

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

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## CRedit authorship contribution statement

**Sarah M. McBain:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review and editing. **Jonn Axsen:** Conceptualization, Supervision, Methodology, Formal analysis, Writing – review and editing. **Charlie Wilson:** Data collection, Supervision, Writing – review and editing.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interest or personal relationships that could have appeared to influence the work reported in this paper.

## **Abstract**

The adoption of transportation innovations can be driven by a variety of motivations, including functional, symbolic and societal considerations. We compare these motives regarding consumer choice of electric and shared mobility, using survey data from a sample of Canadian adopters and non-adopters of electric vehicles, car-sharing and shared ride-hailing (n = 529). Our framework includes 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). We apply two data analytic approaches, finding that positive private-functional perceptions are consistently associated with adoption across all three innovations, especially convenience and compatibility. Other patterns vary by innovation. Most notably, positive private-symbolic considerations are significantly associated with electric vehicle adoption, while “fits with my values/beliefs” is significantly associated with shared mobility adoption. Results suggest that while functional considerations are important, symbolic motives can also be important but with more nuance.

## **Keywords**

Shared mobility; Consumer adoption; Innovation; Electric vehicle; Ride-hailing; Car-sharing

## 1. Introduction

The adoption of transportation innovations can be driven by a variety of motivations, including functional, symbolic, and societal considerations. We explore the cases of electric and shared mobility innovations that offer different types of alternatives to the status quo dominance of privately-owned, fossil-fuel powered vehicles. Both sets of technologies seem likely to play important roles in a transition to deep greenhouse gas (GHG) reductions in the light-duty vehicle sector, especially to be in line with net-zero emissions goals (IPCC, 2022; IEA, 2021). To help researchers and policymakers assess and anticipate the uptake of these innovations and their potential roles in decarbonization, it is important to understand consumer perceptions and motivations.

Electric vehicles (EVs) present consumers with an opportunity to shift away from drivetrains powered purely by fossil fuels. In this study we consider both battery electric vehicles (BEVs) which are powered exclusively by electricity, and plug-in hybrid electric vehicles (PHEVs) that are powered by a combination of electricity and an internal combustion engine. The International Energy Agency (2021) projects that for global emissions to reach net zero by 2050, over 60% of new light-duty vehicle sales will need to be electric by 2030, and nearly 100% by 2050. In our case study of Canada, analyses project GHG emission reductions from deployment of EVs ranging from 98% to 34% relative to conventional vehicles, depending on the region (Kamiya et al., 2019).

In contrast, shared mobility innovations (i.e., the shared use of a vehicle) present an opportunity for consumers to shift away from private vehicle ownership and use (IEA, 2021; Brand et al., 2021). For instance, the IEA's net zero scenario assumes that, 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 remain 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 (UNFCCC, 2022).

In this study we consider two versions of shared mobility. First, we 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 Meerkkerk, 2017). For instance, research finds that car-sharing use could cut transport related GHG emissions from Canadian households by up to 45-55% (Namazu and Dowlatabadi, 2015). However, car-sharing can potentially increase vehicle kilometers traveled (VKT) as car access becomes more convenient for carless households that would have otherwise used transit or active transportation (Sharma, 2020).

The other shared mobility innovation we 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 seems more likely to increase vehicle occupancy rates, while 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 some cases, modeling and market-based consumer 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; Équiterre, 2017). For example, the U.S. Department of Energy consumer choice model (ADOPT) simulates EV adoption as being driven by vehicle price, fuel cost, acceleration, size, and electric driving range (Brooker et al., 2015). However, more in-depth consumer research finds that innovation adoption can also 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 societal considerations, such as protecting the environment, may also be a motivation in consumer adoption (Spurlock et al., 2019; Long and Axsen, 2021).

To better understand what drives electric and shared mobility adoption, we utilize Axsen and Kurani's (2012) two-by-two innovation attributes framework to categorize this broader range of consumer motives and perceptions. Of the four categories of perceptions, the private-functional category represents perceptions of the functional attributes that the innovation provides to the individual, e.g., cost savings and convenience. Second, the private-symbolic 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. Third, the societal-functional category addresses the perceived functional attributes of the innovation that impact society, e.g., reducing GHG emissions and improving road safety. The final category, societal-symbolic, 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 analyses of survey and interview data collected from current and potential owners of EVs (Axsen et al., 2018; Axsen et al., 2013; Axsen et al., 2017), and also applied to consideration of automated and shared vehicles (Sovacool and Axsen, 2018; Axsen and Sovacool, 2019). As a further step in its application, we empirically test the framework in explaining adoption of EVs, car-sharing and shared ride-hailing. We also explore two different ways of applying the framework. In a theory-based approach, we strictly group consumer perceptions a priori into one of the four categories in the two-by-two framework. In an exploratory-based approach, we instead let the quantitative analysis of the empirical data identify the categories that best fit the data, via exploratory factor analysis.

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).

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 growing 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, especially private-functional attributes (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 an alternative to owning a vehicle altogether (car-sharing and shared ride-hailing). Finally, 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 short, our 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.

In the following section we 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. We then summarize the methods, results, and then discuss their implications.

## **2. Literature review and conceptual framework**

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. As one dominant example, the rational actor model from neoclassical economics represents consumers as rational utility maximizers. Although the rational actor model can cover a range of matters that concern consumers, in practice it tends to focus on perceptions of private and functional attributes, i.e., costs, performance, and convenience) (Scott, 2000; Axsen and Sovacool, 2019).

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 (Ajzen 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 motivation as consumer perceptions are seen to be influenced by social factors. 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). In the following sections, we 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.

**Figure 1 Two-by-two typology of perceived innovation attributes**

	<b>Functional</b>	<b>Symbolic</b>
<b>Private</b>	The functional benefits to the consumer, e.g.: <ul style="list-style-type: none"> <li>• Save money</li> <li>• Convenience (e.g., time savings)</li> </ul>	The symbolic benefits to the consumer, e.g.: <ul style="list-style-type: none"> <li>• Expression of self-identity</li> <li>• Attainment of group membership</li> </ul>
<b>Societal</b>	The functional benefits to society, e.g.: <ul style="list-style-type: none"> <li>• Reduce air pollution, GHG emissions</li> <li>• Help the local community</li> </ul>	The symbolic benefits to society, e.g.: <ul style="list-style-type: none"> <li>• Inspire others</li> <li>• Send message to industry or policymakers</li> </ul>

Source: Adapted from Axsen and Kurani (2012)

## 2.1 Private-functional attributes

Private-functional attributes represent perceptions of the functional attributes of an innovation that impact the consumer. These commonly include 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; Ferguson et al., 2018). 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 connected this category to EV adoption. 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. EV interest and adoption is also associated with the perceived benefit of demonstrating one's care for the environment, or an environmentalist self-identity (Krupa et al., 2014; Carley et al., 2019; Schuitema et al., 2013).

Also, a survey in California demonstrated that EV purchase interest was linked to seeing EV adoption as a way to express a social innovator self-identity (White and Sintov, 2017).

Studies demonstrate mixed results for the role of private-symbolic attributes in shared mobility adoption. In one study, Schaefer (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 from 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). Instead, riders indicate that the potential for a negative social interaction can serve as a deterrent. Similarly, 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. For example, 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. Interestingly, Mohamed et al. (2016) finds that environmental concern is an important component of interest to purchase an EV among Canadian consumers, but is not a significant determinant of behavioural intention toward adoption.

There are also 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. 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; Schaefer, 2013). Using a sample of Dutch car-share users Münzel et al. (2019) found that the environment is not a main reason to adopt the service. The authors observe 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 environmental impacts are not associated with adoption (Lavieri and Bhat, 2019), in one case finding that concern for the environment is negatively associated with interest in adopting shared ride-hailing. (Long and Axsen, 2022).

## **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. More broadly, societal-symbolic motivations have been explored in several social-psychological models which propose that such motivations are driven in part by underlying normative and moral influences (Jackson, 2005). One such model is the Value-Belief-Norm theory (Stern, 1999) which was first developed and explored in the context of understanding support for environmental and social movements. Motivations to contribute to movements were understood to stem in part from the belief that the individual and other social actors have an obligation to alleviate environmental problems.

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 motivated 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.

### **3. Methods**

#### **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. Other analyses of the UK data set have been published elsewhere (Vrain et al., 2022; Wilson et al., 2021), and the online survey dataset, the full survey instrument, and an accompanying methodology document are publicly available on the REShare repository (Wilson, 2021). Our present analysis focuses on the Canadian version of the survey. Specifically, we 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 Using it is convenient Using it is too expensive Using it takes effort Using it is compatible with my daily life
Private-symbolic	Using it makes a good impression Using it fits well with my values and beliefs Using it helps me connect with like-minded people
Societal-functional	Using it helps protect the environment Using it helps tackle climate change Using it helps the local community
Societal-symbolic	Using it helps inspire others 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 adopters 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
<i>Size (n)</i>	79	99	91	98	62	100	35,151,728
<i>Gender</i>							
Female	48%	57%	50%	60%	58%	59%	51%
<i>Age</i>							
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%
<i>Household Income (pre-tax)</i>							
Less than \$40,000	10%	35%	8%	27%	18%	23%	26%
\$40,000 to \$59,999	17%	15%	12%	14%	15%	12%	16%
\$60,000 to \$89,999	19%	20%	16%	25%	13%	20%	20%
\$90,000 to \$129,999	20%	23%	33%	15%	22%	26%	17%
Greater than \$130,000	34%	8%	31%	19%	32%	19%	21%
<i>Education</i>							
High school or less	13%	31%	13%	22%	10%	28%	41%
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%
<i>Residence Type</i>							
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%
<i>Employment</i>							
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
<i>Residential Location</i>							
Urban	56%	63%	77%	69%	71%	71%	N/A
Suburban	32%	17%	19%	17%	17%	17%	N/A
Rural	12%	19%	3%	14%	12%	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”). The items “using it is too expensive” and “using it takes effort” were reverse coded (items shown in Table 1). In addition, “don’t know” responses were coded as 3, representing the middle of the scale. While equating a statement of ignorance with a statement of knowledge of being between two extremes may be a potential limitation of this coding approach, we regard the option of “don’t know” as being synonymous with “neither disagree nor agree.”

To address our first (theory-based) research objective, for each innovation we 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). We then conducted three separate binary logistic regressions with adoption of EVs, car-sharing and shared ride-hailing as dependent variables. We first entered socio-demographics (age, education, income, gender, urbanization level) as independent variables (step 1), followed by the addition of the four theory-based variables (step 2a). Data was checked for multicollinearity for 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 our second (exploratory-based) research objective, we performed an exploratory factor analysis on the 13 individual items in Table 1 across pooled data from adopters and non-adopters of the three innovations. 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). The method of exploratory factor

analysis was similarly used by Khan and Maoh (2022) to identify the latent constructs that describe perceptions toward EVs in commercial fleets. First, we 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), we 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. Due to exhibiting cross loadings across numerous factor analysis iterations, the item "using it fits well with my values and beliefs" was dropped from the factor solution, while all other items were retained in the selected factor solution (Table 5).

Next, to investigate the association between these factors and adoption, we again conducted a series of binary logistic regression analyses. Here we examined the extent to which adoption of each innovation is explained by the exploratory factors. Adoption of EVs, car-sharing and shared ride-hailing were 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). Variables representing the exploratory factors were created by averaging scores across the items that factored together.

As a final note, while the two-by-two framework has been explored in analyses of survey and interview data, the survey items used in this study specifically have not yet been tested as a measurement instrument for the two-by-two framework. As such, we first utilize the theory-based approach as a preliminary test of the relationship between the theorized items. As a next step, we apply exploratory factor analysis on the data in accordance with recommendations across literature that this method is most suitable during early stages of instrument development and when the relationship among items is not known (Knekta et al., 2019; Orçan, 2018; Kline, 2011). We refrain from using confirmatory factor analysis in this study as literature suggests that this method is best reserved for applications in which the constructs in a theoretical model are well understood and the validity evidence on the internal structure of the scale has been previously tested (Knekta et al., 2019).

## **4. Results**

We organize our findings into two-subsections: the theory-based results (Section 4.1), and the exploratory-based results (Section 4.2).

### **4.1 The theory-based approach**

First, we determined the degree to which the scale items represent the theory-based factors proposed by Axsen and Kurani's (2012) two-by-two framework. As shown in Table 3, 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 (expressed as odds ratios) assessing the extent to which the theory-based factors are associated with adoption of EVs, car-sharing and shared ride-hailing. Starting with step 1 (demographics only), we 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 adoption of EVs and shared ride-hailing. 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 living in a rural area is negatively associated with car-sharing adoption.

Step 2a adds the theory-based factors to the models. We 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 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 with shared ride-hailing and EV adoption. Lastly, living in a suburban neighbourhood compared to an urban area becomes positively associated with EV adoption.

**Table 1. Binary logistic regression results for the theory-based approach.**

	<b>Electric Vehicle Adoption</b>	<b>Shared Ride-Hailing Adoption</b>	<b>Car-Sharing Adoption</b>
<b>Step 1.</b>	<i>Exp(B)</i>	<i>Exp(B)</i>	<i>Exp(B)</i>
<b><i>Demographic characteristics</i></b>			
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
<b><i>Neighbourhood type (base=urban)</i></b>			
Suburban	1.918	1.111	0.198**
Rural	0.872	0.168**	0.142*
n	176	188	162
Nagelkerke R <sup>2</sup>	0.235	0.282	0.297
<b>Step 2a. Theory-based Approach</b>			
<b><i>Demographic characteristics</i></b>			
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
<b><i>Neighbourhood type (base=urban)</i></b>			
Suburban	2.612*	1.406	0.105***
Rural	0.845	0.152**	0.208
<b><i>Theory-based factors</i></b>			
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 <sup>2</sup>	0.582	0.502	0.451
Omnibus test of model coefficients	p<0.001	p<0.001	p<0.001

Notes: Odds ratio (*Exp(B)*) and significance levels (\*p<0.1, \*\*p<0.05, \*\*\*p<0.01) indicate the likelihood of being an adopter of mobility innovations. 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 our second approach we used exploratory factor analysis to identify perception categories. The exploratory factor analysis was performed on pooled data from adopters and non-adopters across all three innovations. As mentioned, across numerous factor analysis iterations, the item (from Table 1) “using it fits well with my values and beliefs” had strong cross loadings. For this reason, we removed the item, arriving at a 4-factor structure (Table 5) with some similarities and differences relative to the theory-based factors. We 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.

We 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**

	<b>Factor 1.</b> Private convenience & compatibility	<b>Factor 2.</b> Private financial	<b>Factor 3.</b> Societal functional	<b>Factor 4.</b> Private & societal symbolic
<b>Survey Items</b>				
Using it is convenient	0.89			
Using it is compatible with my daily life	0.61			
*Using it takes effort	0.60			
*Using it is too expensive		0.87		
Using it helps save money		0.38		
Using it helps tackle climate change			0.97	
Using it helps protect the environment			0.89	
Using it helps the local community			0.40	
Using it helps inspire others				0.86
Using it sends a message to those with power and influence				0.79
Using it helps me connect with like-minded people				0.74
Using it makes a good impression				0.73
<b>Cronbach's alpha</b>				
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.

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

Table 6 presents binary logistic regression analyses that examine the extent to which the exploratory-based factors are associated with 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 ( $p < 0.001$ ) 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, we 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.

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. We 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.

**Table 2. Binary logistic regression results from the exploratory-based approach.**

	<b>Electric Vehicle Adoption</b>	<b>Shared Ride-Hailing Adoption</b>	<b>Car-Sharing Adoption</b>
<b>Step 1.</b>	<i>Exp(B)</i>	<i>Exp(B)</i>	<i>Exp(B)</i>
<b><i>Demographic characteristics</i></b>			
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
<b><i>Neighbourhood type (base=urban)</i></b>			
Suburban	1.918	1.111	0.198**
Rural	0.872	0.168**	0.142*
n	176	188	162
Nagelkerke R <sup>2</sup>	0.235	0.282	0.297
<b>Step 2b. Exploratory-based Approach</b>			
<b><i>Demographic characteristics</i></b>			
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
<b><i>Neighbourhood type (base=urban)</i></b>			
Suburban	2.473*	1.452	0.108***
Rural	0.812	0.171**	0.262
<b><i>Exploratory-based factors</i></b>			
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
n	176	188	162
Nagelkerke R <sup>2</sup>	0.571	0.525	0.490
Omnibus test of model coefficients	p<0.001	p<0.001	p<0.001

Notes: Odds ratio (*Exp(B)*) and significance levels (\*p<0.1, \*\*p<0.05, \*\*\*p<0.01) indicate the likelihood of being an adopter of mobility innovations. 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.

## 5. Discussion

Below, we first summarize findings on the extent to which perceived attributes are associated with adoption of each innovation separately. Next, we compare patterns of attributes importance across the three innovations, and then, we discuss the implications of this work for

the two-by-two framework. Finally, we outline the strengths and weaknesses of this research, and outline conclusions.

## 5.2 Attribute perceptions by innovation type

Generally, results are quite similar across innovations, with differences mainly found in the role of symbolic perceptions on adoption. Results for the theory-based and exploratory-based approach are summarized in Table 7.

**Table 7. Summarized results for theory-based and exploratory-based approach**

	<b>Electric Vehicle Adoption</b>	<b>Shared Ride-Hailing Adoption</b>	<b>Car-Sharing Adoption</b>
<b>Theory-based Approach</b>			
Private-functional	+	+	+
Private-symbolic	+		
Societal-functional			
Societal-symbolic		–	
<b>Exploratory-based Approach</b>			
Private convenience & compatibility	+	+	+
Private financial	+	+	
Societal functional			
Private & societal symbolic	+	–	

Starting with EVs we find that positive perceptions of “private convenience and compatibility” and “private financial” attributes are positively associated with EV adoption, which is consistent with studies demonstrating that EV interest and adoption is driven by perceived practicality, including cost-savings from reduced maintenance and operating costs (Ferguson et al. 2018; Ozaki and Sevastyanova, 2011; Axsen et al., 2018; Ryghaug and Toftaker, 2012). We 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, this study finds that EV adoption is not motivated by perceived societal-functional benefits.

For car-sharing we find that positive “private convenience and compatibility” perceptions are positively associated with adoption, which aligns with several other studies (Hartl et al., 2018; Schaefer, 2013). However, we find that car-sharing adoption is not associated with the other perception categories. In that way, our findings conflict with some research suggesting that financial factors are also motivators for car-sharing uptake (Böcker and Meelen, 2017). We also find that societal-functional perceptions are not significantly associated with adoption, which aligns with research suggesting that minimizing environmental impacts is generally not the primary reason to join car-sharing (Bhardi and Eckhardt, 2012; Hartl et al., 2018; Schaefer, 2013). Lastly, our findings demonstrate that car-sharing adoption is not motivated by symbolic perceptions.

Finally, we 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, our 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, perhaps this finding is linked to consumers not liking how ride-hailing “inspires others” (item 11) or what message its

usage sends to “those with power and influence” (item 12). Finally, we find that shared ride-hailing adoption is not associated with societal-functional perceptions (Lavieri and Bhat, 2019; Long and Axsen, 2022), and private-symbolic perceptions (Sarriera, 2017).

### **5.3 Comparing attribute importance across innovations**

Each mobility innovation studied offers an alternative to the dominance of privately-owned, fossil-fuel 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. Results in this study demonstrate how perceived attributes matter differently depending on this innovation context.

For EVs, adoption is related to what the vehicle symbolizes on behalf of the consumer (private-symbolic attributes). In other words, uptake of EVs is motivated by consumer desires that are rooted in private ownership, that is, the opportunity for individuals to identify with their possessions and make a good impression on others by using them. However, for the two innovations that challenge current vehicle ownership models (car-sharing and shared ride-hailing), identification with the innovation is not shown to influence adoption.

In addition, as noted there are some similarities in importance of attributes in adoption across the three innovations. In all cases, adoption is related to what the innovation does for the individual, especially factors of convenience and compatibility. 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). However, for all three innovations, adoption is not associated with societal motivations,

including motivations to help protect the environment (societal-functional attributes). As noted, literature on this topic is mixed. Some find a positive association between adoption and desires to reduce environmental impacts (Prieto et al., 2019; Spurlock et al., 2019; Axsen et al., 2018; Ozaki and Sevastyanova, 2011, Rezvani et al., 2015), while others find no association (Spurlock et al., 2019; Long and Axsen, 2021), or that such perceptions play only a minor role (Hartl et al., 2018; Schaefer, 2013; Nansubuga et al., 2021).

Against a backdrop of privately-owned, fossil-fuel powered vehicles dominating Canadian daily life, what is the outlook of electric and shared mobility innovations in reducing transport emissions? According to this study, the extent to which these innovations are adopted, and thus their contribution to emissions reductions depends on positive perceptions of their convenience. A logical implication is that measures that enhance the practicality and ease of using these innovations compared to private, fossil-fuel vehicles could boost uptake. Policy tools may include preferential or prohibited access schemes for shared and electric travel modes in cities, such as low- and zero-emission zones or differentiated circulation fees. Alternatively, measures might also include access to high-occupancy vehicle lanes or priority parking.

Where EVs are appealing to adopters by offering the opportunity to construct and communicate self-identity through possessing the innovation, policy efforts may also boost uptake through strategic advertising. For instance, marketing of EVs could use normative information (Barth et al., 2016) and align with research demonstrating that adopters can be motivated by expressing an innovative and technology-oriented self-identity (Axsen et al., 2018), or an environmentalist self-identity (Krupa et al., 2014; Carley et al., 2019; Schuitema et al., 2013). For instance, SUV ownership has been shown to be associated with traits such as being “family-oriented” and “sensible” (Axsen et al., 2022).

To ensure uptake across these innovations is consistent with sustainability goals, policy may be needed to guide the use of these innovations to avoid rebound effects, that is, increased driving that could result from the perceived convenience of traveling using these innovations. As noted by Axsen and Sovacool (2019), a high enough carbon tax could guide consumer use of shared and electric vehicles toward a low-carbon direction and/or congestion pricing and vehicle travel-based taxes can reduce and mitigate against rebound effects. In addition, policymakers seeking to promote these shared and electric modes for sustainability benefits should explicitly frame support for these innovations around these goals. For instance, framing of EV policy has been found to shape the prioritization of private or societal attributes in consumer decision making (Brown, 2001).

#### **5.4 Implications for the two-by-two framework and current theory**

By comparing theory-based and exploratory approaches to operationalizing Axsen and Kurani's (2012) two-by-two framework, we can offer some implications for the framework itself. Findings demonstrate that our 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, we'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.

Going forward, theories utilized to study the role of consumer perceptions in adoption of emerging mobility innovations can benefit from considering the diverse perception categories put forth by in the two-by-two framework. Our analysis suggests that consideration should also be placed on further distinguishing between financial and convenience related motivations within the private-functional category.

## 5.1 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, there are other potentially important variables that may influence adoption of electric and shared mobility that were not included in the analyses we completed (i.e., additional household demographic and contextual variables, consumer values, personality and lifestyle). While some of these variables were measured in the survey, we did not consider such factors in our analyses in light of emphasizing parsimony in the exploration of the two-by-two framework, as well as to avoid overfitting the models by having an excessive number of variables relative to the sample size for each innovation (Ranganathan et al., 2018).

Third, we 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. We opted for pooling together the samples, as opposed to conducting individual factor analyses for each innovation, in light of suggestions that a larger sample size yields results that are generally more replicable and generalizable (Costello and Osborne, 2005).

Finally, as mentioned in Section 3.3, exploratory factor analysis is most suitable in early stages of instrument development and when the relationship among items has yet to be explored. Moving along in the scale development process, results from exploratory factor analysis should

be confirmed using factor analysis on an independent sample (Knekta et al., 2019). Future research utilizing the two-by-two framework in a similar context can further inform the validity of the scale used in this study by conducting confirmatory factor analysis

## **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, we find that a complex array of consumer perceptions impact adoption of EVs, car-sharing and shared ride-hailing. Moreover, we 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 vehicle ownership (car-sharing and shared ride-hailing). Such insights may hold implications for policy, such as information and marketing campaigns that seek to shape the roll out of these innovations.

Moving forward, future research should continue to engage in better understanding consumers to shed light on the potential for future uptake and the impact of electric and shared mobility. As we begin to broaden our understanding of consumers, then policymakers, industry and researchers will be better situated to understand the real-world potential of these innovations.

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## Glossary

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

## Appendix A.

Table A.1 Survey Definitions of Mobility Innovations

<b>Innovation</b>	<b>Definition</b>
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.

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