Car, Bus, Bike, or Walk… What are the Drivers of Mode Choice Decisions in Kelowna?

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Abstract

Discrete mode choice models are usually established for major urban areas with complex transportation systems and not often used for smaller auto-oriented communities, mainly because of lack of appropriate behavioural data and dominant auto mode choice. Unlike many regions of the same size, the Sustainable Transportation Partnership of the Central Okanagan (STPCO) has a regional demand forecasting model and rich trip diary database. However, the current mode choice model has potential to be improved and further analysis to the data can provide more insights about the reasons behind modal choice decisions in smaller communities.

In this study, two discrete mode choice models are developed to understand passengers' preferences and mode choices for work and non-work trips in the City of Kelowna. Data comes from the 2013 Okanagan Travel Survey, the most recent household-based trip diary survey that was conducted in fall 2013 and covered a sample of residents of the Central Okanagan and the City of Vernon. The dataset includes information on the trip (e.g. trip purpose, mode, time, length, etc.) and the trip maker (e.g. age, gender, income, etc.). The developed models provided insights into trip makers' choices and the tradeoffs they make among different attributes when choosing a mode of travel. In light of the developed models, recommendations are made to support effective transportation planning policies and prioritization of transportation investments in the city.

Introduction

The Central Okanagan region of British Columbia's interior is a well-known destination for tourists from all over the world. The City of Kelowna is located at approximately the midpoint of the Okanagan Valley south of Vernon, north of Penticton and borders Okanagan Lake, as seen in Figure 1. Kelowna is the largest city in the Okanagan Valley and is home to approximately 123,500 people with population increasing in summer months due to tourists and seasonal dwellers. The city is known for its orchards and vineyards as well as many other attractions such as fine dining, golfing, hiking areas and water activities such as boating, swimming, and fishing.

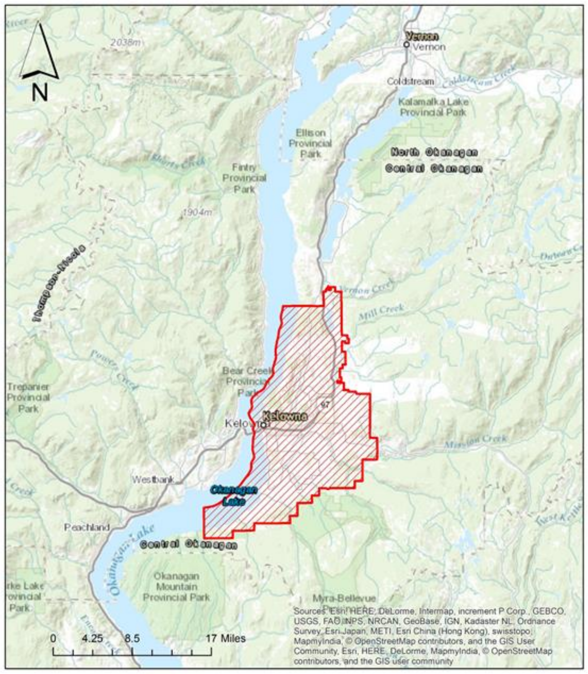

Figure 1 - Map of Central Okanagan

One of Kelowna's main goals, as documented in the 2030 Official Community Plan (OCP), is to implement a more balanced transportation network with increased attractiveness, convenience, and safety for all network users. In more specific terms, the city strives to provide the required infrastructure to support all modes of transportation and reduce peak hour single occupancy vehicle trips (City_of_Kelowna 2011). In 2014, the city allocated a budget of approximately $32.1M for transportation services (City_of_Kelowna 2015b). In order to achieve OCP goals and maximize spending efficiency, it is imperative that the city prioritize funding transportation infrastructure. As such, research is required to understand the drivers of mode choice decisions in Kelowna.

When people decide to make a trip, they choose among a set of different "modes" of transportation including: walking, cycling, public transit, car passenger, car driver, etc. This mode choice behaviour is influenced by various factors related to the passengers themselves, competing modes, and land use. Understanding the relative importance of these factors to travellers can help city planners make policy decisions that ensure the best marginal gain due to transportation investments.

Mode choice is considered one of the most important stages of transportation planning not only for its profound underlying theoretical foundation, but also for providing means to understanding passengers' travel behaviour, which is key to policy making. Discrete mode choice models are usually established for major urban areas with complex transportation systems and not often used for smaller auto-oriented cities such as Kelowna, mainly because of lack of appropriate behavioural data and dominant auto mode choice.

The current mode choice model for Kelowna is very simple and only used as an input to the Regional Model; therefore, it has potential to be improved. Further analysis to the 2013 Okanagan Travel Survey can provide more insights into the reasons behind modal choice decisions in smaller communities. In an attempt to address this problem, and to take advantage of the behavioural data available, this study aims at developing mode choice models for different trip purposes in Kelowna. In specific, two mode choice models are developed for work and non-work trips taking place in the city. The developed models will support effective transportation planning policies and prioritization of transportation investments in Kelowna.

Using the developed models, the determinants of passengers' transportation mode selections for various trip purposes and lengths will be defined. Understanding the factors that influence travellers' mode choices will inform transportation planners' decisions and will help promote sustainable and efficient transportation for Kelowna. For example, if transit users are found to be more sensitive to the waiting time component of their trips, policies that focus on improving the waiting experience on transit stops would increase customer satisfaction and may ultimately lead to higher transit modal share.

Literature Review

Travel demand forecasting models are at the heart of transportation planning and have evolved over many years. The earliest models used to analyze transportation demand were unimodal, concerned with predicting vehicular traffic. In the late 1960s, there was a shift in transportation demand modelling from unimodal to multimodal approaches that consider operational policies, construction of new infrastructure, and pricing. The commencement of discrete choice models was considered a major advancement in travel demand modelling (Ben-Akiva and Lerman 1985). The first discrete mode choice model to include a binary mode choice between car and transit for a given trip was applied by (Warner 1962).

Disaggregate travel demand models are directly estimated using micro-level data (typically household travel surveys) without prior aggregation. These disaggregate models are advantageous in demand analysis as they allow reliable estimates for a wider range of explanatory variables (Ben-Akiva and Lerman 1985; Ortuzar and Willumsen 2011). This enables planners to consider possible policy implications for several socio-economic variables such as car ownership or annual household income.

In order to forecast travel demand (mainly mode choice), transportation planners need to consider factors affecting trip makers' utilities (measure of satisfaction) associated with each mode of travel. According to the Random Utility Maximization (RUM) Theory, utilities are stochastic to the planner while choice strategies are deterministic from the trip maker's perspective. Mode choice decisions can be conceptualized under the RUM framework as follows: when a traveller faces a choice situation among a set of available modes, (s)he assigns weights to the different factors characterizing each mode. Finally, the traveller selects the mode that maximizes her/his utility (with a higher probability of selection) considering her/his sociodemographic characteristics as well as level-of-service attributes of the competing modes (Ben-Akiva and Lerman 1985; Ben-Akiva and Bierlaire 1999; Ortuzar and Willumsen 2011).

Discrete mode choice models are a popular econometric modeling tool used for predicting behavior and estimating travel demand (Ben-Akiva and Lerman 1985). Over the years, numerous RUM-based mode choice models have been developed with various types and mathematical formulations. The simplest form of which is the Multinomial Logit (MNL) model, considering error terms to be Independently and Identically Distributed (IID) following the double exponential (Gumbel Type I extreme value) distribution (Ben-Akiva and Bierlaire 1999; Chih-Wen 2005).

In this research, the MNL modelling approach is adopted for developing two models considering multiple different factors that influence passengers' preferences and travel behaviour in Kelowna. Using the developed models, recommendations are made for policy making in the city.

Dataset

The dataset used in this investigation come from the 2013 Okanagan Household Travel Survey. The dataset is very rich and includes information at the trip, household, and personal levels of over 22,000 observations. At the trip level, the dataset provides information on trip origins, destinations, durations, distances, trip purpose, and mode choice. Household level information includes family income, family size, dwelling type, bike ownership, and vehicle ownership. At the personal level, data provided information on age, gender, occupation, etc. Table 1 below depicts the overall statistics of the collected sample with many of the selected variables that were used in the modelling process.

Missing data was imputed based on prior trip attributes. This means that for each missing data observation, attributes of the prior trip made by the same person were used to impute missing data. If the trip missing data is the only trip made by that individual, all the other variables for that trip would be examined and used to estimate any missing data. If data entries were missing location values they were excluded from the subsets as they gave inaccurate information. After cleaning all the subsets, the total number of trip observations was reduced from 22,441 to 21,507.

Data for this investigation was extracted based on geography and grouped according to trip purpose. The resulting subsets include work and non-work trips undertaken in Kelowna. A Kelowna trip is defined as any trip that has both its origin and destination within the City of Kelowna. A trip is labelled as a work trip if it is home-based, and is destined or originates at work or school. A work or school trip is characterised by its routine nature. A non-work trip, on the other hand, is defined as any trip that does not involve work or school such as a shopping trip, going to the bank, doctor's appointment, etc.

Table 1 - Sample Descriptive Statistics

Descriptive Statistics				
Variable	**Value**	**Description**	**Sample Size**	**Percentage**
Dwelling Type	1	Single Detached House	16,230	72.32%
	2	Apartment or Condo	2,696	12.01%
	3	Townhouse or Row House	2,280	10.16%
	4	Duplex	733	3.27%
	5	Mobile Home	502	2.24%
Number of People in Household	1	1 Person	2,233	9.95%
	2	2 People	10,009	44.60%
	3	3 People	3,666	16.34%
	4	4 People	4,582	20.42%
	5	5 People	1,432	6.38%
	6	6 People	406	1.81%
	7	7 People	97	0.43%
	8	8 People	16	0.07%
Annual Household Income	1	Less than $25,000	1,503	6.70%
	2	$25,000 to Less than $45,000	3,089	13.76%
	3	$45,000 to Less than $65,000	4,102	18.28%
	4	$65,000 to Less than $100,000	6,637	29.58%
	5	$100,000 or more	5,984	26.67%
	-999	Not selected	1,126	5.02%
Number of Vehicles in the Household	0	0 Vehicles Owned	592	2.64%
	1	1 Vehicles Owned	6,113	27.24%
	2	2 Vehicles Owned	10,343	46.09%
	3	3 Vehicles Owned	3,709	16.53%
	4	4 Vehicles Owned	1,238	5.52%
	5	5 Vehicles Owned	332	1.48%
	6	6 Vehicles Owned	92	0.41%
	7	7 Vehicles Owned	0	0.00%
	8	8 Vehicles Owned	10	0.04%
	9	9 Vehicles Owned	12	0.05%
Number of Bikes in the Household	0	0 Bikes Owned	4,622	20.60%
	1	1 Bikes Owned	3,537	15.76%
	2	2 Bikes Owned	5,422	24.16%
	3	3 Bikes Owned	2,847	12.69%
	4	4 Bikes Owned	3,359	14.97%
	5	5 Bikes Owned	1,203	5.36%
	6	6 Bikes Owned	826	3.68%
	7	7 Bikes Owned	257	1.15%
	8	8 Bikes Owned	237	1.06%

	9	9 Bikes Owned	131	0.58%
Trip Purpose	1	To Work / Work meeting	3,518	15.68%
	2	To School	0	0.00%
	3	To a Restaurant	627	2.79%
	4	For Recreation (gym, swimming, etc.)	1,079	4.81%
	5	For a Social outing / Meeting friends	802	3.57%
	6	For Shopping	2,492	11.10%
	7	For Personal business (bank, doctor, etc.)	1,549	6.90%
	8	To Home	7,943	35.40%
	9	To drive or pick-up someone	1,684	7.50%
	10	Other	1,199	5.34%
	11	Grad School	862	3.84%
	12	Post-Secondary School	579	2.58%
	-999	Not selected	107	0.48%
Gender	1	Male	9,766	43.52%
	2	Female	12,630	56.28%
	0	Did Not Specify	45	0.20%
Age (in years)	1	00-04	0	0.00%
	2	05-14	2,099	9.35%
	3	15-24	2,210	9.85%
	4	25-34	2,877	12.82%
	5	35-44	3,635	16.20%
	6	45-54	3,859	17.20%
	7	55-64	4,421	19.70%
	8	65 and over	3,293	14.67%
	99	Unknown	47	0.21%
Has a Bus Pass	0	Did Not Specify	45	0.20%
	1	Yes	1,513	6.74%
	2	No	20,883	93.06%
Driver's License Holding	0	Did Not Specify	45	0.20%
	1	Yes	19,165	85.40%
	2	No	1,321	5.89%
	3	Not old enough to drive.	1,910	8.51%
Work	1	Full Time	9,544	42.53%
	1	Part Time	3,379	15.06%
	1	School Full Time	3,608	16.08%
	1	School Part Time	301	1.34%
	1	Not Working	934	4.16%
	1	Retired	4,661	20.77%

Mode Choice Modelling

After a series of specification tests, the subsets were used to develop disaggregate Multinomial Logit (MNL) models using Biogeme. Biogeme is an open source freeware designated for maximum likelihood estimation of parametric models, specifically discrete choice models (Bierlaire 2003). The developed models are derived from the fundamental Random Utility Maximization (RUM) Theory, such that:

$$V_{mode} = ASC + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_n X_n,$$

where:
V_{mode}: utility function for a specific mode
ASC: Alternative Specific Constant
β: parameter value
X: explanatory variable

Models were developed using a stepwise approach. In other words, utility functions were constructed by adding or removing one variable at a time. Within the stepwise approach, forward selection and backward elimination strategies were implemented. Forward selection is the process of adding variables based on the significance of their estimated coefficients until all suitable variables are incorporated. Backward elimination is the process of beginning with all possible variables in the model and eliminating the least significant ones. The model was deemed satisfactory when a rho-squared value of at least 0.25 and the explanatory parameters were significant.

The current investigation considers six modes as follows: (1) auto driver, (2) auto passenger, (3) public transit, (4) school bus, (5) cycle, and (6) walk. Figure 2 illustrates the overall model structure of the developed mode choice model.

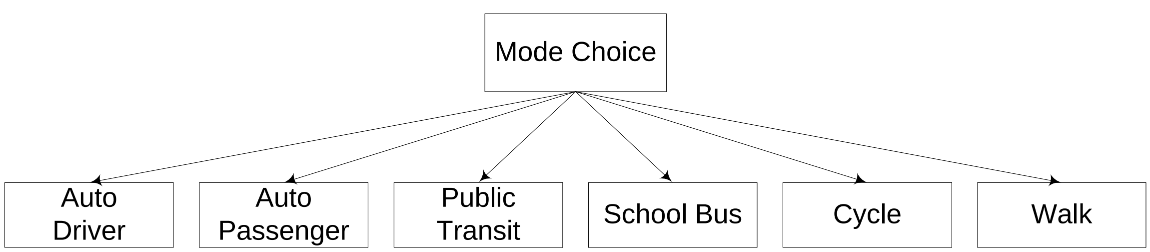

Figure 2. Mode Choice Model Structure

In order to formulate the probabilistic choice model, the distribution of the random component of utility is assumed to be Independently and Identically Distributed (IID) Extreme Value Type I. The previous assumption leads to the following closed form probability of mode selection (Ben-Akiva and Lerman 1985):

$$P_{im} = \frac{e^{V_{im}}}{\sum_{m \in C_i} e^{V_{im}}},$$

where:
P_{im} : Probability that individual (i) selects mode (m)
V_{im}: Utility that individual (i) obtains from mode (m) (i= 1, ..., I ; m, n= 1, …, N)
C_i : Choice set of feasible alternative modes (N) for individual (i)

Separate mode choice models were developed for each subset after examining a set of alternative modelling structures and specifications. The specifications of the final models are derived based on the accommodation of variables with proper signs and statistical significance. The critical value (1.96) of the t-statistic with a 95% confidence limit is considered as the threshold value of considering variables in the model. However, some parameters with t-statistics values lower than 1.96 are retained in the models because the corresponding variables provide considerable insights into the behavioural process. Possible policy implications derived from the models are also presented.

Two MNL models were developed to investigate Kelowna's work and non-work trips mode choice, as shown in Table 3. The developed models estimate the probability that an individual trip-maker will choose any given mode from the set of feasible alternatives described earlier in this section.

Table 2. Kelowna Trips Mode Choice Models Estimation Results

Mode Choice Model for Kelowna Trips		**Mode 1 Work Trips**		**Model 2 Non-Work Trips**	
Rho-Squared Value		**0.560**		**0.631**	
Variable	**Mode**	**Parameter**	**t-Stat**	**Parameter**	**t-Stat**
Alternate Specific Constant	Auto Driver	0	-	0	-
	Auto Passenger	3.57	14.24	1.41	7.41
	Transit	0.312	0.93	-1.14	-2.88
	School Bus	-1.36	-2.87	-	-
	Walk	3.97	15.53	2.31	9.98
	Cycle	1.51	5.07	0.986	2.68
Travel Time	Auto Driver	-0.042	-2.79	-0.0408	-2.03
	Auto Passenger	-0.104	-6.31	-0.0121	-0.59
Travel Distance	Cycle/Walk	-0.702	-19.31	-0.826	-19.54
Driver's Licence Holding	Auto Driver	3.49	17.24	2.55	12.41
	Auto Passenger	-	-	-1.01	-5.69
	Transit	-	-	-0.222	-0.89
	Cycle	-	-	-0.926	-3.01
Bus Pass Holding	Auto Driver	-1.28	-5.98	-1.41	-8.00
	Auto Passenger	-0.628	-2.92	-1.17	-5.90
	Transit	3.16	14.45	1.46	6.11

	Cycle	-0.481	-1.25	-0.685	-2.01
Number of Vehicles per Person	Auto Driver	1.78	11.31	0.496	3.88
	Auto Passenger	-	-	-0.322	-1.90
	Transit	-0.441	-1.62	-1.86	-3.87
	Cycle	-	-	-0.902	-3.33
Zero Household Vehicle Ownership	Auto Driver	-	-	-1.41	-3.16
	Auto Passenger	-	-	-0.658	-1.5
	Transit	-	-	1.00	1.97
	Walk	-	-	1.26	3.14
Number of Bikes per Person	Auto Driver	-0.956	-5.06	-0.161	-3.18
	Auto Passenger	-0.573	-2.99	-	-
	Transit	-0.577	-2.43	-	-
	Walk	-0.503	-2.23	-	-
	Cycle	0.655	3.11	1.04	9.51
Zero Household Bike Ownership	Cycle	-	-	-10.2	-0.31
Annual Household Income	Auto Driver	-	-	0.103	1.31
> $100,000	Transit	-0.465	-2.25	-0.844	-2.15
	Cycle	-	-	0.436	2.20
Annual Household Income $25,000 to $45,000	Transit	0.465	2.27	-	-
Annual Household Income	Transit	-	-	1.08	5.11
< $25,000	Cycle	-	-	1.50	6.35
Trip Purpose:	Auto Driver	-	-	0.589	5.05
Shopping	Auto Passenger	-	-	0.593	4.10
	Transit	-	-	0.474	1.79
Gender:	Auto Passenger	-	-	-0.588	-7.03
Male	Transit	-	-	-0.825	-3.75
	Cycle	0.407	2.62	0.642	3.97
Full-Time Work	Auto Driver	1.22	8.12	-	-
	Auto Passenger	-1.29	-6.32	-	-
	Transit	1.43	6.79	-	-
	Walk	1.71	10.43	-	-
	Cycle	2.68	13.51	-	-
Full-Time School	School Bus	2.47	6.93	-	-
Age < 24	Auto Driver	-	-	0.232	1.29
	Auto Passenger	-	-	1.77	9.71
	Transit	-	-	0.948	3.57
	Cycle	-	-	-0.736	-2.05
Age 65+	Auto Driver	-	-	0.363	2.20
	Auto Passenger	-	-	0.887	4.47
	Transit	-	-	1.74	4.22

	Cycle	-	-	0.779	2.33
Retired	Auto Driver	-	-	-0.507	-3.59
	Auto Passenger	-	-	0.093	0.52
	Transit	-	-	-0.968	-2.35
	Cycle	-	-	0.192	0.65

Given the presented rho-squared value of 0.560 and 0.631 for the work and non-work mode choice models respectively, the developed models have acceptable goodness of fit and explanatory power. The examination of variables in the developed models shows that travel time (trip length for non-motorized options) has correct (negative) sign that match expectations. Attempting to include travel cost in the models resulted in an insignificant wrong signs. This may show that travel cost is not an important factor to motorists in Kelowna when selecting which mode of transportation to use for their work or non-work trips.

The most positive parameters associated with auto driving are driver's license holding and auto ownership (number of vehicles per person). In other words, as obvious as it sounds, if someone have a driver’s licence and owns a car, (s)he will be more likely to drive. This observation is further supported by the negative “zero vehicle ownership” parameter associated with vehicle driver, being positive for other modes. A possible policy implication to shift more trip-makers to more sustainable mode choices is to impose a fee on households that own several vehicles, and also increase the cost or easiness of obtaining a driver’s licence, or promote car sharing in order to reduce vehicle ownership.

It can also be observed that high-income earners are more likely to use the car (especially for shopping trips), compared to mid- and low-income earners who are more likely to use public transit. Travellers may prefer driving for shopping trips as it gives them flexibility especially when they have to carry purchases, which is not the case with active transportation options (i.e. cycling and walking).

The most negative parameter associated with car driving are bus pass holding. By having a bus pass, travellers are less likely to choose to drive for both work and non-work trips. As such, the City of Kelowna could increase transit ridership (especially for work trips) by facilitating bus pass purchases by introducing mobile ticketing and promoting bus pass holding through designated programs such as employee passes or the U-Pass program for university students.

As expected, travel time has a negative associated parameter, but with a limited influence in comparison to other variables. People in Kelowna may prefer driving their vehicle, regardless of the length of trip. This might also reflect Kelowna’s relatively congestion-free transportation network. Similarly, increased distance has a negative effect on cycling and walking as other modes become more appealing for longer trips. The cumulative trip length distribution by mode (Figures 2 and 3) for Kelowna work and non-work subsets show that 95% of walking trips are less than one kilometer and two kilometres respectively.

Interestingly, full-time workers are more inclined towards public transit and active transportation (cycling and walking), with the highest parameter value associated with cycling. It is also clear that bike ownership (number of bikes per person) is one of the most influential parameters in bike mode choice, being positive for bike and negative for other modes. This is further supported by the negative “zero bike ownership” parameter associated with bike. It also seems that males are more inclined to cycle than females. A possible policy would be to introduce a bike-share program to Kelowna. Since Kelowna is a sprawling city with lower density, this policy may be considered only for the downtown core.

By looking at age, it seems that younger people (age < 24) as well as seniors (age 65+) are more likely to be car passengers and can be considered potential users of public transit. Full-time students are more likely to take the school bus.

Conclusions

This paper investigated the factors that influence people's’ mode choices in Kelowna. The investigation made use of data from the 2013 Okanagan Travel Survey, the most recent household-based trip diary that was conducted in fall 2013 and covered a sample of residents of the Central Okanagan and the City of Vernon. The dataset is rich and includes information on the trip (e.g. trip purpose, mode, time, length, etc.) and the trip maker (e.g. age, gender, income, etc.).

Demand forecasting models were developed to be used by transportation planners at the City of Kelowna and the Sustainable Transportation Partnership of the Central Okanagan (STPCO). The developed mode choice models will support evidence-based transportation policymaking and prioritizing future transportation investments.

The modelling results showed that level-of-service attributes (i.e. travel distance, time, and cost) do not seem to be major issue for motorists in the city. This finding reflects Kelowna’s relatively congestion-free transportation network and has substantial policy implications. To attain more balanced transportation choices in the city, policies may not necessarily target changes to the network.

Instead, the developed models showed that imposing fees on households that own several vehicles and hindering driver’s licence holding could shift more trip-makers to more sustainable mode choices. However, alternative options (e.g. car sharing, bike sharing, etc.) should be provided beforehand. In addition, facilitating bus pass purchases and promoting bus pass holding could increase transit ridership (especially for work trips).

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