# Function, Symbolism or Society? Exploring Canadian Consumer Interest in Electric and Shared Mobility


**by**

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## Abstract

Electric and shared mobility offer alternatives to the dominance of privately-owned, fossil fuel powered vehicles. I explore consumer perceptions and motivations regarding these innovations, using survey data from samples of Canadian adopters and non-adopters of electric vehicles, car-sharing and shared ride-hailing (n = 529). I apply a framework with four perception categories: private-functional (e.g., costs and convenience), private-symbolic (e.g., making good impressions), societal-functional (e.g., protecting the environment) and societal-symbolic (e.g., spreading inspiration). Using a theory-based approach, I regressed the four perception categories noted above as predictors of adoption for each innovation. Results show that positive private-functional perceptions are consistent predictors across all three innovations, while private-symbolic perceptions are only associated with electric vehicle adoption. Societal-functional and societal-symbolic perceptions have no association with adoption. I also apply an exploratory-based approach using factor analysis to identify unique perception categories. Findings are largely consistent with the first method, with some nuanced insights.



**Keywords**: technology adoption; consumer research; new mobility; electric vehicle; ride-hailing; car-sharing

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## List of Acronyms

| | |
|---|---|
| BEV | Battery electric vehicle |
| EV | Electric vehicle |
| GHG | Greenhouse gas |
| NZE | Net zero emissions |
| PHEV | Plug-in electric vehicle |
| SILCI | Social Influence and disruptive Low Carbon Innovation |
| VKT | Vehicle kilometer traveled |

# Chapter 1.

# Introduction

Electric and shared mobility innovations offer alternatives to the current dominance of privately-owned, fossil fueled powered vehicles. This study explores consumer perceptions and motivations regarding these innovations to better understand what drives electric and shared mobility adoption and the potential for widespread uptake.

First, electric mobility presents consumers with an opportunity to shift away from drivetrains powered purely by fossil fuels. In this study I consider two types of electric vehicles (EVs). Battery electric vehicles (BEVs) which are powered exclusively by electricity. Plug-in hybrid electric vehicles (PHEVs) that are powered by a combination of electricity and an internal combustion engine. Research presents a compelling outlook for the role of EVs in reducing transport emissions. For instance, the International Energy Agency (2021) projects that for global emissions to reach net zero by 2050, 60% of new vehicle sales will need to be electric by 2030, and nearly 100% by 2050. In Canada alone, analyses project greenhouse gas (GHG) emission reductions from deployment of EVs ranging from 98% to 34% relative to conventional vehicles, depending on the region (Kamiya et al., 2019).

On the other hand, shared mobility innovations might present an opportunity for consumers to shift away from private vehicle ownership and use. Several studies estimate that shared mobility will play an important role in reducing transport emissions through enabling a transition away from privately-owned, single occupancy vehicles (IEA, 2021; Brand et al., 2021). For instance, the IEA assumes that to reach global net zero emissions (NZE) by 2050, 20-50% of passenger trips in large cities will need to shift from single-occupancy vehicles to shared mobility. However, the ultimate GHG impacts of shared mobility remains unclear, as these depend on the travel mode these innovations are replacing (i.e. a higher or lower carbon mode per km), and their true impact on vehicle ownership and usage.

In this study I explore two versions of shared mobility. First, I consider car-sharing, where members reserve, pay for and temporarily access a network of shared vehicles. On one hand, studies have shown that car-sharing uptake is associated with reduced vehicle ownership (Shaheen et al., 2019), and reductions in GHG emissions (Nijland and van Meerkerk, 2017). For instance, research finds that car-sharing use could cut transport related GHG emissions by up to 45-55% per Canadian household (Namazu and Dowlatabadi, 2015). However, car-sharing can potentially increase vehicle kilometers traveled (VKT) as households without car ownership gain access to shared vehicles (Sharma, 2020).

The other shared mobility innovation I explore is shared ride-hailing. More generally, ride-hailing is a form of on-demand ride service where users request a driver and pay for their ride using a smartphone app. Shared ride-hailing is where the application matches multiple passengers with similar travel destinations. Some studies have shown that ride-hailing in general can reduce car ownership (Rodier, 2018). Although, other research indicates that much of the potential emission reductions offered by ride-hailing are offset by increased vehicle travel and users switching away from public transit (Coulombel et al., 2019). However, the role of shared ride-hailing is more promising for transport decarbonization. That is, shared ride-hailing can potentially increase vehicle occupancy rates, reducing VKT and emissions (Santos, 2018). For instance, a US study finds that GHG reductions are more likely for ride-hailing usage on weekends, as this is when rides are more typically shared (Wang et al., 2022).

While research on the actual and potential impacts of electric and shared mobility has grown, there is still much to learn about consumer adoption behaviour in the present and future. In particular, I contribute to the growing literature on consumers perceptions and motivations towards these innovations. Modeling and consumers studies commonly depict consumer adoption in simplistic ways, often assuming that decision-making is driven purely by financial and technical considerations (Bergman et al., 2017). For example, the U.S. Department of Energy consumer choice model (ADOPT) estimates EV adoption as being driven by vehicle price, fuel cost, acceleration, size and range (Brooker et al., 2015). However, more in-depth consumer research finds that innovation adoption can be driven by more than perceptions of functional aspects of an innovation. For instance, research has shown that consumer adoption of new mobilities may be driven by symbolic desires, such as being able to signal aspects of self-identity through using an innovation (Heffner et al., 2007; Prieto et al., 2019). Other studies have demonstrated that protecting the environment may be a motivation in consumer adoption (Spurlock et al., 2019; Long and Axsen, 2021).

To better understand what drives electric and shared mobility adoption, I utilize Axsen and Kurani's (2012) two-by-two innovation attributes framework to categorize this broader range of consumer motives and perceptions. The two-by-two framework provides a comprehensive perspective of consumer perceptions of innovation attributes. Of the four categories of perceptions, the first category represents perceptions of the functional attributes that the innovation provides to the individual (e.g., cost savings and convenience), while the second category acknowledges that an innovation can hold symbolic meaning for the individual consumer (e.g., makes a good impression on others and expresses aspects of self-identity). The third category addresses the perceived functional attributes of the innovation that impact society (e.g., GHG emissions and safety). Finally, the fourth category relates to symbolic meaning that the innovation represents for society more broadly (e.g., spreads inspiration, supports technology development).

The development of the two-by-two framework was informed by a review of theoretical and empirical literature, and has since been explored in surveys and interviews with current and potential owners of EVs (Axsen et al., 2018; Axsen et al., 2013; Axsen et al., 2017), and also conceptually applied to consideration of automated and shared vehicles (Sovacool and Axsen, 2018). As a further step in its application, I empirically test the framework in predicting adoption of EVs, car-sharing and shared ride-hailing. I also explore two different ways of applying the framework. In a theory-based approach, I strictly group consumer perceptions into one of the four "bins" noted above. In an exploratory-based approach, I instead let the quantitative analysis of the empirical data (factor analysis) identify the most appropriate way to group consumer perception categories.

As such, the contributions of this study are two-fold. First, this research helps uncover what consumer perceptions drive adoption of electric and shared mobility. Secondly, by comparing both approaches, this study provides an opportunity to examine the convergence or lack thereof between the two approaches, potentially offering new theoretical and analytic insights.

This study uses a sample of Canadians (n = 529) that includes adopters and non-adopters of EVs, car-sharing and shared ride-hailing. At the national level, EVs accounted for approximately 4% of total new vehicle registrations in 2020, of which two-thirds are BEVs and one-third are PHEVs (Statistics Canada, 2021). As of 2018, Canada had 20 car-sharing services, with approximately 336,000 memberships and roughly 3,000 car-sharing vehicles on the road in Vancouver, followed by 2,080 in Montreal and 1,650 in Toronto (Britten, 2021). Ride-hailing was first introduced in Canada in 2012, starting in Toronto and following with expansions in Montreal, Calgary, and other major cities. In 2017, approximately 7% of persons aged 18 and older in Canada used ride-hailing services, such as Uber and Lyft (Statistics Canada, 2017).

In the following section I describe Axsen and Kurani's (2012) framework in more depth and summarize relevant research on consumer perceptions that relate to interest in and adoption of electric and shared mobility. Next, I describe my research objectives and hypotheses. Section 3 provides details on the survey instrument, data collection and analyses. Section 4 presents results, organized by data analytic approach. In Section 5, I discuss findings, overall implications, and study limitations. Section 6 concludes.

# Chapter 2.

# Conceptual framework and literature review

Given the complexity of consumer motives and perceptions in innovation adoption, a wide variety of theories and conceptual frameworks have been applied in consumer-focused research. Drawing from reviews of theoretical models provided elsewhere (Jackson, 2005; Rezvani et al., 2015), I present a brief overview of dominant frameworks from economics, social psychology and sociology. First, the rational actor model from neoclassical economics represents consumers as rational and socially isolated, in which decision making is driven purely by maximizing individual utility. In theory, the rational actor model can cover a range of matters that concern consumers, though in practice tends to focus on perceptions of private and functional attributes (i.e., costs, performance, and convenience). While such a focus can yield in-depth insights into these specific factors, this simplistic depiction of consumers overlooks the fact that consumer behaviour is embedded in diverse social contexts and excludes other potentially important motivations (Axsen and Kruani, 2012).

Other theories stemming from social psychology and sociology consider a broader set of motivating factors and perceptions. Frameworks including Value-Belief-Norm Theory (Stern, 2000), Cultural Theory (Thompson et al., 1990), and Theory of Planned Behaviour (Azjen and Fishbein, 1980) explore factors such as values, culture, attitudes and norms as motivations that shape consumer perceptions and behaviour. The Diffusion of Innovations framework (Rogers, 2003) considers the characteristics of consumers and the innovation, along with the process of information sharing across social systems. More comprehensive-level frameworks such as semiotics (Heffner et al., 2007) and lifestyle theory (Axsen et al., 2012) can uncover a greater degree of symbolic and societal motivations as consumer perceptions are seen to be influenced by social factors. For example, symbolism or semiotics approaches view how a consumer may assign meaning to an innovation based on social interactions and relations (Heffner et al. 2007). Across frameworks, there are of course trade-offs in the breadth and depth of what processes and motivators can be studied (Axsen and Sovacool, 2019).

As previously mentioned, Axsen and Kurani's (2012) two-by-two framework of innovation attributes categorizes perceptions of an innovation into four categories (see Figure 1). The framework considers consumer perceptions of both symbolic and functional attributes of an innovation, along with how these relate to the individual or society. As such, application of the two-by-two framework in understanding consumer innovation adoption, provides an opportunity to explore a range of factors identified across consumer-focused research.

| | Functional | Symbolic |
|---|---|---|
| **Private** | The functional benefits to the consumer, e.g.:<br>• Save money<br>• Convenience (e.g. time savings) | The symbolic benefits to the consumer, e.g.:<br>• Expression of self-identity<br>• Attainment of group membership |
| **Societal** | The functional benefits to society, e.g.:<br>• Reduce air pollution, GHG emissions<br>• Help the local community | The symbolic benefits to society, e.g.:<br>• Inspire others<br>• Send message to industry or policymakers |

**Figure 1. Two-by-two framework of perceived innovation attributes**
Note: Adapted from Axsen and Kurani (2012)

In the following sections, I will describe each category of the two-by-two framework in depth, relating each to literature regarding adoption of EVs, car-sharing and shared ride-hailing. I will then conclude with a discussion of research gaps and objectives.

## 2.1. Private-Functional attributes

Private-Functional attributes represent perceptions of the functional attributes of an innovation that impact the consumer. This commonly includes perceptions such as cost-savings, convenience, price and practicality. EV users frequently identify cost-savings from reduced maintenance and operating costs, as well as perceived practicality, as motivations for adoption (Lashari et al., 2021; Axsen et al., 2018; Ozaki and Sevastyanova, 2011). In interviews with EV users in Norway, most owners indicated that saving time and money were their primary motivations for purchasing an EV (Ryghaug and Toftaker, 2014).

Similarly, a number of studies indicate that perceived cost-savings and convenience are the motivations for interest in and adoption of car-sharing (Bhardi and

Eckhardt, 2012; Böcker and Meelen, 2017; Hartl et al., 2018; Schaefers, 2013). In particular, interviews with car-share users across three major cities in the United States revealed that car-sharing use was motivated by eliminating the hassles associated with owning a car and reducing transportation costs (Burkhardt and Millard-Ball, 2006). Trip cost, travel time and convenience are also highly valued attributes influencing ride-hailing adoption (Tirachini, 2021; Loa and Habib, 2021). In interviews with shared ride-hailing users in metropolitan areas of the United States, 83% of respondents indicated that their use of the innovation was influenced by perceived affordability, and 85% highlighted time-savings compared to transit or walking (Sarriera et al., 2017). Similarly, according to a survey of Canadian Uber riders, 82% noted that convenience was the most important reason for their use of the service (Uber, 2021) Avoiding difficulties associated with finding and paying for parking is also cited as being among the top reasons to use ride-hailing services according to users across seven major cities in the United States (Clewlow and Mishra, 2017).

## 2.2. Private-Symbolic attributes

In contrast to Private-Functional attributes, Private-Symbolic attributes relate to perceptions of how the innovation helps an individual express self-identity, connect with others or make a good impression. A number of studies have investigated how interest in and adoption of EVs is influenced by perceptions of Private-Symbolic attributes. In interviews with EV adopters in Canada, Axsen et al., (2018) found that uptake was motivated by desires to express an innovative and technology-oriented self-identity. The perceived benefit of demonstrating one’s care for the environment, or rather an environmentalist self-identity through EV use is also documented as a predictor of interest and adoption in a number of studies (Krupa et al., 2014; Carley et al., 2019; Schuitema et al., 2013). Also a survey of consumers in California demonstrated that seeing EV adoption as a way to express a social innovator self-identity was linked to greater interest in purchasing an EV (White and Sintov, 2017).

Studies demonstrate mixed results for the role of Private-Symbolic attributes in shared mobility adoption. In one study, Schaefers (2013) interviewed car-sharing users in the United States and identified that the desire for status and interaction with others was a motivation for car-sharing use, whereby users viewed the labeling and design of vehicles as a way to create a sense of community. Similar findings were presented by

Prieto et al., (2019) in which the potential for car-sharing services to allow consumers to self-identify with vehicles beyond what they might otherwise afford had a positive effect on intention to adopt the service. In contrast, other research has revealed that car-sharing users tend to dissociate themselves with the vehicles, and do not view the service as a means to facilitate connections with others (Bhardi and Eckhardt, 2012). One study on shared ride-hailing revealed that users in major cities across the United States do not perceive the possibility of interacting and connecting with others as a positive attribute of the service (Sarriera, 2017). Rather riders indicate that the potential for a negative social interaction can serve as a deterrent. Further, Spurlock et al. (2019) found that viewing car-sharing and shared ride-hailing as an opportunity to interact with others was not significantly associated with adoption.

## 2.3. Societal-Functional attributes

Societal-Functional attributes address the perceived functional impacts that the innovation has on society, such as reducing GHG emissions. Some studies show that interest in and adoption of EVs is motivated by positive perceptions of their environmental impacts or a desire to help protect the environment (Axsen et al., 2018; Ozaki and Sevastyanova, 2011; Rezvani et al., 2015). For instance, 76% of EV adopters interviewed in British Columbia, Canada, mentioned that their decision to adopt was motivated by the desire to help protect the environment (Axsen et al., 2018). Similarly, Skippon and Garwood (2011) found that among participants who trialed an EV in the UK, those that expressed concern for protecting the environment were most likely to adopt one. However, other research shows that perceived environmental aspects of EVs do not influence adoption. Spurlock et al. (2019) found that viewing EVs as a way to minimize environmental impacts was not significantly associated with being a PHEV adopter in California.

Research also finds mixed results for the role of Societal-Functional attributes in shared mobility adoption. Some studies indicate that concern for the environment is positively associated with car-sharing use and interest (Spurlock et al., 2019; Shaheen and Cohen, 2012). A survey across London (UK), Paris (France), and Madrid (Spain) finds that individuals with greater concern for the environment were more inclined to adopt car-sharing (Prieto et al., 2019). On the other hand, other studies have found that environmental reasons are not a motivation among car-sharing users. For example, Long and Axsen (2020) found that stronger environmental concern was negatively associated with car-sharing interest in Canada. Notably, a number of studies have recognized that minimizing environmental impacts is valued simply as an added bonus among car-share users, rather than a dominant motive for joining the service. (Nansubuga et al., 2021; Hartl et al., 2018; Schaefers, 2013). Using a sample of Dutch car-share users Münzel et al. (2019) finds that the environment is not a main reason to adopt the service and notes that while a few earlier studies demonstrated environmental aspects to be a major motivation among car-sharing members, these motivations have lost ground over the years to financial and convenience related motivations.

In the case of ride-hailing, some studies indicate that the perceived environmental benefits the innovation provides or desires to protect the environment are associated with ride-hailing use. Spurlock et al. (2019), found that individuals in the San Francisco Bay Area who see ride-hailing as a way to minimize environmental impacts were slightly more likely to have already adopted shared ride-hailing services. However, other research reveals that desires to reduce environment impacts are not associated with adoption (Lavieri and Bhat, 2019; Long and Axsen, 2020) and that perceived environmental-related benefits of ride-hailing (non-shared) is negatively associated with adoption (Acheampong et al., 2020).

## 2.4. Societal-Symbolic attributes

Societal-Symbolic attributes relate to perceptions of the innovation's ability to contribute to social movements, inspiring others and communicating support for technological advancements. While the role of Societal-Symbolic factors in consumer interest in and adoption of car-sharing and shared ride-hailing is less studied, some studies have explored such perceptions in the context of EV interest and adoption. In interviews with Canadian EV adopters, several participants mentioned that their decision to purchase the vehicle was motived by wanting to support innovative companies (Axsen et al., 2018). Albeit in the context of hybrid electric vehicle (HEV) adoption, Heffner et al. (2007) interviewed HEV owners in California and found that uptake was motivated by desires to send a message to car companies to channel their innovation into more environmentally-friendly vehicles.

## 2.5. Research gaps and objectives

This study is novel in undertaking analyses that examine the relative importance of a comprehensive set of consumer perceptions in innovation adoption. With the exception of a number of EV studies, research examining the role of consumer perceptions in electric and shared mobility adoption has a tendency to focus on one or two attribute categories. As mentioned, a focus on private functional attributes tends to dominate research on mobility innovations (Bergman et al., 2017). By applying Axsen and Kurani's (2012) framework, this study considers a complex array of consumer motivations identified across consumer models from economics, social psychology, and sociology. Further, by applying the framework across multiple innovations within the mobility sector, this research may shed light on how the importance of perceived attributes differs depending on whether the innovation is an alternative to owning a fossil-fuel powered vehicle (EVs) or owning a vehicle altogether (car-sharing and shared ride-hailing).

Finally, this study adopts both a theoretical and exploratory based approach to understanding consumer perceptions and motivations towards electric and shared mobility. In a theory-based approach, I group consumer perceptions into the four categories presented in the two-by-two framework. I also apply an exploratory-based approach, where I use quantitative analysis of the empirical data to identify categories of consumer perceptions of the innovations. Including an exploratory-based approach in this study allows for potentially new perception categories to emerge, providing a novel opportunity to gain insight into further development of the framework and our understanding of consumer perceptions. In addition to such theoretical contributions, this study examines the extent to which the theory-based, two-by-two perceptions and those that arise from an exploratory approach, predict adoption of EVs, car-sharing and shared-ride hailing.

Specifically, my research objectives are to explore consumer perceptions of these three different innovations using two different approaches:

1. Apply a theory-based approach, examining the explanatory power of each two-by-two category regarding adoption of the three innovations.

2. Apply an exploratory-based approach, by:

a) Performing exploratory factor analysis to identify attribute categories that best fit the data, then

b) Examining the relationship between these exploratory factors and adoption of the three innovations.

While my second research objective is exploratory in nature, I do have several hypotheses for the outcome of my first research objective. I hypothesize that more positive perceptions of Private-Functional attributes will be positively associated with adoption of each innovation and that more positive perceptions of Private-Symbolic and Societal-Symbolic attributes will be positively associated with EV adoption. Due to limited research on the role of Private- and Societal-symbolic perceptions in the case of car-sharing and shared ride-hailing adoption, the direction of association between these categories of attributes and adoption of these innovations remains unknown. Lastly, given mixed results regarding the influence of Societal-Functional related perceptions on innovation adoption, I refrain from making specific hypotheses regarding associations between this category and adoption of each innovation.

# Chapter 3.

# Method

In this chapter, I outline the survey instrument, methods of data collection and analyses used in this study.

## 3.1. Survey instrument

The survey used in this study was part of a larger project conducted by the Social Influence and disruptive Low Carbon Innovations (SILCI) research team at the University of East Anglia, UK. The SILCI team developed a UK and Canadian version of the online survey, which included questions about 16 low-carbon innovations related to transport, homes, food and energy. My present analysis focuses on the Canadian version of the survey. Specifically, I assessed responses in relation to perceptions of EVs, car-sharing and shared ride-hailing attributes. The survey presented respondents with definitions of each of the innovations (see Appendix Table A.1), and asked them about their current experience having or using the innovations. Respondents were asked to indicate their level of agreement with items shown in Table 1, on a scale where response options ranged from 1 ("strongly disagree") to 5 ("strongly agree"). A "don't know" response option was also included.

**Table 1. Two-by-two perceived innovation attributes scales**

| Attributes | Items |
|---|---|
| Private-Functional | Using it helps save money<br>Using it is convenient<br>Using it is too expensive<br>Using it takes effort<br>Using it is compatible with my daily life |
| Private-Symbolic | Using it makes a good impression<br>Using it fits well with my values and beliefs<br>Using it helps me connect with like-minded people |
| Societal-Functional | Using it helps protect the environment<br>Using it helps tackle climate change<br>Using it helps the local community |
| Societal-Symbolic | Using it helps inspire others<br>Using it sends a message to those with power and influence |

Note: Items were presented in the conditional tense to non-adopters of each innovation (ex. Using it *would* help save money)

## 3.2. Data collection

The survey was fielded across all Canadian provinces by market research company Dynata between December 2019 and February 2020, where respondents were recruited from Dynata's panel. A quota sampling design was used to target 100 adopters and 100 non-adopters of each innovation. After being presented with a definition of each innovation, if the respondent indicated that they had heard of the innovation but had never used or experienced it, then the respondent was allocated as a "non-adopter" to a specific variant of the survey corresponding to one particular innovation. Otherwise, if the respondent expressed experience having or using the innovation, then they were allocated as an "adopter."

A series of data cleaning and quality control measures were implemented to ensure reliable data. Respondents were removed if they identified as adopters but failed to provide an example of the innovation adopted or indicate how long they have used it for. Further, adopters were removed from the sample if they provided incorrect innovation examples (e.g., the respondent confused shared ride-hailing with informal car-pooling with co-workers to and from work), examples of different but related innovations or suspect examples (e.g. "I can't remember"). Given the relative novelty of the innovations, specific care was taken to ensure that the data represented respondents that clearly understood and correctly identified their use of the innovation.

In total, 529 Canadian respondents participated in the survey as either an adopter or non-adopter of EVs, car-sharing and shared ride-hailing (Table 2). After data cleaning procedures were applied:

- 62 participants were identified as car-sharing adopters, and 100 participants as car-sharing non-adopters
- 91 were classified as shared ride-hailing adopters, and 98 as shared ride-hailing non-adopters
- 79 respondents were considered EV adopters, and 99 were identified as EV non-adopters

Table 2 summarizes the demographic and contextual distributions of Canadian adopters and non-adopter respondent samples for EVs, car-sharing and shared ride-hailing, as well as Canadian Census data. First, adopter samples across the three innovations tend to be younger, of higher income, full-time employed and have a higher level of education compared to their non-adopter counterparts, and Census data. Similar trends are generally reflected in other research assessing characteristics of electric and shared mobility users (Spurlock et al., 2019; Axsen and Sovacool, 2019). In terms of residence type, EV adopters are more likely to live in a detached house compared to EV non-adopters. Conversely, car-sharing adopters are less likely to live in a detached house than car-sharing non-adopters. Shared ride-hailing and car-sharing adopters tend to reside in urban neighbourhoods compared to their non-adopter counterparts, while EV adopters are less likely to live in urban areas compared to EV non-adopters.

**Table 2. Demographic characteristics of Canadian adopter and non-adopter samples for electric vehicles, car-sharing and shared ride-hailing, and Canadian Census data (2016)**

| | Electric Vehicles | | Shared Ride-Hailing | | Car-Sharing | | Canada |
|---|---|---|---|---|---|---|---|
| | Adopters | Non-Adopters | Adopters | Non-Adopters | Adopters | Non-Adopters | Census |
| **Size (n)** | 79 | 99 | 91 | 98 | 62 | 100 | 35,151,728 |
| **Gender** | | | | | | | |
| Female | 48% | 57% | 50% | 60% | 58% | 59% | 51% |
| **Age** | | | | | | | |
| 18-34 | 27% | 17% | 42% | 28% | 44% | 18% | 30% |
| 35-44 | 18% | 6% | 24% | 10% | 23% | 20% | 16% |
| 45-54 | 17% | 20% | 18% | 25% | 24% | 17% | 17% |
| 55-64 | 22% | 26% | 11% | 26% | 2% | 20% | 17% |
| 65+ | 18% | 30% | 6% | 12% | 8% | 25% | 20% |
| **Household Income (pre-tax)** | | | | | | | |
| <$40,000 | 10% | 35% | 8% | 27% | 18% | 23% | 26% |
| $40,000-$59,999 | 17% | 15% | 12% | 14% | 15% | 12% | 16% |
| $60,000-$89,999 | 19% | 20% | 16% | 25% | 13% | 20% | 20% |
| $90,000-$129,999 | 20% | 23% | 33% | 15% | 22% | 26% | 17% |
| $130,000+ | 34% | 8% | 31% | 19% | 32% | 19% | 21% |
| **Education** | | | | | | | |
| High school or less | 13% | 31% | 13% | 22% | 10% | 28% | 41% |

| | Electric Vehicles | | Shared Ride-Hailing | | Car-Sharing | | Canada |
|---|---|---|---|---|---|---|---|
| | Adopters | Non-Adopters | Adopters | Non-Adopters | Adopters | Non-Adopters | Census |
| Other training/diploma | 27% | 42% | 26% | 45% | 23% | 31% | 34% |
| Bachelor's degree | 35% | 21% | 39% | 24% | 45% | 20% | 17% |
| Above Bachelor's | 26% | 5% | 22% | 9% | 23% | 21% | 8% |
| **Residence Type** | | | | | | | |
| Detached House | 71% | 59% | 53% | 54% | 32% | 55% | 59% |
| Attached House | 12% | 14% | 21% | 16% | 31% | 15% | 12% |
| Apartment | 10% | 27% | 24% | 27% | 32% | 27% | 28% |
| Other | 7% | 0% | 2% | 3% | 5% | 3% | 1% |
| **Employment** | | | | | | | |
| Full-time employed | 45% | 40% | 69% | 39% | 66% | 47% | N/A |
| Part-time employed | 13% | 8% | 3% | 10% | 8% | 6% | N/A |
| Self-employed | 13% | 4% | 6% | 11% | 3% | 2% | N/A |
| Unemployed | 1% | 3% | 4% | 7% | 3% | 2% | N/A |
| Student | 4% | 3% | 6% | 7% | 7% | 3% | N/A |
| Retired | 23% | 36% | 10% | 22% | 10% | 31% | N/A |
| Other | 1% | 6% | 2% | 3% | 3% | 9% | N/A |
| **Residential Location** | | | | | | | |
| Urban | 56% | 63% | 77% | 69% | 94% | 71% | N/A |
| Suburban | 32% | 17% | 19% | 17% | 5% | 17% | N/A |
| Rural | 12% | 19% | 3% | 14% | 2% | 12% | N/A |
| Other | 0% | 0% | 1% | 0% | 0% | 0% | N/A |

Note: Some categories may not total to 100% due to rounding errors.

## 3.3. Data analysis

All statistical analyses were completed using IBM SPSS statistical software (Version 25). Prior to conducting analyses, adopter and non-adopter responses to the attribute items were coded on a scale from 1 ("strongly disagree") to 5 ("strongly agree). "Don't know" responses were coded as 3, representing the middle of the scale and items "using it is too expensive" and "using it takes effort" were reverse coded (items shown in Table 1).

To explore my first (theory-based) research objective, for each innovation I calculated Cronbach's alpha values for the items within each category in Table 1. The alpha values indicate the extent to which items within a given scale measure the same construct (Tavakol and Dennick, 2011). I then conducted three separate binary logistic regressions with adoption of EVs, car-sharing and shared ride-hailing as dependent variables. I first entered socio-demographics (age, education, income, gender, urbanization level) as independent variables (step 1), followed by the addition of the four theory-based factors (step 2a). Data was checked for multicollinearity in which variance inflation factors for independent variables were well below a value of concern (i.e. below a value of 15) (Hair et al., 1995; Ringle et al., 2015).

To achieve my second (exploratory-based) research objective, I performed an exploratory factor analysis on the 13-items designed to measure Axsen and Kurani's (2012) framework (Table 1). Factor analysis is a procedure designed to identify a smaller set of latent variables that share a common variance and represent a larger number of observable variables (Young and Pearce, 2013). I performed the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy which examines partial correlations within the data to suggest whether there is at least one latent factor underlying the data. The KMO for the data is above the recommended minimum value of at least 0.50 for applying factor analysis (Williams et al., 2012). Bartlett's test of sphericity was applied which tests if the correlation matrix is significantly different from an identity matrix. Results reveal a significant value less than 0.05, indicating that the data does not produce an identity matrix and is acceptable for further analysis (Field, 2000). Following best practices to exploratory factor analysis presented by Costello and Osborne (2005), I used principal axis factoring as the factor extraction method, and oblique promax rotation. A factor solution was selected based on maximizing factor interpretability, minimizing cross-loadings between factors, and retaining items with loadings above 0.30.

Next, to test the predictive significance of the factors derived from exploratory factor analysis, I conducted a series of binary logistic regression analyses. Here I examined the extent to which adoption of each innovation is predicted by the exploratory factors. Adoption of EVs, car-sharing and shared ride-hailing was used as the dependent variables. Socio-demographic characteristics and urbanization levels were included as independent variables in the first step of the regressions (step 1). Next, exploratory factors were added to the model as independent variables (step 2b).

Finally, to confirm the pattern of results presented in the theory-based models and exploratory-based models, I performed a series of additional forward stepwise regressions (See Appendix A.2 and A.3). That is, I performed three separate forward stepwise regressions for each innovation using the theory-based factors as predictors of adoption, and three separate forward stepwise regressions for each innovation using the exploratory-based factors as predictors of adoption. This additional check demonstrates the consistency of variable effects for adoption of the three innovations. Starting with a model with no independent variables, the forward stepwise regression adds variables one-by-one based on which variable is most statistically significant, until there are no remaining statistically significant variables (Smith, 2018).

# Chapter 4.

# Results

I organize my findings into two-subsections. Section 4.1 summarizes results pertaining to my first theory-based research objective (see Section 2.5). In section 4.2, I present results concerning my second exploratory-based research objective (see Section 2.5).

## 4.1. The theory-based approach

First, I determined the degree to which the scale items represent the theory-based factors proposed by Axsen and Kurani's (2012) two-by-two framework. Results shown in Table 3 reveal that across the three innovations, the theory-based factors have alpha scores within the range of 0.50 to 0.70 indicating moderate reliability, and between 0.70 and 0.90 suggesting high levels of reliability (Hinton et al., 2004). Notably, alpha scores are particularly strong for the three-item scale measuring societal-functional attributes.

**Table 3. Cronbach's alpha scores for theory-based factors (two-by-two attribute scales)**

| | | Electric Vehicles | Shared Ride-Hailing | Car-Sharing |
|---|---|---|---|---|
| Private-Functional | *(5-items)* | 0.822 | 0.707 | 0.727 |
| Private-Symbolic | *(3-items)* | 0.795 | 0.703 | 0.631 |
| Societal-Functional | *(3-items)* | 0.865 | 0.815 | 0.834 |
| Societal-Symbolic | *(2-items)* | 0.737 | 0.685 | 0.582 |

Table 4, presents findings from binary logistic regression analyses assessing the extent to which the theory-based factors predict adoption of EVs, car-sharing and shared ride-hailing. The extent to which a given independent variable predicts adoption of the innovation is indicated by an odds ratio. An odds ratio of 1.000 means that there is no higher or lower odds of being an adopter of the innovation. An odds ratio above 1.000 indicates that there is greater likelihood of being an adopter, or in other words that the independent variable positively predicts adoption. On the other hand, an odds ratio below 1.000 indicates there is lesser likelihood of being an adopter, or that the variable negatively predicts adoption.

Starting with step 1, I find adoption of each innovation is negatively associated with being older, and positively associated with having a higher education. Having a higher household income is positively associated with electric vehicle and shared ride-hailing adoption. In terms of neighbourhood type, living in a suburban area compared to an urban neighbourhood is negatively associated with shared ride-hailing and car-sharing adoption, and further living in a rural area is negatively associated with car-sharing adoption.

Step 2a in Table 4 adds the theory-based factors to the models. I tested for model improvement using the Omnibus Test of Model Coefficients. For each innovation, step 2a is a statistically significant ($p<0.001$) improvement and explains more of the variance in predicting adoption compared to step 1.

Among the theory-based factors, only the Private-Functional factor demonstrates a consistent (positive) association with adoption across the three innovations (all significant at a 99% confidence level). The Private-Symbolic factor is only significant for EVs (positive, at a 99% confidence level). Surprisingly, the Societal-Functional factor is not statistically associated with adoption for any of the innovations. Also unexpectedly, the Societal-Symbolic factor is negatively associated with shared ride-hailing adoption (at the 99% confidence level), and is not significantly associated with adoption of the other two innovations.

As mentioned, I conducted forward stepwise regressions as an additional check (Appendix Table A.2). Results completely replicate the findings presented in step 2a below, thus providing confirmation for the pattern of results described. Notably, the forward stepwise regression replicated the unexpected result that the Societal-Symbolic factor is negatively associated with adoption of shared ride-hailing.

As a final note of this analysis, with step 2a, some results concerning socio-demographic and contextual variables are different from those shown in step 1. Household income is no longer significantly associated with EV adoption, having a higher education loses its significance in the case of car-sharing adoption and age is not significantly associated shared ride-hailing and EV adoption. Lastly, living in a suburban neighbourhood compared to an urban area becomes positively associated with EV adoption.

**Table 4. Binary logistic regression results for the theory-based approach. Odds ratio (Exp(B)) and significance levels (*p<0.1, **p<0.05, ***p<0.01) indicate likelihood of being an adopter of mobility innovations**

| | Electric Vehicle Adoption | Shared Ride-Hailing Adoption | Car-Sharing Adoption |
|---|---|---|---|
| **Step 1.** | *Exp(B)* | *Exp(B)* | *Exp(B)* |
| **Demographic characteristics** | | | |
| Age (continuous) | 0.833* | 0.696*** | 0.616*** |
| Education (dummy: Bachelor's or higher) | 2.906*** | 1.163*** | 2.136** |
| Household Income (continuous) | 1.122** | 2.727*** | 1.055 |
| **Neighbourhood type** (base=urban) | | | |
| Suburban | 1.918 | 1.111 | 0.198** |
| Rural | 0.872 | 0.168** | 0.142* |
| n | 176 | 188 | 162 |
| Nagelkerke $R^2$ | 0.235 | 0.282 | 0.297 |
| **Step 2a. Theory-based Approach** | | | |
| **Demographic characteristics** | | | |
| Age (continuous) | 0.925 | 0.842 | 0.657*** |
| Education (dummy: Bachelor's or higher) | 4.546*** | 2.764*** | 1.505 |
| Household Income (continuous) | 1.016 | 1.147** | 1.049 |
| **Neighbourhood type (base=urban)** | | | |
| Suburban | 2.612* | 1.406 | 0.105*** |
| Rural | 0.845 | 0.152** | 0.208 |
| **Theory-based factors** | | | |
| Private-Functional | 4.015*** | 7.850*** | 4.466*** |
| Private-Symbolic | 4.333*** | 1.237 | 1.373 |
| Societal-Functional | 0.876 | 0.650 | 0.893 |
| Societal-Symbolic | 0.640 | 0.370*** | 0.612 |
| n | 176 | 188 | 162 |
| Nagelkerke $R^2$ | 0.582 | 0.502 | 0.451 |
| Omnibus test of model coefficients | p<0.000 | p<0.000 | p<0.000 |

Notes: Gender was removed from the model due to being insignificant across all innovations. The Omnibus test is a likelihood-ratio chi-square test, indicating if the addition of theory-based factors (step 2a) is a significant improvement from step 1 in predicting the model outcome.

## 4.2. The exploratory-based approach

For my second approach I used exploratory factor analysis to identify exploratory-based factors. The exploratory factor analysis was performed on adopters and non-adopters across all three innovations. Across numerous factor analysis iterations, the item (from Table 1) “using it fits well with my values and beliefs” had strong cross loadings, suggesting the attribute is a distinct construct. For this reason, this item is included as a separate factor, and separate independent variable in the subsequent regression models.

After removing the item “using it fits well with my values and beliefs”, I arrive at a 4-factor structure (Table 5) with some similarities and differences relative to the theory-based factors. I address each resulting factor in turn:

- Items developed to measure perceived Private-Functional attributes load onto two separate factors that uniquely represent perceived “Private Convenience and Compatibility” attributes (Factor 1) and perceived “Private Financial” attributes (Factor 2).
- Factor 3 represents “Societal Functional” attributes, where the three-items designed to measure this attribute category load on to one factor (matching the theory-based factor).
- Factor 4 represents items associated with “Private and Societal Symbolic” attributes. Unlike the theory-based factors, the factor analysis loads all items measuring symbolic perceptions (aside from the item “using it fits well with my values and beliefs”) onto one factor.

I calculated Cronbach’s alpha scores for the exploratory-based factors, where alpha scores across the three innovations range from moderate (0.50 to 0.70) to high (0.70 to 0.90) levels of internal reliability (Hinton et al., 2004).

**Table 5. Exploratory factor analysis of the two-by-two attribute items**

| Survey Items | **Factor 1.** Private Convenience & Compatibility | **Factor 2.** Private Financial | **Factor 3.** Societal Functional | **Factor 4.** Private & Societal Symbolic |
|---|---|---|---|---|
| Using it (is/would be) convenient | 0.89 | | | |
| Using it (is/would be) compatible with my daily life | 0.61 | | | |
| *Using it (would) take(s) effort | 0.60 | | | |
| *Using it (is/would be) too expensive | | 0.87 | | |
| Using it (would) help(s) save money | | 0.38 | | |
| Using it (would) help(s) tackle climate change | | | 0.97 | |
| Using it (would) help(s) protect the environment | | | 0.89 | |
| Using it (would) help(s) the local community | | | 0.40 | |
| Using it (would) help(s) inspire others | | | | 0.86 |
| Using it (would) send(s) a message to those with power and influence | | | | 0.79 |
| Using it (would) help(s) me connect with like-minded people | | | | 0.74 |
| Using it (would) make(s) a good impression | | | | 0.73 |
| **Cronbach's alpha** | | | | |
| Electric Vehicles | 0.737 | 0.684 | 0.865 | 0.863 |
| Shared Ride-Hailing | 0.671 | 0.620 | 0.815 | 0.826 |
| Car-Sharing | 0.752 | 0.627 | 0.834 | 0.738 |

*Item is reverse coded

Table 6 presents results from binary logistic regression analyses that examine the extent to which the exploratory-based factors predict adoption of EVs, car-sharing and shared ride-hailing. Step 1 results are identical to those for step 1 of the theory-based analysis, as this model only includes socio-demographic predictors. The Omnibus Test of Model Coefficients indicates that the addition of the exploratory-based factors in step 2b is a statistically significant ($p<0.000$) improvement from step 1 in explaining a greater degree of variance in predicting adoption.

Across exploratory-based factors, "Private Convenience and Compatibility" (Factor 1) is the only factor that shows a consistent (positive) association with adoption of each innovation. The "Private Financial" factor (Factor 2) is positively associated with shared ride-hailing and EV adoption (at the 95% confidence level), but is not significantly associated with car-sharing adoption. As with the theory-based approach, I find that the "Societal Functional" factor (Factor 3) is not significantly associated with adoption of the three innovations. Interestingly, the "Private and Societal Symbolic" factor (Factor 4) is positively associated with EV adoption (but only at a 90% confidence level) and is negatively associated with shared ride-hailing adoption (at a 99% confidence level), though is not significantly associated with car-sharing adoption. I find that the item “using it fits well with values and beliefs” is positively associated with shared ride-hailing and car-sharing adoption (at the 95% confidence level), but is not significantly associated with EV adoption.

Step 2b results concerning socio-demographic and contextual variables are similar to those presented in step 2a, demonstrating that the significance of these variables varies by innovation. Older age is negatively associated with car-sharing adoption, but is not significant for the other two innovations. Having a higher education is positively associated with EV and shared ride-hailing adoption, though is not significantly associated with car-sharing adoption. I find that higher household income is only significantly associated with adopting shared ride-hailing. Living in a suburban area compared to an urban neighbourhood is negatively associated with adopting car-sharing but positively associated with EV adoption. Lastly, living in a rural area compared to an urban area is negatively associated with shared ride-hailing adoption.

On a final note, I performed a series of forward stepwise regressions as an additional check of the patterns of results presented in step 2b, Table 6 (Appendix Table A.2). Results largely reproduce findings demonstrated above, with slight differences.

**Table 6. Binary logistic regression results from the exploratory-based approach. Odds ratio (Exp(B)) and significance levels (*p<0.1, **p<0.05, ***p<0.01) indicate likelihood of being an adopter of mobility innovations**

| | **Electric Vehicle Adoption** | **Shared Ride-Hailing Adoption** | **Car-Sharing Adoption** |
|---|---|---|---|
| **Step 1.** | *Exp(B)* | *Exp(B)* | *Exp(B)* |
| **Demographic characteristics** | | | |
| Age (continuous) | 0.833* | 0.696*** | 0.616*** |
| Education (dummy: Bachelor's or higher) | 2.906*** | 1.163*** | 2.136** |
| Household Income (continuous) | 1.122** | 2.727*** | 1.055 |
| **Neighbourhood type** (base=urban) | | | |
| Suburban | 1.918 | 1.111 | 0.198** |
| Rural | 0.872 | 0.168** | 0.142* |
| n | 176 | 188 | 162 |
| Nagelkerke $R^2$ | 0.235 | 0.282 | 0.297 |
| **Step 2b. Exploratory-based Approach** | | | |
| **Demographic characteristics** | | | |
| Age (continuous) | 0.948 | 0.890 | 0.702** |
| Education (dummy: Bachelor's or higher) | 3.857** | 3.005** | 1.774 |
| Household Income (continuous) | 1.064 | 1.156** | 1.067 |
| **Neighbourhood type (base=urban)** | | | |
| Suburban | 2.473* | 1.452 | 0.108*** |
| Rural | 0.812 | 0.171** | 0.262 |
| **Exploratory-based factors** | | | |
| 1. Private Convenience & Compatibility | 1.972** | 4.543*** | 3.750*** |
| 2. Private Financial | 2.078** | 1.931** | 1.185 |
| 3. Societal Functional | 0.988 | 0.776 | 0.770 |
| 4. Private & Societal Symbolic | 1.957* | 0.329*** | 0.594 |
| 5. Fits with values/beliefs | 1.686 | 1.888** | 1.766** |
| n | 176 | 188 | 162 |
| Nagelkerke $R^2$ | 0.571 | 0.525 | 0.490 |
| Omnibus test of model coefficients | p<0.000 | p<0.000 | p<0.000 |

Notes: Gender was removed from the model due to being insignificant across all innovations. The Omnibus test is a likelihood-ratio chi-square test, indicating if the addition of exploratory-based factors (step 2b) is a significant improvement from step 1 in predicting the model outcome.

# Chapter 5.

# Discussion

To better understand what drives electric and shared mobility adoption, this study explores consumer perceptions and motivations regarding these innovations, using survey data from a sample of Canadians (n = 529) that includes adopters and non-adopters of EVs, car-sharing, and shared ride-hailing. I adopt a theoretical and exploratory driven approach to applying Axsen and Kurani's (2012) two-by-two framework of consumer perceptions of innovation attributes. Here, I first summarize findings on the extent to which perceived attributes predict adoption of each innovation separately. Next I highlight patterns in the influence of attributes that consistently predict adoption across the three innovations. I then discuss the implications of this work for the two-by-two framework, followed by a discussion of what findings from this study mean for these innovations as alternatives to privately-owned fossil-fuelled vehicles. Lastly, I outline strengths and weaknesses of this research and conclusions.

## 5.1. Attribute perceptions by innovation type

Generally, results are quite similar across innovations, with differences mainly found in the role of symbolic perceptions on adoption. Starting with EVs I find that positive perceptions of "Private Convenience and Compatibility" and "Private Financial" attributes are positively associated with EV adoption. Other studies similarly demonstrate that EV interest and adoption can be driven by perceived practicality, including cost-savings from reduced maintenance and operating costs (Ozaki and Sevastyanova, 2011; Axsen et al., 2018; Ryghaug and Toftaker, 2012). I also find that positive Private-Symbolic perceptions are positively associated with EV adoption, which aligns with research showing that interest and adoption can be motivated by desires to make a good impression on others and signal aspects of self-identity (White and Sintov, 2017; Schuitema et al., 2013). However, Societal-Symbolic perceptions were not significant in this study, which contrasts research demonstrating that EV adoption can be driven by wanting to encourage others to use the technology and communicate support for innovative companies (Axsen et al., 2018). Finally, where some studies have found that EV adoption is motivated by perceived Societal-Functional related benefits (Rezvani et al., 2015; Axsen et al., 2018), including reducing environmental impacts, my findings support research demonstrating that such perceptions have no effect on adoption (Spurlock et al., 2019).

Next, for car-sharing I find that positive “Private Convenience and Compatibility” perceptions are positively associated with adoption, which aligns with several other studies (Hartl et al., 2018; Schaefers, 2013). However, I find that car-sharing adoption is not associated with the other perception categories. While some research suggests that financial factors are also motivators for car-sharing uptake (Böcker and Meelen, 2017), I find that perceptions of “Private Financial” attributes are not associated with adoption. I also find that Societal-Functional perceptions are not significant. Where there are mixed results in literature, this finding supports research suggesting that minimizing environmental impacts is generally not the primary reason to join car-sharing (Bhardi and Eckhardt, 2012; Hartl et al., 2018; Schaefers, 2013). Lastly, my findings demonstrate that car-sharing adoption is not motivated by symbolic perceptions, which aligns with research indicating that users avoid identification with the service (Bhardi and Eckhardt, 2012).

Finally, I find that shared ride-hailing adoption is associated with positive Private-Functional perceptions, including “Private Convenience and Compatibility” and “Private Financial” attributes. Others similarly find that shared ride-hailing adopters are motivated by factors like predictable travel costs (Spurlock et al., 2019), convenience (Loa and Habib, 2021), and time-savings and affordability (Sarriera et al., 2017). Interestingly, my findings demonstrate that positive Societal-Symbolic perceptions are negatively associated with shared ride-hailing adoption. While more in-depth research is needed to explore this result, this finding may reflect rising concerns among users of the service regarding the ethics of ride-hailing companies gathering large amounts of privacy-sensitive data (Mitropoulos et al., 2021). Finally, I find that shared ride-hailing adoption is not associated with several perception categories. Societal-Functional perceptions are not found to be associated with shared ride-hailing adoption, supporting other studies that find a lack of connection between environmental interest and adoption of ride-hailing in general (Lavieri and Bhat, 2019; Acheampong et al., 2020). Lastly, my findings reveal that Private-Symbolic perceptions are not significant, supporting research showing that users are not motivated by the potential to interact with fellow riders (Sarriera, 2017).

## 5.2. Comparing attribute importance across innovations

Across innovations, I find more similarities regarding the role of functional related perceptions than I do for perceptions related to symbolic attributes. First, positive Private-Functional perceptions are positively associated with adoption across all three innovations. As mentioned, the exploratory-based approach demonstrates that there are two subcategories of Private-Functional attributes, namely “Private Financial” and “Private Convenience and Compatibility” attributes. In particular, I find that “Private Convenience and Compatibility” perceptions are positively associated with adoption across all three innovations. Other studies similarly find that factors such as travel time savings, ease of use, and flexibility are important motivations for EV, car-sharing, and shared ride-hailing adoption (Axsen et al., 2018; Ozaki and Sevastyanova, 2011; Ryghaug and Toftaker, 2014; Burkhardt and Millard-Ball, 2006; Loa and Habib, 2021).

Next, I find that adoption across all three innovations is not associated with positive Societal-Functional perceptions. As noted, literature on this topic is mixed. Some studies find a positive association between desires to reduce environmental impacts and electric and shared mobility interest and adoption (Prieto et al., 2019; Spurlock et al., 2019; Axsen et al., 2018; Ozaki and Sevastyanova, 2011, Rezvani et al., 2015). Other research finds that such perceptions play a minor role (Hartl et al., 2018; Schaefers, 2013; Nansubuga et al., 2021), while some studies find no association with EV (Spurlock et al., 2019), car-sharing (Long and Axsen,2020) and general ride-hailing (Lavieri and Bhat, 2019, Acheampong et al., 2020) adoption.

Finally, the role of perceived symbolic attributes appears to play out differently for each innovation. According to the theory-based approach, only EV adoption is associated (positively) with Private-Symbolic perceptions. As mentioned, other EV studies demonstrate that adoption can be driven by desires to connect with others and signal aspects of self-identity (Axsen et al., 2018; White and Sintov, 2017), while shared ride-hailing users are not found to be motivated similar motivations (Sarriera, 2017) and research on car-sharing is mixed. The theory-based approach also revealed that only shared ride-hailing is associated (negatively) with Societal-Symbolic perceptions. Few studies have explored similar motivations in shared mobility uptake, though unlike findings in this study some EV research has shown that adoption can be driven by wanting to support innovation (Axsen et al., 2018; Heffner et al., 2007)

## 5.3. Implications for the two-by-two framework

In this study, I explore two ways of applying Axsen and Kurani's (2012) two-by-two framework. In a theory-based approach, I group consumer perceptions into the four theoretically derived categories. An exploratory-based approach is also applied, whereby factor analysis is used to identify perception categories that best fit the data. Findings demonstrate that my exploratory-based approach produces factors representing perceptions of electric and shared mobility that share some similarities to Axsen and Kurani's (2012) theory-based factors.

First, the exploratory-based approach identified a Societal-Functional factor that completely replicates the theory-based Societal-Functional perception category. This finding demonstrates a fit between the empirical data and the previously conceptualized, and theoretically grounded perception category. As such, this result provides strong evidence for the grouping of different societal-functional concerns into a single perception category, for future analyses of consumer perceptions.

Second, I've found some evidence that the "Private Functional" category might be better represented as two different sub-categories, specifically: "Private Financial" and "Private Convenience and Compatibility" attributes. Depending on the innovation under study, consumers may be drawn to use the innovation purely out of the convenience it offers. In other cases, consumers might just be trying to save money. Going forward, future analyses of consumer perceptions ought to consider both categories to uncover the unique role of these two perceptions.

Third, the study did not find differences in the Private-Symbolic and Societal-Symbolic perception categories. Instead, the exploratory-based approach suggested that these two categories represent the same underlying construct. However, without distinguishing between these two categories, important nuances regarding the role of symbolic perceptions in innovation adoption can be overlooked. For example, the theory-based approach demonstrates that perceptions of Private-Symbolic, rather than Societal-Symbolic attributes are positively associated with EV adoption. This important distinction was not identified when these two perception categories were collapsed into a single category. This is a case in point of when researchers are best advised to consider both theoretically and empirically derived constructs in conjunction with each other, as a way of gaining further insight into predictors of adoption.

Finally, I find that the item “using it first well with my values and beliefs “might be a stand-alone factor. It may be that due to the degree to which this item is open to diverse interpretations, that respondents’ evaluations of the item did not fit easily within a particular attribute category. However, further investigation is required to better understand this factor.

## 5.4. Implications for innovations as alternatives to privately-owned, fossil-fueled vehicles

Each mobility innovation studied offers an alternative to the dominance of privately-owned, fossil-fueled powered vehicles. EVs present consumers with the opportunity to shift away from fossil fuel powered drivetrains, while car-sharing and shared ride-hailing offer the potential to shift away from private vehicle ownership and use. Against a backdrop of privately-owned, fossil fueled powered vehicles dominating Canadian daily life, what is the outlook of electric and shared mobility innovations in reducing transport emissions?

According to this study, uptake of both shared mobility innovations is associated with positive perceptions of convenience. A logical implication is that further improvements in service quality could boost uptake of these shared modes. Further roll out of shared-ride hailing can also be supported by maintaining trip affordability.

Unlike the two shared mobility innovations studied, EVs are appealing to adopters by offering the opportunity to construct and communicate self-identity through possessing the innovation. Though according to this study, the extent to which EVs are adopted, and thus their contribution to emission reductions will also depend on consumers perceiving the innovation as convenient and financially appealing. As such, built out of infrastructure that supports accessible vehicle charging and closing the between the purchase price of EVs and conventional cars may help support further EV uptake.

## 5.5. Strengths and Weaknesses

The strength of the current study is in the examination of the relative importance of a comprehensive set of consumer perceptions in the adoption of multiple innovations, within the mobility sector. Notably, this study incorporates a methodologically robust approach to examining the construct validity of Axsen and Kurani's (2012) two-by-two framework.

However, despite addressing important gaps in electric and shared mobility research, this study has several limitations that are important to note. First, the scale used in this study included an option allowing respondents to indicate "don't know". This option was coded as a 3 in the five-point scale ranging from strongly disagree to strongly agree, based on the assumption that it represented the mid-point on this continuum. Whether respondents used this response option to truly indicate the mid-point on the scale is not clear, though the other option was to remove participants who provided this response; however, this significantly reduced my sample size.

Second, there are other potentially important variables that may influence adoption of electric and shared mobility that were not included in the analyses I completed (i.e., additional household demographic and contextual variables, consumer values, personality and lifestyle). While some of these variables were measured in the survey, I excluded such factors to avoid overfitting the models by having an excessive number of variables relative to the sample size for each innovation. (Ranganathan et al., 2018).

A final limitation of note is that I applied exploratory factor analysis to uncover the underlying dimensionality of perceived innovation attributes across adopters and non-adopters of all three innovations, where differences may occur at the innovation level, as well as between adopters and non-adopters. I opted for this approach in light of suggestions that a larger sample size yields results that are generally more replicable and generalizable (Costello and Osborne, 2005).

# Chapter 6. Conclusions

While research on the impacts of electric and shared mobility has grown, less is known about consumer perceptions and motivations toward these innovations. Consumer adoption is commonly depicted as being driven purely by financial and technical concerns, however more in-depth consumer research suggests that a more nuanced approach is needed to better understand consumer behaviour. Overall, I find that a complex array of consumer perceptions impact adoption of EVs, car-sharing and shared ride-hailing. Moreover, I find differences and similarities in the influence of perceptions across innovation type - i.e. whether the innovation is an alternative to fossil-fueled vehicles (EVs) or private vehicles ownership (car-sharing and shared ride-hailing).

Such insights may hold implications for policy, information and marketing campaigns that seek to shape the roll out of these innovations. For instance, policy and campaigns can enable uptake and usage of these innovations by focusing on attributes that align with the finding that adoption across innovation types is primarily related to privately focused attributes. Moving forward, future research should continue to engage in better understanding consumers to shed light on the potential for real-world uptake and impact of electric and shared mobility. As we begin to broaden our understanding of consumers, then policy-makers, industry and researchers will be better situated to understand the real-world potential of these innovations.

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# Appendix.

## Supplementary tables

**Table A.1. Survey definitions of mobility innovations**

| Innovation | Definition |
|---|---|
| Electric vehicles | Electric vehicles are powered by on-board batteries, which are recharged by plugging the vehicles in at designated charging points. (Please note: this does not include hybrid vehicles, which can also run over long distances on gasoline or diesel). Examples of electric vehicles include Tesla Model 3, Nissan Leaf. |
| Car-sharing | Car-sharing networks allow members to book, pay for, and use vehicles belonging to a network which may be parked in specific places or be locatable through an app or website. (Please note: this does not include car rental companies or group of car enthusiasts). Examples of car-sharing networks include car2go, ZipCar. |
| Shared ride-hailing | Shared ride-hailing services can be called using an app which matches multiple passengers with similar pickup points and destinations so the ride can be shared. (Please note: this does not include a group of people who already know each other taking a taxi or ride-hailing services like Uber together). Examples of shared ride-hailing include Uber Pool, Lyft Shared. |

**Table A.2 Forward stepwise binary logistic regression results for the Theory-based model. Odds ratio (Exp(B)) and significance levels (*p<0.1, **p<0.05, ***p<0.01) indicate likelihood of being an adopter of mobility innovations.**

| Electric Vehicle Adoption | | Shared Ride-Hailing Adoption | | Car-Sharing Adoption | |
|---|---|---|---|---|---|
| | *Exp(B)* | | *Exp(B)* | | *Exp(B)* |
| **Step 1.** | | **Step 1.** | | **Step 1.** | |
| Private Functional | 5.638*** | Private Functional | 3.795*** | Private Functional | 4.546*** |
| **Step 2.** | | **Step 2.** | | **Step 2.** | |
| Education (dummy: Bachelor's or higher) | 4.971*** | Societal Symbolic | 0.323*** | Age (continuous) | 0.951*** |
| Private Functional | 5.798*** | Private Functional | 8.208*** | Private Functional | 4.318*** |
| **Step 3.** | | **Step 3.** | | **Step 3.** | |
| Education (dummy: Bachelor's or higher) | 4.920*** | Education (dummy: Bachelor's or higher) | 3.138*** | Age (continuous) | 0.949*** |
| Private Symbolic | 2.628*** | Societal Symbolic | 0.312*** | Suburban (base = urban) | 0.118** |
| Private Functional | 3.578*** | Private Functional | 8.632*** | Private Functional | 4.662*** |
| **Step 4.** | | **Step 4.** | | | |
| Education (dummy: Bachelor's or higher) | 4.673*** | Education (dummy: Bachelor's or higher) | 2.657*** | | |
| Suburban (base = urban) | 2.766** | Household Income (continuous) | 1.129** | | |
| Private Symbolic | 2.882*** | Societal Symbolic | 0.310*** | | |
| Private Functional | 3.601*** | Private Functional | 8.159*** | | |
| | | **Step 5.** | | | |
| | | Education (dummy: Bachelor's or higher) | 1.149** | | |
| | | Household Income (continuous) | 2.551** | | |
| | | Rural (base = urban) | 0.137** | | |
| | | Societal Symbolic | 0.311*** | | |
| | | Private Functional | 8.451*** | | |

**Table A.3 Forward stepwise binary logistic regression results for the Exploratory-based model. Odds ratio (Exp(B)) and significance levels (*p<0.1, **p<0.05, ***p<0.01) indicate likelihood of being an adopter of mobility innovations.**

| Electric Vehicle Adoption | | Shared Ride-Hailing Adoption | | Car-Sharing Adoption | |
|---|---|---|---|---|---|
| | ***Exp(B)*** | | ***Exp(B)*** | | ***Exp(B)*** |
| **Step 1.** | | **Step 1.** | | **Step 1.** | |
| Private Financial | 3.805*** | Private Convenience & Compatibility | 3.150*** | Private Convenience & Compatibility | 3.904*** |
| **Step 2.** | | **Step 2.** | | **Step 2.** | |
| Education (dummy: Bachelor's or higher) | 4.914*** | Private & Societal Symbolic | 0.392*** | Age (continuous) | 0.696*** |
| Private Financial | 3.925*** | Private Convenience & Compatibility | 4.863*** | Private Convenience & Compatibility | 3.391*** |
| **Step 3.** | | **Step 3.** | | **Step 3.** | |
| Education (dummy: Bachelor's or higher) | 4.938*** | Education (dummy: Bachelor's or higher) | 4.111*** | Age (continuous) | 0.698*** |
| Private Convenience & Compatibility | 2.397*** | Private & Societal Symbolic | 0.355*** | Suburban (base = urban) | 0.158** |
| Private Financial | 2.427*** | Private Convenience & Compatibility | 4.433*** | Private Functional | 3.584*** |
| **Step 4.** | | **Step 4.** | | **Step 4.** | |
| Education (dummy: Bachelor's or higher) | 4.903*** | Education (dummy: Bachelor's or higher) | 4.108*** | Education (dummy: Bachelor's or higher) | 2.387** |
| Private & Societal Symbolic | 1.941** | Private & Societal Symbolic | 0.263*** | Age (continuous) | 0.730** |
| Private Convenience & Compatibility | 2.082** | Private Convenience & Compatibility | 4.433*** | Suburban (base = urban) | 0.143** |
| Private Financial | 1.971** | Fits with values/beliefs | 1.970*** | Private Convenience & Compatibility | 3.556*** |
| | | **Step 5.** | | | |
| | | Education (dummy: Bachelor's or higher) | 3.585** | | |
| | | Household Income (continuous) | 1.135** | | |
| | | Private & Societal Symbolic | 0.249** | | |
| | | Private Convenience & Compatibility | 4.336*** | | |
| | | Fits with values/beliefs | 2.007*** | | |
| | | **Step 6.** | | | |
| | | Education (dummy: Bachelor's or higher) | 3.395*** | | |
| | | Household Income (continuous) | 1.155*** | | |
| | | Rural | 0.162** | | |
| | | Private & Societal Symbolic | 0.251*** | | |
| | | Private Convenience & Compatibility | 4.254*** | | |
| | | Fits with values/beliefs | 2.076*** | | |