Identifying Drivers & Barriers to Potential Adoption of Electrically-Assisted Bicycles by Post-Secondary Students in Region of Waterloo, Canada

by

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Author’s Declaration

I hereby declare that I am the sole author of this thesis. This is a true copy of the thesis, including any required final revisions, as accepted by my examiners.

I understand that my thesis may be made electronically available to the public.

Abstract

The electrically-assisted bicycle (EAB) is a relatively new innovation to the Canadian market with little adoption so far, though it could be a solution to sustainability issues in passenger transport for several groups of people, including students. Due to its limited uptake in much of the world, there is little previous research on EAB adoption by students and in North America in general. As with other environmentally-friendly innovations, the Innovation-Decision Process from Roger's (1962/2003) Diffusion of Innovations was identified as a useful framework for understanding adoption potential for EAB's. The IDP model outlines a process of stages towards adopting an innovation, as affected by five different influences, three of which are investigated in this study: prior conditions, characteristics of the potential adopter, and characteristics of the innovation. Using a predictive, pre-adoption perspective, this study aimed to identify the most influential drivers and barriers to potential EAB adoption through a web survey of post-secondary students in the Region of Waterloo in Ontario. Specifically, it set out to do this with the following objectives: to understand students' perceptions of the EAB's innovation characteristics; to identify relationships between those perceived characteristics of the EAB and students' commuting needs; and to investigate how those EAB perceptions may be related to separate factors such as students' socio-demographics, their environmental behaviour, and contextual prior conditions. Response data from 364 students included variables about the students themselves, their commuting situations, and their evaluations of the EAB and other transportation modes. These data included participants' responses to two sets of questions on 5-point Likert scales, which were used to assign multi-item scores for students' levels of environmental behaviour and favourability towards the EAB. The results show that students' awareness of the EAB prior to the survey is generally low and allow the categorization of EAB characteristics as either potential drivers or barriers to its adoption. Potential drivers are its simplicity (important driver), eco-friendliness (moderate), pleasant travel experience (moderate), effect on physical health (moderate), and effect on social image (weak), while its barriers are its cost (important), trip timing and routing (important), and safety (moderate). Statistical analyses also found certain characteristics of the students and their commuting situations to be predictors of their EAB favourability, which include their previous experience with EAB's, awareness and previous experience with kick-style e-scooters, and their backgrounds as either domestic or international students with experience living in different regions of the world. Their environmental behaviour and existing commuting habits were also found to be

weaker predictors. Ultimately, this study contributes knowledge on the EAB's adoption potential from across more kinds of influential factors than usually covered in previous studies, since it used as comprehensive a framework as the IDP model. Its method of evaluating the EAB on multiple aspects of performance also provides a model that can be followed for evaluating and comparing all different options for commuting. Finally, this predictive research provides practical recommendations for promoting EAB adoption among students at a relatively early stage of its emergence into the Canadian market.

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I must also thank many friends, family, mentors, and teammates outside of the Faculty of Environment and the University of Waterloo, of whom there are too many to list all of you here one-by-one. Thank you for your support and patience while I've been on this journey! Special thank you to my husband, Brian, and to my parents. You've been with me the longest on this journey and not only have you helped me through it immensely, but I wouldn't have even gotten to the starting line for it if it weren't for you.

Dedication

For Brian Bright and baby Bright.

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1 Introduction

1.1 Background

As an essential part of everyday life, commuting – how people travel routinely from their homes to places of work or study – has strong implications for sustainability**.**

Transportation is responsible for 37% of the GHG emissions from energy use in Canada (182 Mt of CO2e out of a total 488 Mt (37%) in 2017), more than any other sector, including the industrial sector (Natural Resources Canada (NRCan), 2019). In the Region of Waterloo (RoW) in particular, transportation is by far the heaviest emitter, accounting for half of all GHG emissions released (2.1 Mt CO_2e in 2015; ClimateActionWR, n.d.), 68% of which came from passenger vehicles, rather than from transit or commercial vehicles (ClimateActionWR, 2017). Nationwide, passenger transportation accounts for more than half of the GHG emissions from the entire transportation sector (NRCan, 2019). Out of the passenger transport category's near 95 Mt CO_2e, three quarters (72 Mt CO_2e) comes from cars and light trucks alone, as opposed to travel by motorcycle, bus, air, or rail (NRCan, 2019). This highlights the struggle for sustainable passenger transportation in Canada, and locally in RoW, where vehicle ownership from 2010 to 2015 rose at twice the rate of the region's population growth (ClimateActionWR, 2017).

Fortunately, several broad strategies for reducing emissions from passenger mobility are already known. Historically, cars have been mostly powered by fossil fuels (Brand, Anable, & Tran, 2013), but more recently, alternative fuel vehicles (AFV's), including electric vehicles (EV's), have become more established as low-emissions substitutes (Baptista et al., 2015; Jansson, Marell, & Nordlund, 2008; Lin, Wells, & Sovacool, 2017; Weiss, Dekker, Moro, Scholz, & Patel, 2015). Depending on the fuel or electric charge for AFV's, substituting one of these vehicles for a conventional car can reduce GHG's and other pollutant by ranging amounts (Jansson, Marell, & Nordlund, 2010; Lin et al., 2017; Steenhof & Weber, 2011; Weiss et al., 2015). Another strategy for reducing emissions is to use vehicles that each serve more passengers at a time rather than fewer (i.e. mass transit), which has great potential to curtail emissions through reductions in number of vehicles, in vehicle operating time, and ultimately in energy used (Baptista et al., 2015; Woods & Masthoff, 2017). Emissions can be reduced even further using this strategy when the shared vehicles have lower emissions based on their fuel or charge source (Li, 2016). Another final strategy is to replace a portion of motorized passenger mobility with active transportation instead (Baptista et al., 2015;

Woods & Masthoff, 2017). Multiple approaches need to be used together to achieve the greatest reductions in emissions of GHG's and other air pollutants.

Aside from the car's impact on the environment, it can also have an impact on transportation system performance that it depends on. Cars require significant space on roadways and for parking, an issue that is exacerbated as more cars are used, and that contributes to traffic congestion (Santucci, Pieve, & Pierini, 2016; Woods & Masthoff, 2017). Shared and mass mobility are not immune to transportation system challenges either as their service quality can be subject to on-road congestion and to fluctuating or excessive rider demand (Johnson & Rose, 2013; Transport Canada, 2019).

Another major problem associated with motorized transportation is a problem of human health. As previously mentioned, these methods for commuting typically produce emissions, which affect respiratory health (Kennedy, 2002). Additionally, such dependence on motor vehicles for transportation is a contributing factor to physical inactivity and consequently, to the associated health impacts, as seen commonly in Canada and the USA (Abelsohn, Bray, Vakil, & Elliott, 2005; Public Health Agency of Canada, 2018).

A final significant area to consider in comparing various methods for commuting is economic cost. Kennedy's (2002) study in the Greater Toronto Area (GTA) demonstrated that it is extremely challenging to understand all the economic costs (as well as benefits) associated with people's mobility choices and transportation systems and sustainability at the community level. Moreover, the specific economic costs, benefits, payers, and beneficiaries vary across cases depending on the systems in place (Kennedy, 2002). Total financial costs of car commutes in the GTA have been estimated to equal roughly 13.7% of residents' total incomes, of which only a relatively small component is public expenditure on roads (Kennedy, 2002). Otherwise, the financial costs of commuting by car are mostly consist of private spending – the direct user costs – for vehicle ownership or leasing, fueling or charging, insurance, and vehicle maintenance and repair (Kennedy, 2002; White & Sintov, 2017); this differs greatly from the direct user costs for other mobility options, i.e. the much lower costs for trip fare, or for ownership and maintenance or for use of transportation options that are active or shared (Baptista et al., 2015; Edge, Dean, Cuomo, & Keshav, 2018; Kennedy, 2002; Pucher & Buehler, 2008). Perhaps this suggests that car drivers deem the direct costs of their commute to be justified, given the benefits they receive from it. However, not all commuters

have the financial means to own or lease a car because of high direct use costs (Edge et al., 2018; Weinert, Ma, & Cherry, 2007).

A more affordable option could be an electrically-assisted bicycle (EAB), a relatively new technology to Canada, which could be part of the solution to the previously discussed sustainability issues for passenger transport (Johnson & Rose, 2013). Referred to oftentimes as “an e-bike” (as some other similar electric two-wheelers also are) or also commonly as “a pedelec” in Europe (from *pedal + electric*) (Vlakveld et al., 2015), the EAB looks much like a conventional, non-motorized bicycle, but it also uses a battery-powered motor to supplement the power that the "e-cyclist" generates from pedaling (Johnson & Rose, 2013; Weiss et al., 2015). Compared to a non-motorized bicycle, this electrically-assisted one is easier to propel with less physical exertion by the person pedaling it (Edge et al., 2018; Gojanovic, Welker, Iglesias, Daucourt, & Gremion, 2011; Johnson & Rose, 2013). This makes it easier to ride the bike at faster speeds, up hills, and over longer distances (Baptista et al., 2015; Gojanovic et al., 2011).

The EAB is powered by electric battery rather than by fuel, so unlike vehicles that run on fossil fuels, it does not directly produce GHG emissions (except for the relatively minimal CO_2 exhaled by the exercising e-cyclist) (Gojanovic et al., 2011). Depending on how power in the electric grid is produced, charging the EAB may be associated indirectly with a certain level of GHG emissions or none at all (Santucci et al., 2016). Like automotive EV’s, the EAB often stands as a lower-emission substitute for the conventional car (Weiss et al., 2015). Furthermore, its effectiveness in reducing emissions in transportation ultimately depends on the user’s previous mode of transportation, which it is used to replace (Fishman & Cherry, 2015; Winslott Hiselius & Svensson, 2017).

EAB’s are also a form of active transportation like conventional cycling and walking, but their electric power assistance allows them to meet more travel requirements (e.g. covering longer distances, reducing travel time, moving uphill with less physical exertion) for more individuals with varying commuting needs and across various levels of cycling ability (Wolf & Seebauer, 2014). Ultimately, the EAB may offer a more suitable or desirable option for active transportation without the usual barriers that other active transportation options may have against their use (Johnson & Rose, 2013).

EAB’s are another possible transportation alternative to the car, which takes up more space per user on streets, contributing to traffic congestion (Santucci et al., 2016; Woods & Masthoff, 2017).

EAB's can also serve as an alternative to public transit, which at times may suffer from congestion from high user demand or may not offer users the most convenient routes or schedules between locations (Johnson & Rose, 2013). The EAB offers these private transportation advantages at much lower purchase and operating costs than the private car (Edge et al., 2018; Pucher & Buehler, 2008), which could make it an attractive commuting option for individuals with limited income or even for post-secondary students – a segment of the population going through a life stage that is typically marked with financial constraint. Furthermore, when EAB's are made available through sharing schemes, which have already been gaining popularity with other vehicles, the upfront cost of ownership to an individual user is further reduced as a barrier to adoption (Parkes, Marsden, Shaheen, & Cohen, 2013).

The Region of Waterloo aims to reduce the carbon footprint of its transportation sector, while also balancing the task of improving service capabilities to people travelling in the community (Region of Waterloo & IBI Group, 2019; Waterloo Region, 2018), also making it interesting to consider the potential for EAB use in the region.

1.2 Study Rationale, Objectives, and Aims

Although EAB's offer many sustainability benefits, their uptake in Canada has been slow (Edge et al., 2018). In particular, the EAB could be a suitable and sustainable mode of transport for post-secondary students. Few studies are concerned with the barriers to EAB adoption in the context of Canada specifically (Edge et al., 2018; Gorenflo, Rios, Golab, & Keshav, 2017; MacArthur, Dill, & Person, 2014; MacArthur & Kobel, 2014) or elsewhere in North America (Dill & Rose, 2012; Fishman & Cherry, 2015; Ji, Cherry, Han, & Jordan, 2014; Langford, Cherry, Yoon, Worley, & Smith, 2013; MacArthur et al., 2014; MacArthur & Kobel, 2014; Popovich et al., 2014) as the the detailed literature review in Chapter 2 will outline.

Where most existing EAB research is focussed is in the contexts of developing countries, since their markets are where EAB's have seen their greatest and earliest spread alongside other styles of electric two-wheelers. Markets there present very different conditions from those of the Canadian market, so the existing research on adoption of the EAB in those contexts is often not relatable to its potential transition into Canada.

Furthermore, EAB research in other developed countries has focussed the most on mature adults (age 55 years and upwards) as the most promising group of potential adopters or even as existent earlier adopters of the EAB. Inherently, the focus for the EAB's application in that research then is on its potential for continuing independence in mobility and maintaining or improving physical fitness into later life. This, however, misses the opportunity for uptake by post-secondary students as another possible group of adopters. If students adopt the EAB (or at least develop an interest for adopting it) while in this early stage of adulthood, then the EAB could potentially serve as a sustainable transportation mode that they continue (or begin) to use beyond graduation. Few studies, however, offer insight specifically on this group as potential or existing users of the EAB, despite the arguments that students stand to benefit greatly from adopting it (Edge et al., 2018; Plazier, Weitkamp, & van den Berg, 2017b; Pucher & Buehler, 2008), as would their communities and environment from its integration into the mix of passenger transportation.

Therefore, the aim of this research is to identify the most influential drivers and barriers to post-secondary students' adoption of EAB's in the Region of Waterloo (RoW), Canada.

Specifically, this study pursues the following objectives:

Objective 1: To describe students' perceptions of the EAB in terms relative to other commute options and in terms of specific aspects of performance for commuting.

Objective 2: To identify relationships between students' perceptions of the EAB's performance and their requirements for commuting performance.

Objective 3: To identify relationships between students' perceptions of the EAB and their socio-demographics, their environmental behaviour, and contextual factors.

Rogers' theory of the Diffusion of Innovations (DoI; 1962/2003), with its subsequent Innovation-Decision Process (IDP) model, is identified in the literature review as the framework for exploring this research problem, because it is most comprehensive about and most commonly

associated with the adoption of high-involvement technological innovations (Faiers, Cook, & Neame, 2007; Jansson et al., 2008; Kaplan, 1999; Parthasarathy, Rittenburg, & Ball, 1995; Petschnig, Heidenreich, & Spieth, 2014). It can be said that the decision-making process about beginning to use an EAB demands high involvement from the decision-maker, based on existing research about EAB adoption specifically by freelance couriers, who each independently decide for themselves which vehicle to use for their work (Gruber & Kihm, 2016; Gruber, Kihm, & Lenz, 2014). Also similarly to previous studies on conventional cars and automotive AFV's (Jansson, 2011; Jansson et al., 2010; Lambert-Pandraud, Laurent, & Lapersonne, 2005; Lapersonne, Laurent, & Le Goff, 1995; Petschnig et al., 2014), this thesis includes the EAB among high-involvement innovations.

This thesis aims to be predictive in its approach and so it investigates three determinants of adoption (DoA's) that have influence in the IDP leading up to its Decision stage: prior (existing) conditions, characteristics of the decision-making unit (the individual), and perceived characteristics of the innovation. Understanding these DoA's can inform about what drivers and barriers there are to EAB adoption by post-secondary students early in the course of the IDP, and thus give an understanding of students' potential as earlier adopters of the EAB in RoW.

Furthermore, nearly all EAB adoption studies retrospectively explore the conditions within markets, in which the EAB is introduced successfully (or unsuccessfully) either prior to the study or as part of the study, such as in a pilot. Few studies have been used to predictively investigate scenarios where the EAB has potential to be adopted yet. This thesis also aims to contribute to the body of predictive research that explores adoption of innovations ahead of their introduction (known as "acceptability" studies; Rogers, 1962/2003). It would also be beneficial to investigate what factors could promote or prevent the spread of EAB's in a certain market before actually attempting it with some potential earlier adopters.

In summary, this study fills the following gaps:

i) lack of studies in a Canadian context, where the EAB is still largely unfamiliar;
ii) understanding post-secondary students and their potential to become adopters of the EAB; and
iii) using a predictive approach in attempt to understand the motivators and barriers there may be for EAB adoption.

1.3 List of Abbreviations and Acronyms

AFV	alternative fuel vehicle
ANOVA	Analysis of Variance
CO_2e	carbon dioxide equivalent
Conestoga	Conestoga College
DoA	Determinant of Adoption (specific to Rogers' Diffusion of Innovations theory)
DoI	Diffusion of Innovations (specifically, Rogers' theory of)
EAB	electrically-assisted bicycle (aka. "pedelec")
EV	electric vehicle
GHG	greenhouse gas
GTA	Greater Toronto Area
IDP	Innovation-Decision Process (specific to DoI)
Q	question, specifically a question in the survey for this study
RoA	rate of adoption (specific to DoI)
RoW	Region of Waterloo, Ontario
UW	University of Waterloo
WLU	Wilfrid Laurier University

2 Literature Review

The purpose of this literature review is to describe the theoretical framework to be used as the basis for this study on the potential for adoption of electrically-assisted bicycles (EAB's). Additionally, this chapter also reviews the existing literature on adoption and perceptions of EAB's as well as other sustainable transportation options such as electric vehicles (EV's) and conventional cycling options. The purpose of reviewing these existing studies is to understand factors about other forms of sustainable transportation that could be relevant to EAB's in influencing their adoption.

2.1 Diffusion of Innovations Theory

The DoI theory aims to provide an explanation of how, at what rate, and why an innovation is adopted and spread through populations (Rogers, 1962). Everett Rogers, a professor of rural sociology, studied the theory extensively and popularized it through the publication of his 1962 book of the same title, which has since gone through four more editions (Rogers, 1962/1983, 1995, 2003; Rogers & Shoemaker, 1971). He provides this definition of diffusion, in which he also highlights four essential elements:

> *"... the process by which (1) an* innovation *(2)* is communicated *through certain channels (3) over* time *(4) among the members of a* social system*"*
>
> (Rogers, 1962/2003, p.11).

Elaborating further on just the first element, Rogers defines innovation as "an idea, practice, or object that is perceived as new by an individual or other unit of adoption" (1962/2003, p.12). Note that the EAB for passenger transportation applications is the innovation in question for this study.

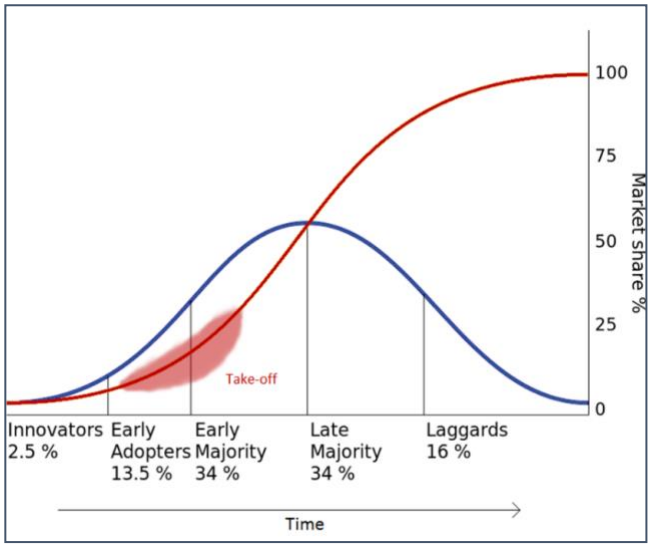

Figure 2–1 The *Diffusion of Innovations curve* (in red) illustrating the spread to all adopters aggregately within the given market or population (Rogers, 1962/2003, p.11), which Rogers refers to specifically as the *rate of adoption* (1962/2003, p.23). It is accompanied by the rate of uptake by new adopters (blue curve) across five typical *innovativeness categories* as shown (Rogers, 1962/2003, p.281) over time. Figuratively, the blue curve for new adoption is to the red diffusion curve as acceleration is to speed in basic kinetics.

Regardless of the innovation, diffusion will – in theory – follow an S-shaped curve known as the *rate of adoption* (RoA), as illustrated in red in Figure 2–1, and which is represented by the number of individuals who adopt the innovation in a period of time. It is characterized by a slow pick-up before gaining critical mass and taking off (the red curve's area of increasing acceleration highlighted in pink in Figure 2–1). Then after rapid diffusion, the RoA slows as diffusion through the whole population approaches higher levels (Rogers, 1962/2003). The slope of this curve differs, however, from innovation to innovation because different innovations have different rates of adoption (Rogers, 1962/2003, p.23).

DoI attempts to describe the processes of adoption and diffusion in a broad, comprehensive manner that can apply to many different kinds of innovations. Straub identifies three categories of characteristics commonly found across most change theories: *individual*, *innovation*, and *contextual* characteristics (2009). *Individual characteristics* are state- or trait-based characteristics that are specific to an individual (e.g. basic socio-economic characteristics), making them more or less predisposed to seeking or to avoiding change (Straub, 2009). *Innovation characteristics* pertain to the innovation itself (e.g. its advantageous and disadvantageous feature, and how they compare to those of other competing solutions) while *contextual characteristics* are related to the environment and

surroundings (e.g. social norms) around the individual as they move through the adoption process (Straub, 2009).

DoI is comprehensive because it incorporates aspects from each of these categories (Table 2-1): the *characteristics of the decision-making unit* DoA corresponds to the individual characteristics category; *perceived characteristics of the innovation* to innovation characteristics; and *prior conditions*, *change agent programs*, and *communication channels* to contextual characteristics. While other frameworks exist for investigating either the innovation in question or the potential adopters as the sole subject of their social acceptability research, DoI encompasses all aspects. In particular, the micro-level aspect, or Innovation-Decision Process (IDP) is particularly suited to researching barriers and drivers to adoption of EAB's.

Table 2-1 *Five Determinants of Adoption* (according to Rogers, 1962/2003) organized by the characteristics category (from Straub, 2009) that they relate to

Characteristics Categories Found Across Change Theories (after Straub, 2009)	Corresponding DoA(s)
Individual Characteristics	- Characteristics of the Decision-Making Unit
Innovation Characteristics	- Perceived Characteristics of the Innovation
Contextual Characteristics	- Prior Conditions - Change Agent Programs - Communication Channels

2.2 Innovation-Decision Process: Overall Model and Stages

The IDP represents the micro-level of adoption and consists of five stages (Figure 2–2) (Rogers, 1962/2003).

In stage 1, *Knowledge*, individuals encounter an innovation for the first time and will perhaps proceed to stage 2, *Persuasion*, where they are persuaded to learn more about the innovation (Rogers, 1962/2003). Individuals might then actively gather information about the innovation and from this, they might decide to either accept or reject it in stage 3, *Decision* (Rogers, 1962/2003). Depending on the innovation's level of trialability, individuals may have the opportunity to use it on a small-scale

trial basis, which will assist them in evaluating its usefulness to them in practice (Rogers, 1962/2003). Alternatively, they might simply fail to even consider using the innovation, resulting in *passive rejection* (also referred to as *non-adoption*), which differs from the deliberate consideration and decision against adoption, called *active rejection* (Rogers, 1962/2003). Beyond the Decision stage, they may continue onto stage 4, *Implementation*, where they put the innovation into application, and then on to stage 5, *Confirmation*, where they will evaluate their experience of using the innovation and decide whether to *continue* or *discontinue adoption* (Rogers, 1962/2003).

An individual can proceed through the stages of the IDP only in this order and they cannot have arrived at one stage (e.g. the final stage, Confirmation) in the IDP without having progressed through the other stages preceding it. It is possible, however, that individuals take a lot of time to proceed through the various stages or even fail to continue to the next stage of the IDP (usually meaning they disengage from the process altogether) because doing so does not interest them or because they decide to reject the innovation. Likewise, *later adoption* can occur should they initially reject the innovation at the Decision stage, but later learn more about the innovation that eventually persuades them to decide to accept it and continue through the subsequent stages (Rogers, 1962/2003, p. 170). On the other hand, individuals' receiving such additional information about an innovation later after having initially rejected it, conversely, might reinforce their rejection decision (called *continued rejection*).

The last three stages of the IDP could be exemplified in the case of EAB adoption firstly with an individual's purchase of (or conversely, their refusal to purchase) an EAB after informed deliberation. This point of purchase or refusal to purchase would be the Decision stage in this scenario. The Implementation stage would subsequently occur as the individual uses their acquired EAB. The individual can make their final evaluation about their experience using the new EAB (respectively, the Confirmation stage) after any amount of time and number of instances using it, which will determine whether or not they deliberately use it again. Alternatively, in the case of initial rejection, they may also reconsider and decide to later adopt the EAB innovation.

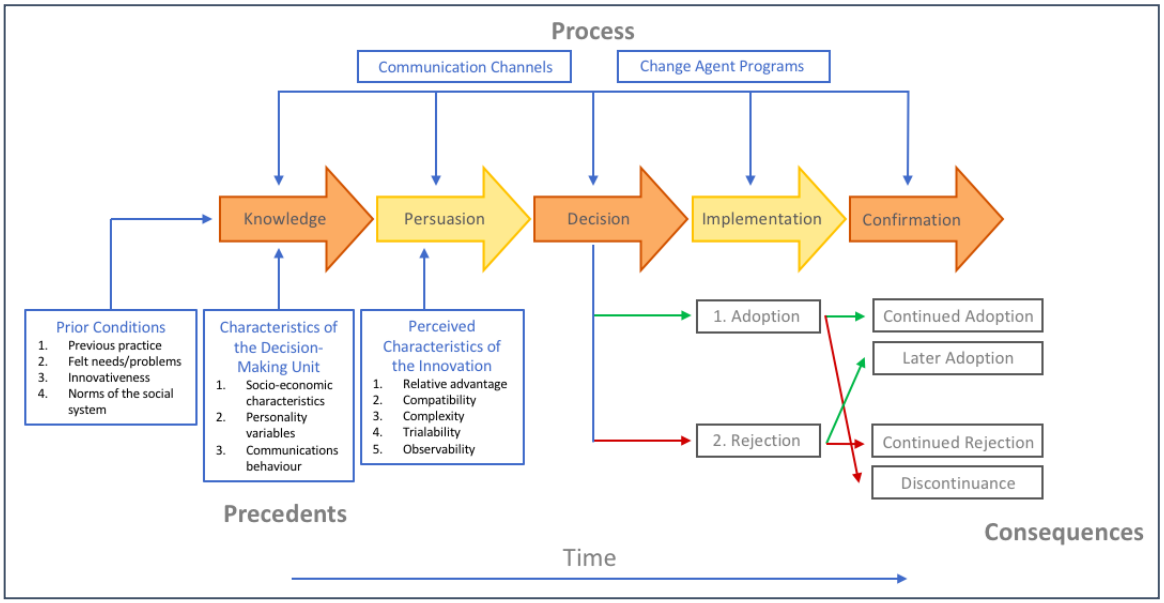

Figure 2–2 An individual advances through the Innovation-Decision Process in a sequence of stages (shown by the set of large arrows), influenced by various Determinants of Adoption along the way (labelled in the blue rectangular boxes), arriving at adoption of the given innovation as a result if the full progression is successful (Rogers, 1962/2003, p. 170).

There are also five *Determinants of Adoption* (DoA's) that can play roles over the course of the IDP (as listed in Table 2-1 and also as labelled in some of the rectangular boxes in Figure 2–2). In the bigger picture, the five stages of the IDP and the three final DoA's (perceived characteristics of the innovation, communication channels, and change agent programs) together can be considered like a *process* in themselves (Rogers, 1962/2003). Relative to this process, the first two DoA's (prior conditions and characteristics of the decision-making unit) are *precedents* and the results of the Decision and Confirmation stages are *consequences* of the process.

The degree to which the DoA's *communication channels* and *change agent programs* influence the rate of adoption can vary across the different stages of the process and their roles in either of the stages ahead of the Decision are difficult to isolate (Morris, Mills, & Crawford, 2000; Rogers, 1962/2003, p. 170, 222).

However, the three other DoA's are most relevant to the pre-Decision stages and to this thesis. *Prior conditions* (also referred to in this thesis as *existing* conditions) along with the *characteristics of the individual* will influence the process right at the Knowledge stage and the perceived characteristics of the innovation will influence it at the Persuasion stage (Faiers & Neame, 2006; Ozaki & Sevastyanova, 2011) ahead of the decision to adopt or reject. Furthermore, these three

DoA's break down into several distinctly defined components as shown in Figure 2–2 (Rogers, 1962/2003, p. 170). These three DoA's, as well as the Knowledge and Persuasion stages, require further exploration, since their earliness in the IDP means they are most relevant to this study.

2.2.1 Knowledge Stage

As a decision-maker becomes aware of a given innovation and starts building an understanding of how it works, they enter the initial stage of the IDP, *Knowledge* (Rogers, 1962/2003, p. 171). Ideally, this stage is the optimal time for individuals to gain full understanding of the innovation's attributes and how they function in order for the Persuasion stage to begin (Moreau, Lehmann, & Markman, 2001).

Rogers outlines three types of knowledge individuals can build about an innovation in this initial stage of the IDP: *awareness-knowledge*, *how-to knowledge*, and *principles-knowledge* (1962/2003). *Awareness-knowledge* refers simply to the individual's knowing that the innovation exists and it may motivate them to seek out further knowledge of the other two types (Rogers, 1962/2003). Gaining awareness-knowledge alone, however, may not be sufficient in leading individuals to use the innovation, as is typically the case with pro-environmental innovations, since individuals are rarely motivated to take up pro-environmental behaviours for purely altruistic reasons (Kaenzig & Wüstenhagen, 2008) and often consumers do not carry out these behaviours despite being aware of environmental issues (Jansson, 2009). Thus, the awareness-knowledge about pro-environmental innovations usually leads environmentally-motivated individuals to seek out further information about other attributes of the innovation, which could eventually motivate them towards adoption (Kaenzig & Wüstenhagen, 2008). This highlights the importance, especially regarding pro-environmental innovations, of understanding consumer behaviour beyond the influence of awareness alone. Next, *how-to knowledge* refers to the individual's understanding of how to use an innovation. The greater an innovation's relative complexity, the more how-to knowledge is required for the individual to proceed on through later stages of the IDP (Rogers, 1962/2003). Finally, *principles-knowledge* is the individual's understanding of the functioning principles that underlie how the innovation works, and which may also factor into an individual's continuance or discontinuance onward through later stages of the IDP (Rogers, 1962/2003).

For the individual to progress beyond the Knowledge stage, they need not only to engage in information-seeking activities, but must also be capable of the information-processing activities required at this stage (Rogers, 1962/2003). Leading up to this, characteristics about the individuals themselves, such as personality variables as well as their socio-economic characteristics and communication behaviour, will affect what innovation information gets to them and how (Rogers, 1962/2003; refer to Figure 2–2). If the individual does not find the innovation information relevant to their situation, or if they do not gain the knowledge sufficient to become adequately informed, then they most likely will not further consider the innovation for uptake (Rogers, 1962/2003, p. 174).

2.2.2 Persuasion Stage

Following the Knowledge stage of the IDP is the *Persuasion* stage, where the individual or other unit of adoption "forms a favourable or unfavourable attitude towards the innovation" (Rogers, 1962/2003, p. 174). An *attitude* here is defined by Rogers as a "relatively enduring organizing of an individual's beliefs about an object that predisposes his or her actions" (Rogers, 1962/2003, p. 174). In contrast to the Knowledge stage, where the mental activity taking place is mainly cognitive (knowing), the mental activity happening in the persuasion stage is mostly affective (feeling) (Rogers, 1962/2003). Rogers' definition of Persuasion also specifies that it is in fact the direction of "attitude formation and change on the part of the individual" (p. 174) and not merely the direction of change intended by another entity that is sourcing innovation information to the individual (1962/2003, p. 175).

With that, the individual becomes more psychologically involved in learning about the innovation in this stage (Rogers, 1962/2003). They actively seek information to reduce uncertainty about potential consequences of using the innovation in their present or anticipated future situation, deciding what messages they deem credible and how they interpret the information found in the process (Rogers, 1962/2003). While the further information-seeking activities of the Persuasion stage are underway, the individual's selective perception will often prove important in determining their behaviour and it will influence the general perception of the innovation they develop (Rogers, 1962/2003). Perceived characteristics of the innovation – understood in the categories of relative advantage, compatibility, and complexity – are a particularly influential Determinant of Adoption in shaping the individual's general perception of it (Rogers, 1962/2003). Ultimately, this stage of the

IDP primarily results in the formation of an attitude toward the innovation that is either favourable or unfavourable and which usually leads to a change in behaviour (meaning adoption or rejection) in line with that attitude (Rogers, 1962/2003).

2.3 Determinants of Adoption in the IDP

Three of the five DoA's are relevant only in the pre-Decision stages of the IDP, making them important for this study and needing further exploration. They are *prior conditions, characteristics of the individual,* and the *perceived characteristics of the innovation*.

2.3.1 Prior Conditions

The first Determinant of Adoption to influence an individual's progression through the IDP, even before the Knowledge stage, is prior conditions. This DoA consists of several components, which are *previous practice*, *felt needs or problems, innovativeness*, and *norms of the social system*. From findings throughout the rest of this literature review chapter, it is found that the components, previous practice, felt needs or problems, and social system norms, are very applicable to personal transportation. Given their nature, it is also feasible to investigate them within the limited scope of a master's thesis, even in situations where the innovation in question has yet to be introduced.

The components of innovativeness and social system norms, however, are complicated constructs requiring many pieces of information in order to give a sufficient understanding about their state in a given case (Rogers, 1962/2003). While social system norms can be evaluated to a limited extent, it is especially difficult to assess people's innovativeness without information on their previous innovation adoption relative to other adopters (Im, Bayus, & Mason, 2003; Keller & Holland, 1978; Kirton, 1976; Rogers, 1962/2003). A simpler construct similar to innovativeness but from a separate theory is psychological temporal distance from Construal Level Theory, which asserts that the distance – psychologically – from a point of decision-making affects an individual's readiness to face that decision (Broman Toft, 2014; Trope & Liberman, 2003). The nearer an individual perceives the possible innovation adoption to be in time, the more concretely they will reason about it and the readier they are to make specific, context-related considerations about it (Broman Toft & Thøgersen, 2015). However, when they expect the possible adoption to be farther away in the distant

future, they will only reason (if at all) about it more abstractly and on a general level (Broman Toft, 2014). With this concept in mind, it could be used to investigate individuals' readiness for facing a possible adoption decision in a simplified way, giving some information relating to innovativeness.

The three components, previous practice, felt needs or problems, and norms of the social system, are further described here to give an understanding about how they are examined in this study.

2.3.1.1 Previous Practice

An innovation stands as a new option for course of action and a way to solve or cope with problems differently from *previous practice* (Rogers, 1962/2003). Previous practice refers to the ideas, practices, products, or technologies individuals use, which would be displaced if a given innovation were adopted (Rogers, 1962/2003). As Kaplan states, previous practice serves as an individual's experience base and it can contribute greatly not just to their knowledge on the innovation, but also to their behavioural intentions and actual adoption decisions (Kaplan, 1999, p.471).

2.3.1.2 Felt Needs or Problems

Rogers defines a need as "a state of dissatisfaction or frustration that occurs when an individual's desires outweigh the individual's actualities" (1962/2003, p. 172), which makes a need something that is subjectively determined. In the perspective of DoI theory, *felt needs* exist if the individual perceives them.

The said actualities of an individual's experience can of course include their previous practices. So, one way an individual may begin to feel a need for a given innovation is when they experience issues with their previous practice (Rogers, 1962/2003). Another possible way an individual may develop a need is when they learn about a particular innovation and build an understanding of its function, in which case, they do not perceive the need until they become aware of the innovation and this awareness creates the need (Rogers, 1962/2003). While researchers have attempted to determine which comes first – problem recognition or awareness of an innovation – leading to the perception of a need, the answer remains unclear since the empirical findings point to one as the precedent in some cases and to the other in other cases (Rogers, 1962/2003).

With this in mind, felt needs or problems do not always stand as a complete explanation why individuals begin the IDP (Rogers, 1962/2003). For instance, some individuals may become aware of

an innovation as they actively seek out a solution to a perceived problem or need. Alternatively, other individuals may become aware of the innovation by chance or before they begin actively seeking information, making their role in addressing a given problem more passive by comparison. Furthermore, individuals do not always recognize when a problem exists to begin with and thus may not perceive a need, even in instances where experts would see one (Rogers, 1962/2003).

2.3.1.3 Norms of the Social System

Social norms are the established behaviour patterns, by which individuals abide as members of a social system (Rogers, 1962/2003, p. 26). Individuals' behaviour is often heavily influenced by social norms and pressures, and depending on the strength of these norms regarding a particular innovation, they can contribute to that individual's adoption or rejection of the innovation (Ozaki & Sevastyanova, 2011; Rogers, 1962/2003). A social system's norms may hold higher priority with an individual than their own personal values and attitudes do, and so an individual may be persuaded to adopt or not to adopt a given innovation according to the view of the social norm (Parthasarathy et al., 1995). With greater strength of the social norm, an individual is more likely motivated to obey the norm than to defy it. With this, it is possible for an individual to approve of an innovation themselves and symbolically accept it, but without tangibly adopting it. Likewise, an individual may adopt an innovation if social norms favour its adoption, if those social norms take precedence over any conflicting individual factors, as has been observed in Ozaki's study on household adoption of renewably-sourced electricity in the United Kingdom (2011).

While it may be straight-forward enough to understand that adoption in theory is partly influenced by social norms, it is not always so simple to determine what they are exactly and their strength in just a few measures. Social norms can be described in a full picture using several different conceptualizations and dimensions (Barth, Jugert, & Fritsche, 2016), and like innovativeness, require many pieces of information to be defined in practice.

2.3.2 Characteristics of the Decision-Making Unit

The next Determinant of Adoption to have an influence right in the first stage of the IDP is *characteristics of the decision-making unit* – or in other words, characteristics of the individual – which consist of their *socio-economic characteristics*, *personality variables*, and *communication*

behaviour (Rogers, 1962/2003). However, the communication behaviour component is not further explored in this study because of the complexity of testing any single one of the ten general hypotheses Rogers outlined specifically about this component (1962/2003, p. 290-291) and because it would require collecting and analyzing data about a multitude of variables. Focus is set though, on how the other two components, socio-economic characteristics and personality variables, are applicable in certain ways to the personal transportation category of innovations and so they are described further here.

2.3.2.1 Socio-Economic Characteristics

Of all the DoA's and their comprising variables, *socio-economic characteristics* of the decision-making unit have probably been researched the most, likely because it is relatively easier to gather and measure data indicative of these characteristics than of others, and especially because consumer research and marketing have already been examining these characteristics for so long for consumer profiling and segmenting (Jansson, 2011). While these characteristics can be helpful for profiling environmentally conscious consumers, results of some studies conflict with this view (Diamantopoulos, Schlegelmilch, Sinkovics, & Bohlen, 2003) and it is worthy to note that socio-economic characteristics alone do not always have high power in explaining the adoption of innovations (Rogers, 1962/2003).

Based on some decades' worth of studies, Rogers formulated several very general hypotheses about adopters' socio-economic characteristics, two of which are listed below as they would be relevant to examining post-secondary students as potential adopters in a broad survey (1962/2003, p. 288):

- *Earlier adopters are no different from later adopters in age.*
- *Earlier adopters have more years of formal education than do later adopters.*

Some other hypotheses of Rogers' on socio-economic characteristics have to do with literacy and size of the decision-making unit (ex. farms, companies, schools; 1962/2003), but these are not very applicable to post-secondary students as individual potential adopters of a mode of private transportation. Other hypotheses of his about characteristics of this kind are concerned with social status (indicated by variables such as income, standards of living, wealth, occupational prestige, social class, etc.) and social mobility (the ability to move upwards in social status; Rogers,

1962/2003). However, these characteristics are usually understood through a number of variables – variables that could be difficult to define for data collection from individuals, especially students.

2.3.2.2 Personality Variables

Unlike socio-economic characteristics, *personality variables* have yet to receive much research attention (Rogers, 1962/2003) although investigating them further could prove greatly promising in helping better understand scenarios when economic factors fail to offer a complete explanation for innovative behaviour, as they sometimes do. The lack of existing research here is partly due to the difficulties of accurately measuring personality dimensions in connection with innovation adoption in surveys (Rogers, 1962/2003). However, across all his research in many innovation areas, Rogers did compile a set of ten (not so few) general hypotheses (Rogers, 1962/2003, p. 289-90). These hypotheses involve constructs that are complex to measure in practice (ex. that greater *empathy* tends to be related to earlier adoption; p. 289) and despite the effort to summarize, testing any one of these general hypotheses alone would usually require collecting data about many variables in order to define the constructs involved. One of these general hypotheses could reasonably be (at least partly) investigated in a survey to post-secondary students (1962/2003, p. 290):

- *Earlier adopters have higher aspirations (for formal education, higher status, occupations, and so on) than do later adopters.*

Evidently, formal education attributes may be pertinent to more than one of Rogers' general hypotheses and they are certainly relevant when post-secondary students are the study population. A study could reasonably collect students' data that includes their years of study and the type of credential they are pursuing. It could then test the hypothesis that these academic characteristics are related to the students' likelihoods to adopt an innovation.

In an investigation about adoption of environmentally-friendly innovations, assessing environmentally-related personality traits would arguably be important as well. One way this could be done that this literature review found is by measuring pro-environmental attitude. The most tested and reliable ways to assess this across many individuals are to use either Dunlap & Van Liere's 12-item, 3-facet New Environmental Paradigm (NEP) Scale (1978) or the later 15-item Revised NEP Scale (with 2 new facets; Dunlap, Liere, Mertig, & Jones, 2000) as survey instruments. A similar, but even

more concise version of these instruments is Dunlap's lesser-known 6-item Short NEP Scale, although this version requires more testing to assure its validity (Dunlap, 2008).

Other researchers, however, would criticize using a measure of environmental attitude, like Dunlap and Van Liere's NEP Scale, to inform about a part of a person's personality and then about their expected behaviour (or even to try to use an individual's personality to forecast their adoption-rejection decision, like Rogers). Stern (2000) and Ajzen (1991), for example, are well known for arguing that actual behaviour is not reliably predicted by attitudes or intentions. The implication then is that pro-environmental attitudes may not actually be so predictive of a person's likelihood to adopt a new environmentally-friendly innovation. Rather, their already demonstrated pro-environmental behaviour, as shown through past actions and existing habits, should be more informative than their attitudes about their likelihood to adopt the innovation as yet another environmentally-friendly action.

Thus, further research was directed towards the existing literature on past pro-environmental behaviours as predictors of future pro-environmental action and on survey instruments to collect this data. Barr and Gilg conducted a survey exploring pro-environmental action characterized by 36 specific environmental behaviours in and around the home in four areas: energy saving, water conservation, waste management, and green consumption (2006). Olli, Grenstad, and Wollebaeck tested another survey instrument using fewer (16) example household environmental behaviours across five categories: responsible consumerism, resource conservation, use of nature, anti-toxic, and waste handling (2007). Using a survey instrument of 16 questions – let alone 36 of them – to measure only environmental behaviour could take up too much research space in such a comprehensive study on innovation adoption. Additionally, several of the environmental behaviours from their survey instruments are not typically applicable to post-secondary students (namely those behaviours that are tied heavily to home ownership). However, several of the highly specific pro-environmental behaviours and the broader categories encompassing them in these questionnaires are certainly worth consideration in designing a method to measure such behaviour across a wide range and to do so concisely with fewer variables.

2.3.3 Perceived Characteristics of an Innovation

The third Determinant of Adoption is made up of *perceived characteristics of an innovation*, which affect the formation of an individual's attitude towards it in the Persuasion stage (Rogers, 1962/2003).

Studies looking at the successes or failures of innovations to be adopted in the past (aptly referred to as *past* research as well as *postdictive* research) have often looked at the innovation's characteristics in attempting to explain its RoA (Rogers, 1962/2003). Examinations of the perceived innovation characteristics DoA can also be used, however, to predict the RoA of innovations yet to embark on their course through the IDP and diffusion, which this thesis aims to do about EAB's. Such predictive sorts of investigations, according to Rogers, are sometimes called *acceptability research* because they aim to understand what it is about an innovation that will make it more or less acceptable to potential adopters (1962/2003, p. 227). While an innovation's progression towards adoption is affected by other DoA's as well, understanding perceptions of its characteristics is an important key to understanding its acceptability.

Rogers had observed that – even up to the writing of his latest edition of Diffusion of Innovations from 2003 – most diffusion research had studied "people" differences in innovativeness (i.e. the characteristics of the different adopter categories) as opposed to "innovation" differences (i.e. the characteristics of innovations as they are perceived by potential adopters) (p. 221). As mentioned above, he argued that research on the characteristics of innovations themselves are valuable for understanding how people will react to the innovations. This is because it is an oversimplification to assume all innovations as being equivalent across different adoption scenarios, as had been done by research that focussed on the characteristics of the individuals only (Rogers, 1962/2003).

Stressing the importance of the innovation's characteristics in adoption and diffusion, Rogers claims that 49-87% of variance in the RoA can be explained by the five categories of innovation characteristics: *relative advantage*, *compatibility*, *complexity*, *trialability*, and *observability* (Rogers, 1962/1995, p. 206). Of these categories, relative advantage, compatibility, and complexity have been shown to hold the most influence over the decision to adopt or not (Faiers & Neame, 2006; Rogers, 1962/2003). Likewise, empirical studies from other researchers have also found that the perceived characteristics of the innovation are generally better predictors of adoption than socio-demographic characteristics of the individuals, such as their education and income levels (Faiers & Neame, 2006; Labay & Kinnear, 1981). It is important to note that it is not the innovation characteristics as objectively identified by experts or change agents that are of concern here, but it is those that potential adopters subjectively evaluate the innovation to have (Rogers, 1962/2003, p. 223; Straub, 2009).

Five categories for perceived characteristics of an innovation, are outlined in Table 2-2, each with a brief description and general hypothesis about their relationship to the RoA from Rogers (1962/2003). Each of them is explored further in their own subsequent sub-section, especially the three identified as most influential and most relevant for this study: relative advantage, compatibility, and complexity.

Table 2-2 Five categories of perceived characteristics of an innovation (Rogers, 1962/2003)

Category	Description: *The degree to which…*	Hypothesis
Relative Advantage	… an innovation is perceived to be better than the idea it supersedes (p. 229).	*Positively* related to RoA (p. 233)
Compatibility	… an innovation is perceived to be consistent with the existing values, past experiences, and needs of the potential adopters (p. 240).	*Positively* related to RoA (p. 249)
Complexity	… an innovation is perceived to be relatively difficult to understand and use (p. 257).	*Negatively* related to RoA (p. 257)
Trialability	… an innovation may be experimented with on a limited basis (p. 258).	*Positively* related to RoA (p. 258)
Observability	… the results of an innovation are visible to others (p. 258).	*Positively* related to RoA (p. 258)

The Persuasion stage of the IDP is where these perceived characteristics of an innovation play a role (Rogers, 1962/2003). From having learned about the innovation and evaluating its characteristics for themselves, individuals will have formed favourable or unfavourable attitudes towards the innovation (Rogers, 1962/2003). Typically, having developed a favourable attitude will lead the individual to eventual adoption in the Decision stage (Rogers, 1962/2003).

2.3.3.1 Relative Advantage

Relative advantage concerns the degree to which a given innovation is considered superior to the idea it supersedes, as is expressed through any characteristics that are relevant to potential adopters such as economic profitability, low initial cost, social status conferral, decrease of discomfort, improved convenience, and immediacy of reward (Rogers, 1962/2003). Such advantage can be perceived in technical, economic, environmental, or social terms that usually differ from innovation to innovation

(Rogers, 1962/2003; Tapaninen, Seppänen, & Makinen, 2009). Relative advantage can also be thought of like a ratio of the expected benefits against expected costs of adoption (Rogers, 1962/2003, p. 233).

In addition, other researchers have proposed another model of categorizing innovation characteristics, which separates them into instrumental (aka. functional), environmental, and symbolic types of characteristics (Noppers, Keizer, Bolderdijk, & Steg, 2014; White & Sintov, 2017). They specifically apply this model to sustainable innovations and thus, it provides another way alongside Rogers' five categories for thinking about the characteristics of innovations for sustainable transportation like the EAB.

Change agent programs, though a separate DoA on their own, can be particularly useful in influencing how characteristics of relative advantage are perceived in a social system. For example, change agents may offer incentive programs, which reward individuals or systems for behaviour change, and which, in theoretical terms, function by increasing the innovation's degree of relative advantage (Rogers, 1962/2003, p. 236). Another example, mandates by authorities, push the individuals of a system to change their behaviour in ways that they themselves do not desire, but that the authority demands. This second example of a change agent program works as a mechanism for systems to pressure the individuals within them into recognizing the relative advantage of the mandated innovation (Rogers, 1962/2003, p. 239-240).

2.3.3.2 Compatibility

The next most influential category of innovation characteristics is *compatibility* (Rogers, 1962/2003, p. 249). It describes how much an innovation is perceived to be consistent with the existing values, past experiences, and needs of potential adopters (Rogers, 1962/2003, p. 240) and can apply in both technical and social senses (Tapaninen et al., 2009). In theory, the more compatible the innovation, the more certainty and the less risk there is for an individual in adopting it, and thus higher compatibility is related positively to the RoA (Rogers, 1962/2003, p. 240). Conversely, an innovation lacking such compatibility can be expected not to be adopted as quickly as an innovation with a higher degree of compatibility. Rogers notes that some studies found relative advantage and compatibility not to be distinct empirically. However, these two categories of innovation characteristics are distinct conceptually (Rogers, 1962/2003, p. 249).

In order to be adopted, an innovation must be compatible with regards to three aspects, the first one of which lies in the *socio-cultural values and beliefs* of potential adopters (Rogers, 1962/2003). A second area is in the innovation's *compatibility with previously introduced ideas*, since older ideas, with which individuals are already familiar, help them to evaluate the new innovation (Rogers, 1962/2003, p. 243). It is important, however, to find a suitable balance between an idea being compatible with other previously introduced ideas and it also being unique enough to be separate from already existing ideas (Jansson, 2009; Rogers, 1962/2003, p. 245). Additionally, innovations, with their compatibility or incompatibility with familiar ideas, can also encourage or discourage the eventual adoption of other innovations that are related or similar to them (Rogers, 1962/2003). Thus, not only is the innovation's compatibility or incompatibility in this respect important for the adoption of it and its innovation cluster, but so is the acceptance (or unacceptance) of the previously existing idea that it compares to (Rogers, 1962/2003). The final compatibility area is found in the individual's *needs*, and so it is important to accurately understand potential adopters' needs (or to carefully make them aware of new ones) that are to be fulfilled by their use of the innovation (p. 246).

2.3.3.3 Complexity

Complexity is the perceived relative difficulty to understand and use an innovation (as can be classified on a complexity-simplicity continuum) and unlike the other categories of innovation characteristics, it is usually negatively related to the RoA (Rogers, 1962/2003). The meaning of certain innovations may be clear to potential adopters and some others may not be (Rogers, 1962/2003). The more an innovation is perceived to be difficult to understand and use, the less likely it usually is to be adopted and so, even though complexity may not be as important as the relative advantage or compatibility characteristics for many innovations, it may stand as a strong barrier to adoption for some other innovations (Rogers, 1962/2003).

2.3.3.4 Trialability

Rogers defines *trialability* as "the degree to which an innovation may be experimented with on a limited basis" (1962/2003, p. 258), which, simply put, refers to the ease and practicality for a potential adopter to test out the innovation before committing to adoption. Making a trial use of an innovation may involve re-inventing it as well, so that it is better customized to the individual's needs and conditions (Rogers, 1962/2003). Trialability is positively related to the RoA since the personal

trial of an innovation offers a way for individuals to give meaning to it and to learn how it works under their own conditions, which in turn increases how-to knowledge and reduces risk perception (Rogers, 1962/2003).

Studies have found that trialability is perceived as important by earlier adopters more so than by later adopters, since earlier adopters have no precedent to follow when they decide to adopt (Rogers, 1962/2003). Meanwhile, later adopters may try the innovation vicariously through their peers, whose evaluation of having used the innovation is more accessible and convincing to them (Rogers, 1962/2003). For this reasoning, the experiences of existing adopters can be more readily communicated to potential adopters (Janssen & Jager, 2002), making trialability less important for later adopters.

While the trialability component may be more important for influencing adoption the earlier it is in an innovation's entry to a market, it still is not as influential in the decision to adopt as relative advantage, compatibility, and complexity typically are (Faiers & Neame, 2006; Rogers, 1962/2003).

2.3.3.5 Observability

According to Rogers, *observability* is the extent to which the results of an innovation's adoption are visible to others (1962/2003, p. 258). It is positively related to the RoA – that is, as long as the results of its use are viewed positively by potential adopters. It also relates to how easily the benefits of using the innovation can be communicated to potential adopters, also contributing to the innovation's RoA (Rogers, 1962/2003). Some innovations are easily observable and explicable to other people, and others are not (Rogers, 1962/2003). Higher visibility will generally stimulate peer discussion of the innovation and encourage potential adopters around an existing one to seek out more information about the innovation (Rogers, 1962/2003). An innovation's low observability can stand as a barrier to its adoption, since the lack of observability reduces awareness and knowledge about the innovation (Jager, 2006). Despite all this, practical research has not found observability to be as influential as relative advantage, compatibility, and complexity in the decision to adopt (Faiers & Neame, 2006; Rogers, 1962/2003).

2.4 Adoption of EAB's and Other Innovations for Sustainable Mobility

This chapter section explores the existing research on EAB's and other related innovations in order to understand what is already known about the EAB's potential for adoption how it could be affected by the EAB's own characteristics, the characteristics of its potential adopters, and existing contextual conditions.

The vast majority of EAB adoption studies have examined this process of adoption postdictively. Such studies have examined the EAB's uptake (or lack thereof) and its implications, in cases where it has already made its emergence in a given market or it has been introduced to participants through interventions (i.e. pilots or trials; such as in Cairns, Behrendt, Raffo, Beaumont, & Kiefer, 2017; Edge et al., 2018; Fyhri & Fearnley, 2015; Fyhri, Heinen, Fearnley, & Sundfør, 2017; Fyhri & Sundfør, 2014; Gorenflo et al., 2017; McLoughlin et al., 2012; Nocerino, Colorni, Lia, & Luè, 2016; Plazier, Weitkamp, & van den Berg, 2017b). Several of these interventions found that participants used the EAB's when provided with them and developed positive views of the EAB because of their experience trying them out (Cairns et al., 2017; Fyhri & Fearnley, 2015; Fyhri et al., 2017; Fyhri & Sundfør, 2014; McLoughlin et al., 2012), although a few found that participants generally would still choose conventional bicycles or public transit instead (Gorenflo et al., 2017; Plazier et al., 2017b). Studies based on surveys or interviews are even more common, in which existing EAB users (alongside non-EAB users in some cases) were recruited for postdictive research on various reasons for their adoption (An, Chen, Xin, Lin, & Wei, 2013; Astegiano, Tampère, & Beckx, 2015; Dill & Rose, 2012; Fyhri & Sundfør, 2014; Haustein & Møller, 2016a; Johnson & Rose, 2013, 2015; Langford et al., 2013; Lee, Molin, Maat, & Sierzchula, 2015; Lin et al., 2017; Lin, Wells, & Sovacool, 2018; Ling, Cherry, MacArthur, & Weinert, 2017; Ling, Cherry, Yang, & Jones, 2015; MacArthur et al., 2014; Popovich et al., 2014; Rudolph, 2014; Seebauer, 2015; Strömberg, Smith, & Wallgren, 2016; Weinert, Ma, Yang, & Cherry, 2005; Wolf & Seebauer, 2014). There are very few studies to look to for examples of predictive approaches, which investigate potential or hypothetical EAB uptake before study participants have actually underwent IDP about it and chosen either to adopt or reject it at the Decision stage. These few studies work predictively to measure constructs of intention by using stated (as opposed to *revealed*) choice experiments (Arsenio, Dias, Lopes, & Pereira, 2018; Kaplan, Wrzesinska, & Prato, 2018; van den Berg, Vinken, Geurs, & Arentze, 2018). However, out of these few studies, only one of them indicates any particular framework as their basis in understanding how innovation adoption can work: Kaplan, Wrzesinkska,

and Prato focus on the individual in using Alderfer's ERG (existence, relatedness, growth) theory of needs, rather than DoI, as the basis of their stated choice study on bicycle use in general (including EAB's; 2018). The model that Kaplan et al. use based off of the ERG theory of needs shares many similarities with the IDP model, but ultimately misses some pieces that IDP offers. Besides these few studies, one other article, which is further discussed later, takes a predictive approach in reviewing existing literature to propose hypotheses for further study about potential drivers and barriers for EAB uptake by students as well as by commuters and rural residents (Plazier, Weitkamp, & van den Berg, 2018). The knowledge contributed from these studies is outlined in the rest of this chapter section.

As shown in the above discussion, the existing studies do not use as comprehensive a framework as DOI for understanding EAB adoption. Thus, no single existing study alone offers a full picture of EAB adoption. Multiple studies are reviewed in this chapter section to gather many different pieces of information about EAB adoption and attempt to fill in a fuller understanding about it in terms of the DOI framework. Some other EAB studies about concerns aside from their adoption are consulted as well for contributions to understanding the full picture of EAB adoption.

2.4.1 Innovation Characteristics of the EAB

Chapter section 1.1 already mentioned cost, freedom of movement (including effect by and contribution to transport congestion), quality of the travel experience, effect on the environment, and effect on users' physical health as several aspects and characteristics of EAB's and other transportation modes. Looking further across existing studies on EAB adoption expands the range of characteristics that have been explored about the EAB, with diverse studies lending their focus to different aspects about transportation innovations and adding different characteristics about the EAB into the collection.

Additionally, to examine the EAB's characteristics specifically with a DoI lens means to recognize the importance of people's subjective perceptions of the innovation and its characteristics, rather than attempting to objectively define its characteristics (Rogers, 1962/2003). Thus, an increasing number of different – and sometimes conflicting – perceived characteristics can be gathered about the EAB as such perceptions are collected from more sources.

A particular EAB trial study by Gorenflo et al. used the most comprehensive set of aspects of transportation innovation characteristics, by which to evaluate the EAB (2017). Study participants rated ten different aspects of transportation innovations for how important each were to them and also evaluated the EAB and other modes of transportation for their performance in each aspect (Gorenflo et al., 2017). Those ten aspects used were: *independence* ("How much independence does a given mode of transportation provide?"), *stress-free travel*, *high cost*, *social status* ("How well does it fit in with the participant's perceived social status?"), *fun*, *eco-friendliness*, *reliability*, *comfort*, *safety*, and *healthiness* (Gorenflo et al., 2017). These aspects are all applicable to EAB's and to other transportation modes and enabled comparison between them. The results found about these different aspects are examined in the following chapter sub-sections along with other previous findings on favourably and unfavourably perceived EAB characteristics from existing literature.

A few pilot projects have been implemented, trialling the EAB's with very specific groups of individuals and particular contexts. The WeBike trial project in Waterloo (Edge et al., 2018; Fink, Golab, Keshav, & de Meer, 2017; Gorenflo et al., 2017) found amongst its technical results that university student and staff participants still preferred conventional bicycles over EAB's even after using them in the trials (Gorenflo et al., 2017). Other trial and pilot projects, however, received positive reviews of EAB's afterwards, as did a trial project involving car-owners in Norway in 2013 (Fyhri & Fearnley, 2015; Fyhri et al., 2017; Fyhri & Sundfør, 2014), another trial project involving commuters (working employees) in Brighton, UK (Cairns et al., 2017), and a small pilot with 37 students in the Netherlands (Plazier et al., 2017b).

2.4.1.1 Cost

As an attribute, the cost associated with the EAB is a very important one, according to individuals' stated (Arsenio et al., 2018; Gruber et al., 2014) and revealed choices in existing studies (Fyhri & Sundfør, 2014). Although the EAB is altogether relatively low-cost for a private commuting option – one undeniably less expensive than the car in particular (Fink et al., 2017) – it has a higher purchase price relative to a conventional bicycle of comparable build (Baptista et al., 2015; Popovich et al., 2014; Simsekoglu & Klöckner, 2019). Interestingly, a survey conducted in China, where EAB use is more common than anywhere else, found EAB prices to be positively related to their adoption, possibly from higher EAB prices being associated with better quality and performance, which adopters are willing to pay for (Lin, Wells, & Sovacool, 2018). In western contexts, however, the

EAB's purchase price is a significant barrier for its adoption especially by students, who have relatively lower purchasing power but also typically have access to other alternatives at even lower costs, such as conventional cycling and low-cost or free public transit (Fyhri et al., 2017; Peine, van Cooten, & Neven, 2017; Plazier et al., 2017b; Santucci et al., 2016).

The purchase price is the greatest cost of the EAB, which also makes it sensitive for theft (Engelmoer, 2012; Rudolph, 2014). The next highest costs may be for maintenance and repairs or for battery replacement, which may be required every few years (Cherry & Cervero, 2007). EAB users pay the low, marginal cost per trip either in the form of the portion of their electricity bill for charging the EAB or through fees to the bike-sharing scheme they use (Cherry & Cervero, 2007).

For bikeshare operators, the costs for employing EAB's in their fleets are much greater than for conventional bicycles (Campbell, Cherry, Ryerson, & Yang, 2016; Ji et al., 2014; Kaplan et al., 2018), although the advantage of bike-sharing schemes, where available, is that they are usually expected to alleviate direct user costs as a barrier to adoption (Ji et al., 2014; Kaplan et al., 2018). Locally in WR, these sharing schemes are not unfamiliar, since one using conventional bicycles has already been established since 2013 (The Working Centre, 2020; Thompson, 2018) and similarly, a 2-phase sharing pilot with kick-style e-scooters was also in operation temporarily in 2018 and 2019 (Jackson, 2019a, 2019b; Lam, 2018). Depending on a number of situational factors, the reduced user costs for using an EAB through a bike-sharing scheme, compared to private ownership, can also come with additional benefits of convenience or flexibility in trip timing and routing, or alternatively, it may come at their expense (Fishman, Washington, & Haworth, 2013; Gu, Kim, & Currie, 2019; Ji et al., 2014; Médard de Chardon, Caruso, & Thomas, 2017).

2.4.1.2 Trip Timing and Routing

At a lower user cost than cars, EAB's can provide a similar benefit of independent, flexible trip timing and routing that comes with their potential as a personal, motorized commuting option (Edge et al., 2018; Plazier, Weitkamp, & van den Berg, 2017a; Pucher & Buehler, 2008). The EAB can provide a direct, door-to-door service without a shared schedule, which shared transportation options, such as public transit or carpooling, cannot typically offer (Lin et al., 2017; Plazier et al., 2017b). This aspect of convenient, independent trip timing and routing is also characterized in other studies as "reliability" and "independence" (Gorenflo et al., 2017) and as a "high degree of commuting control and 'arrival-time reliability'" (Wild & Woodward, 2019). Researchers have found that, for

individuals who choose to use EAB's or conventional bicycles, this aspect is an important one to them and they perceive the EAB favourably in this respect (Gorenflo et al., 2017; Leger, Dean, Edge, & Casello, 2019; Wild & Woodward, 2019).

Since EAB's are regulated to only provide assistance up to maximum speeds between 25-32 km/hr depending on the jurisdiction (Gruber et al., 2014; Peterman, Morris, Kram, & Byrnes, 2016; Rudolph, 2014; Vlakveld et al., 2015), they are not capable of speeds comparable to those of fully motorized modes like cars and buses. However, the focus should not be on the moving speed of the particular vehicle, which may not always be associated with amount of time spent travelling (de Kruijf, Ettema, Kamphuis, & Dijst, 2018; Plazier et al., 2017a), but rather on the trip timing that the mode allows, which is also dependent on where the commuter is travelling to and from and the route they must take to get there (Plazier et al., 2017a). In places, where suitable infrastructure does not exist to support sufficient cycling routes (for either conventional or electric) (Arsenio et al., 2018; Edge et al., 2018; Fyhri & Fearnley, 2015; Fyhri & Sundfør, 2014; McLoughlin et al., 2012), the EAB can be considered incompatible. Commuter satisfaction is not dictated solely by reduced travel time, but rather is complex in how it is influenced by a number of other factors as well (Jang & Ko, 2019).

2.4.1.3 Safety

Safety as a single topic constitutes an entire cluster of EAB research, much of it coming from technical and engineering perspectives aiming to objectively measure various impacts on the safety of EAB users and others around them (Salmeron-Manzano & Manzano-Agugliaro, 2018). For example, numerous studies investigate regulations, operating speed, rider behaviour, and interactions with other vehicles as factors for safety outcomes (Bai, Liu, Chen, Zhang, & Wang, 2013; Du et al., 2013; Haustein & Møller, 2016b; Lin, He, Tan, & He, 2008; MacArthur & Kobel, 2014; Petzoldt, Schleinitz, Heilmann, & Gehlert, 2017; Schepers, Fishman, Hertog, Wolt, & Schwab, 2014; Schleinitz, Petzoldt, Franke-Bartholdt, Krems, & Gehlert, 2017). While this literature highlights safety as a concern to researchers, EAB safety in the subjective perceptions of potential users must also be explored, given the focus of this particular study on perceptions.

User safety is typically a very important aspect to the people considering using EAB's (Gorenflo et al., 2017). Existing research shows mixed opinions on how safe EAB's are for their users. They are often perceived as less safe than other transportation modes due to reduced user

protection, their vulnerability in interactions with larger and faster vehicles, and their risk for theft (Engelmoer, 2012; Gorenflo et al., 2017; Ling et al., 2015; Popovich et al., 2014; Strömberg et al., 2016). Comparing specifically to conventional bicycles, some people consider them equally or even less safe (Gorenflo et al., 2017), with their faster speed, heavier weight, and more complex operating systems contributing to difficulties for manoeuvring safely, especially for older adults (Johnson & Rose, 2015; Strömberg et al., 2016). Conversely, other people – even among older adults – feel safer using an EAB over conventional bicycles, because of the speed, the weight, and perceptions of greater stability (Dill & Rose, 2012; Gruber et al., 2014; Johnson & Rose, 2015; MacArthur et al., 2014; Plazier et al., 2017b; Rose, 2012). Battery safety has been cited previously as a safety concern (Weinert, Ogden, Sperling, & Burke, 2008; Weinert, 2007), although it seems to have become less of a concern over time as technology has advanced (Engelmoer, 2012).

Considering all these particular safety issues, it is clear that safety (or lack thereof) can be an aspect of the EAB itself in some cases, but in others, the concern may actually stem from the EAB user or their commuting environment instead (Du et al., 2013; Fyhri et al., 2017; Langford et al., 2013; Lin et al., 2008; Lin et al., 2017; MacArthur et al., 2014; Plazier et al., 2017b; Rudolph, 2014; Weinert, Ma, Yang, & Cherry, 2005). As with trip routing, the EAB can also be considered compatible or incompatible on safety depending whether suitable infrastructure exists to support safe cycling where potential users are (Arsenio et al., 2018; Edge et al., 2018; Fyhri & Fearnley, 2015; Fyhri & Sundfør, 2014; McLoughlin et al., 2012; van den Berg et al., 2018; Wolf & Seebauer, 2014). Whether the EAB is safe to other commuters (besides its own user) is a separate concern as well, which is often connected to how EAB users behave on roads and paths (Lin et al., 2008; Lin et al., 2017; MacArthur et al., 2014; Weinert et al., 2008; Weinert et al., 2005).

2.4.1.4 Quality of the Travel Experience

Aspects like cost, trip timing and routing, and safety would be categorized as functional innovation characteristics by Noppers et al. (2014), which, while important to commuters in choosing a mode of transportation, are often not the only aspects commuters might care about (Jang & Ko, 2019). Gorenflo et al. found fun, comfort, and stress-free travel, as qualities of the travel experience, to be at least somewhat important to commuters (2017). While these kind of characteristics may not be as important as more functional-type aspects, their importance to commuters is certainly not negligible (Arsenio et al., 2018; Gorenflo et al., 2017).

As for perceptions of the EAB in this respect, most pilot studies show that participants consider the EAB to be a low-stress, comfortable, or fun way to travel after having used one (Edge et al., 2018; Fyhri et al., 2017; Fyhri & Sundfør, 2014; McLoughlin et al., 2012; Plazier et al., 2017b) as do some studies surveying existing EAB users (Haustein & Møller, 2016b; Lee et al., 2015; Popovich et al., 2014). The electric-assist can make cycling more comfortable for users in general (Haustein & Møller, 2016a; Langford et al., 2013; Lee et al., 2015; Plazier et al., 2017a; Popovich et al., 2014; Weinert et al., 2005), but especially for groups of people who cycle less, such as older adults or others with reduced mobility (Edge et al., 2018; Johnson & Rose, 2015; Langford et al., 2013; Popovich et al., 2014), women (Dill & Rose, 2012; MacArthur et al., 2014), and those with sedentary lifestyles (Gojanovic et al., 2011; Seebauer, 2015). Compared to other modes of transportation that provide more weather protection and require less physical exertion, however, the EAB may be considered less comfortable (Engelmoer, 2012; Gorenflo et al., 2017; Plazier et al., 2018). On the other hand, people may consider it a less stressful, more fun option than those modes, such as cars and public transit (Gorenflo et al., 2017).

2.4.1.5 Indirect Effects of EAB Use

Other aspects to consider in choosing a mode of transportation are the indirect effects of using that mode, such as its effect on the environment, the user's physical health, and their social status.

Whether an individual's switch to an EAB is beneficial or harmful to the environment depends on the mode of transportation they were using previously (Weiss et al., 2015). Objectively, the EAB produces no tailpipe emissions (Cherry, Yang, Jones, & He, 2016; Weiss et al., 2015), which is an improvement when it is used to replace fossil-fueled modes of transportation (Behrendt, 2018; Fyhri & Fearnley, 2015; Lee et al., 2015). However, it is associated with environmental effects from production for its battery and the electricity to charge it (the impact of which varies by electricity market), thus giving it a more harmful environmental impact when it is used in a modal shift away from a fully non-motorized mode (Cairns et al., 2017; Fishman & Cherry, 2015; Fyhri & Fearnley, 2015; Lee et al., 2015; Rose, 2012; Weiss et al., 2015; Winslott Hiselius & Svensson, 2017). Subjectively though, people recognize the EAB generally as an environmentally-friendly mode of transportation (Gorenflo et al., 2017; Gruber & Kihm, 2016; Gruber et al., 2014). Some individuals, though few, recognize the relative environmental harm that EAB's bring compared to non-motorized modes of transportation (Plazier et al., 2017b). Eco-friendliness has been gaining

importance in the minds of commuters over time (Santucci et al., 2016) although, despite the rise in awareness, it still is not important to everyone. EAB studies specifically have found eco-friendliness to be one of the factors important to EAB earlier adopters and pilot participants, although the more functional aspects are usually of greater importance (Gorenflo et al., 2017; Haustein & Møller, 2016a; Popovich et al., 2014; Santucci et al., 2016; Seebauer, 2015; Wolf & Seebauer, 2014). Looking beyond EAB's, other studies have found that, for other innovations in the areas of sustainable transportation and energy, their environmental characteristics are strongly linked to adopters' uptake (Noppers et al., 2014; White & Sintov, 2017).

Similarly to the EAB's environmental impact, its effect on physical health for its users depends which other transportation mode it is being compared to. As an alternative to fully motorized modes of transportation, it requires comparatively more physical exertion, thus generally contributing to better physical health (Behrendt, 2018). Compared to fully non-motorized modes though, such as the conventional bicycle and walking, it requires less physical exertion (Rose, 2012; Winslott Hiselius & Svensson, 2017). This, however, can still be a benefit of the EAB for physical health since the EAB stands as an alternative to fully motorized transportation options that is nevertheless active to some degree for people who would not want to or be able to travel by a more physically demanding means (Fyhri et al., 2017; Gojanovic et al., 2011; Rose, 2012). Significant segments of people have been found to use the EAB for this reason of keeping some level of physical activity in their commute, rather than losing that physical activity entirely to a fully motorized transportation option (Johnson & Rose, 2015; Lee et al., 2015; MacArthur et al., 2014). Some smaller numbers of people remain though, who prefer the conventional bicycle over an EAB because of the greater physical activity level of the conventional bike (Langford et al., 2013; Plazier et al., 2017b).

Finally, the EAB's effect on social status stands as a symbolic innovation characteristic that has not been researched beyond surface level, possibly because it is considered to be of lesser importance to researchers and potential adopters than other characteristics. The study by Gorenflo et al., specifically asked participants about the importance of social status to them in choosing a mode of transportation, finding it not to be important (2017). A few other studies, however, have found some importance for this aspect and for symbolic innovation characteristics in general. Lin et al., found in China that EAB users are often seen to be "poor, not well-educated" (whereas preference is given for car users, who are viewed as wealthy and well-educated), even though their survey found these opinions not to be completely consistent with the actual facts about EAB users (2017). In developed

countries, there are often stigmas that EAB's are a type of bicycle for older adults or people with reduced physical ability and that using one is "cheating", since EAB's require less physical exertion than conventional bicycles (Behrendt, 2018; Dill & Rose, 2012; Edge et al., 2018; Jones, Harms, & Heinen, 2016; MacArthur et al., 2014; Plazier et al., 2017b; Popovich et al., 2014; Simsekoglu & Klöckner, 2019; Strömberg et al., 2016). (Interestingly, Strömberg et al. pointed out that "car drivers never get accused of cheating" (2016)). These views have not stopped the early adopters (i.e. people of a high degree of "innovativeness"; Rogers, 1962/2003), who are aware of them and still use their EAB's, but they may be deterrents for the remaining majority of potential users. Looking beyond EAB's, other studies have found that, for other innovations in the areas of sustainable transportation and energy, their symbolic characteristics, such as effect on social status, can be related adopters' uptake when viewed positively (Noppers et al., 2014; White & Sintov, 2017).

2.4.2 Individual Characteristics of Potential Adopters of EAB's

As explained earlier in 2.3.2, this study focusses on two components of characteristics of the individual: socio-economic characteristics and personality variables. This chapter sub-section explores what is already known from existing literature about those components with regards to EAB adoption.

2.4.2.1 Socio-Economic Characteristics of Potential Adopters

Several groups of interest, in terms of socio-economic groups, for have been investigated for EAB adoption in the existing literature.

Within existing EAB research in developed countries, mature adults as a group receive the most focus as promising potential adopters or even as existent earlier adopters of EAB's. The EAB is often considered to be suitable for this group because of the opportunity it brings for uptake or continuation of bicycling habits later into life for purposes both of transportation and of recreation (Dill & Rose, 2012; Edge et al., 2018; Gruber et al., 2014; Johnson & Rose, 2015; Langford et al., 2013; MacArthur et al., 2014; Plazier et al., 2017b; Popovich et al., 2014; Rose, 2012). Several studies identify greater age (age groups covering 55+ years) as a common characteristic of existing adopters of the e-bike in developed countries (Haustein & Møller, 2016a; Lee et al., 2015; Wolf & Seebauer, 2014) and others specifically focus on people of later age groups as the earlier adopters of

the e-bike in these contexts (Johnson & Rose, 2015; Kohlbacher & Hang, 2011; Peine et al., 2017; Seebauer, 2015; Wolf & Seebauer, 2014).

Similarly, women have also been identified as important potential adopters, since they already use conventional bicycles less than men do and may find EAB's to be a more appealing cycling option (Dill & Rose, 2012; MacArthur et al., 2014). Several studies found that women may be influenced to adopt the EAB more so than men, usually because of the power-assist (Fyhri & Fearnley, 2015; Fyhri & Sundfør, 2014; Haustein & Møller, 2016a; Kaplan et al., 2018; Lee et al., 2015; van den Berg et al., 2018). Langford et al., however, found more women than men stating preference for the conventional bicycle option in an on-campus bikeshare over the EAB option, citing easier manoeuverability and greater opportunity for exercise (2013).

Another group of interest is students, although they have received less attention than mature adults in the existing research. If students adopt the EAB (or at least develop an interest for adopting it) while in this early stage of adulthood, then it could potentially serve as a sustainable transportation mode that they continue (or begin) to use beyond their time in formal studies (Simons, Bourdeaudhuij, Clarys, & Geus, 2017). Despite this, few studies offer insights specifically on their motivations or reservations as potential or existing EAB users, whether for students in secondary school (as in Arsenio et al., 2018) or at the post-secondary level (as in Plazier et al., 2018, 2017b). Similarly, some other studies examine e-bikes' use where they've been deployed specifically in campus communities, which include faculty and staff members as well as students, both in Waterloo (Edge et al., 2018; Fink et al., 2017; Gorenflo et al., 2017) and abroad (Langford et al., 2013; McLoughlin et al., 2012). For students, existing research has found that cost is a barrier to students because of their relatively lower purchasing power (Plazier at al 2017b), which can be alleviated by bikeshare programs on or near campus (Langford et al., 2013; McLoughlin et al., 2012), and that students will more likely prefer the use public transit if it is subsidized for them, as has been seen in the Netherlands (Plazier at al 2017b; van den Berg et al).

An interesting but less studied group is parents escorting children to school. An intervention study in southern Norway found that, when equipped with an e-bike instead of conventional bicycle, parents cycled to work and to their children's' school in all seasons and that they made these trips less frequently by car (Bjørnarå et al., 2019). A survey of parents in China found that they are more likely to escort their child to school by e-bike if the school is out-of-the-way of their route to work but that

they are more likely to use a car the farther it is to the school from home (Liu, Ji, Liu, He, & Ma, 2017).

2.4.2.2 Personality Variables Relevant to EAB Adoption

Existing EAB research explores personality variables relatively little with a few studies having included pro-environmental and technophile values specifically among the variables they explore related to EAB adoption.

Studies of EAB adopters in Austria and the US determined using a few survey and interview questions that they tend to have pro-environmental personalities (Dill & Rose, 2012; Seebauer, 2015; Wolf & Seebauer, 2014). Pro-environmental values were found not to be predictors of EAB adoption, however, in a study from Norway (Fyhri et al., 2017).

The survey of EAB adopters in Austria found that they tend to hold technophile values even though they also tend to be older in age, a trait not typically associated with technophilia (Seebauer, 2015; Wolf & Seebauer, 2014).

2.4.3 Prior Conditions Around Market Introduction of the EAB

Each market for the EAB – potential or established – comes with its own set of prior conditions. It is helpful for this study to look at previous practice, felt needs or problems, and social system norms as components of prior conditions, all which can differ between geographic markets (although prior conditions are not necessarily dependent on geography). Existing EAB-specific knowledge on these three components of prior conditions is covered in the next sub-sections.

Broadly, research on EAB adoption is globally focused, including studies especially in China and Europe, and to a lesser extent also in Australia (Johnson & Rose, 2013, 2015), the USA (Dill & Rose, 2012; Fishman & Cherry, 2015; Ji et al., 2014; Langford et al., 2013; MacArthur et al., 2014; MacArthur & Kobel, 2014; Popovich et al., 2014), and Canada (Edge et al., 2018; Gorenflo et al., 2017; MacArthur et al., 2014; MacArthur & Kobel, 2014).

While the EAB has already seen much adoption in a number of developing countries, those markets present very different conditions from those of the Canadian market, and so the existing research on EAB adoption in those countries, such as China, often is not relatable to its potential

transition into Canada. In China for example, research has shown that several factors unique to that country have helped the EAB entrench its oldest and strongest popularity there. Unlike many places in the world, China has especially long-established bicycle production and city bicycling infrastructure, which resulted from their treatments as national priorities shortly after the founding of the People's Republic of China in 1949 (Ruan, Hang, & Wang, 2014; Weinert et al., 2008; Weinert, 2007; Wells & Lin, 2015). While private car ownership was restricted to government officials until the mid-1980's, widespread habit for two-wheeled vehicle use was established, which eventually came to include gasoline-powered motorcycles and moped-style scooters alongside conventional bicycles (Weinert et al., 2008; Weinert, 2007; Weinert et al., 2005; Wells & Lin, 2015). By the time that electric two-wheelers began their emerging stage and experimental stage in China (roughly 1995-1999), the strong existing use habits and infrastructure for the similar conventional versions served their emergence particularly well while improvements in motor and battery technologies evolved (Ruan et al., 2014). At the same time, many Chinese cities began to ban gasoline-powered two-wheeled vehicles because of their contributions to air pollution, so electric two-wheelers, such as EAB's as well as electric motorcycles and moped-style scooters, were often taken up as substitutes (Ruan et al., 2014; Weinert et al., 2005). Since then, improvements, production, and diffusion of electric two-wheelers advanced exponentially and they became a first inexpensive step towards private mobility for massive numbers of people (Baptista et al., 2015). However, such a fast diffusion of EAB's and other electric two-wheelers in China was also disruptive, so they attracted restrictions on certain features and capabilities, even complete use bans in some areas (Behrendt, 2018; Gu et al., 2019; Ling et al., 2015; Wells & Lin, 2015). Although EAB sales continue there, their rate of new adoptions eventually slowed (Lin et al., 2018; Ruan et al., 2014).

Over the course of these developments, the EAB spread to other countries as well, where there are already strong norms for conventional cycling, where governments adjusted regulations to allow its use, and where satisfactory cycling infrastructure exists, such as in countries in Europe (Baptista et al., 2015; Johnson & Rose, 2013; van den Berg et al., 2018; Wolf & Seebauer, 2014). The EAB has had successful market penetration in a few areas, but in a broader global perspective, it is still just emerging as a personal transportation solution.

2.4.3.1 Previous Practices and Social Norms in Commuting

Existing knowledge on both previous practice and social norms relevant to EAB's are discussed in this sub-section as components of prior conditions, since they share commonalities.

As discussed previously, the EAB is well established and its use widespread across the general population already in China (Lin et al., 2018; Ruan et al., 2014). In some European countries, there are strong social norms for conventional cycling (as well as the infrastructure that supports people actually commuting by bike), so this is one factor that supports EAB adoption in those places (van den Berg et al., 2018; Wolf & Seebauer, 2014). In developed countries in general though, strong car cultures are often the norm as cars are often used and the EAB is usually viewed as a bicycle option for older people or those with reduced physical ability and fitness (Behrendt, 2018; Dill & Rose, 2012; Edge et al., 2018; Jones et al., 2016; MacArthur et al., 2014; Plazier et al., 2017b; Popovich et al., 2014; Simsekoglu & Klöckner, 2019; Strömberg et al., 2016). Otherwise, the existing EAB research explores the effect of social norms very little. One study has found that encouragement from personal connections can have a positive influence towards e-bike adoption (Popovich et al., 2014).

While social norms are often related to the commuting practices of many people together, an individual's previous commuting practices can play a role in their likelihood to take up the EAB as well. In developed countries, most e-bike users had made the modal shift from using cars previously for some or most of their trips (Cairns et al., 2017; Johnson & Rose, 2015; Lee et al., 2015; Popovich et al., 2014). Fyhri and Sundfør, however, found that trips taken by public transit were most often replaced by EAB in their trial in Norway (2014). Students in the Netherlands were also found to replace their trips by conventional bicycle the most by EAB (Plazier et al., 2017b). Another trend that has been building in developed countries is for people, who used to cycle, but who specifically do it less now because of age, to switch to using an EAB in order to continue cycling (Johnson & Rose, 2015; Lee et al., 2015; Popovich et al., 2014). In China, EAB trips generally replace trips that would be or previously were taken by public transit, conventional bike, and walking (An et al., 2013; Lee et al., 2015; Lin et al., 2017), especially with people in areas underserved by public transit being motivated to take up EAB's (Weinert et al., 2005).

2.4.3.2 Felt Needs or Problems About Commuting

As explained in 2.3.1.2, the felt needs or problems component of prior conditions is subjective and will vary among different individuals (Rogers, 1962/2003).

Gorenflo et al. provide a method to define individuals' differing felt needs by asking the individuals how important particular aspects of the innovation are to them (2017). That study asked participants to rate a comprehensive set of different aspects for importance to them specifically in choosing a mode of transportation for commuting and generally found independence, stress-free travel, reliability, and safety, but not social status, to be deemed as important aspects (Gorenflo et al., 2017).

Across many other e-bike studies, several other very specific needs relevant to active transportation were identified that the EAB can address: for overcoming hills (Cairns et al., 2017; Fyhri & Sundfør, 2014; Ling et al., 2017; MacArthur et al., 2014; McLoughlin et al., 2012; Rudolph, 2014), going longer distances (Lee et al., 2015; MacArthur et al., 2014), travelling in hot or windy weather (Cairns et al., 2017; Popovich et al., 2014), less sweating less (Lee et al.; McLoughlin). However, the EAB was found to fall short on the needs for travelling in cold climates (Edge et al., 2018; Ling et al., 2015) (Edge et al; Ling et al, 2015) or travelling through environments lacking in supportive infrastructure (Edge et al., 2018; Fyhri & Fearnley, 2015; Fyhri & Sundfør, 2014; McLoughlin et al., 2012).

Needs in transportation can also be depend on trip purpose such as utility (for commuting to work or running errands, for example) or recreation (Strömberg et al., 2016). In Europe and North America, for example, utilitarian trips more often than recreational ones are the type of travel that people use EAB's for (Astegiano et al., 2015; Cairns et al., 2017; Johnson & Rose, 2015; Lee et al., 2015; MacArthur et al., 2014; Popovich et al., 2014). In China, EAB's are used for all trip types, including commuting to work (Lin et al., 2017).

3 Methods

This research uses a quantitative approach, using the Innovation-Decision Process (IDP) from Rogers' Diffusion of Innovations (DoI) theory as the theoretical framework. This chapter covers methods in three areas: the theoretical framework and constructs, procedures for survey distribution and design, and methods for data analysis.

3.1 Study Model Framework

This study follows the assumption that the more positively individuals perceive the characteristics of the electrically-assisted bicycle (EAB) innovation, the more likely they would be to have (or to eventually have) a greater willingness or interest for its adoption. Thus, this research puts an emphasis on study respondents' perceptions of the EAB or, in other words, their evaluations of it based on their impressions of it as the dependent variable (illustrated in Figure 3–1).

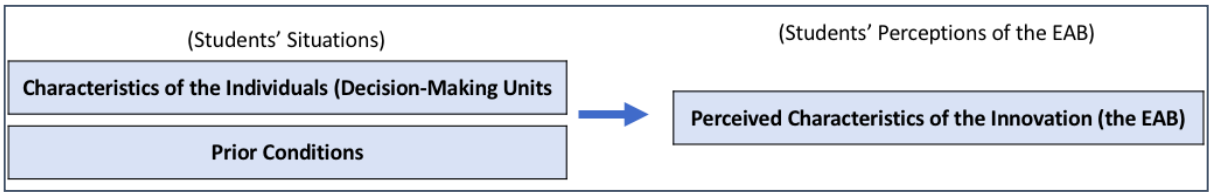

Figure 3–1 Basic model of the research approach to searching for relationships between students' perceptions of the EAB and other conditions of their situations

Since this study is concentrated on the pre-adoption portion of the Innovation-Decision Process (IDP), only the determinants of adoption (DoA's) prior conditions, characteristics of the individuals, and perceived characteristics of the innovation make up the foundation of the model.

However, not all components of these DoA's could be feasibly explored in this study and so they are excluded from the more detailed study model (see Figure 3–2), which outlines the DoA's and dissects their components that this study focusses on. The detailed study design excludes innovativeness (a component of prior conditions), communications behaviours (a component from characteristics of the individual) as well as the innovation's trialability and observability (under characteristics of the innovation), because of the difficulty and lack of reliability for measuring these

DoA components using self-reported participant data from surveys. Within the included DoA's, the model still includes social norms to a minor degree but treats it more as a variable of characteristics of the individual than one of prior conditions.

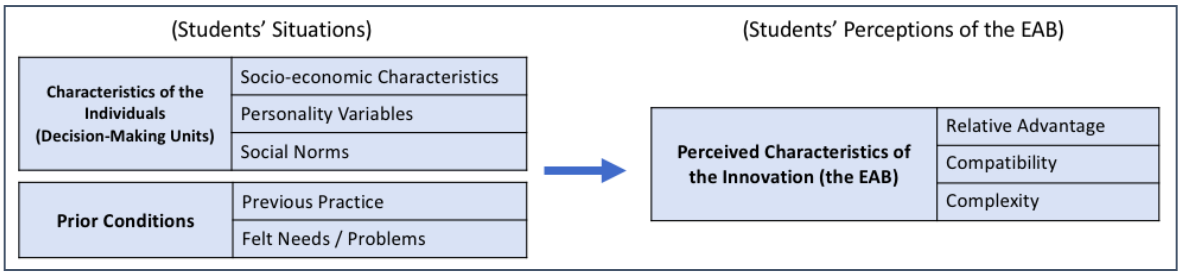

Figure 3–2 Detailed model of the research approach for exploring the relationships between students' perceptions of the EAB and other conditions of their situations

3.2 Survey Sampling and Administration

Web-based surveys are generally recommended as an effective form of survey delivery for reaching more participants and doing so in a timely and cost-effective manner (Bradburn, Sudman, & Wansink, 2004; Bryman, 2012). This study's survey was delivered in the fall of 2019 on the Qualtrics survey platform, which potential participants accessed in their browser on its own page using an anonymous URL. Posters, postcards, and digital announcements through emails and social media were used to invite potential participants to the opening page to learn more and start the survey (see the examples under Appendix C:).

3.2.1 Population Criteria and Sample

Participation in this study was open to students attending post-secondary studies on-campus within Region of Waterloo Region (RoW) at the University of Waterloo (UW), Wilfrid Laurier University (WLU), and Conestoga College. The following criteria were used as the basis for determining respondents' eligibility to be in included in the study population:

Age: 18 years and older.

Enrolment type: Enrolled in either a) a semester of on-campus instruction or research, or b) a co-op term with workplace in RoW, except for those enrolled in either i) in a

distance education (online) program, or ii) a co-op term with workplace outside RoW.

Institution: Enrolled at UW (including its affiliated or federated Conrad Grebel University College, Renison University College, St. Jerome's University, and St. Paul's University College), at WLU (including its affiliated Martin Luther University College), or at Conestoga College.

Campus Locations: Studying at any of the eligible institutions' campuses in the cities of Waterloo, Kitchener, or Cambridge, ON, but not if they study at an eligible institution's campus located outside WR.

The age criterion was included for research ethics purposes, as it is much more challenging to survey minors. There would likely be very few students under 18 and so this should not affect the representativeness of the sample. All other criteria were based on the focus of the study being the RoW (i.e. locations of students' post-secondary study programs).

3.2.2 Recruitment Efforts and Channels

With the initial approval from the Office of Research Ethics (at UW), recruitment efforts were permitted at locations and through affiliated channels specifically of that institution, as well as in the local community off campus. Additional approval was later requested and received from the Research Ethics Board at Conestoga College to allow recruitment efforts to be made at locations and through affiliated channels of that institution, in order to boost the weak reach to potential participants studying there.

For on-campus recruitment at UW and Conestoga College, printed recruitment materials were physically displayed in designated posting spaces of on-campus organizations, with their permission, such as campus libraries, student societies, and academic faculties or departments. These same organizations were also asked to share digital versions of the recruitment invitations through their networks via email updates and social media posts as they deemed suitable.

Off-campus recruitment efforts were made in order for the invitation to reach potential participants from any of the eligible institutions while off-campus out in the local community in Waterloo, Kitchener, and Cambridge. Printed recruitment materials were posted, where permission

from the appropriate organization was granted, in locations likely frequented by post-secondary students, such as the local libraries as well as cafes, eateries, and shops offering community posting space. Additionally, a few local non-profit organizations were asked to share the digital recruitment invitations through their networks as appropriate.

3.3 Survey Design and Features

The questions (Q's) and other content in the survey are summarized in their order of appearance in Table 3-1 with a full copy of the survey included in Appendix A:. The order of appearance of survey content was taken greatly into consideration in order to create a logical flow to help participants best understand the questions and to avoid the negative effects of survey fatigue. Care was also taken to put the survey content into plain language wording that would be better understood by all respondents regardless of their level of technical knowledge on the subject.

To elaborate further on the Q's directly concerned with the EAB, that section of the survey started with a brief explainer on the EAB before beginning the questioning. The explanation included the very most essential information to know about the EAB, some visual aids, and clarification about which other vehicles also often referred to as "electric bikes" or "e-bikes" (i.e. seated, two-wheeled, light vehicles) were not of concern for the survey. This explanatory content aimed to ensure firstly, that participants were all specifically considering the EAB type of "e-bike" instead of any other types in giving their responses to the subsequent questions. Secondly, it aimed to ensure that all participants – regardless of prior levels of knowledge on EAB's – had a common understanding of EAB basics.

Most Q's throughout the survey were closed response questions.

Some Qs were open response questions that served purposes other than collecting data for analysis, such as allowing a way for respondents to provide further clarification, if needed, about their previous response(s), which a few open response Q's did. A few other open response Q's asked participants to describe EAB's or e-scooters in one or a few words of their own (under Q sets 5 and 7), which were intended to create some more engaging moments in the survey for the participants. They were also used to prime participants for answering more detailed, subsequent questions about the EAB by helping them to engage more thoughtfully with the idea of using one for commuting.

Table 3-1 Outline of survey questionnaire

Survey Flow		
Section Focus	**Question/Content Focus**	**Question #**
Introduction	Study information and consent	[Explanation] Q SE0
Study Eligibility (SE) Q's	To screen out ineligible respondents	SE1-5
Characteristics of Participants (Part 1 of 2)	Socio-demographic & academic characteristics: - Gender - Credential (aka. diploma/degree level) pursuing - Years and subjects of study - Distance to campus, residing on-/off-campus - Domestic vs. international status - Where else resided in the world	Q set 1
Existing Conditions	Existing commuting habits Psych. temporal distance (Construal Level Theory) Felt needs in commuting (aspects' importance) Lime e-scooter experience and awareness	Q set 2 Q 3 Q set 4 Q set 5
The E-Bike (EAB)	Briefing on the EAB EAB experience and awareness EAB characteristics EAB evaluations in terms of: - Performance in specific aspects - Overall performance compared to other transportation options	[Explanation] Q set 6 Q set 7 Q set 8 Q set 9
Characteristics of Participants (Part 2 of 2)	Environmental behaviours	Q set 10
Survey Closing	Additional comments Thanks and draw entry link	Q 11 [Explanation]

To avoid issues of survey fatigue, participant drop-out, and survivorship bias in long-form questionnaires, it is recommended that respondents not be forced to respond to every single question should they wish to withhold a response for any reason (Bryman, 2012; Décieux, Mergener, Neufang, & Sischka, 2015; Stieger, Reips, & Voracek, 2007). The survey only forced responses on the eligibility screener Q's, or in other words, students' responses were mandatory only for select

Q's in order to proceed further into the survey. This means that, after the screener Q's, participants in most cases were able to complete the survey to the end while withholding responses to some survey Q's they were asked along the way.

For analyzing the survey data as outlined in the following chapter section, each eligible participant was included in a given analysis if they had provided sufficient data about the variables involved in the particular analysis. For this reason, the numbers of respondents analyzed are not consistent across all data analyses.

3.4 Data Analysis Techniques

The data collected in the survey was analyzed using Statistical Package for Social Sciences (SPSS) software (version 26.0).

3.4.1 Comparing Sample Data to Population Data

The sample's representativeness of the local post-secondary student population was evaluated on several socio-demographic and academic variables. Comparable population data was compiled from the three RoW post-secondary institutions' Fall 2018 term data using the provincial Ministry of Advanced Education and Skills Development (MAESD) statistical reporting systems for colleges (2019a) and for universities (2019b). However, it accounts for students registered for full-time studies, but not for part-time.

3.4.2 Statistical Analyses to Justify Using Measurements from Multi-Item Scores

As constructs, a student's EAB perception[1] and their environmental habit[2] are not concretely defined, and any single survey item alone is unlikely to properly capture each of them (Rickards, Magee, &

[1] Refer to Q set 8.

[2] Refer to Q set 10. The first eight sub-questions of the Q set focused on environmental habits, but the final, ninth sub-question of the set measured a different environmental behaviour for separate analysis on its own.

Artino, 2012; Sullivan & Artino, 2013). Each of these constructs is an example of an unmeasurable quantity, which, if it is to be assessed, must be measured indirectly through the use of a multi-item score as an indicator. Ideally, this indicator can be reduced to a simple average across a series of survey sub-questions that define the construct. Careful attention must be given to define sub-questions before the survey is released. Furthermore, after conducting the survey, the proper construction of each indicator must be verified by validating the sub-questions' collected response data, which is done through two ways: Cronbach's Alpha and Principal Component Analysis (PCA).

Cronbach's alpha is the most commonly used test score reliability coefficient (Bryman, 2012; Cho, 2016; Rickards et al., 2012). It measures internal reliability, which is the tendency for a sub-question to be related to all the other sub-questions in a Q set that defines the indicator (Cortina, 1993; Cronbach, 1951; Nunnally & Bernstein, 1978; Rickards et al., 2012; Sullivan & Artino, 2013). Conventionally, a Q set is considered to be a reliable measure if Cronbach's alpha is greater than 0.7 (Bryman, 2012; Michelsen & Madlener, 2013; Nunnally & Bernstein, 1978; Wang, Douglas, Hazen, & Dresner, 2018). Cronbach's alpha tests found satisfactory resultant coefficients of 0.762 for the EAB perception Q set and 0.801 for environmental habit, thus validating the internal reliability of both multi-item Q sets.

Although a high Cronbach's alpha is useful for verifying the reliability of a Q set, it alone does not provide enough assurance that a simple average can be used to construct the indicator (Cortina, 1993). For example, all sub-questions may be correlated with each other, but they may have accidentally measured multiple loosely-related underlying constructs (Cortina, 1993). In order to determine unidimensionality, a variety of factor analysis techniques are available, of which Principal Component Analysis (PCA) is used here (Cortina, 1993; Ramsey & Schafer, 1997; Rencher, 2002). Being a form of analysis, PCA does not strictly test for unidimensionality, but rather, interpreting its results suggests the validity of using indicators to measure central constructs. Two primary features are to be noted:

1. As a rule of thumb, principle components with eigenvalues greater than 1 are considered to be statistically significant (Bryman & Cramer, 2004; Kaiser, 1960);
2. The positive and negative values within the loading matrix can be inspected to interpret how survey Q's measure the underlying construct. (Bryman & Cramer, 2004; Ramsey & Schafer, 1997).

For the purpose of this analysis seeking a unidimensional construct here, we expect an appropriate Cronbach's alpha, an eigenvalue greater than 1 for the first principal component, and all positive loadings under the first principal component. All these conditions are met for both multi-item Q sets, as shown in Table 3-2 and Table **3-3**. The results indicate that a simple average of each Q set's sub-questions provides a reliable indicator of the unmeasurable constructs of EAB perception[3] and environmental habit[4] (Ramsey & Schafer, 1997; Rencher, 2002).

Table 3-2 Validation test results for the Q set on EAB performance in different aspects. PCA results are shown here only for principal components considered significant by their minimum eigenvalue of 1.

Results of Cronbach's alpha and PCA for EAB Perception Question Set			
Cronbach's alpha = 0.762			
	Principal Component		
Explanatory Power	**1**	**2**	**3**
Eigenvalue	3.135	1.288	1.052
Variance Explained	34.8%	14.3%	11.7%
PCA Loadings for Sub-Questions			
Cost (own)	0.544	-0.013	0.587
Cost (shared)	0.565	-0.085	0.532
Timing & routing	0.641	-0.369	-0.016
Safety	0.612	-0.412	-0.100
Travel Experience	0.684	-0.382	-0.344
Social image	0.606	0.004	-0.456
Eco-friendliness	0.492	0.647	-0.129
Physical health	0.558	0.578	-0.168
Simple to Use	0.589	0.275	0.025

[3] Nine sub-questions covered eight aspects of performance that students evaluated the e-bike on. Each aspect was addressed by a single sub-question, except for the aspect of cost, which was assessed using two sub-questions, each for a different e-bike usage scenario: one for the student using an e-bike of their own and the other for use through a bikeshare. A 5-point Likert scale provided the response options for e-bike performance, which ran from "Not very well at all" (coded as = 1 for the data analysis) up to "Extremely well" (= 5).

[4] Sub-questions asked students to indicate how frequently they perform eight different environmental habits on a 5-point Likert scale for frequency from "Not at all" = 1 up to "Every time" = 5.

Table 3-3 Validation test results for the Q set on students' environmental habits. Like in the previous table, PCA results are shown here only for principal components with a minimum eigenvalue of 1.

Results of Cronbach's alpha and PCA for Environmental Habit Question Set		
Cronbach's alpha = 0.801		
	Principal Component	
Explanatory Power	**1**	**2**
Eigenvalue	3.383	1.214
Variance Explained	42.3%	15.2%
PCA Loadings for Sub-Questions		
Sell/give away unwanted items	0.492	0.629
Repurpose items	0.610	0.462
Sort waste	0.532	0.182
Buy recycled / unharmful products	0.706	0.127
Avoid disposable products / packaging	0.728	0.120
Reduce electricity use	0.701	-0.279
Lower the temperature	0.693	-0.472
Reduce water use	0.698	-0.490

3.4.3 Evaluating Perceptions of EAB Performance in Specific Aspects Given Their Levels of Importance to Students

A specific way that EAB perception is measured was through survey Q's that asked students to evaluate the EAB in eight separate performance aspects, as explained previously in 3.4.2 in full detail.

Prior to that point in the survey, Q set 4 asked students to rate seven[5] of those aspects for importance to them personally, using a 5-point Likert scale running from "Not at all important" = 1 up to "Extremely important" = 5. By having students provide their importance ratings on the different

[5] Q set 4 asked students about the importance of seven different performance aspects to them, but when Q set 8 asked about the e-bike's performance in each of the aspects, it also added an eighth one into the set: Q set 8 asked students about their evaluations of the e-bike in the aspect of simplicity to use. The importance of this particular aspect to students was not asked about in Q set 4, because the DoI theory assumes that simplicity – or rather, its inverse, complexity – is an important part of individuals' perceptions of the innovation in question, regardless whether the individuals recognize it or not.

aspects, this part of the survey is designed to gather data that help define what their felt needs are regarding the way they commute.

In the analysis, this data on aspect importance was cross-tabulated with the Q set 9 data, which were students' performance evaluations of the EAB in each of the different aspects. Since both of these sets of response data used similar Likert scales, it is assumed that a student finds the EAB's performance sufficient in a given aspect, when their evaluation rating for it is an equivalent or higher scale rating than their importance rating for that aspect. These aspects, in which students perceive the EAB to perform sufficiently, can be considered drivers to the EAB's adoption. Conversely, the EAB's performance in a certain aspect is assumed to be insufficient, when the student's EAB performance rating in the aspect is lower than their importance rating for it. These aspects, in which students perceive the EAB's performance as insufficient, can be considered as barriers to adoption. The analysis done with this cross-tabulation allowed the counting of students in these two categories for each performance aspect: those, for whom the EAB's performance in the aspect was sufficient, and those, for whom it was insufficient.

3.4.4 Inferential Statistics to Analyse Influences on EAB Favourability

The aim of this final part of the data analysis was to test if EAB favourability is influenced by other factors, namely by certain prior conditions and student characteristics, which are treated as the independent variables. Non-parametric comparisons of means and correlation tests were used to analyze the relationships of these other factors to the dependent variable of EAB favourability. Again, as explained in 3.4.2, EAB favourability for each student is measured using a multi-item score derived by averaging their nine ratings for the EAB across the different performance aspects.

3.4.4.1 Comparison of Means

For descriptive statistics on the EAB favourability data, one can observe the mean value and variance of a distribution. The smaller the variation, the more certain it is that the measurement is precise about the mean. For inferential statistics on EAB favourability being influenced by other factors, respondents can be categorized into different groups based on their response about a given factor and then the means for EAB favourability can be compared between the different groups to see if they affect the measurement. If the means are sufficiently spread out and the variances sufficiently small, it

can be fairly certain that belonging to a certain group affects the measurement of EAB favourability. However, when the means are close or the variances are widely spread, it can be hard to discern if the impact of belonging to a group is statistically significant. Such comparisons of means are appropriate to use where the respondents are categorized into groups based on independent variable data that is categorical.

A variety of statistical tests focus on comparison of means. Of these, Kruskal-Wallis tests specifically were used in these analyses, where means from two or more groups were to be compared. Furthermore, Kruskal-Wallis tests were also appropriate to use over other comparison of means tests since normal distribution could not be assumed for the dependent variable data in these analyses.

For each comparison of means test conducted, the null hypothesis was that the means for respondents' EAB favourability do not differ between different groups of respondents. The null hypothesis thus assumes that all groups have equal means, so interpreting its resulting p-value allows for the null hypothesis to be rejected and for the confirmation that at least one group has a mean unequal to those of the others. Where the null hypothesis is rejected in a comparison of more than two groups, a Dunn's test was then used to examine the means of the groups in pair-wise combinations. Any pair-wise combinations of the groups, in which the means are not equal, indicate a rejection of the null hypothesis.

3.4.4.2 Correlation

Correlation tests were also used to assess whether EAB favourability is influenced by other factors, specifically where the independent variable data was ordinal or scalar. Statistically, correlation tests for and measures a linear relationship between the independent and dependent variables.

Various statistical tests exist for correlation. Arguably the most widely used is Pearson's R test, which measures the linear relationship between two continuous values and was thus used to test for relationships between EAB favourability and independent variables based on continuous value data. For ordinal data, Kendall Tau and Spearman's Rho are the applicable correlation tests. Kendall Tau is favoured when using smaller datasets as it is generally considered more accurate, though computationally more expensive than Spearman's Rho. Given the sample size, Kendall Tau is calculated in approximately the same amount of time as Spearman's Rho and thus it was used for the ordinal correlation tests.

For each correlation test conducted, the null hypothesis was that respondents' EAB favourability does not have a linear relationship to the independent variable in question. Interpreting the resulting p-value allows for the null hypothesis to be rejected. Where it is rejected, the direction and strength of the correlation is then examined.

3.5 Limitations

The limitations of this study include those for its generalizability and those specific to its use of the survey method.

Surveys often can encounter issues stemming from participant recruitment. One such issue is self-selection bias, which comes from study participation mostly by people who already have an interest in the topic of study. In this case, the data collected from this sample is likely not be generalizable to a whole student population that includes those of all levels of awareness and interest for EAB's and sustainable modes of transportation. Another participant recruitment issue that this particular study encountered was in the differences in difficulty to recruit certain groups of students. Students enrolled in co-op terms are often absent from or less-involved on campus than they are during their on-campus study terms, making it more difficult for recruitment efforts to reach them. Similarly, this study's ethics permissions and its connection to the University of Waterloo meant that it was much easier to recruit student participants from the University of Waterloo compared to those from Wilfrid Laurier University and Conestoga College. Thus, this study has somewhat disproportionate representation of some student groups, which must be recognized.

Beyond participant recruitment, there can also be issues of collecting data from potentially unmotivated or unreliable survey respondents. One issue associated with this is survey fatigue, which is the disinterest that people develop towards surveys because they encounter them so much or because the questionnaires are too long (or both). There is no absolute solution for the problem of survey fatigue, but its effect can be minimized by restricting the length of the survey, designing it to be more engaging, and offering an interesting incentive, all which this study has attempted to do. Self-reporting bias is another potential issue in surveys, specifically those asking participants about their own characteristics, knowledge, opinions, and behaviours. This bias occurs where the

respondent, being aware that they are under observation, tries to answer in a particular way that they think is favourable, but is, however, not an accurate representation of the truth.

4 Results

This chapter covers the respondents' demographics, prior conditions, perceptions of the electrically-assisted bicycle (EAB), and the various factors found to influence those perceptions.

4.1 Demographics

Of the eligible respondents, 62.5% were female and 37.5% were male (see Table 4-1). For comparison, the population of post-secondary students for the Region of Waterloo (RoW) is 48.8% female and 51.2% male. While self-selection bias for females is well-observed in numerous other survey studies, it must be taken into account depending on the domain of study (Dickinson, Adelson, & Owen, 2012; Harber, Zimbardo, & Boyd, 2003).

A large number of students were between 20-24 years (44.2%), with another 23.4% being between 18-19, and 20.6% between 25-29. There is underrepresentation in the age groups spanning 18-24 years old, relative to the student population, and overrepresentation in the 25-29-year age group, because of the overrepresentation of graduate students at University of Waterloo (UW) in particular, whose mean age is 27 years. Furthermore, a majority of the respondents were from UW (66.5%), with the remaining respondents being from Wilfrid Laurier University (WLU; 17.3%) and Conestoga College (16.2%). There is a slight over-representation of respondents from UW relative to the population, but this is expected since it was easier to distribute the survey at UW because of the researcher's affiliation.

Most students in the sample were either doing a bachelor's degree (46.7%) or graduate degree (34.5%), the latter being over-represented compared to only 8.1% of the population who are pursuing graduate degrees. A smaller number of students were doing diploma or certificate programs, over half of whom were studying in those programs at Conestoga College.

The sample was representative of domestic and international students relative to the population. One of the key hypotheses of this study expects domestic/international study status to be linked to likelihood for EAB adoption and the representativeness of the sample here suggests that the result of testing this hypothesis will be extendable to the RoW.

Table 4-1 Respondent demographics compared to Region of Waterloo (RoW) post-secondary student population data (Ministry of Advanced Education and Skills Development, 2019a, 2019b). Survey participants, who indicated non-binary gender or chose not to disclose, are excluded from comparison here due to inconsistent reporting for them across the sources of the population data.

	Survey Sample		RoW Student Population
	#	%	%
Gender	**357**		
Female	223	62.5	48.8
Male	134	37.5	51.2
Age	**364**		
0–17	0	0	0.5
18–19	85	23.4	34.3
20–24	161	44.2	55.2
25–29	75	20.6	5.2
30–34	24	6.6	2.3
35–39	8	2.2	1.1
40–44	6	1.6	0.7
45–49	2	0.5	0.4
50–54	2	0.5	0.2
55–59	0	0	0.1
60+	1	0.3	0.0
Institution	**364**		
University of Waterloo (UW)	242	66.5	56.4
Wilfrid Laurier University (WLU)	63	17.3	21.6
Conestoga College	59	16.2	22.0
Credential Type	**362**		
Certificate	6	1.7	2.4
Diploma	44	12.2	13.1
Graduate-level certificate	11	3.0	3.8
Undergraduate degree (Bachelor's)	169	46.7	71.6
Graduate degree	125	34.5	8.1
Master's	81	22.4	NA
PhD	44	12.2	NA
Other (or otherwise unspecified)	7	1.9	1.0
Domestic/International Status	**364**		
Domestic	291	80.0	78.9
International	73	20.1	21.2

4.2 Prior Conditions

The prior conditions considered were previous commuting habits, and knowledge and awareness of e-transportation modes.

4.2.1 Commuting Habits

The most commonly used transportation modes are public transit and walking (Table 4-2), with 41% of the students walking 6 to 7 days a week, and 16% walking 3 to 5 days per week, while 27% and 29% took public transit 6 to 7 days or 3 to 5 days per week, respectively. Bike was the least used mode of transportation with 72% of the students reporting that they never use it. Car-based options were never used by 66% of the students for car driving alone and 47% never carpooling.

For the sub-question, which asked about frequency of using any other modes of transportation besides the five kinds listed, a response was not required. Most students did not answer this sub-question and furthermore, 91% of those who did responded to it specifically indicating that they don't use any other modes of transportation at all. Of the students indicating travel at all by another transportation mode, one specified the EAB as that vehicle, which they use quite regularly (3-5 days/week).

Table 4-2 Commuting habits of students based on different transportation modes

	Not at all		< 1 d/term		> 1d/term, < 1d/mth		1-3 days/mth		1-2 days/wk		3-5 days/wk		6-7 days/wk		Total
	#	%	#	%	#	%	#	%	#	%	#	%	#	%	#
Drive Alone	232	65.9	16	4.5	10	2.8	19	5.4	33	9.4	26	7.4	16	4.5	352
Carpool	165	46.7	29	8.2	48	13.6	56	15.9	40	11.3	12	3.4	3	0.8	353
Transit	35	9.7	9	2.5	23	6.4	36	10.0	56	15.6	104	29.0	96	26.7	359
Bike	254	72.4	12	3.4	13	3.7	18	5.1	18	5.1	20	5.7	16	4.6	351
Walk	61	17.2	11	3.1	18	5.1	26	7.3	35	9.9	58	16.4	145	41.0	354
Other*	146	90.7	3	1.9	2	1.2	1	0.6	3	1.9	5**	3.1	1	0.6	161

* Because of the wording of the survey question, "other" modes of transportation here means those modes other than driving alone, carpooling, public transit, conventional bike, or walking.

** One of these respondents specified an EAB as the mode of transportation they use to this frequency level.

4.2.2 Awareness and Previous Experiences of Innovations in Light E-Mobility

An e-scooter-share was piloted in recent years only in a select area of the City of Waterloo. The majority of participants were aware of the pilot (69%) and can be further broken down into sub-groups of those who have used it (14.2% of the sample), those interested in trying it (35.6%), and those uninterested in trying (19.2%). By contrast, 21.4% were unaware of the pilot and an additional 9.7% were also unaware of e-scooters in general. These results are displayed in Table 4-3.

Comparing to EAB's in general, a greater share of students (16.4%) were unaware of them, these students also having confirmed that they had no experience using EAB's. Considering the other students without EAB experience, 22.5% of the sample responded with some uncertainty that they might have heard of the EAB before and 45.3% were certain that they had. The remaining 16.1% of the sample had actually used an EAB before, these students having also indicated prior awareness of the EAB. These results are displayed in Table 4-3 as well.

Table 4-3 Prior awareness and experience with e-scooters and EAB's

Students' Exposure to Light E-Mobility Innovations	#	%
E-Scooter Exposure	**360**	
Have used e-scooter in local Lime pilot	51	14.2
Aware of Lime pilot, but not interested in trying it	69	19.2
Aware of Lime pilot, and interested in trying	128	35.6
Unaware of Lime pilot	77	21.4
Unaware of e-scooters in general	35	9.7
EAB Exposure	**360**	
Never heard of the EAB	59	16.4
May have heard of the EAB and certainly have not used one	81	22.5
Heard of the EAB but have not used one	163	45.3
Have used an EAB	58	16.1

For the next step in the line of questioning, those respondents, who had heard of EAB's before (either with certainty or without) but hadn't actually used one, were then asked further survey Q's in order to gain an understanding of how much and in which ways they had had exposure to EAB's, despite not having so much exposure as to have used one before. Generally, their responses show that these participants' exposures to EAB's are still low across all channels at that point in time, especially

for exposure through their interpersonal connections, since the mean exposure scores are less than 2 (for some exposure, on the scale of 0 – 4). Those participants' responses are shown in Table B-1 in Appendix B: for each of the three different ways of exposure.

4.3 Student Perceptions of the EAB

There is more than one way to understand how students perceive the EAB innovation. How they view the EAB relative to other commuting options is only one way to understand those perceptions. Another way is in their evaluations of the EAB in specific aspects of commuting performance.

4.3.1 Perceptions of the EAB Relative to Other Transportation Modes

Students were asked to rate their perception of the overall performance of different transportation mode options on a Likert scale (with responses coded 1 – 5 to assist analysis). The distribution of their ratings for each of the transportation modes is shown in Table 4-4.

The conventional bike and both car options most frequently received ratings of "Very well" (= 4) from students for their perceived overall performance levels, while public transit and both EAB options were most often rated as performing "Moderately well" (= 3). On average, however, students rated public transit the highest, followed by carpooling. Closely following next are the options of driving alone and using a personally-owned EAB, which tie for mean overall performance rating, but with ratings more concentrated around the mean for the EAB option than for the car option. Next is the conventional bike also closely following and then the e-bikeshare option as the most lowly rated on average.

Table 4-4 Likert scale ratings for perceived performance (overall) of each transportation mode

	Not well at all (1)		Slightly well (2)		Moderately well (3)		Very well (4)		Extremely well (5)		Total		
	#	%	#	%	#	%	#	%	#	%	#	Mean	Std Dev
Transit	8	2.2	38	10.6	142	39.4	132	36.7	40	11.1	360	**3.44**	0.90
Carpool	16	4.4	58	16.1	111	30.8	119	33.1	56	15.6	360	**3.39**	1.07
Drive Alone	34	9.4	56	15.6	88	24.4	108	30.0	74	20.6	360	**3.37**	1.24
EAB (Own)	12	3.3	50	13.9	137	38.1	115	31.9	46	12.8	360	**3.37**	0.98
Bike	9	2.5	63	17.5	123	34.2	127	35.3	38	10.6	360	**3.34**	0.97
EAB (Shared)	14	3.9	88	24.4	138	38.3	98	27.2	22	6.1	360	**3.07**	0.96

4.3.2 Perceptions of EAB Performance in Specific Aspects

To give a better understanding of how students' perceptions of the EAB are shaped by various characteristics of the EAB itself, the survey also asked students to provide their Likert scale ratings for the EAB's performance in specific aspects relevant to commuting. Table 4-5 shows the distribution of their ratings for each of the different aspects of commuting performance.

The EAB most often received ratings of "Very well" (= 4) from students for its perceived performance in the aspects of eco-friendliness, simplicity (aka. anti-complexity), effect on physical health, and trip timing and routing. Specifically, in the aspects of the travel experience, cost, effect on social image, and safety, the EAB was most frequently rated as performing "Moderately well" (= 3). Table 4-5 lists each of the aspects of performance in order by the EAB's mean rating in the given aspect, descending from highest to lowest. On average, the EAB was best rated by students for its performance specifically in the aspects of eco-friendliness, simplicity, and effect on physical health. The worst-rated aspects of its perceived performance on average are effect on social image, safety, and cost. Regarding cost in particular, the EAB was rated lower on average for its performance in the aspect of cost when considered in a private ownership scenario than when considered in the context of a bikeshare.

Table 4-5 Likert scale ratings for perceived performance (aspect-specific) of the EAB

	Not well at all (1)		Slightly well (2)		Moderately well (3)		Very well (4)		Extremely well (5)		Total		Std
	#	%	#	%	#	%	#	%	#	%	#	Mean	Dev
Eco-Friendliness	6	1.7	15	4.2	64	17.8	127	35.3	148	41.1	360	**4.10**	0.95
Simplicity	7	1.9	27	7.5	110	30.6	140	38.9	76	21.1	360	**3.70**	0.95
Physical Health	12	3.3	40	11.1	105	29.2	110	30.6	93	25.8	360	**3.64**	1.08
Timing & Routing	11	3.1	49	13.6	122	33.9	137	38.1	41	11.4	360	**3.41**	0.96
Travel Experience	10	2.8	51	14.2	141	39.2	115	31.9	43	11.9	360	**3.36**	0.96
Cost (Shared)	11	3.1	91	25.3	124	34.4	98	27.2	36	10.0	360	**3.16**	1.01
Social Image	29	8.1	64	17.8	142	39.4	85	23.6	40	11.1	360	**3.12**	1.08
Safety	20	5.6	95	26.4	140	38.9	76	21.1	29	8.1	360	**3.00**	1.01
Cost (Own)	57	15.8	91	25.3	126	35.0	53	14.7	33	9.2	360	**2.76**	1.16

4.3.2.1 Distinguishing Aspects as Drivers or Barriers Given Levels of Importance to Students

Before being asked to consider the EAB or any other modes of transportation in particular, students were asked how important each of the different performance aspects (excluding simplicity[6]) were to them in choosing a means for commuting. They were asked to indicate importance level on 5-point Likert scale running from "Not very well at all" = 1 up to "Extremely well" = 5. To give a summary, Table 4-6 provides the means and standard deviations of students' responses for each aspect.

Furthermore, these importance ratings were cross-tabulated with students' performance evaluations of the EAB in each of the different aspects to determine how many students found the EAB's performance sufficient in a given aspect, and how many found it insufficient. This method is described earlier in 3.4.3. For each aspect of the EAB's performance, Table 4-6 also presents a comparison of the shares of students, for whom the EAB performs sufficiently in the aspect, to those, for whom it does not.

The EAB's performance is found sufficient for the majority of students in the aspects of effect on social image, eco-friendliness, effect on physical health, and quality of the travel

[6] Students were not asked about the importance of simplicity to them, because the DoI theory considers it important to individuals' perceptions, regardless whether the individuals recognize it or not.

experience. However, these four aspects are the ones of least importance to students with effect on social image being the very least importance and the other three being of medium importance. Thus, they can be considered as mid- and low-importance drivers for EAB adoption by students. On the other hand, the four aspects most important on average to students were those in which the EAB's performance is insufficient. These are the aspects trip timing and routing, safety, and cost, which stand as relatively important barriers to EAB adoption.

Table 4-6 Summary table of each aspect of performance with i) its importance to students and with ii) the shares of students, for whom the EAB performs sufficiently in the aspect, compared to those, for whom it performs insufficiently

	Importance Rating (1 – 5)		% for Whom the EAB's Performance in the Aspect is…	
	Mean	Std Dev	Sufficient	Insufficient
Effect on Social Image	1.80	1.06	91%	9%
Eco-Friendliness	3.50	1.08	82%	18%
Effect on Physical Health	3.29	1.13	73%	27%
Travel Experience	3.41	0.97	65%	35%
Trip Timing & Routing	4.15	0.85	47%	53%
Safety	3.78	1.07	42%	58%
Cost (Shared)	*4.12	*0.963	38%	62%
Cost (Own)	*4.12	*0.963	27%	73%

* Note: Students were asked about cost in a general sense for its importance to them, but when they were asked about the EAB's performance in the aspect, they were asked to rate for cost distinctly in the two separate contexts: under private ownership and in a bikeshare.

4.4 Influences on Perceptions

This study aimed to determine if EAB favourability is influenced by other factors, namely by certain prior conditions and student characteristics. Correlation and comparison of means tests were used to analyze relationships of these factors to EAB favourability as a dependent variable.

4.4.1 Prior Conditions

Among prior conditions, the analyses found statistically significant relationships to EAB favourability specifically for the prior conditions of i) previous experience and awareness of light e-mobility

innovations and ii) existing commuting habits. Other prior conditions were tested for relationships to EAB favourability, but statistically significant results were not found for them and thus, their results are not presented in this chapter (see Table B-2 in Appendix B: for those results).

4.4.1.1 Previous Experience and Awareness of Light E-Mobility Innovations

The following section analyzes the connection from respondents' e-mobility experience and awareness levels to their overall EAB performance ratings. It was hypothesized that students' EAB performance ratings would be affected by their previous experience and awareness (or lack thereof) of it and of other similar light e-mobility innovations.

Regarding the EAB itself, there were three categories of respondents based on different combinations of experience and awareness. These groups are presented in Table 4-7 with their numbers of students, mean EAB favourability, and their variance.

Table 4-7 Analysis of students' EAB favourability levels depending on their previous experience and awareness of EAB's

		p-Value	
Kruskal-Wallis for EAB exposure/awareness levels		**0.003**	
	#	**Mean**	**Variance**
Group According to Level of Prior EAB Use			
Not aware of EAB (also no prior experience)[7]	58	3.44	0.313
Have not used EAB (are aware of EAB)[8]	244	3.30	0.354
Have used EAB[9]	58	3.60	0.453

A Kruskal-Wallis test confirmed with a statistically significant p-value of that EAB favourability is influenced by these different categories of prior EAB awareness and experience.

[7] Students were grouped into this category for having responded they were "Not at all" aware of EAB's before.

[8] Students were grouped into this category for having responded "Yes" or "Maybe" that they were previously aware of EAB's and for also having responded that they had not used an EAB.

[9] In addition to responding that they had used an EAB, students in this category had also responded "Yes" or "Maybe" that they were previously aware of EAB's.

A Dunn's test showed a significant difference (p-value = 0.001) in overall EAB performance rating only in the following comparison pair: It found higher ratings for students who had used EAB's before (n=58) compared to students who were aware of EAB's but had never used them (n=244).

Regarding a similar innovation to EAB's, the e-scooter, there were five categories of respondents based on different levels of experience and awareness. These categories range from those who have tried an e-scooter in a local pilot to those unaware of e-scooters altogether and they are presented in Table 4-8 with their numbers of students and mean EAB favourability.

Table 4-8 Analysis of students' EAB favourability levels depending on their levels of experience and awareness of the local Lime e-scooter pilot and of e-scooters in general

		p-Value	
Kruskal-Wallis for e-scooter exposure / awareness levels		**< 0.001**	
	#	**Mean**	**Variance**
Group According to E-Scooter Exposure / Awareness Level			
Have used e-scooter in local Lime pilot	51	3.42	0.380
Aware of Lime pilot, but not interested in trying it*	69	3.11	0.286
Aware of Lime pilot, and interested in trying it*	128	3.44	0.343
Unaware of Lime pilot	77	3.33	0.385
Unaware of e-scooters in general	35	3.55	0.456

* Note: To clarify, students in these groups had not tried e-scooters in the Lime pilot.

A Kruskal-Wallis test confirmed with a very statistically significant p-value of that EAB favourability is influenced by these different categories of prior e-scooter awareness and experience.

A Dunn's test followed up, showing statistically significant differences between certain comparison pairs of student groups as listed in Table 4-9. The students aware of the Lime pilot and interested to try it have higher EAB favourability levels on average than students in the categories "Unaware of Lime pilot", "Aware of Lime pilot but not interested in trying", and "Yes, tried Lime pilot", but students, who are unaware of e-scooters altogether, have highest favourability for the EAB.

Table 4-9 Dunn's test p-value results from comparisons of EAB favourability levels between students of different e-scooter experience/awareness levels

Student Group	Other Group in Comparison Pair	p-Value
Aware of Lime pilot and interested in trying it*	Unaware of Lime pilot	0.026
	Have used e-scooter in local Lime pilot	0.024
	Aware of Lime pilot, but not interested in trying it*	< 0.001
	Unaware of e-scooters in general	< 0.001

* Note: To clarify, students in these groups had not tried e-scooters in the Lime pilot.

4.4.1.2 Existing Commuting Habits

It was hypothesized that students' commuting habits, specifically how frequently they use different modes of transportation, would affect their performance ratings of the EAB. This was hypothesized because of the assumption that students' existing commuting habits have been set according to their options, requirements, and preferences for commuting given their personal situations, and that these same factors would affect how favourably or unfavourably they view the EAB.

Kendall's Tau tests showed that there were statistically significant correlations between students' overall rating of EAB performance and their commuting habits, specifically in terms of public transit, walking, or driving alone habits (Table 4-10). The tests found positive correlations to EAB favourability for frequencies of commuting by public transit and by walking. Conversely, a negative correlation was found for driving alone, indicating that the more frequently students commute by driving alone, the less favourably they rate the EAB. The coefficients for these Kendall's Tau test results (all < 0.2), however, signify only weak correlations (Botsch, 2011).

There were no statistically significant correlations between students' overall rating of EAB performance and the other forms of commuting besides public transit, walking, and driving alone.

Table 4-10 Kendall's Tau results for correlation between EAB favourability and levels of frequency for commuting to campus using certain transportation options

Commuting Habits Related to EAB Favourability	Kendall's Tau Coefficient	p-Value
Frequency for commuting by public transit	0.13	0.001
Frequency for commuting by walking	0.10	0.010
Frequency for commuting by driving alone	-0.08	0.044

4.4.2 Student Characteristics

Two aspects of students' characteristics were found to be important in their rating of the EAB's overall performance: their geographical background and experience, and their environmental behaviours. Other kinds of student characteristics were tested for relationships to EAB favourability, but statistically significant results were not found for them and thus, their results are not presented in this chapter (see Table B-2 in Appendix B: for those results).

4.4.2.1 Backgrounds and Experiences from Different Geographic Regions

The following section analyzes the connection from students' geographic backgrounds to their overall EAB performance ratings. Since certain geographic areas have already seen significant EAB adoption, it was hypothesized that students' EAB performance ratings would be affected by their backgrounds and lived experiences in different geographies.

One way that students can be categorized is by their status as either domestic or international students. On average, the EAB received higher favourability ratings from international students than from domestic students as illustrated in Table 4-11. A Kruskal-Wallis test confirmed that the difference in means between these two groups of students is very statistically significant.

Table 4-11 Analysis of students' EAB favourability levels depending on their status as either a domestic or international student

		p-Value	
Kruskal-Wallis for domestic/international student status		**< 0.001**	
	#	**Mean**	**Variance**
Group According to Study Status			
Domestic	288	3.28	0.341
International	72	3.67	0.377

Another way to categorize students is by looking specifically into the geographic areas where they have lived. These groups are presented in Table 4-12 with their numbers of students, mean EAB favourability, and their variance.

Table 4-12 Analysis of students' EAB favourability levels depending on what geographic areas they have lived in besides Canada

		p-Value	
Kruskal-Wallis for geographic areas students lived		**0.007**	
	#	Mean	Variance
Group According to Geographic Area Student Has Lived In			
US	13	3.11	0.282
(Nowhere else besides Canada)	196	3.28	0.326
Middle East & North Africa	12	3.33	0.281
Europe	17	3.42	0.261
East and Southeast Asia	36	3.59	0.389
Central and South Asia	31	3.62	0.355
Latin America and the Caribbean	10	3.67	0.321
Sub-Saharan Africa	4	3.31	1.328

A Kruskal-Wallis test confirmed with a statistically significant p-value that EAB favourability can be influenced by a student's experience having lived in certain regions beyond Canada, as illustrated in Table 4-12. To note here, is that a small number of students, who have lived in more than one of any of the listed regions besides Canada (n = 46), make up a group that had to be excluded from the comparison of means tests since their categorizations would be non-mutually exclusive from the others.

Subsequently, Dunn's tests showed statistically significant differences between certain comparison pairs of student groups as listed in Table 4-13. The results suggest significant differences between the following groups of students:

- Those who have lived previously in the US compared to those lived in Latin America and the Caribbean, East and Southeast Asia, and Central and South Asia, and
- Those who have only ever lived in Canada compared to those lived in Central and South Asia and East and Southeast Asia.

Table 4-13 Dunn's test p-value results from comparisons of EAB favourability levels between students grouped by single regions around the world, where they have lived besides Canada.

Student Group	Other Group in Comparison Pair	p-Value
Central/South Asia	Nowhere else besides Canada	0.005
Central/South Asia	US	0.013
East/Southeast Asia	Nowhere else besides Canada	0.004
East/Southeast Asia	US	0.014
Latin America / Caribbean	US	0.031

4.4.2.2 Pro-Environmental Behaviours

It was hypothesized that students' pro-environmental behaviours would influence their performance ratings of the EAB. Since the EAB is considered to be an environmentally-friendly innovation, it is hypothesized that the EAB would receive higher performance ratings from students with stronger pro-environmental behaviours.

A Pearson's R test was used to examine correlation between their EAB overall performance ratings and their domestic pro-environmental behaviour level, both variables that were measured using multi-item scores. The test found a coefficient of 0.188, denoting a positive correlation between the domestic pro-environmental behaviour measure and EAB favourability (p-value < 0.001), as illustrated by the line in Figure 4–1. Such a coefficient for Pearson's R (between 0.1 and 0.3), however, signifies only a weak correlation within social science disciplines (Akoglu, 2018).

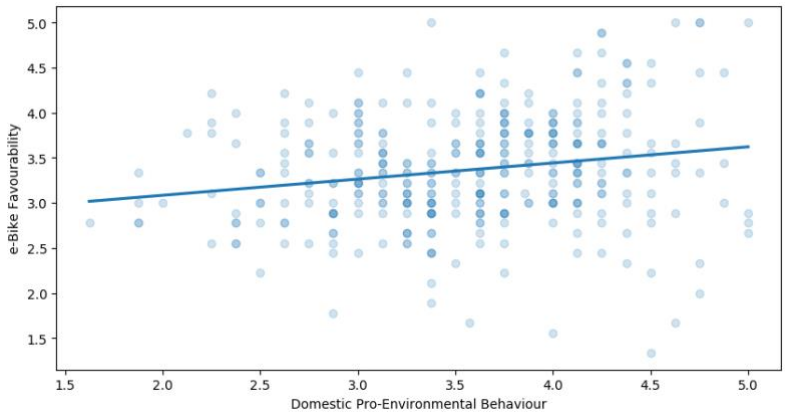

Figure 4–1 Distribution and correlation of students' EAB favourability levels by their domestic pro-environmental behaviour levels. The colouring of the points gets increasingly darker to signify greater numbers of students at that point on the chart.

Doing environment-related work outside the home was a different pro-environmental behaviour measure based off of a single survey item and with different response options from the other kinds of pro-environmental behaviours, which often have to do with behaviour in the home. Thus, this particular pro-environmental behaviour was tested separately for its relation to EAB favourability. A Kendall's Tau test verified a positive correlation of 0.13 to a statistically significant level as presented in Table 4-14. This coefficient for Kendall's Tau (< 0.2), however, signifies only a weak correlation (Botsch, 2011).

Table 4-14 Kendall's Tau results for correlation between students' EAB favourability and their frequency for doing environment-related work in a professional or volunteer capacity

Type of Pro-Environmental Behaviour Related to EAB Favourability	Kendall's Tau Coefficient	p-Value
Doing environment-related work outside the home	0.13	0.002

4.5 Summary

The results as presented in this chapter and further interpreted in Chapter 5 address the three objectives of this study as outlined initially in 1.2.

The first objective is to describe students' perceptions of the EAB. For comparison across commuting options, the results in 4.3.1 show how students rated the EAB and other modes of transportation for overall performance. Then looking more indepth at the EAB specifically, the results in 4.3.2 outline how students perceive it as broken down into different aspects of commuting performance, thus revealing the aspects they rate it better in and those, in which they rate it worse.

With a focus again on the different aspects of commuting performance, the results in 4.3.2.1 address the study's second objective in identifying relationships between aspect-specific perceptions of the EAB and the importance of those aspects to students for commuting performance. Looking at these results differentiated each of the aspects as either a driver or barrier to EAB adoption, each of their own level of importance.

Results in 4.4 address the final study objective in identifying which features about socio-demographics, environmental behaviour, and contextual factors demonstrate relationships to students' EAB perceptions.

5 Discussion

5.1 Introduction

The aim of this study was to determine the level of interest in electrically-assisted bicycles (EAB's) among post-secondary students, and to understand the drivers and barriers to their adoption. Areas needing further research are also highlighted in the following sub-sections where applicable.

The study objectives as outlined initially in 1.2 are restated here:

Objective 1: To describe students' perceptions of the EAB in terms relative to other commute options and in terms of specific aspects of performance for commuting.

Objective 2: To identify relationships between students' perceptions of the EAB's performance and their requirements for commuting performance.

Objective 3: To identify relationships between students' perceptions of the EAB and their socio-demographics, their environmental behaviour, and contextual factors.

5.2 Awareness, Interest, and Perceptions About the EAB

This chapter section describes and discusses students' awareness levels, interest levels, and their perceptions of the EAB as demonstrated by the results. Because basic awareness of a given innovation is the first requirement for an individual to begin the Innovation Decision Process (IDP) at the Knowledge stage (Rogers, 1962/2003), the upcoming sub-section focusses on the results about EAB awareness and how awareness levels relate to different stages of IDP. Then another sub-section follows to discuss the next parts: levels of interest for EAB's and perceptions about them. Other chapter sections will later discuss the influences of the EAB's innovation characteristics, student characteristics, and existing contextual conditions on students' perceptions of the EAB.

5.2.1 Amount of Awareness for Starting and Progressing through IDP

The survey results suggest that most students in the Region of Waterloo (RoW) have at least some awareness of the EAB, having already entered the Knowledge stage of IDP towards potential adoption (refer to Figure 2–2). Only some students in the sample reported having no awareness of the EAB at all prior to the survey (16% of those who answered Q 6a; see Table 4-3 in 4.2.2).

The vast majority of students though, who have already entered the Knowledge stage (86%), have done so to varying extents and so they have differing levels of familiarity with the EAB. This variance was expected partly because of the existence of other kinds of vehicles very similar to the EAB, which could have led some respondents to be uncertain about whether it was specifically the electrically-assisted concept of e-bike or another kind of electric two-wheeler that they might have encountered before. For this reason, a descriptive section of the survey explained about EAB's (before Q set 6; see Appendix A:), aiming ensure that all respondents had the minimum necessary information on the EAB and a common, consistent foundation of understanding for answering survey Q's about it. Their responses in the next Q set confirm that many students were in the Knowledge stage to varying degrees, though most of them seem to have a basic if not quite low level of prior EAB awareness and exposure (see Table 4-3 as well as Table B-1 of Appendix B:). At minimum, they have what Rogers refers to as awareness-knowledge (1962/2003), but probably have some gaps in their how-to knowledge and principles-knowledge remaining to be filled in order for them to advance further along the course of IDP. There is also a small minority of these students who have likely greater levels of all of these kinds of knowledge about the EAB, due to the greater exposure they have had to them through different channels, even without having used an EAB yet.

Rather few respondents have used an EAB at least once (16% of those who responded at the start of Q set 6). Students of this group could have been in various stages beyond the Knowledge stage of IDP before taking the survey. Most of them were probably in the Persuasion stage, but it is also possible that some may have actually advanced to the Decision stage and had decided to reject the EAB innovation or, alternatively, had adopted it, continued through the Implementation stage, and then eventually decided to discontinue using it at the Confirmation stage. From the response data from Q set 2 on use habits for different modes of transportation (Table 4-2 in 4.2.1), it is known for certain that one respondent uses an EAB on any regular basis. To elaborate, this places that individual beyond the Knowledge and Persuasion stages altogether – most likely in the Implementation stage or even into continued adoption from the Confirmation stage. Considering that the EAB reached

successful adoption with this one student (< 1% of the respondents that answered Q set 2), that would make them an Innovator in terms of innovativeness categories of adopters along the diffusion curve (see Innovators category making up 2.5% of adopters in Figure 2–1; Rogers, 1962/2003).

Overall, most students were found to be pre-adoption portion of the IDP about EAB's, at some point in the Knowledge stage in particular. This would contend that the EAB is still rather early in its diffusion into the student market, with potential yet to spread to more beyond the first few Innovators if it proves successful.

5.2.2 Levels of EAB Interest and Perception Favourability

The results on participants' evaluations of all transportation modes for overall performance (see Table 4-4) together with their evaluations of the EAB across multiple aspects of performance (Table 4-5) provide a picture of the levels of interest that students had for EAB's at the time of the survey.

Examining respondents' overall performance evaluations of the various transportation options (Table 4-4) gives an idea about the EAB's relative advantage (or disadvantage; refer to 2.3.3.1) compared with their perceptions of the other commuting options. In these data, the respondents are generally spread across all of the rating levels with a uni-modal distribution, giving either "Moderately well" or "Very well" most frequently for performance ratings of the different transportation modes. The mean ratings for each mode of transportation place them somewhat higher than the middle "Moderately well" performance rating, which is a 3 on the 5-point scale used. As a generalization, the motorized options are rated higher on average than the two-wheeled, active transportation options (the EAB and conventional bicycle options), the exception being that the driving alone and personally-owned EAB options tied for the middle place among all modes. The EAB as used in a bikeshare was rated most negatively (or unfavourably) on average relative to all other transportation modes.

Next, ratings for the EAB within specific aspects of performance (from Q set 8; shown in Table 4-5) can be examined in order to explore what factors about the EAB may have led students to rate its overall performance the way they did. The aspect of cost, was expected to be a noticeable differentiator between EAB under private ownership vs. under a bikeshare scheme, so respondents were asked to provide two separate ratings for the EAB's performance in cost (Table 4-5) based on

these two variations. Amongst all the different aspects of the EAB's performance, cost for both EAB variations received less favourable ratings on average than most other aspects. Cost, specifically for the private ownership scenario, received the very lowest ratings of all aspects on average (mean = 2.76). The notion of a bikeshare for using the EAB seems to reduce the negative ratings related to cost, which is in line with expectations since sharing schemes aim to offset the costs of actual ownership (Ji et al., 2014; Kaplan et al., 2018). Other aspects, for which the EAB was rated less favourably, were safety and its effect on social image. The aspects of trip timing and routing as well as travel experience rank in the middle out of all aspects for average ratings. Finally, the best perceived characteristics of the EAB are its eco-friendliness, simplicity to use (or low complexity; refer to 2.3.3.3), and effect on physical health. Overall, the EAB received uni-modal rating distributions, around the middle for all aspects of performance in general. With a few exceptions, the mean ratings for all aspects put them between the "Moderately well" and "Very well" performance ratings (between 3 and 4 out of the 5-point scale). Exceptions to this were eco-friendliness (with average ratings slightly better than 4, "Very well"), safety (with average ratings of 3.00, equal to "Moderately well"), and private ownership cost (with average ratings somewhat lower than 3, "Moderately well").

While having more questions in the survey increases the risk of participant withdrawal, it would have been very interesting to include more questions asking participants for such aspect-specific ratings on any of the other transportation modes for more detailed comparison to the EAB.

5.3 EAB Perception Affected by Evaluations of its Performance in Specific Aspects

While examining student's aspect-specific ratings of the EAB is part of investigating their EAB perceptions more in-depth, it is also worth considering how important students feel those different performance aspects are to them in choosing a mode for commuting.

The reasoning here is that the aspects, which an individual deems highly important, define their felt needs (as in the component of the existing conditions Determinant of Adoption (DoA), explained in 2.3.1 and 2.3.1.2). The next step is to consider how well the individual perceives the particular innovation to deliver on different aspects, each of varying importance. Doing this informs

about the innovation's compatibility with the potential adopter's needs and values (compatibility, as in the category of innovation characteristics explained in 2.3.3.2). It is quite possible that an innovation is perceived to deliver well in a certain aspect, even if the individual deems that particular aspect to be of little importance (in other words, an aspect they feel little need in). However, what is crucial in order for an innovation to be successfully compatible is that it at least meets the individual's needs as defined by the aspects they deem important, instead of falling short in them. This chapter section discusses the EAB in this respect.

The EAB received its worst ratings for perceived performance among the more functional kind of aspects (see Table 4-5). An exception to this trend for poor performance in functional aspects, however, is the aspect of trip timing and routing. The EAB's cost, specifically for use under private ownership, was its most unfavourably perceived aspect, even compared to its rating on cost for use under a bikeshare, which points in opposition to findings from Table 4-4 showing that it received worse overall performance ratings for use under shared access than under private ownership. This suggests that the cost advantages, which a bikeshare has over private ownership, are still not enough to make students prefer a shared EAB over one they would own themselves. In other words, another aspect(s) besides cost alone must have influenced the general preference for privately-owned EAB's over shared ones.

By contrast, the two best-rated aspects about the EAB are those that provide benefits beyond its narrower commuting function or may also serve more symbolic and environmental purposes (as characterized by Noppers et al., 2014), which are eco-friendliness and effect on physical health. One might naively attempt to state at this point that the functional aspects of the EAB tend to be barriers to its adoption while its symbolic and environmental aspects tend to be drivers. However, making interpretations on drivers and barriers requires taking into account how individuals hold varying levels of importance for different aspects, i.e. considering whether or not they value functional aspects over symbolic and environmental ones. A more complete assessment in identifying drivers and barriers could consider students' varying needs for different aspects in their commute.

5.3.1 Areas to Look to for the EAB's Compatibilities and Shortcomings

This sub-section examines, in which aspects the EAB may or may not be compatible with students' needs, and looks to Table 4-6 in carrying out this discussion. That table shows the shares of students,

for whom the e-bike performs sufficiently in the different aspects, compared to those, for whom its performance is insufficient.

The e-bike's performance is found sufficient for the majority of students (> 50%) in these four aspects: effect on social image, eco-friendliness, effect on physical health, and quality of the travel experience. This generally means that, in these specific aspects, the EAB can be considered compatible with students' felt needs. The importance ratings for these aspects must be considered further though: the mean importance ratings show that, effect on social image is the very least important to students (average rating < 2, "Slightly important", on the 5-point scale) and the other three aspects are of medium importance (average rating between 3, "Moderately important", and 4, "Very important"), relative to all performance aspects. Students feel little need for the EAB's social image benefits, although, compared to that aspect, they feel relatively greater need for the EAB's eco-friendliness, physical health effects, and quality travel experience. They do, however, view their commuting needs in other aspects as even more important than in these ones.

The EAB's performance is found insufficient for the majority of students (> 50%) in the following aspects: trip timing and routing, safety, and cost. Again, when it comes to cost, the EAB was rated for perceived performance on cost in two scenarios: under private ownership and under a bikeshare. The EAB was found insufficient on cost for the majority of students in both of those user scenarios. Ultimately, the EAB is not compatible with the felt needs of most students in the three aspects. Crucially, however, students rated these as the three most important aspects on average. Safety received a mean importance rating only slightly less than 4 ("Very important") on the 5-point scale, while cost and trip timing and routing received average importance ratings slightly greater than 4. Especially with their higher levels of importance to students, it is problematic that the EAB is less compatible with students' needs in these three aspects.

After this examination, it is noted that the EAB is in fact less compatible with student needs in the functional aspects of commuting (in reference back to Noppers et al., 2014). Trip timing and routing, safety, and cost are certainly considered to be functional innovation characteristics of the EAB, for all of which it is not compatible for most students. It is nearly the opposite case for the other aspects, in which it is compatible with student needs. The EAB's effect on social image is one of its symbolic innovation characteristics and its eco-friendliness is evidently an environmental one. The effect on physical health and positive travel experience do not seem to be strictly functional

characteristics of the EAB; they may be considered to be symbolic characteristics that are related to the function of the EAB.

The findings of this discussion are summarized in Table 5-1.

Table 5-1 Summary table of discussion highlights about different aspects of the EAB

	Type of Innovation Characteristic	% of Students for Whom the EAB's Fulfilment on Needs in the Aspect is…		Mean Importance (1 - 5)	Driver or Barrier to Adoption
		Compatible	Incompatible		
Timing & Routing	functional	47%	**53%**	**4.15**	Strong barrier
Cost	functional	*For own EAB:* 27% *For shared EAB:* 38%	**73%** **62%**	**4.12**	Strong barrier
Safety	functional	42%	**58%**	**3.78**	Moderate barrier
Eco-friendliness	environmental	**82%**	18%	**3.50**	Moderate driver
Travel Experience	symbolic / functional	**65%**	35%	**3.41**	Moderate driver
Physical Health	symbolic / functional	**73%**	27%	**3.29**	Moderate driver
Social Image	symbolic	**91%**	9%	**1.80**	Weak driver

5.3.2 Perceived Simplicity-Complexity Level of the EAB

Finally, one performance aspect to consider on its own is the level of simplicity (anti-complexity) of the EAB. The EAB received its second-best ratings in perceived performance on average for its simplicity (see Table 4-5). However, importance ratings were not gathered for simplicity-complexity like they were for other performance aspects because it aligns with a component of perceived characteristics of the innovation that is important on its own, regardless whether the individuals themselves consider it important or not, according to the Diffusion of Innovations (DoI) theory (Rogers, 1962/2003; refer to 2.3.3). According to the theory, greater complexity of an innovation should be negatively related to successful adoption, so conversely, greater simplicity is positively related to adoption. The EAB's higher performance ratings on simplicity (average rating somewhat < 4, "Very well", on the 5-point scale) indicate that complexity

is not a barrier to EAB adoption by students. In fact, the EAB's simplicity could be a potential driver for its adoption.

5.4 External Factors Affecting EAB Interest and Potential Adoption

According to DoI theory, an innovation's progression towards adoption is also affected by factors outside of those about the innovation itself (Rogers, 1962/2003). The results of the survey under 4.4 point to some particular characteristics about students as potential adopters and about their present context as those external factors that would likely have influence in EAB adoption.

5.4.1 Students' Characteristics Affecting Their EAB Perceptions

Regarding student characteristics, the survey results and analysis determined that students' geographical backgrounds and their environmental behaviours are more or less related to how favourably they will view the EAB. These particular variables are explored further in the next sub-sections, so here, the remaining discussion is focused on the other student characteristics.

Inferential statistics did not point to the following student characteristics as being related to EAB favourability levels (refer to Table B-2 in Appendix B:): their gender, age, type of credential they are pursuing, program year, or amount of time they have left in their program.

Concerning gender, some existing EAB literature asserts that the EAB could make cycling more appealing to women (Fyhri & Fearnley, 2015; Fyhri & Sundfør, 2014; Haustein & Møller, 2016a; Kaplan et al., 2018; Lee et al., 2015; van den Berg et al., 2018), who tend to cycle less than men (Dill & Rose, 2012; MacArthur et al., 2014). A Kruskal-Wallis test was used to verify whether a greater appeal to women – if the EAB in fact has that – might lead women to perceive the EAB more favourably than men do. However, the result does not support this notion, nor the notion that a student's gender (either male or female) would be related at all to how favourably they perceive the EAB. Perhaps this is the case because, even if women may tend to prefer the EAB over the conventional bicycle, it would not necessarily mean that they would have a tendency to favour the EAB to any level different from how men do.

For age, a Pearson's R test found no correlation to EAB favourability level, which is aligned with DoI theory's hypothesis that earlier adopters are no different from later adopters in age (1962/2003). Age was investigated as a potential influence in this study, however, given the focus of existing EAB research on mature adults (ages 55 years and upwards) and to a lesser extent on students (refer to 2.4.2.1). With this study being focussed on post-secondary students though, the sample actually was not very diverse in terms of age (88% of respondents were between ages 18 and 29 years, with 44% of the sample being in the 20 to 24 years age group in particular). Thus, the study's focus on post-secondary students could have been the underlying reason why age was found to be an insignificant factor. There is the possibility that a general population survey, with a more inclusive representation of all age groups, could find a correlation between age and likelihood to adopt the EAB.

The inferential statistics also do not support that students' EAB perceptions are related to factors about their credential type or years of education. Rogers had proposed a general hypothesis that earlier adopters of an innovation have more years of formal education than later adopters (1962/2003) and so, this study tested for influence depending on students' program year. Similarly, it was also expected, based off of this hypothesis, that there could be differences in students' EAB favourability depending on how many years they had remaining in their program of study. Also based off of Rogers' hypothesis, it was similarly expected that students pursuing higher credentials would have shown more favourability towards EAB's than students of the credential programs under them or of the more practical training programs. These hypotheses, however, are very broad, having been based on observations covering an extremely wide range of adopters and diverse subject innovations, studied through investigations around the world. They are not necessarily generalizable to all cases and thus, may not apply to a narrower population like post-secondary students. Concerning different credential types in particular, even though students are studying for seemingly very different kinds of post-secondary programs, perhaps they do not actually differ so much from each other in terms of formal education because they all have already the foundations of at least primary and secondary education. It is still possible, however, that sample data from a broader population could demonstrate an influence from years of education completed on tendency to adopt. It could also be the EAB as the innovation, to which the general hypothesis is not applicable. Differences in formal education may not be related to differing likelihoods to adopt the EAB the way that they are for other innovations.

This study did not find that the characteristics discussed above necessarily relate to how favourably students perceive EAB's, yet further research into them using different methods could be attempted. Further research is also certainly needed to understand the roles of some other adopter characteristics. The general personality variables, communications behaviour, and the socio-economic variables of social status and mobility, which Rogers provided broad hypotheses about (1962/2003), are all constructs that would require collecting many pieces of data in order to describe them about individuals. A survey, which already asks participants about so many other diverse variables as the one for this study did, is not appropriate for including the questions required to explore any of these more complex constructs and would run greater risk of causing survey fatigue if it did. Despite their measurement difficulties, any of these potential influences towards adoption of innovations, especially students' access to financial means (as with their willingness-to-pay), would be interesting to examine in other studies.

5.4.1.1 Influence of Students' Geographical Backgrounds

In the context of this survey, someone's status as either a domestic or international student is really a characteristic about them as an individual. Yet, knowing this about them and knowing what other places they may have lived in around the world is also informative in another way about what they may be accustomed to for local social norms regarding commuting, which falls under the prior conditions DoA in Rogers' adoption theory (1962/2003). Furthermore, the EAB, as the subject innovation, is known to have already made its introduction into certain markets around the world (refer to 2.4.3), so differences in EAB favourability would be expected between students depending on another global region they have lived in.

A Kruskal-Wallis test found that international students view the EAB more favourably than domestic students do (see Table 4-11). While EAB's do not fit into norms about commuting in Canada (perhaps yet), this result suggests that international students, who certainly have a great deal of lived experience outside of Canada, tend either to carry social norms that include EAB's or, at least, not to be tied so strongly to social norms that exclude EAB's (ex. car culture).

Kruskal-Wallis tests and Dunn's tests were used to test the different regions, in which students have lived, for relationships to their EAB favourability (see Table 4-12 and Table 4-13). The test found that students, who have lived in the Central and South Asia region or in the East and Southeast Asia region, view the EAB more favourably than those, who have lived in Canada only or

in the US. Additionally, students, who have lived in the Latin America and Caribbean region, view the EAB more favourably than those, who have lived in the US. Notably, those who have lived in the US or only in Canada have the lowest average EAB favourability levels out of all groups. On the other hand, those, who have lived in Central and South Asia, in East and Southeast Asia, or in Latin America and the Caribbean, have higher average EAB favourability levels than all other groups. Based on existing research and the established market presence of the EAB in China (in the East and Southeast Asia region; Lin et al., 2018; Ruan et al., 2014), it was expected that students, who have lived in that region, would view the EAB more favourably than students, who have only lived within North America (Canada and the US). The findings on lived experience in the Central and South Asia region and the Latin American and Caribbean region are interesting findings since no existing research was found on EAB's in these regions to suggest any expectations for comparatively higher or lower favourability.

While these findings suggest the possible influence of underlying social norms related to geography, they do not provide enough information to characterize the social norms and isolate them as contributing factors. Further research could be done to better characterize social norms for commuting in Canadian contexts, with descriptions beyond the existing data on what modes people commute by and how frequently. The same would also need to be done for other geographic contexts, if comparisons are to be made. More information would be needed to better understand social norms because doing so not only means knowing the observable indicator behaviours but also understanding the reasons behind them, which partly define social norms.

5.4.1.2 Influence of Students' Environmental Behaviours

Pro-environmental personality variables are usually expected to serve as motivators to adopt innovations that are seen as environmentally-friendly, such as the EAB (Dill & Rose, 2012; Seebauer, 2015; Wolf & Seebauer, 2014). This study investigated environmental behaviours in and outside the home as indicators of pro-environmental personality traits and found that they are correlated, though only weakly, to EAB favourability among the students (see 4.4.2.2). They may be weak predictors of an individual's likelihood to adopt the EAB and other factors likely have greater influence.

While pro-environmental personality traits made up the only aspect of personality investigated by this study, further research could be done to explore the possible influence of other personality variables in EAB adoption.

5.4.2 Existing Conditions and Their Roles in Students' EAB Perceptions

In terms of existing conditions, the survey results and analysis determined that previous EAB experience as well as awareness and previous experience with e-scooters are more or less related to how favourably they will view the EAB. The analysis also found weak relationships to EAB favourability depending on existing commuting habits specifically for public transit, walking, and driving alone. These particular variables of previous EAB experience, awareness and previous experience with e-scooters, and existing commuting habits are explored further in the next sub-sections, so here, the remaining discussion is focused on the other student characteristics.

Inferential statistics did not point to the following existing conditions as being related to EAB favourability levels (refer to Table B-2 in Appendix B:): topic(s) of study in academic program, residing on- vs. off-campus, distance from residence to campus, psychological temporal distance, exposure to EAB's through different channels, and commuting habits specifically for carpooling, conventional bicycle, and other modes of transportation. These particular variables are discussed in this sub-section, with the exception of commuting habits for carpooling, conventional bicycle, and other modes of transportation, which are discussed along with all other commuting habits in 5.4.2.3.

One characteristic that was expected to show influence on students' EAB perceptions was whether their studies include any of the topics relevant to EAB's: transportation planning or technology, environmental sustainability, electrical systems or electronics, community planning, or human health. Kruskal-Wallis tests found no statistically significant influences on students' favourability towards the EAB depending on academic studies in any of the above areas. The reason for this may be because respondents' studies in (and subsequent familiarity with) these topics, which are seemingly related to EAB's, may in fact not be relatable enough to the EAB to influence their perceptions about it. Another possible explanation for the finding is that students may not necessarily involve themselves enough with such topics in their life outside of their studies, in order for them to have such an influence on other areas of their behaviour, such as their commuting habits.

It could also be expected that students' felt needs for their commute to campus would be partly affected depending on whether they lived on- or off-campus or depending on the distance between their residence and campus. However, the inferential statistics found no relationships from

these variables to EAB favourability. Other variables, such as those aspects about the EAB itself (as described in 5.3.1 and 5.3.2), are more important as parts of students' felt needs for their commute.

Another contextual characteristic of the existing conditions DoA, which was not found to be related to students' EAB perceptions, was psychological temporal distance as an indicator of their readiness to adopt a new innovation or, in other words, an indicator of innovativeness (as described in 2.3.1). A possible reason for this finding is that innovativeness, whose role in adoption is meant to be applicable across virtually all innovations according to DoI theory (Rogers, 1962/2003), may not generalize to EAB's in the same way. However, the difficulty in measuring this construct in a survey was also most likely a reason that it was not found to be indicative of the favourability of EAB perceptions. As explained in 2.3.1, consensus is yet to be met about how to measure this construct. Construal Level Theory (Trope & Liberman, 2003) was applied in designing a simple, single survey item to gather data indicative of this construct, but even that approach likely meant examining too few variables to properly understand it for analysis in potential EAB adoption. Further research could be dedicated to understanding this construct of innovativeness alone in the scope of the EAB or of other potential innovations for private transportation.

Finally, students' levels of exposure to EAB's through different channels were not found to be correlated to their favourability levels as verified by Kendall's Tau tests. The survey Q's on exposure through different channels was only asked of the students who had heard of EAB's before the survey but hadn't actually used one (students who had not heard of EAB's or who had used one before the survey were excluded). Generally, this group of students had relatively low exposure to EAB's across all the different channels. The findings of the correlation tests suggest that no particular channel of EAB exposure is related to EAB favourability for this group. As discussed further in the next sub-section, however, this is not the case when comparing this group of students to those who had actually used an EAB before.

5.4.2.1 Influence of Prior EAB Use

Kruskal-Wallis tests highlighted that favourable EAB perceptions are related to respondents, who are aware of the EAB to some degree, depending whether they had used an EAB before or not (see Table 4-7). However, a relationship could not be reliably determined about students, who claimed to have no prior EAB awareness (and thus also had not tried an EAB). The test results support that respondents, who are at least minimally aware of EAB's, are more likely to perceive EAB's more

favourably if they have any experience using one first-hand, giving them just that much more convincing information about it.

As for those with some awareness but no previous EAB use, the data showing low levels of exposure to EAB's through different channels (see Table B-1 in Appendix B:) seem to suggest that they rated the EAB based on impressions of it, which are still missing important information that could persuade them otherwise (Rogers, 1962/2003). For practice, this suggests that letting people actually try an EAB for themselves is the most effective exposure channel for persuading them towards adoption, corroborating existing research (Cairns et al., 2017; Fyhri & Fearnley, 2015; Fyhri et al., 2017; Fyhri & Sundfør, 2014; McLoughlin et al., 2012).

5.4.2.2 Influence of Awareness and Previous Experience with E-Scooters

Kruskal-Wallis and Dunn's tests found statistically significant relationships to EAB perceptions based on whether students had heard of and used the Lime e-scooter pilot specifically in the City of Waterloo, but not based on whether students had heard of kick-style e-scooters in general (see Table 4-8 and Table 4-9).

Regarding the e-scooter pilot in Waterloo, a portion of students, who are aware of the pilot, seem to have decided that they will not be trying it because they do not see it as an advantageous enough innovation (this would mean they had reached the Decision stage of IDP and rejected; Rogers, 1962/2003). The statistical results reliably show that these students, who had decided not to try the e-scooter pilot, also perceive the EAB less favourably than the other students, who are either still interested in trying the e-scooter pilot (but have not had a chance yet) or unaware of this specific pilot altogether. While EAB's and e-scooters share similarities as innovations, these results suggest that these particular students might need some additional, more appealing information about the EAB to become better persuaded about it, or that, as with their decision against trying the Lime e-scooter pilot, they may have already made their decision on their typically less favourable view of the EAB. Of course, there are a few students belonging to this group, who perceive the EAB more favourably than the rest in the group. To these few students, the EAB may be seen as offering certain advantages that e-scooters under the Lime pilot do not deliver on.

5.4.2.3 Influence of Existing Commuting Habits Across Various Modes of Transportation

Existing research has drawn mixed conclusions about individuals' likelihood to adopt EAB's depending on their previous commuting habits. In this study, Kendall's Tau tests found correlations – weak though statistically significant – between students' EAB favourability and their commuting habits, specifically in terms of public transit, walking, or driving alone habits (see Table 4-10). Statistically significant correlations, however, were not found between EAB favourability and students' habits for commuting by carpool, conventional bicycle, or other modes of transportation (see Table B-1 in Appendix B:).

The results, showing that commuting by public transit and walking are positively correlated with EAB favourability, corroborate the previous studies finding that EAB's tend to replace trips made by public transit or walking (An et al., 2013; Fyhri & Sundfør, 2014; Lee et al., 2015; Lin et al., 2017). Thus, students tend to view the EAB more favourably, the stronger their habits for public transit or walking are, which suggests that those relying more on public transit or walking may be doing so despite feeling dissatisfied with it. At the very least, it suggests that the more students commute by public transit or walking, the more they would view the EAB as an improvement for their commuting situation. Rogers has described this latter case as a new need being "created" by the person's new awareness of the innovation (Rogers, 1962/2003). Cost has been previously discussed as an important barrier to students' EAB adoption and it is likely a particularly important one for students the more they rely on public transit and walking, since walking is free and public transit passes are usually subsidized for post-secondary students in RoW.

Conversely, habits of commuting by driving alone are negatively correlated to EAB favourability, which is in opposition to findings from the previous research (Cairns et al., 2017; Johnson & Rose, 2015; Lee et al., 2015; Popovich et al., 2014). This result suggests that the more often a student drives a car to commute, the stronger their habit is for doing so, thus making the EAB less favourable to them to replace those trips by car. It could prove very difficult to modify the commuting behaviour for students with strong drive alone habits.

The weakness of these correlations for public transit, walking, and driving alone habits, however, must be taken into account. It means that these results do not point to these existing commuting habits as strong predictors of EAB favourability.

Regarding conventional bicycle use, one study had found that students in the Netherlands used the EAB to replace their trips by conventional bicycle the most (Plazier et al., 2017b). This trend could not be confirmed or denied in this study, however, since a statistically significant correlation could not be found (see Table B-1 in Appendix B:). Furthermore, conventional bicycle use is very low and students use it the least of all modes of transportation for commuting (see Table 4-2).

No previous research provided expectations on EAB favourability depending on existing habits for commuting by carpool or other modes of transportation. This particular study asked about carpooling, however, because of its similarity to car driving but with significant differences expected in cost and trip timing and routing, like comparing EAB use via privately owned EAB and via bikeshare. Carpooling was in fact found to be an important transportation option for many students (see Table 4-2), but, when it came to being a potential predictor of EAB favourability, it was not found to be significantly related (see Table B-1 in Appendix B:). This study also asked students about their use of any other modes besides the standard options of driving alone, carpooling, public transit, conventional bicycle, and walking. This was done to try to capture a fuller understanding of students' existing commuting habits even though no particular expectations were made for relation to EAB favourability based on previous research. No relationship was found between use of "other" commuting options and EAB favourability, likely because there is little for patterns amongst the relatively few heterogeneous users of "other" modes.

5.5 Recommendations for Further Research and Promotion of EAB's

While this study aimed to explore students' likelihood for EAB adoption using the IDP model (from Rogers' DoI) as a comprehensive framework made up of many parts, it still had certain limitations and still leaves room for further research.

Despite this study's use of a comprehensive framework, it was focussed on a particular population: post-secondary students in RoW. Thus, its results are less generalizable to people who are not (or who are no longer) post-secondary students. The results are also less generalizable to populations in geographic areas beyond RoW, particularly the more the conditions differ from those of the studied region.

Secondly, this study was not able to fully explore all parts of the IDP given the scope as a master's thesis. Certain theory components were not explored at all, which were innovativeness and communications behaviour of the potential adopters. A few other components were investigated to a limited extent, which were personality variables, social norms, and certain socio-economic variables such as social status and social mobility, because of the difficulty in measuring them as complex constructs each of their own within the limitations of a survey. For the purpose of providing a fuller picture of IDP as applied to EAB adoption, these components could be researched further.

A few aspects specific to transportation and to EAB adoption are also identified as areas for further research before making efforts to promote EAB's to Canadian students: cycling infrastructure, sharing schemes, and the trip timing and routing performance aspect. Detailed research on infrastructure suitable for EAB's falls more under the domain of the policy and planning disciplines and so it was not a focus of this IDP-focussed study, but further literature review and original research could be done to better understand it in Canadian communities. A better understanding about infrastructure would contribute to the knowledge on the EAB's compatibility and performance relative to other modes, especially in terms of its delivery on safety, trip timing and routing, and positive travel experience. Regarding sharing schemes and the performance aspect of trip timing and routing, the findings of this study still leave room for further questions about these areas when it comes to promoting EAB adoption. Perceptions of the EAB's performance in each aspect could also be further researched to see how the EAB is viewed in each of those aspects in direct comparison to different modes of transportation.

Despite the identified limitations and needs for further research, this study can, however, provide some recommendations for the promotion of EAB's to students and other groups of people in Canadian contexts.

The very most important recommendations would be to provide opportunities to people to actually use an EAB and to work on building further awareness. This study found that students tended to view the EAB more favourably if they had actually had the chance to use one and so, providing opportunities to trial EAB's is highly recommended. This study also found that most students have some awareness-knowledge about the EAB, but further how-to knowledge and principles-knowledge may be needed to persuade them about EAB's.

Next, certain barriers of the EAB's adoption by students should be addressed. Community planners, policy-makers, and EAB providers within their areas of work should try to alleviate the EAB's most important barriers: safety, cost, and trip timing and routing. Infrastructure plays an impactful role in safety and in trip timing and routing and it should be researched further, as discussed earlier, in order to understand how best to make improvements in these aspects for the EAB. As work is done to alleviate these barriers, EAB promotions can perhaps include messaging around the improvements as well as highlight the EAB's best-perceived advantages, which are its simplicity most importantly and to a lesser extent, its eco-friendliness, benefits for physical health, and pleasant travel experience.

Bikesharing schemes could possibly be a helpful tool for promoting EAB's. Sharing schemes would be expected to alleviate the cost barrier for students to use EAB's and provide more opportunity for people to try out an EAB. It could also be speculated that EAB's may provide better trip timing and routing compared to e-scooters in a sharing scheme, given that e-scooters are limited in their use area by by-laws while e-bikes are much less so. As already mentioned, however, further research is needed in this area in order to understand a bikeshare's viability in different situations. It is recommended to investigate the local conditions for sharing schemes, including any previously-existing sharing schemes for conventional bicycles and e-scooters to learn about their successes and challenges.

Additionally, certain audiences can be leveraged in promotional communications about the EAB. Messaging to students could tailor messaging especially to include international students, those commuting most by public transit or walking, and the environmentally-conscious, perhaps to even try to appeal to them about EAB use for the long-term after they have completed their studies.

Finally, efforts could be made to make either EAB's or conventional bicycles more appealing to students through infrastructure improvements, knowledge-sharing, and opportunities to try them. In fact, efforts to promote the EAB may make conditions better for conventional bikes as well and the uptake of either should be considered a success amongst any target population.

6 Conclusion

This study gathered findings that ultimately fulfill its aim of identifying the most influential drivers and barriers to post-secondary students' adoption of electrically-assisted bicycles (EAB's) in the Region of Waterloo (RoW). Based on students' evaluations of multiple EAB characteristics, the survey results allowed the categorization of these characteristics as either potential drivers or barriers to adoption, identifying the following as drivers: the EAB's simplicity (important driver), eco-friendliness (moderate driver), pleasant travel experience (moderate driver), effect on physical health (moderate driver), effect on social image (weak driver). The EAB's cost and its trip timing and routing were identified as important barriers along with its safety as a moderate one. However, characteristics specifically about the EAB were not the only variables investigated for their possible effects on its favourability as certain characteristics of the students and the existing conditions of their commuting behaviour were also examined. Among these other variables, many could not be substantiated by statistical analysis as being related to EAB favourability. However, the few that were included students' previous experience with EAB's, their awareness and previous experience with kick-style e-scooters, and their backgrounds as either domestic or international students with experience living in different regions of the world. Students' environmental behaviour and existing commuting habits were also found to be weaker predictors. Finally, the results also confirm that students' awareness of the EAB prior to the survey is generally low, which was expected considering that the EAB is a relatively new innovation to the Canadian market with little adoption so far.

This study explored so many variables under the different categories of innovation characteristics, student characteristics, and prior conditions because of its application of the Innovation-Decision Process (IDP) model of adoption (Rogers, 1962/2003) as its theoretical framework. Since it followed such a comprehensive framework, this study investigated and contributes knowledge on the EAB's adoption potential from across more kinds of influential factors than usually covered in previous studies. Furthermore, with the limited existing research on the EAB in North America – particularly in Canada – and on younger people – particularly students – as its users, this study contributes to filling that gap in the research. As a methodological contribution, this study offers its method of evaluating the EAB on multiple aspects of performance. The particular set of commuting-specific performance aspects can be applied in evaluating and comparing all different options for transportation mode. Finally, for practical contributions, the novel, predictive approach of

this study meant that it could provide recommendations for promoting EAB adoption among students even at a relatively early stage of its emergence into the Canadian market.

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Appendices

Appendix A: Survey Questionnaire

Note: *In this Appendix, large white rectangular boxes surround the text and images that were visible to participants in the actual web survey. Text that is either outside the boxes, written in red, or surrounded by square brackets* [ ]*, makes up additional information about the survey was not visible to participants such as question numbers, skip or display logic, and other features.*

Pre-Survey Introduction

Study Introduction

Title of Project: Identifying Drivers & Barriers to Potential E-Bike Adoption by Post-Secondary Students in Waterloo Region

Please review the following information on this study and then respond to the question at the bottom of this page.

You are invited to participate in a study conducted by Brittany Berry, under the supervision of Dr. Goretty Dias in the Faculty of Environment at the University of Waterloo, Canada. The goal of the study is to understand post-secondary students' perceptions of e-bikes. This research study is for a Master's thesis. This survey will be open Sep. 30 – Oct. 28, 2019.

If you decide to participate, you will be asked to complete an anonymous online survey of up to 15 minutes duration. Survey questions are mostly multiple choice, focusing on your personal characteristics, your commuting habits and preferences, and your evaluations of the e-bike. There are no known or anticipated risks from participating in this study.

To be eligible to participate in this study, you must be:

a) 18 years or older AND

b) enrolled at one of the following institutions this semester either studying on-campus or on co-op term at a workplace located within Waterloo Region:

   i. University of Waterloo (UW),

   ii. a UW-affiliated or federated institution (Conrad Grebel, Renison, St. Jerome's, St. Paul's),

   iii. Wilfrid Laurier University (WLU),

   iv. WLU-affiliated Martin Luther University College, or

   v. Conestoga College.

A series of screener questions at the start of the survey will be used to verify your eligibility before proceeding to the rest of the survey questions.

Participation in this study is voluntary. With the exception of the eligibility screener questions, you may skip any questions that you do not wish to answer by withholding your responses (i.e. leaving a blank response or not selecting any of the provided response options), then continuing to the next question. You can also withdraw your participation from the survey at any time by closing the browser window. Please note, however, that there is a prize draw at the end of this study. In order to enter the draw, you must continue through all questions to the very end of the survey, either providing or withholding your response to each question. If you withdraw completely from the survey by closing your browser window, you will not be able to access the draw entry.

In the case that you withdraw from the study before completing the eligibility screener questions, your collected data will be excluded from analysis as it consists only of eligibility data. In the case that you continue to the survey questions beyond the eligibility screener questions but later withdraw from the study partway through, the question responses you do provide will be kept in the study data and may be used in analysis for the research. If you complete any part of the beyond the eligibility screener questions, it is not possible to withdraw your completed survey responses as it is not possible to tell which response data belong to which respondents.

In appreciation of the time you give to completing this study, you can enter your name into a separate draw for 1 of 2 prizes. If you enter the draw, your participation in the draw alone will not be anonymous. However, your responses to the survey questions will remain separate and confidential. The identifying information (i.e. your email address) collected for the draw entry will be stored separately from your survey question responses, then deleted after the prizes have been provided. Furthermore, all of the data will be summarized, and no individual could be identified from these summarized results.

Each prize is a gift card worth $30 for use at your choosing of either Tim Hortons or

Starbucks (if you win, you will get to choose which one of the two stores you'd like to receive a prize gift card from). Your odds of winning one of the prizes is based on the number of individuals who participate in the study. The amount received is taxable. It is your responsibility to report this amount for income tax purposes.

You will be completing the study by an online survey hosted by Qualtrics™. When information is transmitted over the internet, privacy cannot be guaranteed. There is always a risk your responses may be intercepted by a third party (e.g., government agencies, hackers). Qualtrics™ temporarily collects your computer IP address to avoid duplicate responses in the dataset but will not collect information that could identify you personally. We will not use or save this information without your consent. If you prefer not to submit your survey responses through this host, please contact Brittany Berry so you can participate using an alternative method such as through an e-mail or paper-based questionnaire. The alternate method may decrease anonymity, but confidentiality will be maintained.

The data, with no personal identifiers, collected from this study will be maintained on a password-protected computer. As well, the data will be electronically archived after completion of the study. The data will be maintained for at least 1 year and up to 2 years maximum and then erased.

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE#40435). If you have questions for the Committee contact the Office of Research Ethics, at 1-519-888-4567 ext. 36005 or ore-ceo[at]uwaterloo.ca.

For all other questions about the study, please contact either Brittany Berry at b4berry[at]uwaterloo.ca or Dr. Goretty Dias at gdias[at]waterloo.ca. Furthermore, if you would like to receive a copy of the results of this study, please contact either investigator.

If you wish to participate, please provide your consent below to continue to the survey. By agreeing to participate in the study you are not waiving your legal rights or releasing the investigator(s) or involved institution(s) from their legal and professional responsibilities.

Thank you for considering participating in this study.

Consent to Participate

[SE0] With full knowledge of all foregoing, I agree, of my own free will, to participate in this study.

○ I agree to participate.	○ I do not agree to participate.

Branch To: Non-Participation Message if SE0 = I do not agree to participate.*

** (Non-Participation Message: Thank you for taking your time to learn about this study.)*

Study Eligibility (SE)

[SE1] How old are you?

Please enter number value only, for example: 22.

Branch To: Ineligibility Message if SE1 < 18.*

** (Ineligibility Message: Based on your responses here, you do not meet all of the eligibility criteria for participation in this study. You will not be asked to provide any further information. However, we do appreciate the time and interest you've taken in this study. Thank you!)*

[SE2] Are you currently a student at a post-secondary institution?

- o YES, in an on-campus program (incl. programs with co-op)
- o YES, in a distance education (online) program
- o NO

Branch To: Ineligibility Message if SE2 = YES, in a distance education (online) program or NO.

[SE3] Please select the institution where you study:

- o University of Waterloo (UW)
- o a UW-affiliated or federated institution (Conrad Grebel, Renison, St. Jerome's, St. Paul's)
- o Wilfrid Laurier University (WLU)
- o WLU-affiliated Martin Luther University College
- o Conestoga College
- o None of the above

Branch To: Ineligibility Message if SE3 = None of the above.

Display SE4 if SE3 = University of Waterloo, a UW-affiliated or federated institution, or Conestoga College.

[SE4] Please select the location of your campus:

- o Waterloo, ON
- o Kitchener, ON
- o Cambridge, ON
- o None of the above

Branch To: Ineligibility Message if SE4 = None of the above.

Display SE4wlu if SE3 = Wilfrid Laurier University (WLU) or WLU-affiliated Martin Luther University College.

[SE4wlu] Please select the location of your campus:

- ○ Waterloo, ON
- ○ Kitchener, ON
- ○ None of the above

Branch To: Ineligibility Message if SE4wlu = None of the above.

[SE5] What is your enrolment status this semester (Fall 2019)?

- ○ Enrolled in courses or research on campus
- ○ Enrolled in co-op, with workplace in Waterloo Region ⓘ
- ○ Enrolled in co-op, with workplace outside Waterloo Region ⓘ
- ○ Not enrolled

ⓘ is an icon button that participants can click to reveal a small box containing further information if they wish to have more clarification. The boxes for these response options appear as:

Waterloo Region
Consists of the following communities: City of Waterloo, City of Kitchener, City of Cambridge, Township of Wellesley, Township of Woolwich, Township of Wilmot, and Township of North Dumfries.

Branch To: Ineligibility Message if SE5 = Enrolled in co-op, with workplace outside Waterloo Region or Not enrolled.

Survey Body

Socio-Demographic & Academic Characteristics

[1] Please provide the following information about yourself.

[a] Your gender:

○ Male	○ Female	○ Other	○ Prefer not to answer

[b] Level of diploma/degree you are pursuing:

○ Certificate	○ Diploma	○ Bachelor's	○ Master's
○ PhD	○ Graduate-level certificate	○ Other (specify): __	

[c i] What program year are you in?

▼ drop-down options: "Year 1" – "Year 6 or higher"

[ii] How many years does your program typically take?

▼ drop-down options: “1” – “6 or more”

[d] Which of the following topics make up a substantial portion of your program of study? Please select all that apply*:

Clarification: A "substantial portion of your program of study" on any of these topics might be a few courses or might be a component of a major research project (ex. capstone, thesis, a project for your dissertation).

_ Human health		_ Community planning
_ Transportation planning or technology		_ Environmental sustainability
_ Electrical systems or electronics		_ None of these areas**

* topic areas appear here in randomized order, except of the “None of these areas” response option, which appears listed last of all the response options for all respondents.

** for the “None of these areas” response option, the Qualtrics’ “Make Answer Exclusive” feature is enabled so it can only be selected if no other response options are selected.

[e] Do you live in on-campus residence while attending your studies?

○ YES	○ NO

Display 9f if 9e = NO.

[f] What is the approximate distance (km) from where you live to your campus or co-op workplace?

Please enter number value only, for example: 5. If you are unsure of the distance, you may use Google Maps to verify.

[g] Are you attending your studies as a domestic student (from Canada) or as an international student?

○ Domestic student	○ International student

[h] Outside of Canada, where else have you been a resident? Select all that apply:

Clarification: For this question, being a "resident" includes living in a country for at least 2 months.

_ the US		_ Central & South Asia
_ Latin America & the Caribbean		_ East & Southeast Asia
_ Europe		_ Oceania
_ Middle East & North Africa		_ Nowhere else besides Canada* **
_ Sub-Saharan Africa		

* for the “Nowhere else besides Canada” response option, the Qualtrics’ “Make Answer Exclusive” feature is enabled so it can only be selected if no other response options are selected.

** the “Nowhere else besides Canada” response option is set to be displayed amongst the response options ONLY if the response to question 1g = Domestic student.

Existing Conditions – Previous Transportation Experience & Felt Needs

This section will ask about your commuting habits.

[2] Estimate how frequently you typically use the following modes of transportation this Fall 2019 semester:

Transportation mode *	Frequency
Drive alone (incl. by motorcycle)	▼ drop-down options **
Carpool/Get dropped off (incl. with family)	▼
Public transit	▼
Bicycle, non-motorized	▼
Walking	▼
Other (if applicable, specify type; if not applicable, leave blank): _____	▼

* transportation modes appear here in randomized order, except for “Other (specify):”, which appears last of all the modes for all respondents

** drop-down options are:

6-7 days/week	**Less than 1 day/month, but more than 1 day/semester**
3-5 days/week	1 day/semester or less
1-2 days/week	Not at all
1-3 days/month	

[3] When is the next time you expect to be making a decision about buying/leasing any kind of vehicle for commuting?

Clarification: “Commuting” includes trips you take to attend your studies on-campus as well as to attend other commitments you may have on a regular basis (ex. extracurriculars, job, volunteering). They do not include trips that serve a purely recreational purpose (ex. for leisure or sport).

- ○ I expect to be facing such a decision before I finish my current program of studies
- ○ I expect to be facing such a decision soon after I finish my studies
- ○ I haven't been thinking about it

[4] How important are each of the following aspects to you when choosing a mode of transportation for commuting? ⓘ

	Not at all important	Slightly important	Moderately important	Very important	Extremely important
Overall cost ⓘ	○	○	○	○	○
Trip timing & routing ⓘ	○	○	○	○	○
Safety ⓘ	○	○	○	○	○
Pleasant travel experience ⓘ	○	○	○	○	○
Effect on my social image ⓘ	○	○	○	○	○
Eco-friendliness ⓘ	○	○	○	○	○
Effect on physical health ⓘ	○	○	○	○	○

[ⓘ-boxes revealing further info upon clicking]

Commuting

Includes trips you take to attend your studies on-campus as well as to attend other commitments you may have on a regular basis (ex. extracurriculars, job, volunteering). They do not include trips that serve a purely recreational purpose (ex. for leisure or sport).

Overall cost

OVERALL COST includes all applicable costs you pay as a user to own (or alternatively, to use without owning), operate, store, and/or maintain a mode of transportation.

Trip timing & routing

TRIP TIMING & ROUTING includes factors like trip duration, the freedom to depart/arrive when you choose, and the freedom about choosing routes of travel.

Safety

SAFETY includes safety within the vehicle confines and safety in the surrounding area while using the mode of transportation.

Pleasant travel experience

PLEASANT TRAVEL EXPERIENCE includes comfort while using the transportation mode as well as fun, stress-free travel, and peace of mind.

Effect on social image

EFFECT ON SOCIAL IMAGE includes the role that using the transportation mode may play in your social status and social image.

Eco-friendliness

ECO-FRIENDLINESS includes any reduced negative effects and possible benefits that the transportation mode may bring for the natural environment.

Effect on physical health
EFFECT ON PHYSICAL HEALTH includes any benefits (and reduction of negative effects) that the transportation mode may bring for the physical health of its users as individuals and for public health.

Existing Conditions – Lime Scooters

[5a]

Have you heard of e-scooters like the ones pictured here?

○ YES	○ NO

[5b] Are you aware of the pilot scooter-share project for Lime e-scooters in the City of Waterloo?

○ YES	○ NO

Display 5c if 5b = YES.

[5c] Have you used an e-scooter under this scooter-share in Waterloo?

○ YES, I have.	○ NO, but I would like to try it.	○ NO, and I'm not interested in trying it.

Display 5Yp and 5Yn if [5a = YES or 5b = YES], AND 5c = YES, I have.

In one or a few words, please describe...

[5Yp] … one thing you liked most about using the e-scooter: _____

[5Yn] ... one thing you disliked most about using the e-scooter: _____

Display 5Np and 5Nn if [5a = YES or 5b = YES], AND ≠ YES, I have.

In one or a few words, please describe...

[5Np] … one thing that would most attract you to using an e-scooter: _____

[5Nn] ... one thing that would most discourage you from using an e-scooter: _____

The E-Bike – (Explanation)

The E-Bike

The term "e-bike" can be used as an umbrella term to talk about several different varieties of bike-shaped, electrically-powered vehicles.

This survey is concerned specifically with the electrically-assisted bicycle, often referred to simply as an "e-bike". In some places, it is called a "pedelec" (*pedal* + *electric*).

To keep a focused scope, this survey **excludes** e-bikes of the moped scooter-bike variety and the electric motorcycle variety, both of which do not require foot pedaling.

Here are some main things to know about the electrically-assisted bicycle variety of e-bike:

- it looks similar to a conventional, non-motorized bicycle,

but...

- it uses a battery-powered motor to supplement the power from the rider's pedaling,
- so, it requires less physical exertion from the rider to pedal, and
- it is easier to ride at faster speeds, up hills, and over longer distances.

Some final details on this e-bike:

- It comes in a wide variety of makes and styles to suit different tastes.
- An electronic interface is located on the handlebars for control of the electric-assist and for displaying data such as speed, battery level, etc.
- E-cyclists are required to wear helmets while riding; insurance is not required.

The E-Bike – Respondent Awareness

[6a] Before this survey, had you heard of the e-bike as presented on the previous page?

○ Not at all	○ Maybe / Not sure	○ Yes

Skip to 7a if 6a = Not at all.

[6 b] Have you used an e-bike before?

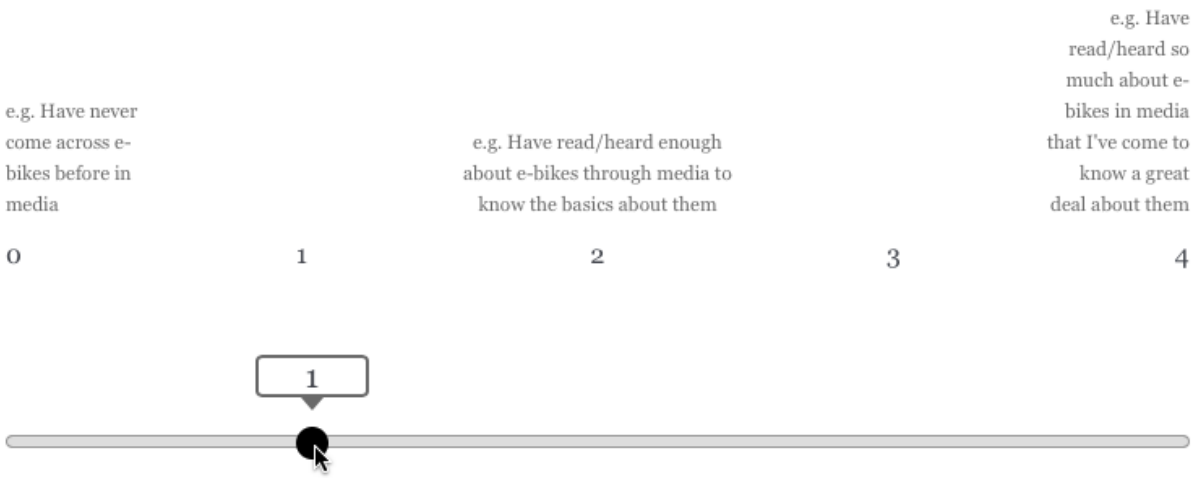
○ YES	○ NO

Skip to 7a if 6b = YES.

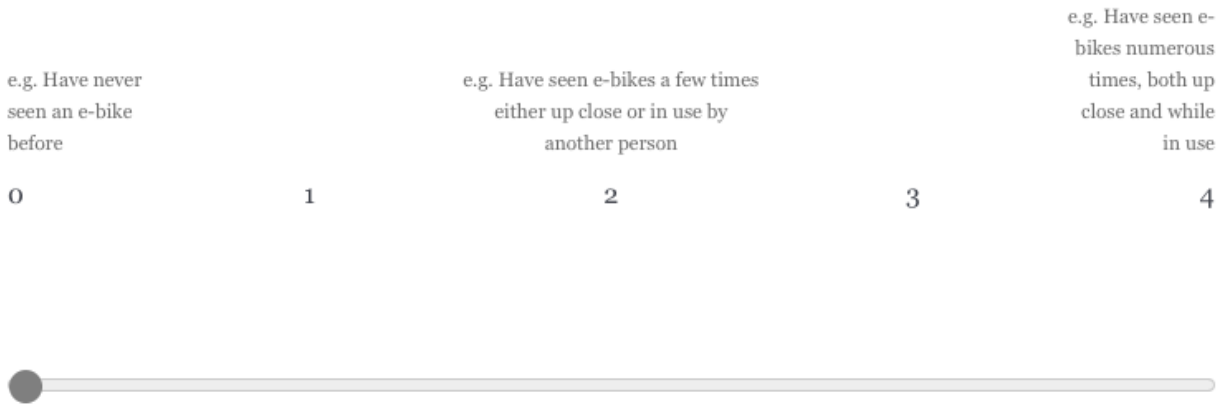
Slide the marker along the scale to indicate how much exposure you had to e-bikes in the following ways. * The scale is from 0 to 4, with 0 being no exposure and 4 being a great amount of exposure. Practical examples are also included along with the scale for demonstration.

*for these questions, participants click the dot set automatically at 0 and slide it along the scale to their answer as shown in the example here. Before they click the slider, it appears as seen in examples shown for 6d and 6e.

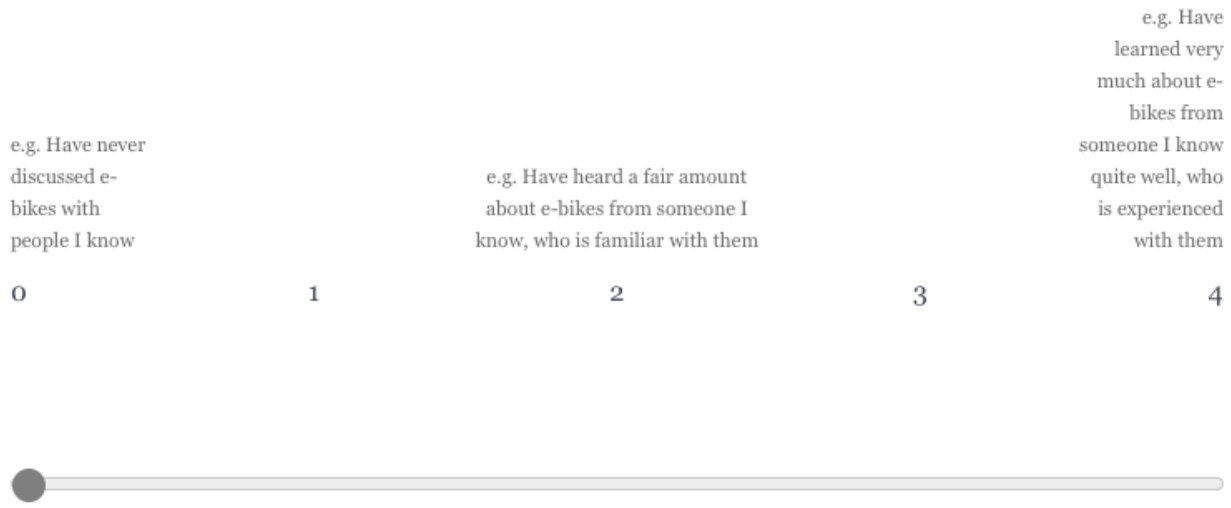
[6c] **How much have you seen or heard about e-bikes before through media?**



[6d] How much have you seen e-bikes before in real life?



[6e] How much have you heard about e-bikes through other people you know (i.e. family, friends, study/work connections, acquaintances)?



The E-Bike – Characteristics

[7] In one or a few words each, please describe...

[a] ... 3 things about e-bikes that would most attract you to using one for commuting:

1 _____

2 _____

3 _____

---

[b] ... and 3 things about e-bikes that would most discourage you from using one for commuting:

1 _____

2 _____

3 _____

[8] To the best of your judgement, how well do you think the e-bike performs in terms of **each of the following aspects**?

If you have not ever used an e-bike before, please evaluate based off of your impression of it.

	Not well at all	Slightly well	Moderately well	Very well	Extremely well
For using e-bike of your own: Low overall cost ⓘ	○	○	○	○	○

For using e-bike in bikeshare: Low overall cost ⓘ	○	○	○	○	○
Convenient trip timing & routing ⓘ	○	○	○	○	○
Safety ⓘ	○	○	○	○	○
Pleasant travel experience ⓘ	○	○	○	○	○
Positive effect on social imageⓘ	○	○	○	○	○
Eco-friendly ⓘ	○	○	○	○	○
Positive effect on physical health ⓘ	○	○	○	○	○
Simple to understand how to use it	○	○	○	○	○

[ⓘ-boxes revealing further info upon clicking]

Overall cost

In the case here of an e-bike you own, OVERALL COST includes all applicable costs you pay as a user to own (or alternatively, to use without owning), operate, store, and/or maintain the e-bike as a mode of transportation.

Overall cost

In the case here of shared e-bikes, OVERALL COST includes all applicable costs you pay to use and operate one as a bikeshare or rental e-bike.

Trip timing & routing

TRIP TIMING & ROUTING includes factors like trip duration, the freedom to depart/arrive when you choose, and the freedom about choosing routes of travel.

Safety

SAFETY includes safety within the vehicle confines and safety in the surrounding area while using the mode of transportation.

Pleasant travel experience

PLEASANT TRAVEL EXPERIENCE includes comfort while using the transportation mode as well as fun, stress-free travel, and peace of mind.

Effect on social image

EFFECT ON SOCIAL IMAGE includes the role that using the transportation mode may play in your social status and social image.

Eco-friendliness

ECO-FRIENDLINESS includes any reduced negative effects and possible benefits that the transportation mode may bring for the natural environment.

Effect on physical health

EFFECT ON PHYSICAL HEALTH includes any benefits (and reduction of negative effects) that the transportation mode may bring for the physical health of its users as individuals and for public health.

[9] To the best of your judgement, how well do you think each mode of transportation delivers in terms of **overall performance**?

If you have not ever used a certain transportation mode before, please evaluate based off of your impression of it.

Transportation mode *	Not well at all	Slightly well	Moderately well	Very well	Extremely well
E-Bike (as your own)	○	○	○	○	○
E-Bike (in a bikeshare)	○	○	○	○	○
Drive alone (incl. by motorcycle)	○	○	○	○	○
Carpool/Get dropped off (incl. with family)	○	○	○	○	○
Public transit	○	○	○	○	○
Bicycle, non-motorized	○	○	○	○	○

* transportation modes appear here in randomized order, except for the 2 e-bike options, which appear first of all the modes for all respondents.

Personal Characteristics – Environmental Behaviours Demonstrating Attitude (Personality Variables)

This section will ask about your habits.

[10] Please indicate how often you do the following:

[a] I give/sell my unwanted clothing and household articles second-hand to others instead of throwing them out to landfill.

○ **Not at all**	○ **Rarely**	○ **Sometimes**	○ **Usually**	○ **Every time**

[b] I repurpose items and choose second-hand clothing and household articles.

○ **Not at all**	○ **Rarely**	○ **Sometimes**	○ **Usually**	○ **Every time**

[c] I sort my waste for organics, recycling, and special disposal items (ex. electronics, hazardous materials waste) separately from waste for landfill.

○ **Not at all**	○ **Rarely**	○ **Sometimes**	○ **Usually**	○ **Every time**

[d] I buy household products that are made from recycled materials or made using less harmful materials and chemicals.

○ **Not at all**	○ **Rarely**	○ **Sometimes**	○ **Usually**	○ **Every time**

[e] When shopping, I avoid products that are disposable or come in unnecessary packaging.

○ **Not at all**	○ **Rarely**	○ **Sometimes**	○ **Usually**	○ **Every time**

[f] I reduce my electricity consumption by turning off/unplugging devices when not in use and by using energy efficient devices.

○ **Not at all**	○ **Rarely**	○ **Sometimes**	○ **Usually**	○ **Every time**

[g] I save energy from heating by lowering the room temperature and reducing my hot water use.

○ **Not at all**	○ **Rarely**	○ **Sometimes**	○ **Usually**	○ **Every time**

[h] I reduce my water use by reducing my time running the water and by reducing my number of showers, loads of laundry, and toilet flushes.

○ **Not at all**	○ **Rarely**	○ **Sometimes**	○ **Usually**	○ **Every time**

[i] I volunteer or work with an environmental club or organization.

○ **Not at all**	○ **On occasion**	○ **On a fairly regular basis**

Survey Closing

[11] This is the end of this survey on e-bikes!

If you have any further comments you'd like to add to your responses in this survey, please share them here (optional). _____

Thank you for completing the survey! Please continue to be redirected to the draw entry.

Separate Post-Survey Draw Entry

Draw Entry

[DE1] Please provide your email address if you would like to be entered into the draw for a prize. Thank you! _____

[After email address submission]

Thank you!

This study has been reviewed and received ethics clearance through a University of Waterloo Research Ethics Committee (ORE#40435). If you have questions for the Committee contact the Office of Research Ethics, at 1-519-888-4567 ext. 36005 or ore-ceo[at]uwaterloo.ca.

For all other questions or if you have general comments or questions related to this study, please contact either Brittany Berry (School of Environment, Enterprise and Development in the Faculty of Environment, University of Waterloo) at b4berry[at]uwaterloo.ca or Dr. Goretty Dias (also School of Environment, Enterprise and Development in the Faculty of Environment, University of Waterloo) at gdias[at]waterloo.ca. If you would like to later receive information on the results of this study when it is available, please contact the researchers at the email addresses above.

Appendix B: Additional Tables

Table B-1 Students' levels of exposure to the EAB through different channels on scales of 0 (no exposure) to 5 (highest level of exposure) from survey questions 6c, 6d, and 6e

	0		1		2		3		4		Total		Std
	#	%	#	%	#	%	#	%	#	%	#	Mean	Dev
Media exposure	20	8.1	73	29.6	108	43.7	35	14.2	11	4.5	247	**1.77**	0.94
Example descriptions along scale	*e.g. Have never come across EAB's before in media*		…		*e.g. Have read/heard enough about EAB's through media to know the basics about them*		…		*e.g. Have read/heard so much about EAB's in media that I've come to know a great deal about them*				
In real life	39	16.4	51	21.4	102	42.9	27	11.3	19	8.0	238	**1.73**	1.11
Example descriptions along scale	*e.g. Have never seen an EAB before*		…		*e.g. Have seen EAB's a few times either close up or in use by another person*		…		*e.g. Have seen EAB's numerous times, both close up and while in use*				
Interpersonal connections	60	26.8	97	43.3	33	14.7	21	9.4	13	5.8	224	**1.24**	1.12
Example descriptions along scale	*e.g. Have never discussed EAB's with people I know*		…		*e.g. Have heard a fair amount about EAB's from someone I know, who is familiar with them*		…		*e.g. Have learned very much about EAB's from someone I know quite well, who is experienced with them*				

Table B-2 Summary of inferential statistical tests conducted, not finding statistically significant results

Variables Tested for Relationships to EAB Favourability	p-Value	Test Used
Variables Pertaining to Prior Conditions		
Topic(s) of study in program	0.153	Kruskal-Wallis
Resides on- / off-campus	0.348	Kruskal-Wallis
Distance from residence to campus	0.449	Pearson's R correlation
Frequency level of commuting by carpooling	0.305	Kendall's Tau correlation
Frequency level of commuting by bicycle (non-motorized)	0.094	Kendall's Tau correlation
Frequency level of commuting by other* modes	0.832	Kendall's Tau correlation
Psychological temporal distance	0.255	Kendall's Tau correlation
Exposure to EAB's through media	0.254	Kendall's Tau correlation
Exposure to EAB's in real life	0.944	Kendall's Tau correlation
Interpersonal exposure to EAB's	0.114	Kendall's Tau correlation
Variables Pertaining to Student Characteristics		
Age	0.707	Pearson's R correlation
Gender	0.157	Kruskal-Wallis
Credential type	0.060	Kruskal-Wallis
Program year	0.400	Kendall's Tau correlation
Years remaining in program of study	0.434	Kendall's Tau correlation

* Note: Because of the wording of the survey question, "other" modes of transportation here means those modes other than driving alone, carpooling, public transit, bicycle, or walking.

Appendix C: Participant Recruitment Materials and Messaging

Figure C–1 Digital version of recruitment poster as used in recruitment emails and social media posts

University of Waterloo – School of Environment, Enterprise and Development (SEED)

PARTICIPANTS NEEDED FOR RESEARCH IN TRANSPORTATION

We're looking for volunteers from University of Waterloo (incl. affiliated and federated institutions), Wilfrid Laurier University (incl. Martin Luther University College), and Conestoga College for a study on students' commuting habits and perceptions of e-bikes.

To be eligible, you must be: a) 18 years or older AND b) enrolled at one of the above institutions this semester either studying on-campus or on co-op term at a workplace located within Waterloo Region.

As a participant in this study, you will be asked to complete an anonymous online survey in one session of up to 15 minutes maximum. This survey's close date is extended to Dec. 23, 2019.

For your participation, you will have the chance to win 1 of 2 gift cards worth $30 for use at your choosing of either Tim Hortons or Starbucks!

For more information about this study, or to volunteer for this study, please contact:
Brittany Berry (SEED) at b4berry[at]uwaterloo.ca or go directly to **tinyurl.com/WRstudentebikesurvey** (https://uwaterloo.ca1.qualtrics.com/jfe/form/SV_6SfQ0a61IP88Rzn).

This study has been reviewed by, and received ethics clearance through research ethics committees at Conestoga College and at University of Waterloo.

Figure C–2 Print version of recruitment poster

University of Waterloo – School of Environment, Enterprise and Development (SEED)

PARTICIPANTS NEEDED FOR RESEARCH IN TRANSPORTATION

We're looking for volunteers from University of Waterloo (incl. affiliated and federated institutions), Wilfrid Laurier University (incl. Martin Luther University College), and Conestoga College for a study on students' commuting habits and perceptions of e-bikes.

To be eligible, you must be: a) 18 years or older AND b) enrolled at one of the above institutions this semester either studying on-campus or on co-op term at a workplace located within Waterloo Region.

As a participant in this study, you will be asked to complete an anonymous online survey in one session of up to 15 minutes maximum. This survey's close date is extended to Dec. 31, 2019.

For your participation, you will have the chance to win 1 of 2 gift cards worth $30 for use at your choosing of either Tim Hortons or Starbucks!

For more information about this study, or to volunteer for this study, please contact:
Brittany Berry (SEED) at b4berry[at]uwaterloo.ca
or go directly to the survey at tinyurl.com/WRstudentebikesurvey
(https://uwaterloo.ca1.qualtrics.com/jfe/form/SV_6SfQ0a61IP88Rzn).

This study has been reviewed by, and received ethics clearance through research ethics committees at Conestoga College and at University of Waterloo.

tinyurl.com/WRstudentebikesurvey