# Who uses shared mobility services?

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**Abstract**

Shared mobility services such as bike sharing, scooter sharing, car sharing, and ride-hailing can act as a catalyst to improve the quality of urban transportation services. This includes making them more accessible, sustainable, and equitable. With proper regulations and planning, shared mobility can enable cost savings, provide convenience, and reduce vehicle ownership. For this to happen, cities need to understand the users' behaviour – e.g., what factors are affecting this choice of travel mode.

This study focuses on investigating the willingness to use shared mobility services and evaluating the associated socio-demographic characteristics of users. Data comes from a survey conducted in Kelowna, British Columbia, which collected information regarding the usage of a wide array of shared mobility services, travel behaviour and attitude towards shared mobility, driving, land use, among others. Exploratory factor analysis results show that there are 11 attitudinal factors representing individuals' travel characteristics. The multivariate probit model results suggest that based on the correlation coefficient values, there is a positive significant relationship with shared e-bike and shared e-scoter usage and shared e-bike and car share usage. It also suggests that there is a negative significant relationship between public transit usage and ride-hailing usage. Substitution effects confirmed by the model are that public transit usage is associated with shared e-scooter, car share, and ride-hailing modes and shared e-bike usage is associated with public transit usage.

The results of the study can be utilized by cities and transit agencies to improve the availability of shared mobility services to enable efficient usage of sustainable travel modes in our day-to-day lives.

Keywords; Micro-mobility services, Car sharing, Ride hailing, Socio-demographics, Attitudes, Mobility Tool Ownership

## Introduction

The transportation industry is responsible for 27% of greenhouse gas (GHG) emissions in Canada [1]. Although technological advances have made vehicles more fuel efficient in the past decades, car usage has increased, subsequently increasing congestion and our carbon footprint. Citizens are therefore suffering in more ways than one such as congestion, excessive noise, poor road safety, and reduced health [2]. All of these issues have led city planners to search for ways to shift travel behaviour away from personal car usage. One way to do this is to offer affordable, accessible, convenient, and sustainable transportation options. This is where shared mobility services become important.

In 1948, the first version of shared mobility was conceived when a group of families in Zurich, Switzerland purchased a single car to share as they could not afford the costs of individual car ownership [3]. Bike sharing came along in the 1960's in Amsterdam. Since then, shared mobility has continued to evolve alongside technological and societal changes. By today's definition, Shared Mobility Services (SMS) offer transportation alternatives, often on an 'as-need' basis, allowing users to access a variety of mode choices. These SMSs are without the costs and responsibilities associated with private vehicle ownership. These services encapsulate a diverse collection of modes including, but not limited to, public transit, micro-mobility (e.g., shared e-bikes, and e-scooters), car sharing (e.g., Modo), and ride-hailing (e.g., Uber) [4]. Public transit remains the more frequently used mode, thanks to its wide availability and affordability. However, bike sharing, car sharing, and ride-hailing are becoming more prominent [5]. These developments in SMS are closely tied to improvements in technologies (GPS, smartphones, and mobile payment), local policy changes and incentives (such as reserved or free on-street parking for shared vehicles), and economic changes (increasing costs of owning a car) [6].

Given the diversity in shared mobility modes, there exists a research gap in understanding how individuals utilize these different types of shared travel options and what factors influence these decisions. This study performs a comprehensive analysis of usage of a wide range of shared mobility options including transit, micro-mobility and shared vehicle services using a multivariate probit approach. It sheds light on travel choices including individuals' joint decisions to select different shared mobility services, considering their socio-demographic and mobility tool characteristics. As well as their perception towards travel characteristics using exploratory factor analysis. Past literature on travel choices have often covered only micro-mobility options, car-sharing, and ride-hailing, lacking public transit analysis. By including attitudinal analysis, we are able to make in-depth comparisons and identify areas of latent demand among population groups that can help shape future policies and services. Another crux of this research is focusing on a mid-sized city in Canada, which is largely ignored in the existing shared mobility literature. Most of the existing studies have investigated shared mobility usage in the context of large metropolitan cities. This could largely be attributed to a higher concentration and availability of SMSs in larger cities, mainly due to higher population densities and more dependence on alternative sustainable travel modes. In contrast, mid-sized cities are often too car-dependent and show symptoms of urban sprawl, making them unattractive to SMS providers and thus limiting the number of cities where user data is available [2].

However, these smaller municipalities often present a unique opportunity for SMS companies as many of the trips made in these areas are shorter in length [7]. Instead of investing only in transit services, having a variety of shared modes available could increase ridership of sustainable travel modes. Therefore, recently, many mid-sized cities such as Kelowna are promoting and investing in shared mobility options. Due to behavioral and geographical differences, it is evident that shared modes will be used differently in mid-sized cities which warrants separate research targeting these cities. This study fills the gap by focusing on Kelowna - a mid-sized city in the Okanagan region of British Columbia, Canada.

**Literature Review**

Shared mobility can be used as an umbrella term to represent a wide range of shared transportation services including transit, ride-hailing, car sharing, shared e-bike, and shared e-scooter services. Public transit has largely been the backbone of SMS, as it is typically planned to serve commuters' needs to travel to/from work [8]. Other modes of shared services have played a critical role by offering more economic and sustainable travel opportunities while serving a variety of trip purposes. Shared e-scooter, bikes and e-bikes are used for a wide range of purposes such as commuting, social/recreational, and exercise trips [9], [10]. These modes, however, come with more external limitations such as adverse weather conditions and a lack of appropriate built environments that might affect mode choice under different temporal and spatial conditions [9], [11]. Car sharing is mostly used for commuting and shopping trips where people prefer to drive themselves and have access to secure cargo space [6]. Ride-hailing services are mostly used for social and recreational trips, offering a suitable alternative for users who are intoxicated and unable to drive themselves [12], [13]. Trip distance also strongly correlates with the choice of shared mobility mode option. For example, Reck et al analyzed GPS and survey data from Switzerland and found that shared scooters are used for very short distances (with a median distance of 730 m), while shared e-bike and e-bike users cover slightly longer distances (1,292 m and 1,595 m respectively) [11] [14]. On the other hand, vehicle-based trips (buses, car sharing and ride-hailing) allow for longer and more diverse travel ranges, although ride-hailing trips are often still only around 5 km in length [12]. User and non-user attitudes are shown in various studies to impact the willingness to use shared modes. A person's feelings towards driving (enjoyment or stress), data privacy issues, and unfamiliarity with new technology all impact the decision to use ride-hailing services [15], whereas concerns of crowding, timing, and environmental sustainability impact the choice of using transit [16].

Many studies have shown the effects of SMS on vehicle ownership. One survey of car sharing users reported that 37% of respondents indicated that vehicle sharing impacted their decision to own a private vehicle, with 83% of this group expressing that they decided against purchasing a vehicle as a result of the SMS [6]. Meanwhile, a San Francisco survey of ride-hailing users reported that 90% of vehicle owners had not changed their ownership levels since beginning to use ride-hailing [12]. Bike sharing also showed a menial effect on vehicle ownership, with a 2.2% reduction [17].

Shared mobility services have been popular among young people, living in single or two-person households, with medium to high-income levels, and a high level of education [6], [13], [18]–[21]. These groups are mainly people without children (small dwelling size), who have the required technology to access SMS (substantial income), and who have the knowledge required to operate and understand the technology of SMS applications (young and well-educated). Students were often also specifically reported in these groups of frequent users, which could relate to their familiarity with technology, eagerness to experience new things, and the financial burden of owning a vehicle [22]. The current mode choice also correlates to people's willingness to adopt SMS. Public transit users are likely to adopt other modes of shared services, often using them (shared bikes and scooters) to access/egress transit services [22], [23]. Vehicle ownership is another critical factor, as auto drivers often enjoy driving as well as the convenience and flexibility of owning their own vehicle, while the habitual nature of driving often prevents them from switching to shared modes [15].

There are also regional differences that impact the demand for, and uses of, shared mobility that need to be accounted for. Most studies are focused on large metropolitan areas such as Munich, Toronto, Auckland, and Detroit, while little effort is given to their medium-sized counterparts. Medium-sized cities have different transportation needs and responses, thus previous findings from larger cities may not be transferable to these settings [24]. The Government of Canada defines medium-sized cities as ranging from 100,000 to 1 million people, though each country has its own definition of this range [25]. These cities often have more suburban area with lower population densities and smaller downtown cores [26]. This corresponds to higher vehicle ownership and worse transit connectivity associated with the suburbs compared to the urban cores. On one hand, these suburban characteristics impose challenges resulting in lower demand for SMS [27]. On the other hand, the shorter lengths of the trips due to the relatively smaller size of these cities present an opportunity for SMS [28].

Therefore, there exists a research gap to understand the usage of shared mobility services in the context of medium-sized cities. Specifically, there is a need to understand the latent demand for SMS among users and non-users. Here, the latent demand for users could be categorized as the trips (e.g., shorter commute trips) made by other modes by the SMS users. For non-SMS users, the latent demand is the unmet demand for alternative travel methods for an existing trip that shared modes can fill.

## METHODS AND DATA

To understand the usage of different types of shared mobility services, an extensive survey was developed and deployed in Kelowna, Canada. This section goes into further detail about the study area, survey, and preliminary analysis of the data.

### Study Area

Kelowna is a lakefront city in the Okanagan Valley of British Columbia, Canada. It is a mid-sized city with a commercial sector along a linear highway that connects the downtown core, the airport, and other nearby cities, with sprawling suburbs lining the valley hills. As of 2021, Kelowna has a population of 144,576 with an expected population increase of 45,000 by 2040 [29] [30]. Kelowna is a fast-growing metropolitan area [31]. It is also one of the most vehicle-dependent cities in Canada, with more than 80% of the commute trips are made using private vehicles [32]. As the population grows, land use patterns, transportation needs, and demographics will shift, thus there is a growing need for sustainable travel options.

To keep up with these changes, shared modes are being implemented in Kelowna. Recently, companies offering shared e-bikes, e-scooters, car sharing, and ride-hailing have entered the transportation market in Kelowna. They aim to complement the existing shared mode network (i.e., public transit and taxis) while working towards the city's sustainable transportation goals. These goals include reducing car dependency, improving travel options, and enhancing travel affordability [33]. Currently the city has Lime as a shared e-bike and e-scooter provider, Modo as car sharing provider, URide and Lucky to Go as ride-hailing providers, BC Transit as the public transit provider, and multiple taxi companies. Introducing emerging shared modes is associated with both opportunities and challenges that need to be addressed. These include updating policies and regulations, designing new infrastructure to fit the needs of shared modes, and incentivizing low-emission options to increase the ridership of shared mobility services [33].

### Survey Overview

An online survey was conducted to understand the usage of different types of shared mobility options. It targeted people over 18 years of age who live and/or work in Kelowna, Canada. The first wave of the survey was deployed from July 4th to July 18th, 2022. The survey was distributed through social media, as well as through the network of the existing shared mobility service providers. After removing incomplete responses, 375 responses were used for the analysis. Of those 375 respondents, approximately 47.2% reported being users of shared mobility, while 52.8% reported being non-users.

The survey was designed in four sections. The first section comprised of socio-demographic characteristics (e.g., age, household size, household income, dwelling type, and vehicle ownership, among others). The second section gathered information about the respondents' general travel behaviour. Specifically, the survey inquired about the primary mode of transportation used in the last two weeks for six different trip purposes, as well as the length of the most frequent one-way trip for each trip purpose. The modes available to report were personal bicycle, shared e-bike, shared e-scooter, public transit, car sharing, ride-hailing, taxi, walking, personal vehicle (driver), personal vehicle (passenger), and other. Trip purposes were reported as either work/school, meal, social events/recreation, shopping, errands, and airport. The third section of the survey covered questions specific to shared mobility services. Respondents were first asked if they currently use shared mobility, and the subsequent questions differ based on their response to this question. For example, users were asked about their frequency and usage of different shared mobility options including shared e-bikes, shared e-scooters, carsharing, ride-hailing, public transit services, and any membership passes they own for any of these services. For non-users, the survey attempted to understand reasons why the respondents do not use shared modes and for what purposes they would be willing to try different shared mobility options. The fourth and final section collected data on the respondents' attitudes towards driving, transit, shared vehicles, micro-mobility, active transportation, land use, and lifestyle. A set of statements were presented to the respondents who answered on a 3-point Likert scale of disagree, neutral, and agree. Furthermore, the fourth section also collected information regarding how beneficial shared mobility is using a 3-point Likert scale (low, medium, high benefit) considering on-demand service, cost-effectiveness, stress level, alcohol consumption, parking, and environmental impact. Another 3-point Likert scale (not concerned, somewhat concerned, very concerned) collected information about how concerned the respondents are regarding when using shared transportation services considering prices, service request process, reliability, technology, travel time, data privacy, coverage area, and safety.

<u>Sample's Socio-demographic Distribution</u>

The distribution of the socio-demographic characteristics of the survey respondents is listed in Table 1. According to the 2021 Census Profile, the average age of the Kelowna population is 43.4 years old. In the survey, about 70% of respondents are under 40 years of age, indicating an overrepresentation of the relatively younger population in the sample. This overrepresentation of younger adults can be explained by two factors: 1) since shared services are largely dominated by younger users, their overrepresentation in the sample is expected [15], [34] and 2) the online method of the surveying may have skewed the data towards younger adults as many older adults might not have an online presence. However, some of the socio-demographic factors reasonably represent the profile of the census population. For example, approximately 48% of the respondents have an income of less than $79,999 similar to the 48.5% reported in the census. Most respondents live in single detached homes, which again represents the Census distribution [31].

*Table 1:Socio-demographic characteristics*

| Variables | Observed Population (%) |
|---|---|
| *Age (years)* | |
| 18 to 29 | 38.6% |
| 30 to 39 | 34.1% |
| 40 to 49 | 13.7% |
| 50 + | 13.7% |
| | |
| *Household Size* | |
| 1 person | 18.2% |
| 2 persons | 25.5% |
| 3 persons | 21.9% |
| 4 persons | 24.3% |
| 5 persons and above | 10.1% |
| | |
| *Household Income* | |
| Under $49,999 | 27.7% |
| $50,000-$79,999 | 20.4% |
| $80,000-$99,999 | 16.5% |
| $100,000 and above | 35.4% |
| | |
| *Dwelling Type* | |
| Single detached | 36.5% |
| Semi-detached | 8.8% |
| Row house | 10.4% |
| Apartment in a low rise (< 5 storey) | 31.9% |
| Apartment in a high rise (> 5 storey) | 11.2% |
| Other | 1.2% |

According to the 2018 Okanagan Travel Survey, 95% of households in Kelowna have at least one vehicle. From our survey sample, 85.1% of respondents reported having at least one car [*34*]. This difference might relate to the fact that shared mobility users may be less vehicle dependent. Figure 1 shows the relationship between vehicle ownership and household income. Around 40% of households with an income lower than $49,999 reported having one vehicle while about 30% reported not having a vehicle. As the household income goes up, the share of households owning zero vehicles decreases.

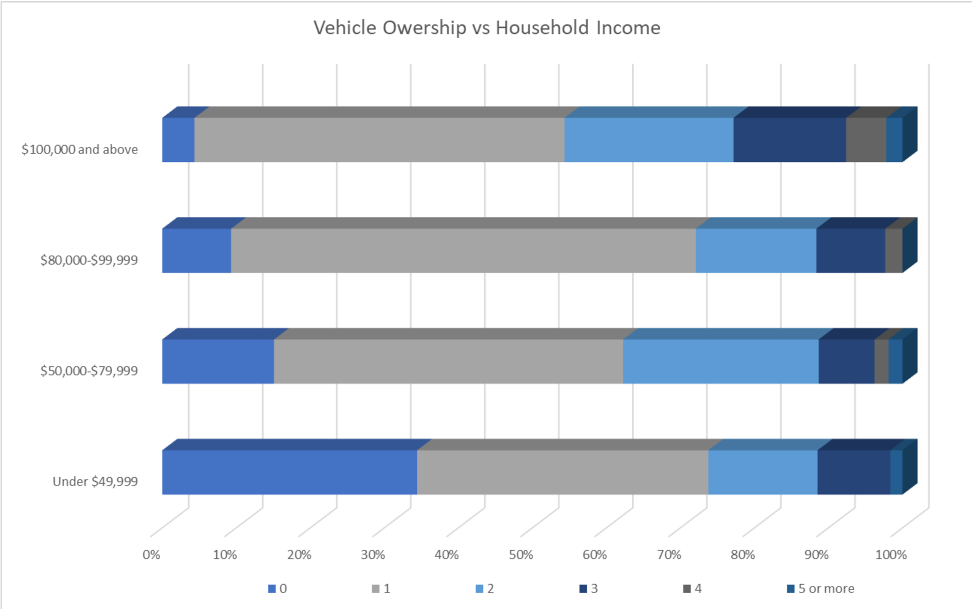


*Figure 1:Vehicle ownership and household income*

<u>Variable descriptions</u>

Five binary dependent variables were selected for this study which indicate whether the respondent is a user of public transit, shared e-bike, shared e-scooter, car sharing, and/or ride-hailing. In the survey, respondents were asked to mention how frequently they used the selected shared mobility services using five options "*daily or almost daily,1-3 times a week, a few times a month, a few times a year or never*". However, after observing the data distributions of each dependent variable, the data were recoded into binary variables (1 = user, 0 = non-user).

The independent variables for the study were categorized into three categories: socio-demographic characteristics, mobility tools, and attitudinal factors. Socio-demographic characteristics include age, type of dwelling, household income, level of education, and current employment type. Mobility tools include driver's license, number of vehicles, bikes and scooters owned by the household, mobile data, and public transit passes. The attitudinal factors are derived from exploratory factor analysis, and includes the categories of driving negative (do not prefer driving), pro driving (prefer driving), ride-hailing negative (do not prefer using ride hailing services), transit positive (have a positive attitude towards using public transit), transit insecurity (having a sense of unease towards using public transit, pro-active transportation(prefer using active transportation), active transportation equity(prefer that active transportation is easily accessible and convenient), sustainable mobility (prefers the available modes are sustainable), pro suburban(Prefer living in sub urban areas), shared mobility concerns (priority is given for concerns regarding SMS when selecting the service) , and shared mobility benefits (priority is given for benefits regarding SMS when selecting the service). Aside from attitudinal factors, all socio-demographic and mobility tool variables were designed into categories after careful observation of their respective data distributions.

Modelling Approach

Exploratory Factor Analysis (EFA) is an approach based on the concept that measurable and observable variables can be reduced to fewer latent variables that share a common variance and are unobservable, which is known as reducing dimensionality [35]. Factor analysis aims to summarize gathered data, offering researchers a straightforward comprehension of patterns and correlations between variables. By identifying shared variance, factor analysis clusters variables, thereby ultimately providing latent or unobservable variables [36]. Using EFA, this study derived 11 attitudinal factors with respect to individuals' travel characteristics.

The next step of the analysis is to develop and test a Multivariate Probit model (MVP) to determine to what extent sociodemographic variables, mobility tools, and identified attitudinal factors relate to the use of selected shared mobility options. MVP is a useful technique for this study since all the dependent variables are binary and it allows for modeling SMS usage jointly since all the dependent variables may be correlated as well. A Conditional Mixed Process (CMP) was further used to address the potential endogeneity. All the MVP and CMP analysis were conducted using STATA [37], [38].

We model the unobserved latent variables (public transit usage as $Y_1^*$, Shared e-bike as $Y_2^*$, Shared e-scooter as $Y_3^*$, Car share as $Y_4^*$ and Ride-hailing as $Y_5^*$ ) using Equations 1-5.". Here $\beta_i$ is a vector representing the coefficients to be estimated for each SMS usage *i* and $x_i'$ is a vector representing the independent variables. $e_i$ represents the error terms for each SMS usage option which are joint normally distributed with zero mean values and covariance matrix Σ [39].

$$Y_1^* = x_1'\beta_1 + a_1Y_2^* + e_1 , Y_1 = 1 \; if \; Y_1^* > 0, 0 \; otherwise \quad (1)$$

$$Y_2^* = x_2'\beta_2 + e_2 , Y_2 = 1 \; if \; Y_2^* > 0, 0 \; otherwise \quad (2)$$

$$Y_3^* = x_3'\beta_3 + a_3Y_1^* + e_3 , Y_3 = 1 \; if \; Y_3^* > 0, 0 \; otherwise \quad (3)$$

$$Y_4^* = x_4'\beta_4 + a_4Y_1^* + e_4 , Y_4 = 1 \; if \; Y_4^* > 0, 0 \; otherwise \quad (4)$$

$$Y_5^* = x_5'\beta_5 + a_5Y_1^* + e_5 , Y_5 = 1 \; if \; Y_5^* > 0, 0 \; otherwise \quad (5)$$

Unobserved propensity to use shared e-bike is a regressor in the equation for $Y_1^*$ and unobserved propensity to use public transit is a regressor in the equations for $Y_3^*$, $Y_4^*$ and $Y_5^*$.

## RESULTS AND DISCUSSION

Chi-square test of association was used to understand the relationship between each dependent variable and the respective categorical independent variables. All variables have a significant association with public transit usage, except for driver's license, mobile data, and public transit passes. While mobile data has an insignificant association with shared e-bike and e-scooter usage, a significant association can be seen with all other independent variables. When looking at the car share usage and its association with independent variables, "age and mobile data" have an insignificant association while other variables have a significant association with car share usage. All the other variables have a significant association with ride hailing usage except mobile data. Table 2 below summaries these results (Note: $\chi^2$= chi square statistic; Sig.= significance level; ** 95% confidence interval).

*Table 2 Chi square test of association*

| Variables | Y1 Public Transit | | Y2 Shared e-bike | | Y3 Shared e-scooter | | Y4 Car Sharing | | Y5 Ride-Hailing | |
|---|---|---|---|---|---|---|---|---|---|---|
| | $\chi^2$ | Sig. | $\chi^2$ | Sig. | $\chi^2$ | Sig. | $\chi^2$ | Sig. | $\chi^2$ | Sig. |
| **Socio Demographic** | | | | | | | | | | |
| People in your household | 15.550 | 0.004** | 31.140 | 0.000 | 37.680 | 0.000** | 19.530 | 0.001** | 35.120 | 0.000** |
| Age | 18.570 | 0.029** | 30.050 | 0.000 | 40.740 | 0.000** | 10.330 | 0.324 | 33.490 | 0.000** |
| Type of dwelling | 14.630 | 0.012** | 29.670 | 0.000 | 21.640 | 0.000** | 31.040 | 0.000** | 32.330 | 0.000** |
| Household income | 20.380 | 0.001** | 32.490 | 0.000 | 33.090 | 0.000** | 22.660 | 0.000** | 25.980 | 0.000** |
| Highest level of education | 36.030 | 0.000** | 31.800 | 0.000 | 39.270 | 0.000** | 39.310 | 0.000** | 33.510 | 0.000** |
| Current employment type | 11.530 | 0.042** | 15.220 | 0.009 | 20.720 | 0.009** | 11.900 | 0.036** | 16.470 | 0.009** |
| **Mobility tools** | | | | | | | | | | |
| Driver's license | 2.390 | 0.122 | 14.710 | 0.000 | 16.030 | 0.000** | 15.680 | 0.000** | 12.660 | 0.000** |
| Motor vehicles household own | 29.830 | 0.000** | 15.950 | 0.007 | 21.980 | 0.007** | 16.920 | 0.005** | 21.510 | 0.007** |
| Bicycles household own | 13.920 | 0.008** | 27.740 | 0.000 | 25.110 | 0.000** | 12.820 | 0.012 | 34.580 | 0.000** |
| Scooters household own | 24.460 | 0.000** | 32.840 | 0.000 | 36.890 | 0.000** | 38.220 | 0.000** | 32.420 | 0.000** |
| Mobile data | 2.750 | 0.252 | 3.850 | 0.146 | 4.160 | 0.146 | 1.150 | 0.562 | 3.370 | 0.146 |
| Public Transit passes | 3.810 | 0.283 | 25.770 | 0.000 | 24.540 | 0.000** | 25.930 | 0.000** | 17.870 | 0.000** |

### Deriving attitudinal factors with respect to travel characteristics using exploratory factor analysis

As mentioned in the literature review, few studies have included individuals' travel perceptions with respect to SMS usage. In this study we have asked respondents to mention their preference in a 3-point Likert scale (agree, neutral, disagree) towards driving, transit, ride-hailing & car sharing, micro-mobility and active transportation, land use, and lifestyle using 40 statements. Respondents were also asked to classify the benefits and concerns with respect to SMS using 14 statements (3 scale Likert scale: low benefit, medium benefit, high benefit for benefits, not concerned, somewhat concerned, very concerned for concerns).

As the first step, Principal Component Analysis (PCA) was used to extract the variables related to suitable travel characteristics to reduce their dimensionality and create more meaningful attitudinal 'factors'. Communalities with a value under 0.5 were removed from the analysis to increase the total variance explained by each model and to improve the model further. Table 3 represents the EFA analysis results for above mentioned variables.

The analysis was again conducted with the more suitable variables. The Kaiser-Meyer-Olkin's (KMO) test was used to check the sampling adequacy (all the values were greater than 0.6) and the Bartlett's test of sphericity was used to test whether the data set is suitable for factorization (all the values were significant <0.05).

The PCA was conducted with a varimax rotation for all the EFA analysis using IBM SPSS Statistics 26.

EFA was conducted with different combinations of statements with the intention of better representing individuals' travel characteristics: Driving and ride-hailing & car share, Transit, Micro-mobility and active transportation, Land use and lifestyle, SM benefits and SM concerns.

*Table 3: EFA Results*

| **KMO** | **Bartlett's Sig.** | **Total Variance Explained %** | **Factor loadings after rotation** | | | |
|---|---|---|---|---|---|---|
| | | | | **Component** | | |
| | | | | **1** | **2** | **3** |
| **0.654** | 0.00 | 64.35 | It is expensive to own a car. | 0.750 | | |
| | | | It is stressful to drive and get stuck in traffic. | 0.747 | | |
| | | | I think ride-hailing and taxis are great alternatives when I go out for drinks. | 0.654 | | |
| | | | Driving is enjoyable. | | 0.822 | |
| | | | I am proud to own a car. | | 0.697 | |
| | | | I don't like using ride-hailing companies. | | | 0.888 |
| | | | I think ride-hailing services, such as Uber, are great for the community. | 0.462 | | -0.609 |
| **0.646** | 0.00 | 58.21 | Using transit saves me money to spend on other things. | 0.774 | | |
| | | | I would like to use transit more than I do today. | 0.752 | | |
| | | | Transit is an essential service in a city. | 0.623 | -0.393 | |
| | | | I only use transit because I don't have the financial means to purchase a vehicle. | | 0.804 | |
| | | | I feel embarrassed taking transit. | | 0.715 | |
| **0.662** | 0.00 | 60.83 | I like seeing people using shared bikes and e-scooters throughout the city. | 0.746 | | |
| | | | It is important for me to live in a walkable neighborhood. | 0.736 | | |
| | | | I would like to walk or bike more than I do today. | 0.696 | | |
| | | | I feel comfortable riding bikes and/or scooters throughout the city. | 0.577 | 0.493 | |
| | | | I only use active transportation modes because I don't have the financial means to purchase a vehicle. | | 0.834 | |

| | | | | | |
|---|---|---|---|---|---|
| **0.730** | 0.00 | 61.10 | I am committed to using a less-polluting means of transportation as much as possible. | 0.770 | |
| | | | I am committed to an environmentally friendly lifestyle. | 0.752 | |
| | | | Having shops and services within walking distance of my home is important to me. | 0.740 | |
| | | | I prefer to live within walking distance to frequent bus routes. | 0.708 | |
| | | | I prefer to live in suburban areas. | | 0.831 |
| | | | I prefer to live in central areas. | 0.454 | -0.668 |
| **0.706** | 0.00 | 49.36 | Not worrying about parking | 0.728 | |
| | | | Reduced environmental impact | 0.719 | |
| | | | On-demand service | 0.681 | |
| | | | Cost-effectiveness | 0.681 | |
| **0.641** | 0.00 | 56.55 | Low reliability | 0.431 | |
| | | | Issues with technologies | 0.457 | |
| | | | Data privacy | 0.441 | |

Based on the factor loading for each component, 11 attitudinal factors were derived from the EFA analysis to represent individuals' travel characteristics: Driving negative, Pro Driving, Ride Hailing Negative, Transit Positive, Transit Insecurity, Pro Active Transportation, Active Transportation Equity, sustainable mobility, Pro suburban, Shared Mobility concerns, Shared Mobility Benefits.

Multivariate Probit Model (MVP) to model the SMS usage

After numerous tests of variables, Table 4 summarizes the joint MVP model results for each SMS usage which is categorized under the categories of socio-demographic related variables, mobility tool related variables, endogenous variables and attitudinal variables. The Wald chi-square value is 171.45 with a p value of 0.000 indicating that the model cannot consist of independent probit equations that can be estimated separately. Therefore, modeling SMS usage considering cross-equation error correlation cannot be rejected.

When looking at the combinations of error covariance matrix, /atanhrho_15, /atanhrho_23, and /atanhrho_24 is significant while other combinations are (/atanhrho_12, /atanhrho_13, /atanhrho_14, /atanhrho_25, /atanhrho_34, /atanhrho_35, /atanhrho_45) subtly non-significant indicating that there are heterogeneous factors influencing the SMS joint usage.

As illustrated by Table 4, using a shared e-bike, having more than two people in the household, having zero or one motor vehicle, having a student transit pass, and the attitude towards sustainable mobility all have a significant positive influence on an individual's public transit usage. Having a household income between $50,000 and $100,000, having more than two people in the household, living in an apartment, having a driver's license, having one bicycle, and attitude towards suburban preferred living all have a significant positive influence on individual's shared e-bike usage. Using public transit, having a household income between $50,000 and $100,000, living in an apartment, having one motor vehicle, having one or more scooters at home, a negative attitude towards driving, and suburban preferred living all have a significant positive influence on individual's shared e-scooter usage. Having one or more than two people in the household and the attitude towards sustainable mobility all have a significant negative influence on shared e-scooter usage.

*Table 4: MVP Results*

| Variables | Y1_public_transit | | | Y2_bike | | | Y3_e_scooter | | | Y4_car_share | | | Y5_ride_hlng | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Coeff. | z | P>z | Coeff. | z | P>z | Coeff. | z | P>z | Coeff. | z | P>z | Coeff. | z | P>z |
| **Socio-demographics** | | | | | | | | | | | | | | | |
| Age_18_34 | | | | 0.24 | 1.28 | 0.19 | 0.40 | 1.55 | 0.12 | | | | | | |
| Age_50_or_above | | | | | | | | | | 0.46 | 1.30 | 0.19 | | | |
| Dwelling_apartment | | | | 0.76 | 4.02 | 0.19 | 0.62 | 2.18 | 0.03** | 0.17 | 0.61 | 0.54 | | | |
| Edu_Diploma_or_below | 0.39 | 1.61 | 0.11 | | | | | | | | | | | | |
| Edu_unidegree_above | | | | 0.03 | 0.19 | 0.18 | | | | | | | | | |
| Income_50000_100000 | 0.24 | 0.94 | 0.35 | 0.48 | 2.38 | 0.20 | 0.92 | 3.31 | 0.00** | 0.24 | 0.84 | 0.40 | | | |
| One_person_household | | | | | | | -1.82 | -4.24 | 0.00** | | | | | | |
| Two_people_household | 0.53 | 1.63 | 0.10* | | | | -1.03 | -3.45 | 0.00** | | | | | | |
| More_than_two_people_household | 1.13 | 2.98 | 0.00** | 1.05 | 5.40 | 0.19 | | | | | | | 0.05 | 0.15 | 0.88 |
| Unemployed_or_retired | | | | | | | | | | | | | -0.66 | -1.43 | 0.15 |
| **Mobility Tools** | | | | | | | | | | | | | | | |
| Bicycle_1 | | | | 0.75 | 3.82 | 0.20 | | | | | | | | | |
| Drivers_license | | | | 0.97 | 2.70 | 0.36 | | | | 1.72 | 2.69 | 0.01** | | | |
| Mobile_data | | | | | | | | | | -0.05 | -0.08 | 0.94 | | | |
| Motorvehicle_1 | 1.39 | 4.29 | 0.00** | | | | 0.71 | 3.00 | 0.00** | | | | | | |
| Motorvehicle_none | 1.64 | 3.56 | 0.00** | | | | | | | | | | -1.08 | -2.35 | 0.02** |
| Pubtrans_pass_student | 2.08 | 3.17 | 0.00** | | | | | | | -1.34 | -2.03 | 0.04** | -0.67 | -1.07 | 0.28 |
| Scooter_1_ormore | | | | | | | 0.60 | 1.93 | 0.05** | | | | | | |
| **Endogenous variables** | | | | | | | | | | | | | | | |
| Y1_public_transit# | | | | | | | 0.36 | 1.84 | 0.07* | 0.78 | 3.44 | 0.00** | 0.86 | 4.65 | 0.00** |
| Y2_bike# | 0.87 | 3.76 | 0.00** | | | | | | | | | | | | |
| **Attitudinal Factors** | | | | | | | | | | | | | | | |
| Driving_negative | | | | | | | 0.42 | 2.40 | 0.02** | | | | | | |
| Pro_Active_Tp | | | | | | | 0.74 | 3.43 | 0.00** | | | | | | |
| Pro_suburban | | | | 0.22 | 2.41 | 0.09* | 0.55 | 3.61 | 0.00** | | | | | | |
| sustainable_mobility | 0.43 | 2.09 | 0.04** | | | | -0.60 | -2.25 | 0.02** | 0.38 | 1.72 | 0.09* | -0.43 | -1.91 | 0.06* |
| Transit_Insecurity | | | | | | | | | | 0.19 | 1.17 | 0.24 | | | |
| **Constant** | -1.40 | -3.06 | 0.00 | -2.62 | -7.11 | 0.37 | -1.62 | -5.64 | 0.00 | -2.54 | -2.73 | 0.01 | -0.76 | -2.67 | 0.01 |

Note: Coeff. = Coefficient; z= z-statistic; P>|z| = significance level; * 90% confidence interval; ** 95% confidence interval

Using public transit, having a driver's license, and attitude towards sustainable mobility all have a significant positive influence on individual's car share usage while having a student transit pass has a significant negative influence. While having no motor vehicles at home and attitude towards sustainable mobility both have a significant negative influence on ride hailing usage, using public transit has a significant positive influence on the decision.

**CONCLUSION**

This study presents findings on how socio-demographic and mobility tool characteristics along with attitudes towards travel behaviour influence the decision of individuals to use shared mobility services.

Data for the study was collected through an online survey distributed in Kelowna from July 4th to July 18th, 2022. The survey collected data on socio-demographic characteristics, general travel behavior, shared mobility services, and attitudes towards these services.

The Exploratory Factor Analysis conducted found 11 factors with significant impact on individuals' travel behavior and mode choice. Chi-square analysis of association tested the association between

SMS usage, socio-demographic variables, and mobility tools. Results showed that aside from age and car sharing, all other socio-demographic characteristics have a significant association with each SMS option. In contrast, mobile data did not present a significant relationship.

According to the Multivariate Probit Model, young adults aged between 18 and 34 that live in apartments tend to have a positive significant impact on shared e-bike and shared e-scooter usage based on the z-statistic value. Individuals older than 50 tend to participate in car sharing. Individuals with income between $50,000 and $100,000 have a significant positive influence regarding shared e-scooter usage, while households with two or less people have a negative influence on e-scooter usage. Individuals in households with two or more inhabitants and individuals with a high education level are the most likely to use public transit. Individuals with a driver's license tend to car share more, while students with a public transit pass have a negative impact towards car sharing. Individuals with zero or one motor vehicle at home and students with a public transit pass use public transit more. Households with one motor vehicle and one or more scooters have significant positive impacts on shared e-scooter usage. Furthermore, people with no motor vehicle are less likely to use ride-hailing services.

The model found that individuals concerned with sustainability tend to use public transit, shared e-scooters, and car sharing more. Those who dislike driving and have a favorable attitude towards active transportation are more likely to choose shared e-scooters and individuals who prefer suburban living tend to use shared e-bikes and shared e-scooters.

Furthermore, the model showed complementary and substitution effect as well. Based on the error covariance values, it can be stated that there are complementary effects, such as an increase in public transit usage which is associated with a decrease in ride-hailing usage. An increase in shared e-bike usage is associated with an increase in shared e-scooter and car sharing usage. Substitution effects suggest that public transit usage is associated with shared e-scooter, car share, and ride-hailing modes. Whereas shared e-bike usage is associated with public transit usage.

A number of limitations are imposed on the study. The most significant is seasonality. In the summer, Kelowna usually has a higher population using active transportation modes than during cooler times of the year, indicating a seasonal specificity of the data. The delivery method with which this survey was deployed must also be taken into consideration, as it was a web-based survey, which could impact the demographics of respondents. Further investigation of how the usage of shared mobility changes seasonally and how to target responses on shared mobility surveys from non-users of the services are necessary.

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