Impact of Free Parking, Transit Accessibility, and Socio-Demographic Attributes on Mode Choice in Toronto

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Outline

- Introduction of the problem
- Trends in mode-split, housing typology, and auto ownership
- Multinomial logit model of mode choice
- Conclusions

Introduction

- Analysis of the impact of free parking, transit accessibility, and socio-demographic attributes on mode choice of **motorized** commute trips that started and terminated in Toronto.
- Non-motorized commute trips during the AM peak period represent a very small segment of the market. Such trips have been excluded from the analysis.
- The analysis is based on a disaggregate database of 21,000 commute trips made during the morning peak period.
- Proximity to transit and other locational factors were added to the database using GIS.

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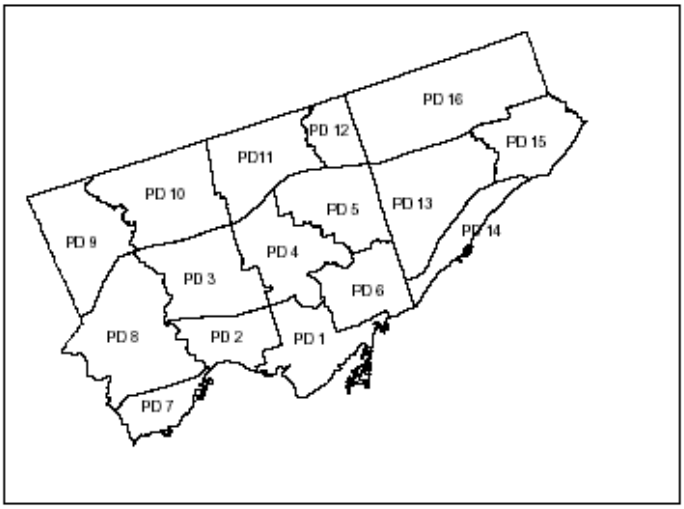
Study Area: Planning Districts in the City of Toronto



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Data

- Data were extracted from the 1996 Transportation Tomorrow Survey (TTS). The Joint Program in Transportation at the University of Toronto maintains the database, which represents a 5% sample.
- This paper focuses on mode choice decisions for motorized commute (work) trips made during the morning peak period (6:00 am – 8:59 am) in the City of Toronto, which has a population of 2.5 million people with an average gross density of 10,000 persons per square mile.
- Using Geographic Information Systems, TTS data are enriched by adding details on proximity to subway system at the origin and destination of each trip.

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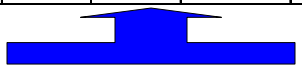
Impact of various factors on mode choice

		Mode Choice			Total	Average
		Transit	Auto Driver	Auto Passenger		Distance
Free Parking at Work						
No	Count	5403	2636	893	8932	
	% within	60.49	29.51	10.00	100	
Yes	Count	2233	8470	1187	11890	
	% within	18.78	71.24	9.98	100	
Sex						
Female	Count	4759	4269	1564	10592	
	% within	44.93	40.30	14.77	100	
Male	Count	2982	6878	536	10396	
	% within	28.68	66.16	5.16	100	
Occupation						
General Office / Clerical	Count	1887	1437	419	3743	
	% within	50.41	38.39	11.19	100	
Manufacturing / Construction/ Trades	Count	1122	2347	521	3990	
	% within	28.12	58.82	13.06	100	
Professional / Management / Technical	Count	3326	5583	739	9648	
	% within	34.47	57.87	7.66	100	
Retail Sales and Service	Count	1381	1770	414	3565	
	% within	38.74	49.65	11.61	100	
Employment Status						
Full time	Count	7115	10429	1919	19463	
	% within	36.56	53.58	9.86	100	
Part time	Count	585	531	160	1276	
	% within	45.85	41.61	12.54	100	
Total						
	Count	7741	11147	2100	20988	8.63 km
	% within	36.88	53.11	10.01	100	



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Housing Type Decision and Household Size

			Dweling Type			Total
			House	Apartment	Townhouse	
Persons in Household	1 person household	Count	620	1730	72	2422
		% within Persons in Household	25.6%	71.4%	3.0%	100.0%
	2 person household	Count	3014	2677	270	5961
		% within Persons in Household	50.6%	44.9%	4.5%	100.0%
	3 person household	Count	3025	1381	252	4658
		% within Persons in Household	64.9%	29.6%	5.4%	100.0%
	4 person household	Count	3439	1052	289	4780
		% within Persons in Household	71.9%	22.0%	6.0%	100.0%
	5 person household	Count	1549	334	154	2037
		% within Persons in Household	76.0%	16.4%	7.6%	100.0%
	6 person household	Count	578	127	42	747
		% within Persons in Household	77.4%	17.0%	5.6%	100.0%
	7 person household	Count	189	25	20	234
		% within Persons in Household	80.8%	10.7%	8.5%	100.0%
	8 person household	Count	59	6	21	86
		% within Persons in Household	68.6%	7.0%	24.4%	100.0%
	9 person household	Count	50	5	8	63
		% within Persons in Household	79.4%	7.9%	12.7%	100.0%
Total		Count	12523	7337	1128	20988
		% within Persons in Household	59.7%	35.0%	5.4%	100.0%

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Auto-Ownership and Dwelling Type

			Dweling Type			Total
			House	Apartment	Townhouse	
Vehicles in Household	0	Count	721	1824	89	2634
		% within Vehicles in Household	27.373	69.248	3.379	100
	1	Count	4842	4162	614	9618
		% within Vehicles in Household	50.343	43.273	6.384	100
	2	Count	5383	1229	361	6973
		% within Vehicles in Household	77.198	17.625	5.177	100
	3	Count	1223	110	51	1384
		% within Vehicles in Household	88.367	7.948	3.685	100
	4	Count	277	5	10	292
		% within Vehicles in Household	94.863	1.712	3.425	100
	5	Count	50	7	2	57
		% within Vehicles in Household	87.719	8.772	3.509	100
Total		Count	12523	7337	1128	20988
		% within Vehicles in Household	59.667	34.958	5.374	100

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Dwelling Type-Mode Choice Tabulations

			Mode Choice			
			Transit	Auto Driver	Auto Passenger	Total
Dweling Type	House	Count	3877	7363	1274	12514
		% within Dweling Type	31.0%	58.8%	10.2%	100.0%
	Apartment	Count	3432	3214	689	7335
		% within Dweling Type	46.8%	43.8%	9.4%	100.0%
	Townhouse	Count	431	562	135	1128
		% within Dweling Type	38.2%	49.8%	12.0%	100.0%
Total		Count	7740	11139	2098	20977
		% within Dweling Type	36.9%	53.1%	10.0%	100.0%

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Proximity to Transit

Proximity to Transport	Indicator	Observations	Trip Distance	%age N
Origin within 250m of SW_STN	No	19953	8.73	95.07
	Yes	1035	6.47	4.93
Origin within 500m of SW_STN	No	18084	8.92	86.16
	Yes	2904	6.75	13.84
Origin within 500m of SW Line	No	17107	9.00	81.51
	Yes	3881	6.96	18.49
Origin within 1 km of SW Line	No	14244	9.33	67.87
	Yes	6744	7.13	32.13
Origin within 1 km of HW	No	16041	8.60	76.43
	Yes	4947	8.69	23.57
Origin within 2 km of HW	No	11007	8.67	52.44
	Yes	9981	8.57	47.56
Destn within 250m of SW_STN	No	14890	8.38	70.95
	Yes	6098	9.21	29.05
Destn within 500m of SW_STN	No	12525	8.34	59.68
	Yes	8463	9.04	40.32
Destn within 500m of SW Line	No	12151	8.35	57.89
	Yes	8837	9.00	42.11
Destn within 1 km of SW Line	No	10153	8.37	48.38
	Yes	10835	8.86	51.62
Destn within 1 km of HW	No	12246	8.36	58.35
	Yes	8742	9.00	41.65
Destn within 2 km of HW	No	7254	8.18	34.56
	Yes	13734	8.85	65.44
Origin-Destination within 250 m of SW STN	No	20603	8.68	98.17
	Yes	385	5.35	1.83

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Proximity to Transit and Mode-split - 1

			Mode Choice			Total
			Transit	Auto Driver	Auto Passenger	
Origin within 250m of SW_STN	No	Count	7229	10685	2039	19953
		% within	36.23	53.55	10.22	100
	Yes	Count	512	462	61	1035
		% within	49.47	44.64	5.89	100
Origin within 500m of SW_STN	No	Count	6244	9946	1894	18084
		% within	34.53	55.00	10.47	100
	Yes	Count	1497	1201	206	2904
		% within	51.55	41.36	7.09	100
Origin within 500m of SW Line	No	Count	5777	9506	1824	17107
		% within	33.77	55.57	10.66	100
	Yes	Count	1964	1641	276	3881
		% within	50.61	42.28	7.11	100
Origin within 1 km of SW Line	No	Count	4611	8087	1546	14244
		% within	32.37	56.77	10.85	100
	Yes	Count	3130	3060	554	6744
		% within	46.41	45.37	8.21	100
Origin within 1 km of HW	No	Count	6022	8416	1603	16041
		% within	37.54	52.47	9.99	100
	Yes	Count	1719	2731	497	4947
		% within	34.75	55.21	10.05	100
Destn within 250m of SW_STN	No	Count	4172	9127	1591	14890
		% within	28.02	61.30	10.69	100
	Yes	Count	3569	2020	509	6098
		% within	58.53	33.13	8.35	100

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Proximity to Transit and Mode-split - 2

			Mode Choice			Total
			Transit	Auto Driver	Auto Passenger	
Destn within 500m of SW_STN	0	Count	2938	8193	1394	12525
		% within	23.46	65.41	11.13	100
	1	Count	4803	2954	706	8463
		% within	56.75	34.90	8.34	100
Destn within 500m of SW Line	No	Count	2824	7967	1360	12151
		% within	23.24	65.57	11.19	100
	Yes	Count	4917	3180	740	8837
		% within	55.64	35.99	8.37	100
Destn within 1 km of SW Line	No	Count	2101	6914	1138	10153
		% within	20.69	68.10	11.21	100
	Yes	Count	5640	4233	962	10835
		% within	52.05	39.07	8.88	100
Destn within 1 km of HW	No	Count	4375	6627	1244	12246
		% within	35.73	54.12	10.16	100
	Yes	Count	3366	4520	856	8742
		% within	38.50	51.70	9.79	100
O-D within 250 m	No	Count	7482	11045	2076	20603
		% within	36.32	53.61	10.08	100
	Yes	Count	259	102	24	385
		% within	67.27	26.49	6.23	100
Total		Count	7741	11147	2100	20988
		% within	36.88	53.11	10.01	100

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Modelling Framework

- Logistic regression: $Prob(Y_i = j) = \frac{e^{\beta_j' x_i}}{\sum_{k=0}^{J} e^{\beta_k' x_i}}$
- J log-odds ratios: $\ln\left[\frac{P_{ij}}{P_{i0}}\right] = \beta_j' x_i$
- Wald Statistics: $\left(\frac{Coefficient}{SE}\right)^2$
- McFadden's Rho-squared: $R^2_{McFadden} = \frac{l(0) - l(B)}{l(0)} = 1 - \frac{l(B)}{l(0)}$
  - Where *l(0)* is the kernel of the log-likelihood of the intercept-only model (only information in the model are sample shares), while *l(B)* is the kernel of the log-likelihood of the final model.

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Mode Choice Model

		B	Std. Error	Wald	df	Sig.	Exp(B)
	Mode Choice						
Intercept	Auto Passenger	-3.773	0.169	501.062	1	0.000	
	Auto Driver	-3.361	0.152	490.516	1	0.000	
N_VEHICL	Auto Passenger	0.399	0.047	70.866	1	0.000	1.490
	Auto Driver	1.888	0.043	1912.989	1	0.000	6.609
N_LICENC	Auto Passenger	0.219	0.037	35.420	1	0.000	1.244
	Auto Driver	-0.925	0.034	731.739	1	0.000	0.397
[O_STN500=0]	Auto Passenger	0.372	0.085	18.977	1	0.000	1.450
	Auto Driver	0.161	0.064	6.318	1	0.012	1.175
[D_STN500=0]	Auto Passenger	0.548	0.090	36.752	1	0.000	1.730
	Auto Driver	0.709	0.074	91.212	1	0.000	2.031
[CBD=.00]	Auto Passenger	0.607	0.074	67.175	1	0.000	1.834
	Auto Driver	0.941	0.058	260.949	1	0.000	2.563
[NEWURB=0]	Auto Passenger	-0.616	0.070	77.826	1	0.000	0.540
	Auto Driver	-0.272	0.066	17.003	1	0.000	0.762
[TRANPASS=0]	Auto Passenger	1.862	0.109	289.417	1	0.000	6.436
	Auto Driver	2.814	0.105	723.287	1	0.000	16.683
MALE =1	Auto Passenger	-0.631	0.061	108.288	1	0.000	0.532
	Auto Driver	0.692	0.046	226.884	1	0.000	1.998
[CONDO=0]	Auto Passenger	0.177	0.062	8.246	1	0.004	1.193
	Auto Driver	0.331	0.051	41.722	1	0.000	1.393
NO FREE PARK	Auto Passenger	-0.626	0.063	98.137	1	0.000	0.535
	Auto Driver	-1.450	0.053	750.194	1	0.000	0.234
[LICENCE=0]	Auto Passenger	-0.132	0.072	3.338	1	0.068	0.877
	Auto Driver	-8.691	0.724	144.160	1	0.000	0.000
[D_SW1K=0]	Auto Passenger	0.147	0.091	2.575	1	0.109	1.158
	Auto Driver	0.280	0.079	12.558	1	0.000	1.323

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Goodness of Fit Statistics

Pseudo R-Square	
Cox and Snell	0.5407
Nagelkerke	0.6396
McFadden	0.4168

Model Fitting Information				
Model	**2-2LL**	**Chi-Square**	**df**	**Sig.**
Intercept Only	23840.34			
Final	7649.90	16190.44	24	0

	Predicted			
Observed	**Auto Passenger**	**Auto Driver**	**Transit**	**Percent Correct**
Auto Passenger	220.00	942.00	916.00	10.59
Auto Driver	52	10081	965	90.8361867
Transit	144	1467	6023	78.89703956
Overall Percentage	2.00	60.02	37.98	78.44

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Model Findings - 1

- The estimated coefficient measures the change in log-odds, e.g., LN[Prob(auto-drive)/Prob(transit)]. Whereas exp(log-odds) gives the odd ratio: Prob(auto-drive)/Prob(transit)].
- Commuters with no parking at work are less likely either to drive or to be a passenger in an automobile. The odds of commuters with free parking to drive against taking transit are 4.27 times higher than the odds for those without parking.
- Similarly, the odds of commuters with free parking to be auto-passenger against taking transit are 2.1 times higher than that of those without free parking.

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Model Findings - 2

- A standard deviation increase in the number of vehicles owned by the household increases the odds of driving against transit by 560%. The odds of being auto-passenger increase by 49%.
- An increase of one standard deviation in the number of licensed drivers in the household increases the odds of being an auto-passenger by 24.4%.
- Interestingly enough the odds of driving to work against transit decrease with a standard deviation increase in the number of licensed drivers in the household.
  - This is perhaps because the model is controlling for household automobile ownership as well.

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Model Findings - 3

- The odds of auto-drive mode for commute trips that do not terminate in CBD are 2.56 times higher than those trips that terminate in CBD.
  - Similarly, the odds of auto-passenger mode against transit are 1.83 times higher for trips that terminate outside of CBD than the rest.
- The odds of commute trips by transit are much higher for trips that originate or terminate in proximity of subway stations and subway line.
- The odds of auto-driver against transit for trips that terminate at more than 500-meters away from a subway station are 2 times higher than those that terminate within 500 meters of a subway station.

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Model Findings - 4

- The odds of males being auto-drivers against transit are 2 times higher than the odds for females.
- Similarly, the odds for males being auto-passengers against taking transit are much lower.
- Commuters who do not live in condominiums or high rises are likely to drive or be auto passenger.
- Commuters with a valid driver's license are also more likely to be auto-passengers than to ride transit.

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Model Findings – 5

- The model did not improve when employment status (full time against part time) is introduced.
- Similarly, age as a continuous or categorical variable does not improve the model fit.
- The model is 91% correct in predicting auto drive mode
- 79% correct in predicting transit trips.
- However, the model fails to predict auto-passenger trips correctly.
  - Groups of unequal sizes in multinomial logit model (e.g., auto-passenger represents only 10% of the total observations) presents unique problem where cases are often classified to the larger group. Overall, the model is 78% correct.

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Conclusions

- Most trip-makers (57%) have reported access to free parking at their work for home-based work trips.
- Almost 85% commuters with access to free parking drove to work against 30% of those without access to free parking.
- Female commuters are more likely to take transit to work, while most male commuters prefer to drive to work.
- Proximity to subway system in Toronto increases the likelihood of transit mode split.
- Proximity to subway system at destination results in higher transit mode split than proximity at the origin.

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Conclusions - 2

- Most one-person households who do not own private automobiles live in high-rise buildings.
- Similarly, most residents of high-rise buildings take transit to work.
- The implicit relation between housing topology and mode choice is further explored in a multinomial logit model.

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