.00		0.205	-6.85	0.00	
B_PT_IVTT_DIST	-0.144	0.0330	-4.36	0.00		0.0360	-4.00	0.00	
B_PT_IVTT_DIST_HIGHINC	-0.0507	0.0416	-1.22	0.22	*	0.0410	-1.24	0.22	*
B_PT_IVTT_DIST_MIDHIGHINC	0.00461	0.0270	0.17	0.86	*	0.0267	0.17	0.86	*
B_PT_WAITT	-0.0365	0.0189	-1.93	0.05	*	0.0175	-2.09	0.04	
B_PT_XFERWT	-0.0941	0.0220	-4.27	0.00		0.0223	-4.22	0.00	
B_SOV_COST_INC	-0.242	0.176	-1.38	0.17	*	0.170	-1.42	0.16	*
B_TERMJ_APAX	-0.260	0.0586	-4.43	0.00		0.0592	-4.39	0.00	
B_TERMJ_SOV	-0.223	0.0693	-3.22	0.00		0.0648	-3.44	0.00	
B_VEH PWRK_DAT	0.732	0.298	2.45	0.01		0.303	2.41	0.02	
B_VEH PWRK_SOV	1.17	0.116	10.08	0.00		0.139	8.40	0.00	
B_WALK_TT	-0.0526	0.00616	-8.54	0.00		0.00593	-8.86	0.00	
B_WAT_WALKT	-0.0491	0.0189	-2.59	0.01		0.0203	-2.42	0.02	

**Table 4–8 HBSHOP Mode Choice Model Estimation for 1990**

Name	Value	Std err	t-test	p-value		Robust Std err	Robust t-test	p-value	
ASC_APAX	0.166	0.333	0.50	0.62	*	0.332	0.50	0.62	*
ASC_DAT	-3.13	0.853	-3.66	0.00		1.01	-3.09	0.00	
ASC_SOV	-0.555	0.331	-1.68	0.09	*	0.350	-1.59	0.11	*
ASC_WALK	0.00	fixed							
ASC_WAT	-1.92	0.439	-4.38	0.00		0.431	-4.46	0.00	
B_APAX_COST_INC	-0.350	0.261	-1.34	0.18	*	0.184	-1.90	0.06	*
B_CAP_APAX	-1.41	0.330	-4.28	0.00		0.318	-4.43	0.00	
B_CAP_SOV	-1.88	0.515	-3.66	0.00		0.466	-4.05	0.00	
B_CAP_WAT	0.596	0.314	1.90	0.06	*	0.299	1.99	0.05	
B_DDENSITY10K_APAX	-0.413	0.101	-4.07	0.00		0.0922	-4.48	0.00	
B_DDENSITY10K_SOV	-0.417	0.100	-4.16	0.00		0.0956	-4.36	0.00	
B_HHSIZ_APAX	0.0774	0.0364	2.12	0.03		0.0366	2.11	0.03	
B_ODENSITY10K_APAX	-0.616	0.104	-5.90	0.00		0.105	-5.89	0.00	
B_ODENSITY10K_SOV	-0.522	0.102	-5.10	0.00		0.107	-4.87	0.00	
B_PT_FARES_DIST	-0.571	0.208	-2.75	0.01		0.236	-2.42	0.02	
B_PT_WAITT	-0.0461	0.0473	-0.97	0.33	*	0.0491	-0.94	0.35	*
B_PT_XFERWT	-0.0812	0.0412	-1.97	0.05		0.0393	-2.07	0.04	
B_SOV_COST_INC	-0.938	0.272	-3.45	0.00		0.200	-4.70	0.00	
B_VEHPER_SOV	1.89	0.176	10.73	0.00		0.198	9.52	0.00	
B_WALK_TT	-0.0728	0.00848	-8.58	0.00		0.00851	-8.55	0.00	

**Table 4–9 HBO Mode Choice Model Estimation for 1990**

Name	Value	Std err	t-test	p-value		Robust Std err	Robust t-test	p-value	
ASC_APAX	-0.329	0.216	-1.52	0.13	*	0.220	-1.50	0.13	*
ASC_DAT	-3.92	0.719	-5.46	0.00		0.566	-6.93	0.00	
ASC_SOV	-0.730	0.208	-3.51	0.00		0.221	-3.30	0.00	
ASC_WALK	0.00	fixed							
ASC_WAT	0.680	0.543	1.25	0.21	*	0.609	1.12	0.26	*
B_APAX_COST_INC	-0.121	0.133	-0.91	0.36	*	0.136	-0.89	0.37	*
B_APAX_TT	-0.0398	0.0198	-2.01	0.04		0.0214	-1.86	0.06	*
B_CAP_APAX	-1.06	0.214	-4.95	0.00		0.223	-4.75	0.00	
B_CAP_SOV	-1.48	0.290	-5.10	0.00		0.291	-5.08	0.00	
B_CAP_WAT	0.809	0.207	3.90	0.00		0.203	3.98	0.00	
B_DDENSITY10K_APAX	-0.274	0.0501	-5.47	0.00		0.0488	-5.61	0.00	
B_DDENSITY10K_SOV	-0.278	0.0529	-5.25	0.00		0.0513	-5.41	0.00	
B_D_CBD_APAX	-0.129	0.141	-0.92	0.36	*	0.133	-0.97	0.33	*
B_D_CBD_SOV	-0.257	0.149	-1.73	0.08	*	0.144	-1.78	0.08	*
B_HHSIZ_APAX	0.176	0.0297	5.92	0.00		0.0335	5.24	0.00	
B_HHVEH_APAX	0.252	0.0768	3.28	0.00		0.0888	2.84	0.00	
B_HHVEH_SOV	0.156	0.0778	2.00	0.05		0.0855	1.82	0.07	*
B_ODENSITY10K_APAX	-0.257	0.0476	-5.39	0.00		0.0466	-5.51	0.00	
B_ODENSITY10K_SOV	-0.274	0.0498	-5.51	0.00		0.0470	-5.84	0.00	
B_PT_FARES_DIST	-0.965	0.168	-5.74	0.00		0.204	-4.73	0.00	
B_PT_IVTT_DIST	-0.128	0.0358	-3.59	0.00		0.0366	-3.51	0.00	
B_PT_IVTT_DIST_HIGHINC	-0.0814	0.0539	-1.51	0.13	*	0.0455	-1.79	0.07	*
B_PT_IVTT_DIST_MIDHIGHINC	-0.115	0.0346	-3.31	0.00		0.0353	-3.24	0.00	
B_PT_WAITT	-0.0406	0.0260	-1.56	0.12	*	0.0215	-1.89	0.06	*
B_PT_XFERWT	-0.102	0.0320	-3.18	0.00		0.0300	-3.39	0.00	
B_SOV_COST_INC	-0.260	0.135	-1.93	0.05	*	0.134	-1.94	0.05	*
B_SOV_TT	-0.0378	0.0198	-1.91	0.06	*	0.0214	-1.76	0.08	*
B_VEHPPER_DAT	1.93	0.635	3.04	0.00		0.458	4.21	0.00	
B_VEHPPER_SOV	1.52	0.140	10.84	0.00		0.177	8.60	0.00	
B_WALK_TT	-0.0544	0.00449	-12.11	0.00		0.00485	-11.22	0.00	
B_WAT_WALKT	-0.0779	0.0213	-3.65	0.00		0.0213	-3.66	0.00	



**Table 4–10 NHBW Mode Choice Model Estimation for 1990**

Name	Value	Std err	t-test	p-value		Robust Std err	Robust t-test	p-value	
ASC_APAX	-1.70	0.262	-6.50	0.00		0.260	-6.55	0.00	
ASC_DAT	-4.19	0.587	-7.15	0.00		0.479	-8.76	0.00	
ASC_SOV	-0.765	0.248	-3.09	0.00		0.243	-3.14	0.00	
ASC_WALK	0.00	fixed							
ASC_WAT	-1.29	0.575	-2.25	0.02		0.575	-2.25	0.02	
B_APAX_TT	-0.0431	0.0197	-2.19	0.03		0.0178	-2.42	0.02	
B_CAP_APAX	-1.43	0.333	-4.30	0.00		0.331	-4.32	0.00	
B_CAP_SOV	-2.34	0.356	-6.57	0.00		0.381	-6.14	0.00	
B_DDENSITY10K_APAX	-0.263	0.0611	-4.31	0.00		0.0606	-4.34	0.00	
B_DDENSITY10K_SOV	-0.312	0.0558	-5.60	0.00		0.0535	-5.83	0.00	
B_D_CBD_PT	0.836	0.259	3.22	0.00		0.248	3.38	0.00	
B_D_CBD_SOV	-0.176	0.127	-1.39	0.16	*	0.130	-1.36	0.18	*
B_ODENSITY10K_APAX	-0.199	0.0646	-3.08	0.00		0.0657	-3.03	0.00	
B_ODENSITY10K_SOV	-0.270	0.0570	-4.73	0.00		0.0548	-4.92	0.00	
B_O_CBD_APAX	-0.736	0.182	-4.05	0.00		0.183	-4.02	0.00	
B_O_CBD_SOV	-0.817	0.166	-4.91	0.00		0.170	-4.80	0.00	
B_PT_FARES_DIST	-1.01	0.187	-5.38	0.00		0.187	-5.39	0.00	
B_PT_IVTT_DIST	-0.113	0.0427	-2.65	0.01		0.0444	-2.55	0.01	
B_PT_IVTT_DIST_HIGHINC	-0.0371	0.0422	-0.88	0.38	*	0.0394	-0.94	0.35	*
B_PT_IVTT_DIST_MIDHIGHINC	-0.0665	0.0359	-1.85	0.06	*	0.0364	-1.83	0.07	*
B_PT_WAITT	-0.0452	0.0369	-1.22	0.22	*	0.0474	-0.95	0.34	*
B_PT_XFERWT	-0.0582	0.0314	-1.85	0.06	*	0.0327	-1.78	0.08	*
B_SOV_TT	-0.0329	0.0195	-1.69	0.09	*	0.0175	-1.88	0.06	*
B_VEHPRK_APAX	0.0140	0.141	0.10	0.92	*	0.148	0.09	0.92	*
B_VEHPRK_SOV	0.303	0.127	2.38	0.02		0.129	2.34	0.02	
B_WALK_TT	-0.101	0.00638	-15.83	0.00		0.00706	-14.31	0.00	
B_WAT_WALKT	-0.0990	0.0225	-4.40	0.00		0.0228	-4.34	0.00	

**Table 4–11 NHBO Mode Choice Model Estimation for 1990**

Name	Value	Std err	t-test	p-value		Robust Std err	Robust t-test	p-value	
ASC_APAX	-0.815	0.354	-2.30	0.02		0.345	-2.36	0.02	
ASC_DAT	-2.91	0.661	-4.40	0.00		0.708	-4.11	0.00	
ASC_SOV	-0.836	0.320	-2.61	0.01		0.303	-2.75	0.01	
ASC_WALK	0.00	fixed							
ASC_WAT	-0.492	0.658	-0.75	0.45	*	0.880	-0.56	0.58	*
B_APAX_COST_INC	-0.0590	0.183	-0.32	0.75	*	0.143	-0.41	0.68	*
B_APAX_TT	-0.0474	0.0273	-1.74	0.08	*	0.0274	-1.73	0.08	*
B_CAP_APAX	-1.82	0.310	-5.87	0.00		0.302	-6.03	0.00	
B_CAP_SOV	-1.95	0.356	-5.49	0.00		0.344	-5.67	0.00	
B_DDENSITY10K_APAX	-0.268	0.0720	-3.72	0.00		0.0734	-3.66	0.00	
B_DDENSITY10K_SOV	-0.265	0.0761	-3.48	0.00		0.0763	-3.47	0.00	
B_D_CBD_APAX	-0.819	0.224	-3.65	0.00		0.210	-3.89	0.00	
B_D_CBD_PT	0.267	0.282	0.95	0.34	*	0.267	1.00	0.32	*
B_D_CBD_SOV	-0.656	0.234	-2.80	0.01		0.219	-2.99	0.00	
B_HHSIZ_APAX	0.219	0.0313	6.99	0.00		0.0330	6.64	0.00	
B_ODENSITY10K_APAX	-0.188	0.0780	-2.41	0.02		0.0785	-2.40	0.02	
B_ODENSITY10K_SOV	-0.269	0.0833	-3.23	0.00		0.0807	-3.34	0.00	
B_PT_FARES_DIST	-0.549	0.165	-3.33	0.00		0.327	-1.68	0.09	*
B_PT_IVTT_DIST	-0.0474	0.0410	-1.16	0.25	*	0.0353	-1.34	0.18	*
B_PT_IVTT_DIST_HIGHINC	-0.0842	0.0621	-1.36	0.18	*	0.0716	-1.18	0.24	*
B_PT_IVTT_DIST_MIDHIGHINC	-0.0746	0.0372	-2.00	0.05		0.0380	-1.97	0.05	
B_PT_WAITT	-0.121	0.0440	-2.76	0.01		0.0405	-2.99	0.00	
B_PT_XFERWT	-0.103	0.0452	-2.28	0.02		0.0441	-2.34	0.02	
B_SOV_COST_INC	-0.290	0.191	-1.52	0.13	*	0.154	-1.88	0.06	*
B_SOV_TT	-0.0480	0.0274	-1.75	0.08	*	0.0274	-1.75	0.08	*
B_TERM_J_APAX	-0.0758	0.0760	-1.00	0.32	*	0.0739	-1.03	0.31	*
B_TERM_J_SOV	-0.109	0.0795	-1.37	0.17	*	0.0757	-1.44	0.15	*
B_VEPPER_APAX	0.268	0.244	1.10	0.27	*	0.247	1.09	0.28	*
B_VEPPER_SOV	1.18	0.231	5.11	0.00		0.228	5.16	0.00	
B_VEPPER_WAT	-0.359	0.291	-1.24	0.22	*	0.280	-1.28	0.20	*
B_WALK_TT	-0.0863	0.00714	-12.09	0.00		0.00773	-11.16	0.00	
B_WAT_WALKT	-0.0753	0.0248	-3.03	0.00		0.0292	-2.58	0.01	

**Table 4–12 Estimated Values of Time for 1990**

Income groups	HBW	HBO	NHBW	NHBO
Low & Middle income	6.17	7.95	6.71	5.18
Mid-High income	5.97	15.11	10.67	13.33
High income	8.34	13.02	8.92	14.38

## **References**

Han, Y. (2015) Temporal transferability assessments of vehicle ownership models and trip generation models for Boston Metropolitan Area. Thesis, MST & MCP, Massachusetts Institute of Technology, Department of Urban Studies and Planning, June.