Econometric Modeling for the Analysis of the Influence of Safety Perceptions on Travelers' Behavior

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Doctoral Thesis in Civil Engineering

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To the memory of my father, who died when I was advancing at my doctoral studies.

To my mother and to my brothers.

To Betty, Mafe and Juanpa, my wonderful Family, who I love more than anyone else in the world.

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Abstract

The objective of this research is to study the influence that safety perceptions have on travelers' behavior in a broad array of choice contexts and investigate issues that have not been sufficiently addressed by the transportation literature, such as the influence of tangible attributes on perceptions and the influence of indicators' complexity on the model estimates.

Using three existing databases, we first study the influence of risk perception on drivers' behavior through an experiment in where individuals decide whether they would use their cell phone while driving. Then, we study the influence of safety and comfort perceptions on individuals' preferences for inland waterway passenger transportation and subsequently we study the influence of these latent variables in the competition between BRT and motorcycle taxis.

We also design two *ad-hoc* surveys, the first one to study the influence of safety perceptions and some individual attitudes toward cycling, on the intention to use the public transportation integration on a bike and ride strategy. We then apply the second survey to study safety and comfort perceptions of riding conventional feeder buses and auto-rickshaws that could become part of a BRT system. These two surveys allow us to study the influence of tangible attributes on safety perception and the influence of indicators' complexity on model estimates. In the first survey, we administrate the relevant tangible attributes by a stated preference experiment based on images while, in the second one, we propose an experiment that allows systematic variations in the number of indicators per latent variable, the scale and the granularity to observe the influence of indicators' complexity on the ratings.

In all cases, we consider the ordered nature of the data by using a software package for simulating the likelihood in a simultaneous way. Our findings have significant policy implications and practical recommendations about data collection and model estimation issues. In the first place, for each case studied, we identify the main socioeconomic characteristics affecting perceptions and thus we proposed policies aimed to shift the use of less safe

transportation modes. Then, we extend stated preference experiments to study tangible attributes affecting perceptions and indicators' complexity affecting model estimates.

We demonstrate that tangible attributes have a significant effect on both the utility and the safety perception of individuals, which allows for the evaluation of policies related to latent variables and studying how a certain policy modifies safety perception. We also prove that the number of indicators per latent variable, the type of the scale and the granularity in which indicators are measured do affect the error variance of the measurement component. In this regard, we show that the use of odd-numbered Likert scales contributes to a lower error variance of the measurement component.

1. Introduction

This dissertation is concerned with the modeling of safety perceptions in travelers' behavior through their incorporation in discrete choice models. Our guiding philosophy is that modeling safety perception, in some particular choice contexts, allows us to broaden our understanding of travelers' behavior and consequently improve policy formulation aimed to shift the use of less safe transportation modes. We investigate issues that have not been addressed sufficiently in the literature such as the inclusion of tangible attributes and indicators' complexity. We further consider a broad array of choice contexts that have still not been sufficiently studied such as inland waterway transportation, competition between Bus Rapid Transit (BRT) service and motorcycle taxis, as well as the intentions to use the bicycle and auto-rickshaws as feeder modes.

1.1. Motivation

The contribution of human factors in traffic accidents has been widely recognized worldwide (Shappell and Wiegmann, 2013; Huguenin, 2005), finding compelling evidence linking the behavior of people in traffic accidents outcomes (Nordfjærn et al., 2011, Eiksund, 2009). It is with this perspective that some studies to develop strategies to reduce road accidents have strongly recommended the implementation of campaigns affecting the individual's behavior (Akaateba et al., 2015). In fact, regarding safety analysis, some authors consider that it can be improved by including latent variables (Bolduc et al., 2005; McFadden, 2013; Mannering and Bhat, 2014). Besides, from the transportation mode choice's perspective, which can be influenced significantly by perceptions of safety, the understanding of individuals' choice behavior is fundamental for forecasting travel demand and implementing transportation policies to encourage the use of more much safe modes of transportation.

For several years, the improvement of transportation applications harmonizes with further progress of discrete choice modeling methods (Ortúzar and Willumsen, 2011). Initially, discrete choice models had only considered socioeconomic characteristics and observable factors, like travel time, waiting time, and cost, among the foremost-observed variables that explain mode choice (Ben-Akiva and Lerman, 1985). Nevertheless, as it has been demonstrated, there are more complex, unobserved factors that may have a relevant effect in the way the choice, in general, is made. Some of these unobserved factors are the decision maker's lifestyle, personal attitudes or perceptions (McFadden, 1986). Today, modelers recognize that a complex interaction between several factors takes place in the decision making process. Consequently, discrete choice models are integrating latent variables into their structures (Walker and Ben-Akiva, 2002; Ben-Akiva et al., 2002) for better representing the decision-making process. This has resulted in an increasing number of researchers and practitioners developing hybrid discrete choice (HDC) models.

Although HDC models are theoretically and statistically superior to models based on the traditional approach (Walker, 2001), its advantage compared to conventional choice models is rather limited for now (Chorus & Kroesen, 2014), especially in cases when a policy modifies perceptions (Yáñez et al., 2010). This is because, usually, the attributes that explain latent variables are only socioeconomic characteristics, capturing in this way the population heterogeneity but not the effect that tangible attributes (Bahamonde-Birke et al. 2010) have on them. However, for the latent variables the evaluation of which depend on the alternative considered (e.g. safety perception of riding a specific transportation mode), it is necessary to study how changes in alternatives affect not only the choices but also the perceptions.

On the other hand, to characterize latent variables and econometrically allow their identification, effect indicators (Bollen, 2002), which are hypothesized to be manifestations of the underlying latent behavioral constructs (Walker, 2001), are required. Therefore, to measure respondents' opinions to a particular question or statement, surveys normally incorporate Likert items by using a specific type of scale and certain granularity, which refers to the number of response levels used for rating the indicators. Statistically, indicators have the particularity of being endogenous to the choice process, and therefore the model in the predictive mode does not use them (Walker, 2001; Rungie et al., 2012). Perhaps, for that reason, sufficient attention has not been paid to the design of indicators for the analysis of travelers' behavior.

Another issue that may be of interest for modelers are assumptions regarding measurement indicators. The standard practice in the literature is to assume that the indicators represent continuous response variables, but this is not necessarily so (Vij and Walker, 2016). Certainly, a Likert item is, in fact, a set of ordered categories, so that it is more natural to think that a couple of cutoffs determines each response option based on respondent's level of opinion (Train 2009). Consequently, it would be better to model individual responses as ordered data because the response levels do have relative position and it is inaccurate to presume that individuals perceive the difference between adjacent levels to be equal, which is a requirement for continuous or interval data. However, it is a challenge for modelers to estimate a large number of threshold parameters resulting from greater complexity.

Based on this, four major factors motivate the work described in this dissertation:

- The interest to incorporate safety perceptions in a broad array of choice contexts, which is especially significant in developing countries. Our interest arises from a variety of reasons, such as better understanding travelers' behavior and improving in policy formulation.
- The importance of understanding individuals' choice behavior for forecasting travel demand and implementing transportation policies and few works studying the effect that tangible attributes have on the latent variables, which, in practice, severely restrict the use of hybrid discrete choice models to evaluate policies related to latent variables.
- The little concern about the broad range of response options and the number of indicators per latent variable in transportation choice studies, despite its implications for respondents and modelers.
- The standard practice to specify measurement equations as generalized linear models assuming that Likert items are continuous when they certainly are a set of ordered categories. Recognizing the ordered nature of the observed indicators motivates us to study how influence on model estimates the number of indicators used to identify each latent variable, the type of scale and the granularity used to measure them.

1.2. The Hybrid Discrete Choice Modeling Approach

Research based on HDC modeling approach continue emerging to study transportation choices, reflecting a steady research interest. This modeling approach allows for incorporating latent variables in discrete choice models through structural equations (Ashok et al., 2002). In the same way as with random utility theory (Thurstone, 1927; McFadden, 1974), when considering the HDC modeling framework (Ben-Akiva et al., 2002), modelers postulate that individuals choose the alternative that maximizes their perceived utility. Nevertheless, in addition to observable individual characteristics, modal attributes, and other tangible variables, the HDC modeling framework extends the traditional models allowing the modeler to form latent variables in order to include them as part of the systematic utility of alternatives, providing a richer explanation of the choice process.

Figure 1 shows the HDC modeling framework (Ben-Akiva et al., 2002), in which are distinguished two sub-models: a multinomial discrete choice model and a latent variable model. Each of these sub-models consists of a structural and a measurement component. In the discrete choice sub-model, utilities may depend on both modal attributes and latent variables of the alternatives meanwhile latent variables depend on modal attributes and observable individual characteristics of the respondents.

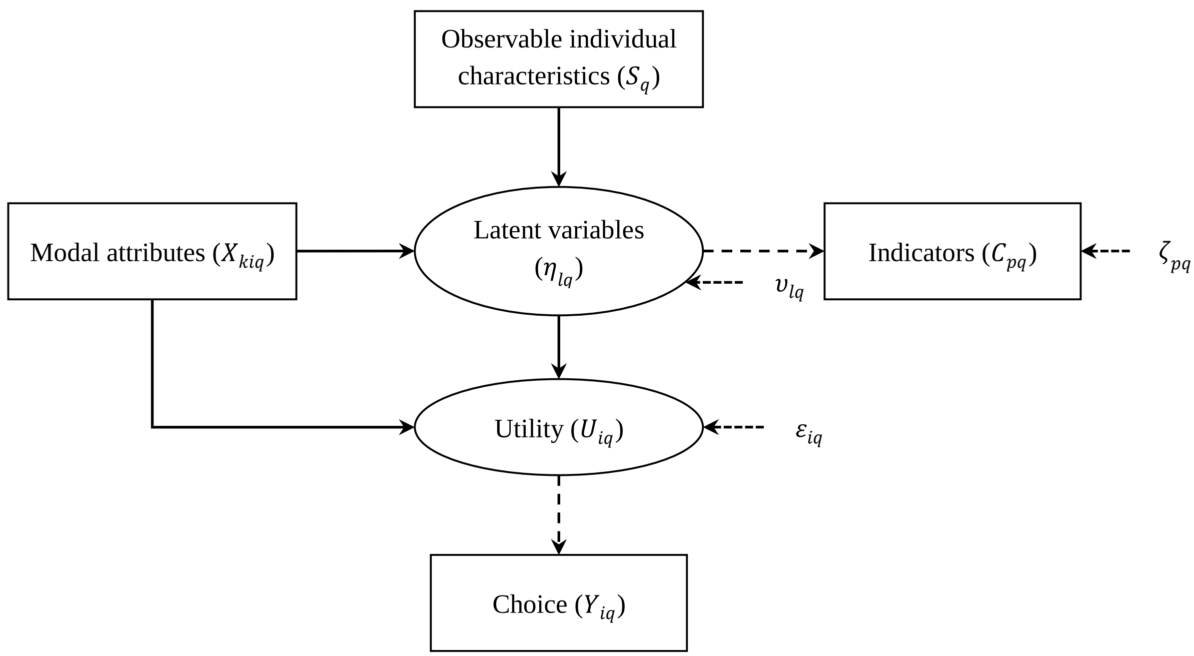

Figure 1. The HDC Modeling Framework

Typically the latent variables (η_l) are specified as a function of observable individual characteristics (S_q), where q relates to an individual, l to a latent variable, and r to an explanatory variable, and $\boldsymbol{\alpha}$ is a set of parameters to be estimated (1). Although the error terms υ_{iq} can follow any distribution, they typically are assumed to distribute Normal with mean zero and a certain covariance matrix.

$$\eta_{lq} = \sum_{r} \alpha_{rl} S_{rlq} + \upsilon_{lq} \tag{1}$$

Although in our view it is correct to model the ordered nature of the data, usually a linear distribution is assumed for the indicators (2).

$$C_{pq} = \sum_{l} \gamma_{lpq} \eta_{lq} + \zeta_{pq} \tag{2}$$

Where p relates to indicators, $\boldsymbol{\gamma}$ is a set of parameters to be estimated and ζ_{pq} are the error terms, which typically are also assumed to distribute Normal with mean zero and a certain covariance matrix.

In the discrete choice sub-model, the individual choices, given the choice set A_q, are expressed as a function of the utilities (3).

$$y_{iqt} = \begin{cases} 1 & \text{if } U_{iqt} \geq U_{jqt}, \forall j \in A_q \\ 0 & \text{otherwise} \end{cases} \tag{3}$$

The HDC modeling framework allows the inclusion of latent variables in the utility function for each alternative i at choice situation t. If we assume a linear specification in the representative component, the utility function can be expressed as (4).

$$U_{iqt} = \sum_{k} \theta_{ki} X_{kiqt} + \sum_{l} \beta_{li} \eta_{liq} + \varepsilon_{iqt} \tag{4}$$

Where $\boldsymbol{\theta}$ and $\boldsymbol{\beta}$ are parameters to be estimated and they are associated with the modal attributes X_{iq} and the latent variables η_{lq}. As usually, each element ε_{iq} is assumed to be independently, identically distributed extreme value across alternatives and respondents, resulting in a multinomial logit kernel for the discrete choice sub-model (5).

$$P\{y_{iqt} | \boldsymbol{\theta}, \boldsymbol{\beta}\} = \frac{\exp(\sum_k \theta_{ki} X_{kiqt} + \sum_l \beta_{li} \eta_{liq})}{\sum_j \exp(\sum_k \theta_{kj} X_{kjqt} + \sum_l \beta_{lj} \eta_{ljq})} \tag{5}$$

Therefore, the joint probability of observing choice and latent variable indicators is built as seen in (6), where $P(.)$ is the choice probability of selecting alternative i, $f(.)$ is the density function of the indicators, and $g(.)$ is the density function of the latent variables.

$$\bar{P}\left(y_{iqt}, C_{iq} | X_{iqt}, S_q, \boldsymbol{\theta}, \boldsymbol{\beta}, \boldsymbol{\gamma}, \boldsymbol{\alpha}, \Sigma_{\varepsilon}, \Sigma_{\zeta}, \Sigma_{\upsilon}\right)$$

$$= \int_{\eta} P\left(y_{iqt} | X_{iqt}, \eta_q, \boldsymbol{\theta}, \boldsymbol{\beta}, \Sigma_{\varepsilon}\right) f\left(C_{iq} | \eta_q, \boldsymbol{\gamma}, \Sigma_{\zeta}\right) g\left(\eta_q | S_q, \boldsymbol{\alpha}, \Sigma_{\upsilon}\right) d_{\eta_q} \quad (6)$$

1.2.1. The Ordered Nature of Likert Responses

Likert (1932) presented the most widely used approach to scaling responses in survey research. Any Likert item is an effect indicator (Bollen, 2002; Bollen and Bauldry, 2011) that has two parts: the statement and the response scale. The literature about the topic, recommends that the statement should be simple, preferably quite short, clear and as unambiguous as possible (Johns, 2012). The response scale is an ordered scale from which respondents choose the option that best aligns with their viewpoint. Odd-numbered and even-numbered response scales can be presented to respondents in formats that can vary significantly (Vagias, 2006), for example, to measure the level of agreement (1-Strongly disagree, 2-Disagree, 3-Neither agree nor disagree, 4-Agree, and 5-Strongly agree), which is the most commonly used.

In practice, at the time of applying the survey, the researcher asks the respondent to express his opinion on the statement. The modeler hypothesizes that each respondent has a level of opinion associated with the statement in question, in which the respondent bases his response (Train, 2009). For example, on the statement “The mechanical condition of feeder bus makes me feel safe,” the researcher assumes that the respondent has an opinion on how safe the mechanical state of the vehicle makes him feel. This unobservable opinion is represented in a variable that researcher labels C^*, where higher levels of C^* mean that the person considers the feeder buses safety is better and lower levels mean he considers the feeder buses safety is poorer.

Notwithstanding, while the researcher asks the respondent to express his opinion on the statement by using, for example, a granularity of 5-point, the concern is that the respondent’s opinion, C*, can actually take more or fewer levels representing his liking or dislike in regard the feeder buses safety, which introduces a measurement error. Despite the above, the respondent picks a relevant Likert point based on his level of C^*. If C^* is above some threshold, which researcher labels τ_4, the respondent chooses the option 5-Strongly agree. If C^* is below τ_4 but above another threshold, τ_3, then he answers 4-Agree, and so on. In this way, the researcher will gather a set of ordered responses, as seen from the Figure 2.

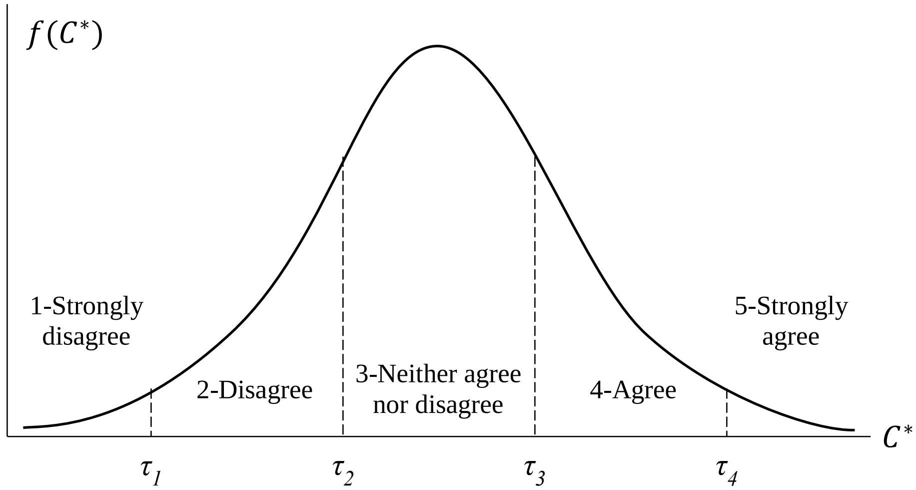

Figure 2. Distribution of Opinion on the Statement

In accordance with our approach that recognizes the ordered nature of the observed indicators, we specified the measurement equations as ordered models. The underlying assumption is that each discrete response k observed within each indicator p is obtained from the latent variables plus an error term through a censoring mechanism that defines different categories of response, according to (7) and (8), where each categorical response in the indicator C_{pq} is defined by a set of threshold parameters ($\boldsymbol{\tau}$) to be estimated.

$$C_{pq} = \begin{cases} 1 & \text{if } (-\infty) < C_{pq}^* \leq \tau_{p1} \\ 2 & \text{if } \tau_{p1} < C_{pq}^* \leq \tau_{p2} \\ \dots & \\ K & \text{if } \tau_{p(K-1)} < C_{pq}^* \leq \infty \end{cases} \tag{7}$$

$$C_{pq}^* = \sum_l \gamma_{pl} \cdot \eta_{lq} + \zeta_{pq} \tag{8}$$

The probability of observing C_{pq} within a discrete indicator or category k can be written as (9), where F is the cumulative distribution function.|

$$P\{C_{pq} \in k|\eta_q\} = F\left(\tau_{pk} - \sum_i \gamma_{pl} \cdot \eta_{lq}\right) - F\left(\tau_{p(k-1)} - \sum_i \gamma_{pl} \cdot \eta_{lq}\right) \tag{9}$$

Contrasting with those cases in where the measurement indicators are treated as continuous response variables, being the terms ζ_{pq} supposed to be distributed normally, our modeling approach assume that it follows a logistic distribution and is independent of the set of parameters, which allows us to use an ordered logit model for the measurement component (10).

$$P\{C_{pq} \in k|\eta_q\} = \frac{1}{1 + e^{-\lambda_q(\tau_{pk} - \sum_l \gamma_{pl} \cdot \eta_{lq})}} - \frac{1}{1 + e^{-\lambda_q(\tau_{p(k-1)} - \sum_l \gamma_{pl} \cdot \eta_{lq})}} \quad (10)$$

Where $\tau_{p0} = -\infty$ and $\tau_{pK} = \infty$. The parameter λ, which is usually normalized to one, is a scale factor inversely proportional to the standard deviation of the logistic error terms (11).

$$\lambda = \frac{\pi}{\sqrt{3}\sigma} \quad (11)$$

1.2.2. Estimation

Regarding the model's identifiability, necessary and sufficient conditions have no yet been developed (Bahamonde-Birke at al., 2015). Furthermore, it is well known that a model that is theoretically identified may often be empirically unidentified due to insufficient variability in the observed data (Vij and Walker, 2014). For these reasons, to deal empirically with the identifiability issues of our model, we verified that the estimated parameters did not lie outside the range of reasonable values. Also, we estimated our models multiple times, employing different starting values for the parameters for each estimation run, verifying that in all cases we reached the same solution, thus ensuring that the solution obtained was a global maximum (Vij and Walker, 2014).

While some authors have demonstrated that the Bayesian approach is suited to a complex HDC model that considers panel effects, correlation, and simultaneity in the determination of the latent constructs (Daziano and Bolduc, 2013; Daziano, 2015), we used maximum likelihood to estimate the unknown parameters of the HDC models. Although the solution requires complex multidimensional integrals and this is not simple. Theoretically, the estimation through the joint integration of the latent variable model and the random utility model is more convenient (Walker, 2001). Furthermore, since sequential approach tends to overestimate the weight of the latent variables (Raveau et al. 2010) slightly, we estimated the model by using all the information simultaneously. We carried out all the work on the computer using OxMetrics (Doornik, 2015), a family of software packages for the econometric modeling and statistical analysis of cross-section and panel data. For simulating the likelihood, we used a certain number of drawings for each individual obtained from a modified Latin hypercube sampling (Hess et al., 2006).

1.3. The Safety Perception in Transportation Choices

We can define safety (or risk) perception as the expectation of an undesirable outcome such as a traffic accident (Hamed and Al Rousan, 1998). Clearly, safety perception is subjective because it can vary from person to person according to their background (experience and information), and how they deal with risks (Adams, 1988). Safety perception is further complex because it differs from one city to another and changes with the environment, and the travel alternatives, among other factors (see, for example, Chataway et al., 2014).

The literature shows that latent variables can improve the safety analysis (Bolduc et al., 2005; Mannering and Bhat, 2014). Some works that initially did not consider the safety perception recommended, at the end, the need to include this latent variable to improve the performance of the models and the analyses derived from them. For example, Tam et al. (2010) did not consider the safety perception in the specification of the model but noted that the tolerance of the margin of safety should be included in the integrated model to provide a better understanding of the passenger's model needs.

Other works considering latent variables related to safety did not prove statistical significance for these variables in all cases. For example, Vredin Johansson et al. (2006), in the context of mode choice between Stockholm and Uppsala, found that safety preferences were insignificant possibly due to the safety differences between the modes being considered too small to be discernible by individuals. In addition, Yang et al. (2009), in a choice context between public transportation and cycling, justified the fact that the safety perception had not been significant due to the level of risk of the baseline being so small that respondents did not perceive the planned changes. However, as explained, it does not mean that safety considerations are not important in the choice of mode. For instance, Yáñez et al., (2010) when seeing that safety was not statistically significant decided to specify the mixed comfort/safety latent variable, which behaved properly in the model.

Finally, some works have reported statistical significance of safety perceptions. In general, they have found significant differences by gender, age, income, vehicle ownership, educational level, seniority in the case of transfers to employees and experiences, such as having been fined or having suffered some accident (e.g. Márquez et al., 2015; Márquez et al., 2014; Habib et al., 2014; Tsirimpa et al., 2010; Yang et al., 2009). In this regard, there is sufficient literature addressing safety perceptions in different contexts of transportation choices. For example, Tsirimpa et al. (2010) developed a model to address the impact of risk aversion on travelers' switching behavior. Daziano (2012) estimated an HDC model to explain consumers' preferences for safety. The perceptions with regard to policies about infrastructure (Wennberg et al., 2010) and the use of public transportation services have been also analyzed, finding that safety has a significant effect on the use of transportation services (Delbosc and Currie, 2012).

1.4. Objectives

The aim of this research is to study the incorporation of safety perceptions in a broad array of choice contexts, some of them particularly significant in developing countries, and simultaneously investigate issues that the literature has not addressed sufficiently. Among the specific objectives are the following:

- To explore the influence of perception of risk on driver's behavior when they decide whether to use a mobile phone while driving.
- To analyze the influence of safety perception on the choice of river transportation by passengers.
- To investigate tangible and latent attributes influencing captive user behavior in the face of choice decision between BRT service and motorcycle taxis.
- To study the influence of tangible attributes on safety perception of bicycle users, in a choice context integrating cycling into a BRT system.
- To study the influence of indicators' complexity on the estimation of HDC models, in a choice context where auto-rickshaws are BRT feeders.

1.5. Contributions

Our findings have significant policy implications and practical recommendations about data collection and HDC models estimation issues. The specific contributions presented in this document are as follows.

1.5.1. Influence of Risk Perception on Driver's Behavior

Using an existing database, we study the influence of risk perception on drivers' behavior when they decide whether phoning while driving. We demonstrate that some socioeconomic characteristics, such as the educational level of individuals and their occupation, influence risk perception. Besides, we establish that certain individual experiences, such as being previously fined and having been in an accident, also modify the perception of risk. Modeling perception of risk in this context shows that despite the slight improvement in the goodness-of-fit of the hybrid model, it improves the representation of the individual behavior because of the effect of the latent variable towards the use of mobile phone while driving.

1.5.2. Safety Perception in Alternative Transportation Modes

We study the influence of safety perception on the individuals' preferences for four alternative transportation modes, which is especially significant in developing countries. Using of existing databases, we first study safety perception in the provision of inland waterway passenger transportation and then in the competition between BRT and motorcycle taxis. Afterward, based on two *ad-hoc* surveys, we study cycling and finally auto-rickshaws as BRT feeder modes. Modeling safety perception in these contexts allows us for understanding passenger behavior and improvement in policy formulation in developing countries.

1.5.3. Tangible Attributes Linking Safety Perception

We extend stated preference experiments to analyze how certain combinations of tangible attributes affect individuals' perceptions. We design an experiment based on images to capture the variability of some tangible attributes linking safety perception. Our results clearly show that tangible attributes have a significant effect on both the utility and the safety perception of individuals. In addition, our approach allows for the evaluation of policies related to latent variables, being possible study how a certain policy modifies safety perception.

1.5.4. The Influence of Indicators' Complexity

Based on an experiment that allowed systematic variations in the number of indicators and the granularity, which at the same time implicitly determined the type of scale, we model the indicators' complexity. We show that the kind of the scale, the granularity, and its quadratic effect as well as the interaction between the granularity, and the number of indicators, affect the error variance of the measurement component. Odd-numbered Likert scales, which are widely used in transportation choice studies, appear to have an incremental effect on scale factor, contributing to a lower error variance of the measurement component.

1.6. Articles Derived from Research

From this dissertation, we produced five papers, two of them already published and the other three submitted for evaluation.

- Paper I: Mobile phone use while driving: A hybrid modeling approach, *Accident Analysis & Prevention*, 2015, 78, 73-80
- Paper II[*]: How are comfort and safety perceived by inland waterway transport passengers? *Transport Policy*, 2014, 36, 46-52
- Paper III: Understanding Captive User Behavior in the Competition between BRT and Motorcycle Taxis, *Transport Policy*, submitted
- Paper IV: How do tangible attributes influence safety perception of bicycle users? *International Journal of Sustainable Transportation*, submitted
- Paper V: Assessing the influence of indicators' complexity on hybrid discrete choice model estimates, *Transportation*, submitted

1.7. Outline of the Dissertation

We organized the dissertation in the following way.

Chapter 2 explores the influence of risk perception on drivers' behavior when they decide whether to use a mobile phone while driving. In this case, we incorporated the latent variable in a mixed logit model with panel effects, in which we specified the coefficient of the fine to be normally distributed. Although the inclusion of the latent variable slightly improved the goodness-of-fit of the discrete choice model, the hybrid model improved the representation of the individual behavior allowing us to understand the drivers' behavior concerning phone use better while driving.

Chapter 3 focuses on the studying safety perception in the field of provision of waterway transportation in remote regions of Colombia. Regarding the specification of measurement

[*] Although this case study was the second we carried out, the paper derived from it had faster review time than the resulting from our first case.

component, due to the few rated responses in the two extreme categories, we aggregated the responses into a 3-point scale, enhancing the significance of the estimates for the measurement equations. Unlike the other case studies, we specified safety perception in interaction with hull condition because individuals faced two unlabeled alternatives.

Chapter 4 focuses on the studying safety perception in the competition between BRT and motorcycle taxis. In this case, we incorporated the safety perception of riding BRT and motorcycle taxis as alternative-specific latent attributes. Furthermore, we used an approach based not only on the modeling results but also on an empirical analysis by diverging stacked bar charts of indicators. These findings enhance our understanding of captive user behavior and allow us formulating and focusing policies regarding latent variables.

Chapter 5 studies the influence of tangible attributes on safety perception of bicycle users, in a choice context integrating cycling into a BRT system. The motivation for the methodology we investigate is that there are often tangible attributes that are important not only to the utility but also to the safety perception. The methodology discussed in this chapter demonstrates that stated preference experiments can be extended to analyze the influence of tangible attributes on perceptions. We proposed an experiment based on images, exploiting their advantages over traditional representations like text.

Chapter 6 studies the influence of indicators' complexity on hybrid discrete choice model estimates. Based on the literature review, we found substantial differences among the number of indicators used to form each latent variable, and the type of scale and the granularity used to measure it, which encouraged us to address this issue. An experiment that systematically varied the three dimensions of complexity allowed us to parameterize proper the scale factor of the measurement component for capturing potential effects of complexity in measurement equations. The case study focuses on the safety perception of riding two BRT feeder modes.

Chapter 7 concludes the dissertation and provides suggestions and directions for further research.

2. The Influence of Risk Perception on Drivers' Behavior: Phoning While Driving

Our guiding philosophy behind the analysis of the influence of safety perceptions in some particular choice contexts is that they allow us to acquire a better understanding of the travelers' behavior and to study in depth issues that have been left outside the scope of previous research in this area. Our first case has to do with the analysis of the influence of risk perception on drivers' behavior, which is a topic of great interest for the scientific community since there is the consensus that using a mobile phone while driving increases the risk of traffic accidents. For this reason, in many countries, it is illegal to drive and use a mobile phone simultaneously (Macario et al., 2010).

Using a mobile phone while driving in Colombia is prohibited –the exception is when a hands-free device is used–. However, this is a common practice that tends to escalate because of an increase in mobile phone coverage and the rate of motorization (University of the Andes, 2009) while the ability of police control by against continuing violations of traffic rules has been rather stagnant. Furthermore, the level of impunity for traffic violations is very high (Ferrer et al., 2013). Therefore, it is essential to study the drivers' behavior in the context of the decisions made with compliance or not to traffic rules.

2.1. Introduction to the Case Study I

Talking on the mobile phone, chatting, sending an e-mail, searching for an address on the GPS, manipulating the sound equipment onboard, or looking at a crash that has just happened on the road, are activities that, if made while driving, might become distractions that might cause an accident. It would be very difficult to estimate how many distracted drivers drive on a particular section of the road, though there is the consensus that distractions are a major cause of accidents. That is because a distracted driver can fail to see a stop sign, not see a red traffic light, violate the speed limit and generally assume attitudes that might put their own safety or that of others at risk.

Distraction when talking on the phone reduces the driver's ability to react in relation to other activities that may occur while driving such as using music players (Consiglio et al., 2003). Research based on simulated situations (Drews et al., 2008; Beede and Kass, 2006; Strayer and Drews, 2007) and in real cases (Collet and Guillot, 2010a, 2010b) concluded that using a mobile phone while driving increases the risk of exposure to traffic accidents. However, many drivers seem to be unaware of the risk related to using mobile phones while driving (Horrey et al., 2008; Rosenbloom, 2006) and, therefore, it is estimated that most drivers use their mobile phone while driving. Due to the complexity of the phenomenon related to the activities of talking on the phone while driving, many researchers have tackled this issue from different perspectives, which today is in the best interest of the scientific community.

White et al. (2004) conducted two studies on risk perceptions of mobile phone use while driving. In the first study, they observed that the use of hand-held sets was seen as a higher risk than other activities, such as looking for music to play or eating and drinking. They also observed that people tend to give more importance to physical distractions rather than the cognitive ones, which explains, in part, why people perceive those activities that do not involve the physical handling of devices as less risky. Other researchers as Backer and Sagberg (2011), who found a significant increase in accident risk for hand-held mobiles and hands-free phones together, has corroborated this behavior. Likewise, Reimer et al. (2011) have found that using the headset can be even more dangerous than using the mobile phone without additional devices because drivers try to compensate for the risk in the first case and they forget to do it when using a hands-free phone (Ishigami and Klein, 2008).

The results of the second study conducted by White et al. (2004) suggested that almost half of the drivers who had a mobile phone had used it while driving. They found that the probability of using the mobile phone was higher for young male individuals, which instead of using a hands-free set, used a hand-held device. Regarding young drivers, Neyens and Boyle (2008) indicated that there are a substantial number of crash-related injuries for teenage drivers due to inattention. They suggested that all teenage drivers were more likely to be severely injured when distracted by mobile phones or passengers. This clearly suggests that inattention is a major problem for teenage drivers. Neyens and Boyle (2008) further asserted that as more devices are being installed on the vehicles, and as mobile phone use continues to increase, the potential for driver distraction is rising, especially for teenage drivers and their passengers.

The study conducted by Wogalter and Mayhorn (2005) suggested that individuals classified as mobile phone non-users have stronger beliefs about the existence of safety problems associated with driving, compared to those individuals they classified as mobile phone users. It is important to highlight how their research found that non-users would be willing to use the phone only in emergencies. This means that despite the condition of an individual user, the decision to use the phone would be clearly determined by the importance or urgency of the call to be made. Nevertheless, the use of mobile phones in vehicles is not harmful *per se* since the evidence suggests that the mass of mobile phones allows a timely response from the emergency services to the accident site so that it could help to reduce the number of fatalities in traffic accidents (Loeb et al., 2009; Fowles et al., 2010).

2.2. Data

With the aim of studying the main factors affecting mobile phone use while driving, we use the database provided in a previous study we conducted in 2010, in Tunja, which is a medium-sized Colombian city, located 150 km northeast of Bogotá.

2.2.1. Context

Colombian laws define "Using mobile communication systems or installed phones in vehicles when driving, except if they are used with accessories or auxiliary equipment that allow it to keep your hands free" as a traffic violation. Statistics of drivers' behavior in Colombia, reflected in the reporting of the offenses punishable by fines, indicate that not using handset devices is in the Top 20 most commonly offenses, representing the 3.5% of 63,000 national traffic offenses committed per year (Comptroller General of the Republic, 2012).

Unlike what happens in other countries, in Colombia, there is no driver demerit point system, but drivers are penalized by fines and sometimes the obligation to attend courses on road safety. The fine for committing this offense is 15 days minimum salary, which in the year 2010 corresponded to COP$ 257,500, roughly US $135. However, a driver can reduce the payment of the fine by 25% if he/she voluntarily accepts liability to the offense and another 25% reduction if he/she agrees to attend a course on road safety so they can achieve a reduction of up to 50% of the nominal fine.

Now, if the driver commits the offense and does not appear before the authorities, the legislation mandates the cost of the fine to rise up to 200% of the initial cost. However, due to an entrenched culture of non-payment combined with the low capacity of authorities in the work of collection enforcement, in Colombia, more than 50% of the fines imposed by police and traffic officers are not collected, which accentuates the growing culture of non-payment and reduces the deterrent effect of the penalty (Ferrer et al., 2013).

2.2.2. Profile of the Drivers

The study engaged 176 individuals. Their mean age was 36, with distributions by age, gender, the level of education and occupation that are shown in Table 1, which also contains the distribution of the population of car drivers in the city (Palacios and Silva, 2004). It is important to highlight that the reference population is based on private car owners in the city, not people in general.

Table 1. Profile of the Drivers

Variable	Sample	Population
Age		
< 30	28 %	21 %
31 – 40	34 %	32 %
41 – 50	23 %	28 %
51 – 60	12 %	14 %
61>	3 %	5 %
Gender		
Male	73 %	69 %
Female	27 %	31 %
Education level		
High School	34 %	32 %
University	29 %	31 %
Technical Diploma	14 %	12 %
Primary	13 %	10 %
Post-graduate	10 %	15 %
Occupation		
Students	11 %	16 %
Workers	72 %	62 %
Other	27 %	22 %

All respondents reported that they had an active mobile phone. It was found that 71% belonged to the mobile operator CLARO, followed by MOVISTAR with 17%, TIGO with a market share of 8%, and a small part of the respondents (4%) who did not reveal their mobile operator. The comparison between this distribution and the participation of each of these operators in the domestic mobile phone market indicates that the sample distribution is close enough to the population distribution of mobile users in the country.

Near 60% of the individuals revealed themselves as having been fined for traffic violations, but only 11% of these reported to have been fined for using mobile phones while driving. Even though these indicators were not subjected to validation, as it was not possible to get access to traffic violations information, we considered the sampling to be representative of the environment in which the survey was conducted.

Over 50% of respondents said that it is very risky to use mobile phones while driving, but 82% of them reported doing so, arguing that it generally is an uncommon practice. Among those who said they use mobile phones while driving, only 30% reported using hands-free devices, despite the majority (67%) who said they slow down while doing so, which is consistent with the perception of risk manifested. One out of five respondents reported has been in accidents, or having been at risk of an accident when using a mobile phone while driving.

2.2.3. Indicators of Risk Perception

In order to form the latent variable, we used as indicators the answers given by the participants to three questions raised during the survey. The individuals rated these questions, listed below, in different response scales, two of these on a 3-point scale, and the other one on a 2-point scale, as follows:

- Stated risk regarding phoning while driving
  (1-Very risky, 2-A bit risky, 3-Totally safe)
- Frequency of mobile phone use while driving
  (1-Not frequently, 2-Almost never, 3-Frequently)
- Reducing speed while talking on a mobile phone
  (1-Reduce speed, 2-No speed reduction)

2.2.4. Stated Preference Survey

The experiment assumed that the individual was driving his/her vehicle when he/she reminded to make a call, with the condition of having their cell phone available but without the opportunity to use the headset. In each of the eight situations faced, we asked the individual to consider the urgency of the call, the condition of traveling with or without someone, speed on the road and the cost of the fine if stopped and fined by a traffic officer. Thus, we asked the respondents to try to recreate every situation regardless of the other situations described in the survey and to answer as frankly as possible whether or not they would use their cell phone.

According to the literature review and based on the results of focus group meetings, the experiment considered the following set of variables: the urgency of the phone call, traveling alone or with passengers, speed, and level of the fine (Table 2). The level of the fine restricts the driver's behavior (Kowalski and Lundman, 2010) against the possibility of committing an offense. The speed is associated with the risk and severity of the accidents (Kononen et al., 2011). Driver's behavior differs depending on the type of conversation (Dula et al., 2011), and it affects the risk of accidents both at high or low traffic congestion (Hennessy and Wiesenthal, 1999; Hennessy and Wiesenthal, 2000). Traffic flow is generally taken as a measure of exposure when computing the risk of being involved in a vehicle crash. When exposure increases then the risk increases too (Forkenbrock and Weisbrod, 2001) and affects the use of mobile phones while driving.

Table 2. Levels of the Experimental Variables

Variable	Level	Description
Urgency	0	A normal phone call
	1	Urgent phone call
Travelers	0	Traveling alone
	1	Traveling with someone
Speed	0	20 km/h
	1	40 km/h
	2	60 km/h
Fine*	0	COP$ 257,500
	1	COP$ 515,000
	2	COP$ 1,030,000

*1UD$ = COP$ 1,900

The application of structured and unstructured interviews helps us to identify various categories from personal drivers' experiences towards the research object. We obtained the initial values from the focus groups and adjusted after applying a pilot test to 30 drivers. The combination of variables and levels formed an experiment $2^2 \times 3^3$ with 108 treatments. We initially decided to use an orthogonal main effects plan through the SAS software, finding a design of 16 treatments that allowed the study of the main effects of the variables. Due to the resulting size of the experimental design, which finally included 16 situations, we divided the design into two blocks to reduce the respondent burden.

2.3. Model Specification

Figure 3 shows the structure of the HDC model used to evaluate the drivers' behavior when they decide whether to use a mobile phone while driving.

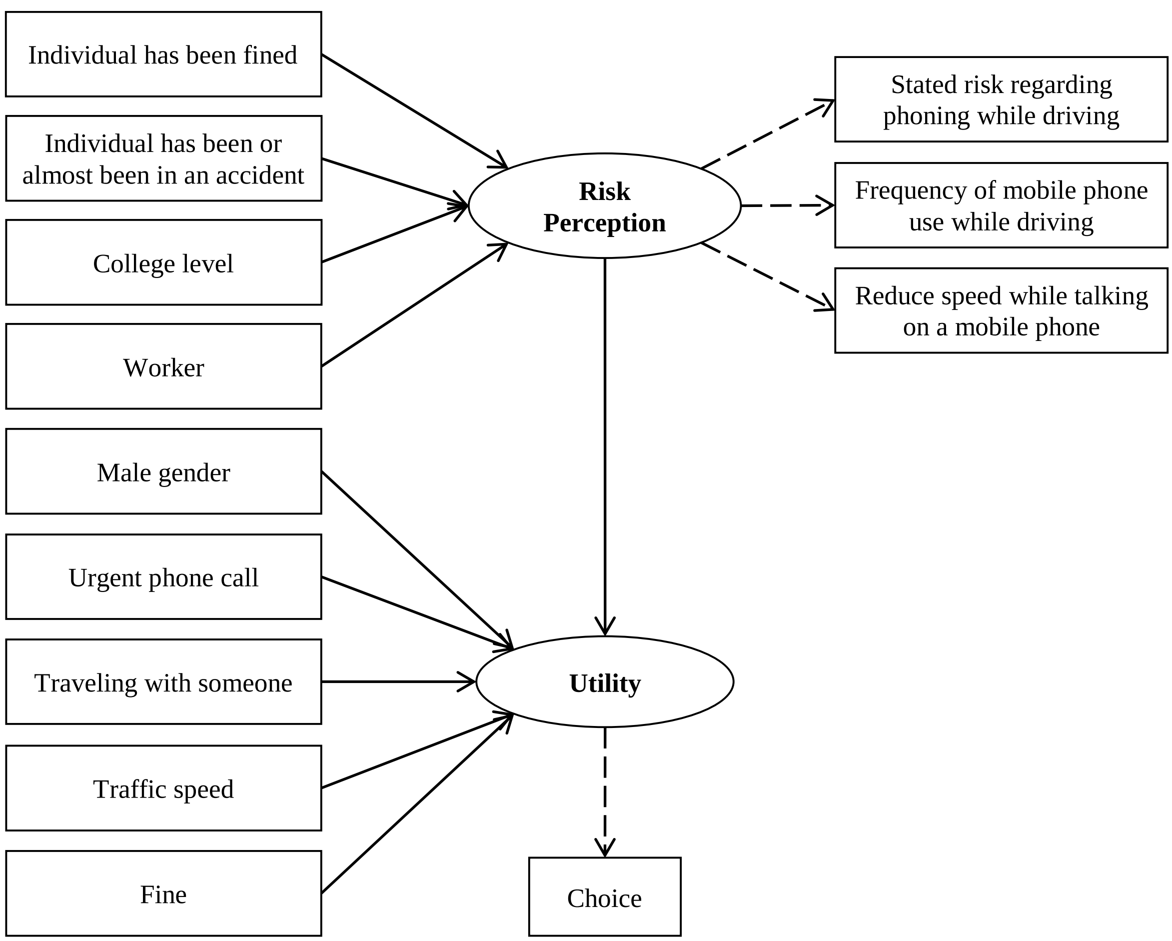

Figure 3. Structure of the HDC Model for Phoning while Driving

2.4. Results and Discussion

Table 3 shows two models: the HDC model and a mixed logit model (ML) in which the fine has a random parameter. Both models were estimated using observations from 145 individuals, 8 choice situations for each one, yielding 1,160 pseudo-individuals. The top panel displays the results of the choice model, which includes the latent explanatory variable “Risk Perception”. The lower panel displays the results of the latent variable model, which consists of four equations: a structural equation for “Risk Perception”, and three measurement equations –one for each indicator–.

Table 3. Estimated Model for Phoning while Driving

CHOICE MODEL	**HDC**		**ML**	
Description	**Estimate**	**Rob. t-value**	**Estimate**	**Rob. t-value**
Male gender	-0.192	-1.11	-0.187	-1.06
Urgent phone call	1.870	11.34	1.870	11.31
Traveling with someone	-0.236	-1.45	-0.245	-1.51
Traffic speed	-0.012	-2.27	-0.013	-2.35
Fine	-1.812	-5.68	-1.82	-5.73
Risk Perception	0.179	1.95		
Deviation standard of parameter Fine	1.062	5.20	-1.10	-5.49
Specific constant for using phone while driving	-0.091	-0.28	0.219	0.72
Log-likelihood at convergence	-656.223		-657,720	
Log-likelihood ratio test	295.66		292.66	
STRUCTURAL MODEL (Risk Perception)				
Individual has been fined	1.057	2.11		
Individual has been or almost been in an accident	0.918	2.67		
College level	0.753	1.94		
Worker	0.626	1.73		
MEASUREMENT MODEL				
Stated risk regarding phoning while driving	0.458	2.72		
Frequency of mobile phone use while driving	1.820	1.37		
Reduce speed while talking on a mobile phone	0.328	1.76		
GENERAL REPORT				
Number of observations	1,160			
Number of draws	1,000			
Estimated parameters	20			

Each of the estimated coefficients is presented along with its corresponding robust t-value, from which it can check its statistical significance. The table also contains the general indicators of fitting each model, presented as the log-likelihood at convergence and the log-likelihood ratio test. As apparent from the results, that is a higher log-likelihood in convergence, the HDC model improved the fit. Actually, the likelihood ratio test between the HDC and ML models was 2.994 (significant at 90% of confidence). This is an expected result because the hybrid model contains an additional error term that is integrated to estimate the joint log-likelihood function so that the HDC model would be better than the ML model without the latent variable.

In the choice model, it was hoped that the coefficient of the variable "Urgent phone call" (1.870) would be obtained with a positive sign because it was foreseeable that the more urgent the call the more likely they were to use a cell phone. Likewise, it was presumed that the sign of the coefficient of the variable "Fine" (-1.812) would be negative because, despite the non-payment culture that characterizes the population from which the sample was drawn, it was still reasonable to assume that the deterrent effect of the fine would be reflected in the model. Regarding the sign of the coefficient of the variable "Traffic speed" (-0.012), it seems for it to be negative as lower traffic flow rates generally make it attractive to use the mobile phone. While the estimated parameter of the variable "Traffic speed" is very close to 0, it can be seen that the coefficient is statistically different from zero as the robust t-value (-2.27) indicates that the confidence of the estimate is much higher than 95%.

Regarding the signs of the other coefficients of the choice model, there were initially no assumptions about them, so the signs obtained gave information about the influence of these variables on the decision to use the phone or not. Thus, the negative signs of the coefficients of variables such as "Gender" (-0.912) and "Traveling with someone" (-0.236) establish that, in this case, women are more likely to use cell phones while driving, as well as individuals traveling alone. Although different specifications of the model were tried, the variable "Gender" was unsuccessful when it was placed in the latent variable model. Neither was it significant when it was placed simultaneously in the model of latent variables and in the choice model. Only when it was specified as an explanatory variable of the choice model did it provide some behavior that could be considered acceptable for the model.

According to the estimated coefficients and the mean values of each variable in the model, it was found that the deterrent attributes in the decision to use a mobile phone while driving are, in order of importance, the following: cost of the fine (-1.812), traffic speed (-0.012), condition of traveling with someone (-0.236) and gender (-0.192). Likewise, we found that the urgency of the call (1.870) and the latent variable of risk perception (0.179) are attributes that stimulate cell phone use while driving. We further found the effect of traffic conditions to be assimilated by the speed variable.

As in the research of Nelson et al. (2009), the safety perception regarding of using a mobile phone while driving clearly had an impact on whether drivers would make a call. In this case, the coefficient of the latent variable “Risk perception” is positive and exhibits a confidence interval over 95%. The structural model indicates that the latent variable is higher among individuals who have been previously fined (1.057); in the same way, people who have been in an accident or almost been in an accident (0.918) have a higher perception of risk. Increasing threshold structure and positive value of the latent variable suggest that an individual who likes the risk will be more prone to use his/her mobile phone while driving than another person will. The educational level of individuals (0.753) was presented in the structural model with a positive sign: consequently, individuals with a higher level of education tend to take more risks than others. Similarly, individuals who have been fined before are more likely to use mobile phones while driving.

Although no evidence was found, it was expected that people with a higher education level would have fewer propensities to use a mobile phone while driving, as it was reasonable to assume that more education would enable individuals to discern the risks and consequences of assuming this attitude when driving, and recognize the importance of compliance with traffic rules. However, we believed that there is a trade-off between risk and time since, in the context of the experiment, an individual has two implicit options: to postpone the driving task to generate the call or make a call while driving to save more time despite the risks assumed. This means that if an individual decides to make the call while driving, he/she makes that trade-off, which is directly related to the importance or urgency of the call to be made. In this regard and based on the literature, the behavior of individuals with higher education can be explained because they have a greater time valuation than that of individuals with less education (Asensio and Matas, 2008). The results are similar to of White et al. (2004), who explain the behavior of individuals in the sense that the perceived benefits of using a mobile phone while driving are believed to outweigh the risks of this behavior.

It is possible that workers use their phones while driving more frequently because they must be aware of their labor issues. Besides, we found that urgency of the phone call is the most important explanatory variable in the choice model. The use of cell phones while driving can be seen as a way to reduce the disutility of travel time. We also found that individuals traveling by themselves are more prone to use mobile phones than individuals traveling with someone are; these results are consistent with existing literature (Dula et al., 2011). However, when it is related to teen drivers, Williams et al. (2007), say just the opposite: “Passenger presence increases crash risk for teenage drivers, especially when the passengers are other teenagers and especially when they are male”.

As the model indicates that mobile phone use tends to increase when traffic speed decreases, it could be suggested that police control operations should be made in areas of low velocity. It is important to exercise control over the areas of lower traffic speeds considering that the attraction of using a mobile phone at lower speeds can put pedestrians at greater risk.

Finally, increasing the amount of the fine would help reduce the probability of using the mobile phone while driving. For example, increasing the cost of the fine from 0.5 to 2.0 minimum wages considerably reduces the probability of using mobile phones. For the current cost of fines, the elasticity of the probability of using the mobile phone with respect to the cost of the fine is -0.28, indicating that a 10% increase in the cost of the fine would produce a 2.8% decrease in mobile phone use while driving.

2.5. Conclusions of the Case Study I

We found that including the latent variable “Risk Perception” with the linear structural equation slightly improved the goodness-of-fit of the discrete choice model. Despite the slight improvement in the goodness-of-fit of the hybrid model compared to the mixed logit model with panel effects, we thought that the hybrid model improves the representation of the individual behavior because it reflects the effect of the individual’s risk attitude towards the potential of using a mobile phone while driving.

Moreover, the fine is an attribute of great importance in order to control the behavior of drivers regarding the use of mobile phones. Nevertheless, the urgency of the phone call was the most important explanatory variable in the choice model and it was understood that individuals traveling by themselves are more prone to use mobile phones than individuals traveling with someone are. In concordance with the results of the model, authorities could be made aware that prevention campaigns should take into account attributes such as driving alone, education level, and gender for raising awareness about the use of mobile phones while driving because these attributes strongly influence the decision on whether or not to use a mobile phone. In addition, authorities should consider that individuals who have been in an accident or almost been in an accident are more prone to use their mobile phone while driving than others are.

This case only studied the action of making the call while driving, not answering it. The particular interest in performing the experiment to regard the generation of the call was to study the variable "Urgent phone call" that in another context would have been difficult to investigate. The results found do not show whether there is symmetry with the action of answering the call or not but there may be a close relationship between the two. For this reason, we believed that it would be of great interest to perform a similar experiment in the future considering the action of answering a call while driving.

Finally, a new experiment that includes the option "making a call using the headset" should be applied which probably does not reduce the risk, but it is an option that individuals must consider in order to make the experiment more realistic. Further research may include the analysis of motorcycle drivers considering their growing rate in Colombia. Besides, it is relevant to study the use of mobile phones while driving in different cities in order to identify the presence or lack thereof, of significant differences according to the local context. It is possible to include other latent variables such as "Attitude regarding authority" in similar studies.

3. Inland Waterway Transportation Users: The Influence of Safety Perception on Travelers' Behavior

A context of choice very little studied, even through traditional choice models, is the inland waterway transportation services. In addition to safety perceptions, which may be of concern to users of such services, we believe that perceptions of comfort are also important to them. For this reason, in the field of provision of waterway transportation in remote regions of Colombia, our second case analyses the influence of perceptions of safety and comfort on the choice of river transportation by passengers. This chapter looks specifically at the provision of waterway transportation in MINEROS S.A., a Colombian company dedicated to the exploitation of the most important alluvial deposit of the country.

Our interest in studying this context arises from two different reasons. In the first place, the plan of the Colombian government and private operators to seek to promote inland waterway transportation and improve their safety. This is because, although Colombia has a major waterway system that could facilitate regional communication, the geographical conditions of the country have functionally disjointed much of the territory. Here, inland waterway transportation could play a major role in facilitating regional connectivity. Secondly, the results of some satisfaction surveys that allowed for showing the dissatisfaction of users regarding the conditions of provision of waterway transport, especially about safety and comfort.

In contrast to the immediately preceding chapter, which only studied safety perceptions, in this case, we also consider the comfort perception of inland waterway transportation services. Furthermore, in the present case study, the specification of the latent variable is dealt with differently by the previous case, assuming an exponential function to preclude negative values, thus facilitating the interpretation of coefficients of the structural models. Furthermore, because of the unlabeled experiment we carried out, we specified the latent variables in interaction with some observable variables of the experimental design.

3.1. Introduction to the Case Study II

Colombia is comprised of three main topographical areas: the Andean mountain system, which is composed of three mountain ranges and different inter-Andean valleys, the lowlands and isolated mountain ranges as the Sierra Nevada de Santa Marta and Macarena. This geographical situation limits the connectivity among regions, preventing communication among them (Roelofs, 2013). Although the country has a major river system that could facilitate regional communication, much of the territory is functionally disjointed, a condition that along with the low population density hinders connectivity, service delivery, infrastructure provision and competitiveness of economic activities.

Colombia's government is aware of this situation and it has made some strategic guidelines that aim to enable the country by improving the existing highway network, expanding ways of development and promoting multimodal (air and river) transportation (DNP, 2010). The promotion of waterway freight would reduce the external costs of transportation (Márquez and Cantillo, 2013) and develop mining and agro-industrial activities (Roelofs, 2013), whereas policies promoting waterway passenger transportation would improve accessibility in regions where the river is the only available path between zones (Berrío and Cantillo, 2012).

In addition to the formulation of policies that seek to promote inland waterway transport, the Colombian government also aims to strengthen the security and safety in the environment of the river corridor, and the use of more efficient technologies in terms of emissions (DNP, 2010). Although comfort is not a priority for the national government, from the perspective of users, it is a relevant attribute that can be improved in the context of the provision of inland waterway passenger transportation. In Colombia, as experimented in the EU countries, and specifically in Italy (Eboli and Mazzulla, 2012), there is a lack of regulations and there is needed to arrange univocal procedures for service quality measurement, where safety has national legislation and control by the state.

In the safety analysis relating to waterway transport, it has been concluded that the boat is a major factor, also finding that passenger boats like barges, tugs, and tankers, are the vessels that produce the greatest consequences when an accident occurs. Likewise, the risk in navigation increases significantly caused by external factors such as bad weather and waterway conditions (Zhang et al., 2013). Regarding the comfort of the waterway transportation mode, some research proposals have been carried out exploring the improvement in the delivery and allocation of boats using simulations software, showing that using mathematical models may help to improve the system (Taylor et al., 2005; Xu et al., 2013).

3.2. Data

We use data from a stated preference survey applied to workers of MINEROS S.A., a company engaged in gold mining that uses the river as the sole transportation mode. The survey, which we applied in 2011, in the port of El Bagre, comprised three bodies. First, it asked for the individual characteristics, such as age, gender, seniority and level of education. Then the individuals rated 10 indicators of safety and comfort of the service. Finally, it was applied a stated preference survey to 129 out of 352 workers randomly selected from all areas of production and maintenance of the company, which together formed the sample of the study.

3.2.1. Context

MINEROS S.A. is a Colombian company dedicated to the exploitation of the most important gold deposit in Colombia, located in the Nechí River, in the northwest of the country. The company provides a transportation service for passengers using waterway transport, mainly for its employees. The system operates 24 hours a day, 365 days a year. A group of harbor captains, a coordinator and several boaters operates the shuttle service.

The company transports more than 1,000 passengers a day through the river, with an average distance between the main port and the production units of 33.8 km. Most of the vehicles used to transport staff are small boats with a maximum capacity of 22 passengers. During the time in which the study was conducted, the rainfall was high and no problems with navigation were detected; however, it is foreseeable that in times of low water level the travel times on the river are increased due to the inaccessibility of certain channels that are available in winter.

The time spent by workers commuting is part of their workday and in the case that it exceeds the statutory working hours, the company pays overtime for the employees. This is a particularly important situation because by doing this part of the paid working hours, the time spent on transportation can be perceived differently than usual. It also highlights the fact that the company provides transportation services to their workers for free.

3.2.2. Indicators of Safety and Comfort

In addition to the socioeconomic characteristics of the respondents, the perception of users regarding the attributes of comfort and safety were recorded (see Figure 4). Initially, we considered that indicators such as hull condition and safety conditions were manifesting the latent variable safety. Likewise, we believed that the latent variable comfort could manifest at indicators such as seat condition, space between seats, allocation of boats, and punctuality. Other indicators such as level of caution when operating, captain education level, the behavior of other users, and travel time may be associated with either latent variables or both.

The survey included 10 indicators on a scale of excellent, good, fair, poor and terrible, through which information on perceptions of safety and comfort of service was obtained (see Figure 5). Due to the few recorded observations in the two extreme categories, an aggregation process by adding “Excellent” + “Good” and “Terrible” + “Poor” was carried out, obtaining a rating scale consisting of only three categories. This treatment allowed obtaining a better performance of ordinal models used in the specification of the measurement equations, thereby enhancing the significance of the estimated parameters.

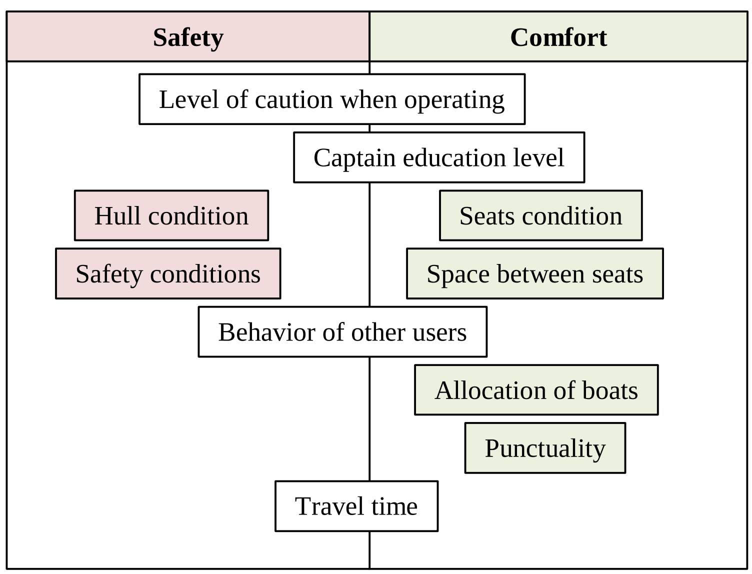

Figure 4. Indicators of Comfort and Safety for Inland Waterway Transportation Users

Before proceeding with the full model estimation, an exploratory factor analysis was performed to identify possible associations between data in order to establish what indicators help measure each of the latent variables. According to the analysis, the first factor is associated with the perception of safety that is explained on the hull condition and the level of caution when operating. The second factor represents the perception of comfort and it is manifested through indicators such as the space between seats and the behavior of other users.

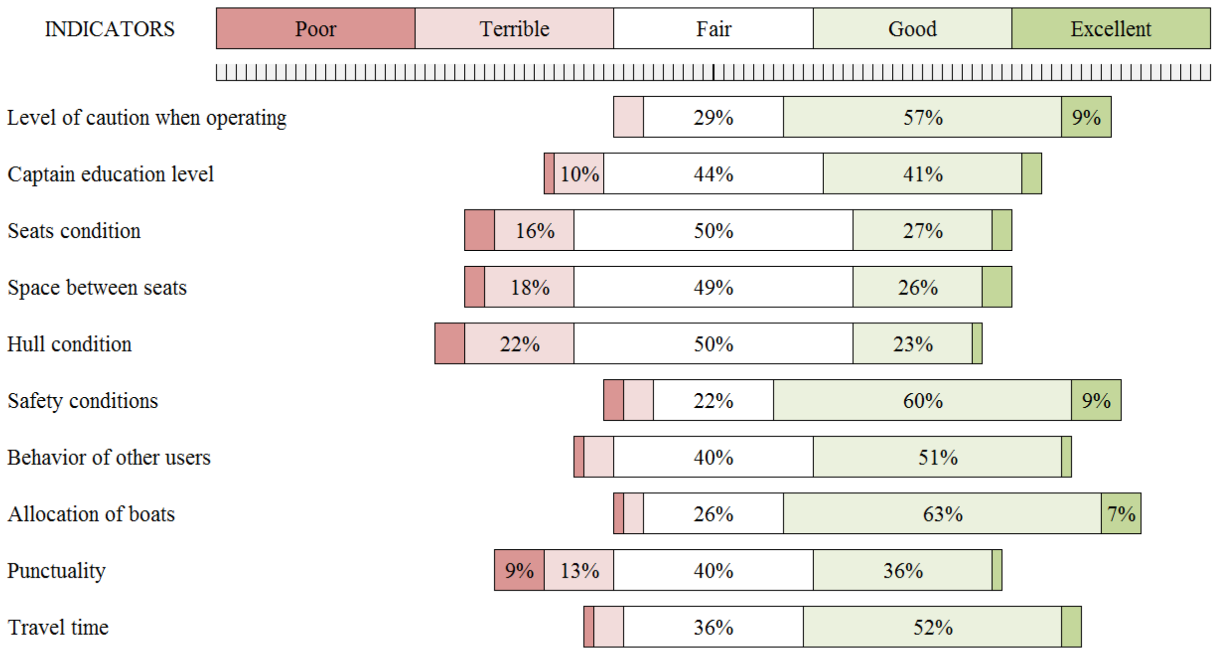

Figure 5. Rating of Indicators for Inland Waterway Transportation Users

3.2.3. Stated Preference Survey

To assess the perception of the comfort and safety of the service, a stated preference survey directed to users of the waterway transportation service was designed and implemented. Each worker was interviewed 9 times, yielding 1,161 observations.

Respondents reported an average age of 39, over a range of ages ranging from 21-61, with an average of 10.3 years working for the company and a distribution by level of education that places the majority of them at the secondary education level. Although it is known that men and women perceive risk differently (Rundmo and Jørgensen, 2009), it is probable that women give more importance to risk than men (Rundmo *et al.*, 2011); during the present study it was not possible to study such behavior as the mining activity is carried out almost exclusively by men. For the former reason, all respondents in the survey were male.

The set of choice alternatives were representing two transportation services in similar conditions to the current service provided by the company. We designed the attribute levels to investigate the effect of the relevant variables in the choice. Then each individual faced two options and they chose the best option among the alternatives A and B, according to the assessment made on each. We considered the following attributes: reliability (trip delay), travel time, boat condition and type of service (exclusive or shared service for employees). For variables associated with travel time, the survey provided different alternative times and it did not include the cost because the service is provided to employees for free. At the end, we found a pattern of nine treatments that allow the study of the main effects of the variables, as shown in Table 4.

Table 4. Experimental Design for Inland Waterway Transportation

Delayed Service (min)	Travel Time (min)	Boat Condition	Type of Service
15	30	Excellent	Exclusive for your group or crew
15	45	Fair	Shared with people who do not work for the company
15	60	Poor	Shared with other workers
30	30	Fair	Shared with other workers
30	45	Poor	Exclusive for your group or crew
30	60	Excellent	Shared with people who do not work for the company
45	30	Poor	Shared with people who do not work for the company
45	45	Excellent	Shared with other workers
45	60	Fair	Exclusive for your group or crew

3.3. Model Specification

Figure 6 shows the HDC model used to study the process of choice of passengers' waterway transportation service. Even we tried the crossover effect between individual socioeconomic variables and the latent variables simultaneously, the specifications tested were not significant.

We modified the specification of the typical HDC model in several ways. In the first place, the latent variables, which typically assume a linear specification, we specified them as exponential models (12).

$$\eta_{lq} = \exp\left(\sum_{r} \alpha_{rl} S_{rlq} + \upsilon_{lq}\right) \tag{12}$$

Secondly, although normally the representative component of the utility also assume a linear specification, we specified it in interaction because of the unlabeled experiment we carried out. In our case, the latent variable "safety" interacts with the variable "hull condition" and the latent variable "comfort" interacts with the variable "travel time".

Finally, due to the few rated responses in the two extreme categories (see Figure 5); we aggregated the responses into a 3-point scale, enhancing the significance of the estimates for the measurement equations.

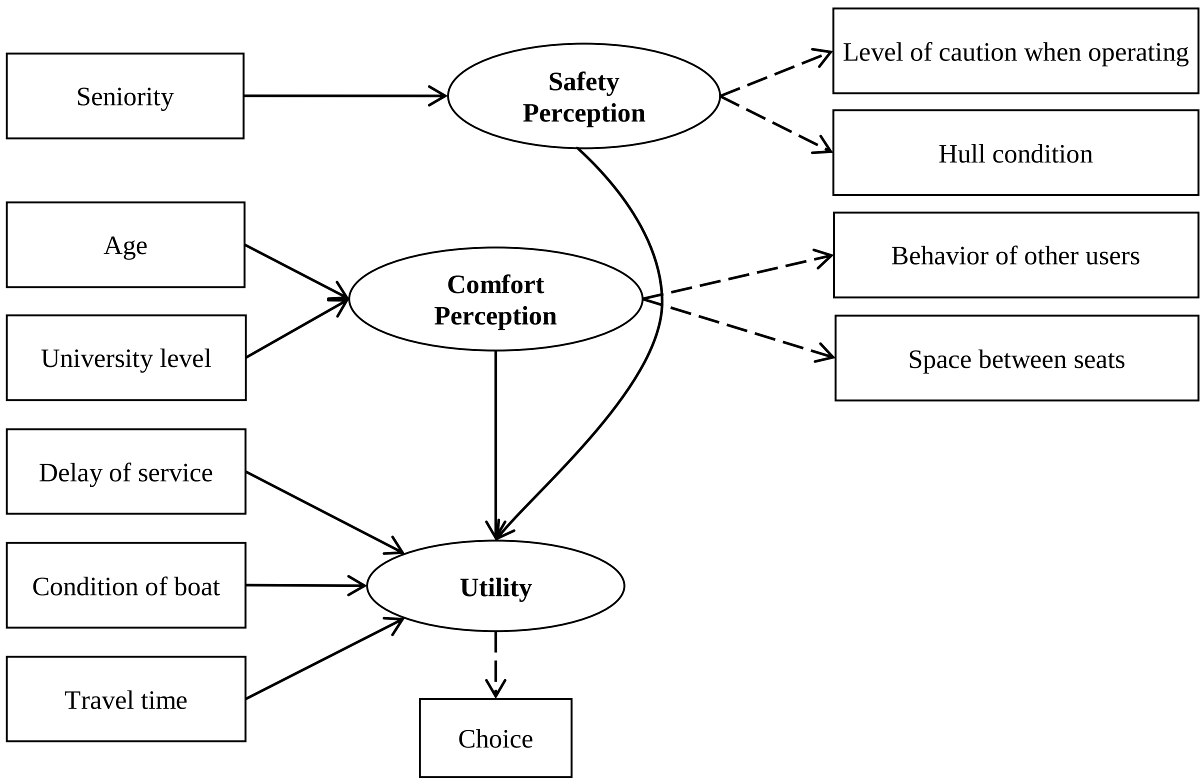

Figure 6. Structure of the HDC Model for Inland Waterway Transportation Users

3.4. Results and Discussion

Table 5 presents the results, showing the HDC model and a mixed logit model (ML). The two models were estimated using 1,000 draws for each random variable and considering the panel effect. The first part of the table presents the estimated parameters of the choice model, the second part shows the parameters of the structural model, and the last one contains the results of the measurement model.

While the indicators used for comfort and safety in this case study are adequate, the structural equation for comfort is not particularly strong because of the limited explanatory variables available for this latent variable. In general, it can be difficult to find causes for the latent variables (Walker, 2001). Analysis of signs and significance of the parameters in the choice model indicates that the "safety" and "comfort" latent variables have a positive effect on the choice. Additionally, a better hull condition increases the perceived utility of the choice and service delays cause the utility to decrease, these two behaviors remain evident.

Table 5. Estimated Model for Inland Waterway Transportation

CHOICE MODEL	**HDC**		**ML**	
Description	**Estimate**	**Rob. t-value**	**Estimate**	**Rob. t-value**
Delayed service	-0.0377	-4.81	-0.0634	-15.60
Boat condition	0.284	3.21	-1.36	-9.26
Travel time	0.1014	7.93	-0.00388	-0.72
Latent variable "safety"	0.899	4.81		
Latent variable "comfort"	0.0021	1.02		
Log-likelihood at convergence	-446.42		-570.90	
Log-likelihood ratio test	716.66		467.69	
STRUCTURAL MODEL				
Safety Perception				
Seniority	-0.420	-1.74		
Comfort Perception				
Age	-0.177	-1.02		
University level	0.484	2.23		
MEASUREMENT MODEL				
Safety Perception				
Level of caution when operating	13.31	1.21		
Hull condition	0.445	1.51		
Comfort Perception				
Behavior of other users	0.331	1.62		
Space between seats	4.154	1.48		
GENERAL REPORT				
Number of observations	1,161			
Number of draws	1,000			
Estimated parameters	20			

All estimated parameters in the choice model were statistically significant at 1%, except for the comfort perception. Comparing the results of the integrated HDC model to those obtained with the ML model, a significant increase in log-likelihood was found, obtaining a likelihood ratio test equal to 248.96, which means a great improvement in the goodness-of-fit thanks to the HDC model. In addition, the sign that reports the ML model for the variable "boat condition" is inconsistent because the rational behavior of individuals might state that the utility increases as the "boat condition" improves.

Unlike the results found in this study, the travel time parameter is obtained typically with a negative sign. In our case, while the service is free, the travel time is part of the working day and for that reason, saving time cannot be relocated to another activity that provides greater utility to the individual. Furthermore, when the normal working day is exceeded due to increased travel time, the company pays its workers overtime, a situation that helps explain the positive sign of the time parameter in the HDC model because that does not represent loss of utility if the employees remain longer in the boat instead of working in the area of mineral extraction. In the ML model, the time sign is negative but not statistically significant.

Regarding the variable delay in the service, it is clear that the conditions under which workers are waiting for the service cause a penalty. The negative sign in the choice model for the delay in the both models reflects this fact. It is necessary to clarify that the waiting is done outdoors and under uncomfortable conditions. In addition, the sign of this coefficient is in line with previous measures of travel time unreliability for transportation services conducted in another context (Arellana et al, 2012).

The structural model indicates that senior workers (> 6 years of service) attach less importance to safety perception when choosing the alternative waterway transportation. As the safety variable interacts with the condition of the boat, it is inferred that senior workers attach less importance to the condition of the boat as they are less concerned about safety compared to other workers.

Although several studies in the field have found significant differences in the perceived risk by gender, age and education (Rundmo *et al.*, 2011; Byrnes *et al.*, 1999; Boholm, 1998; Davidson and Freudenburg, 1996), in our case it was not possible to know how gender affects safety perception because all users are men. Only, seniority proved decisive when explaining the perception of safety in the structural model.

The measurement model shows that safety perception is manifested in the indicator "level of caution when operating". In fact, preliminary surveys of satisfaction that the company had applied before the implementation of this study warned that the lack of caution when operating was one of the key issues to be improved. Likewise, this latent variable is manifested in the indicator "hull condition", although the first indicator seems more crucial due to a higher value of the estimated parameter.

The results of the measurement model indicate that comfort perception is manifested in the indicators called space between seats and behavior of other users. The interaction between comfort and travel time suggests that in the sense that the perception of comfort is improved the workers might experience greater utility in the chosen alternative. The structural model also suggests that the effect on comfort will be higher for young workers (under 38 years) and for those who have a higher level of education (bachelor degree).

The indicators in the measurement model suggest, for the context of waterway transport, that improving the hull condition and the way in which they are operated will produce an increase in the perception of safety for the users. In formulating strategies to improve users' behavior the comfort perception of the given service could be improved; likewise, a more comfortable service could be provided by increasing the space between seats.

Based on the results, we recommend to the CEO of MINEROS perform the following tasks, after the identification of specific individual needs: rebuilding and painting the hulls, changing tents by hard tops with a tilt toward the bow, changing seatbacks, installing upholstered chairs, installing handrail to bow. Besides, we recommended that operators verify the hull condition, on the basis that the boats must remain in perfect condition, to improve the users' satisfaction.

We proposed an education and prevention program aimed at boat's operators. As its name implies, education and prevention are the keys to this program. Since there are never any penalties involved, we considered that it is a great opportunity to learn more about how to improve both the users' satisfaction and boating safety. With respect to safety, the program recommends checking out the safety equipment and other requirements, identifying any problems, and discussing general boating safety issues.

3.5. Conclusions of the Case Study II

This study case demonstrates that perceptions related to comfort and safety are relevant in passengers' choice of waterway transportation services. In addition, the model lets us conclude that senior workers give less importance to the hull condition and safety, while comfort is most valued by young workers and by those users who have a higher educational level. We also found that delays have a negative effect on the attractiveness of river transportation.

The results indicate that the policies to increase the attraction of waterway transportation with respect to comfort and safety attributes must give priority to improving the physical condition of boats, improving boat operation, and improving user behavior.

Several aspects of interest remain for future research. One is to evaluate the impact of port infrastructure on the perception of safety and comfort. Comparing inland waterway with other transportation alternatives is also worthy of investigation.

4. Captive Users: Safety Perception in the Competition of BRT and Motorcycle Taxis

This is the last case based on existing databases. The aim of this chapter is to investigate the attributes influencing the choice process between BRT and motorcycle taxis, popularly called *mototaxis* in some Latin-American countries, including Colombia, to recommend appropriate policies aimed at changing captive user choices.

In contrast to the previous two cases, this one is different in that it incorporates alternative-specific latent attributes for investigating the choice process between BRT and motorcycle taxis. Specifically, in addition to the traditional observable attributes such as access time, travel time and fare, this chapter studies comfort and safety perceptions of riding a motorcycle taxi and a BRT service. Our model only considers captive users, which can provide a better representation of transit choice since it only applies to those who have a choice rather than to the entire population.

4.1. Introduction to the Case Study III

The traditional knowledge about transit users often divides them into two categories: choice and captive users. Choice users, which are also described as discretionary users (Giuliano, 2005), are people with cars; meanwhile, captive users, transit dependent (Polzin et al., 2000) or disadvantaged users (Litman, 2015) are lower-income people who must use transit because they do not own cars. However, far from being captives, people without cars are very sensitive to the quality of service (Jacques et al., 2013), which makes some users opt other alternatives. In some developing countries, especially in those cases in which quality of service offered to captive users is not always a priority for the service providers, some BRT systems have lost ground in relation to informal transportation services (Hidalgo and Díaz, 2014). In other cases, informal transportation systems may be more attractive to users because they offer low costs, high speed and, in many cases, door-to-door services.

Improving informal services (Rahman et al., 2016), integrating them with the BRT (Salazar et al., 2013), or rationalizing them (Chavis and Daganzo, 2013) may be valid options depending on the context of analysis. However, it is becoming increasingly difficult to ignore that the demand for informal transportation services has grown in recent years and today is not just a transportation issue but has become a social problem (Cervero and Golub, 2007). There is increasing concern that many cities in developing countries have to deal with problems of financial self-sustainability of BRT systems and the competition of informal transportation services such as motorcycle taxis, which are the most important option of public transportation system in some developing Asian, African and Latin American countries (Guillen et al., 2013). For instance, motorcycle taxis, which typically carry only one passenger, has become an essential part of the transportation sector in an increasing number of Sub-Saharan African cities (Díaz et al, 2015); also, in some Colombian major cities (Jiménez et al., 2015), where this informal service is illegal.

In comparison with BRT, informal services are certainly less safe, as appears from the high prevalence of traffic accidents involving motorcycle-taxi drivers (Barbosa et al., 2014; Sumner et al., 2014), and possibly less comfortable. The advantages of BRT systems are self-evident. They have resulted in positive impacts due to reductions in operational costs, travel time and traffic fatalities (Wirasinghe et al., 2013; Nikitas and Karlsson, 2015) as well as reductions in air pollutant emissions, particularly for the introduction of cleaner technologies (Galván et al., 2016). Nevertheless, some captive users prefer informal services as can be seen in the metropolitan area of Bucaramanga, Colombia, where the motorcycle taxi service carries about 40,000 passengers per day, representing nearly a quarter of what BRT system transports.

The informal transportation services are problematic to rationalize from a public policy standpoint because of providing important benefits, particularly to the poor people, reason why authorities simply give up in doing anything about them (Cervero and Golub, 2007). However, doing nothing is not a good idea because informal transportation services contribute to congestion and traffic accidents and can produce disproportionate competition, especially in cities with high unemployment, increasing accident rates. In Bucaramanga, Colombia, for instance, the accident rates are correspondingly 1.17 and 3.68 times higher than the national rates of death and injury respectively (Vargas, 2015). Therefore, it is necessary to address the problem.

Some authors point to a need to analyze how transit service factors related to mode captivity and mode choice (Beimborn et al., 2003; Krizek and El-Geneidy. 2007). These works highlight the importance of accessibility and connectivity on captivity and describe how specific transit service characteristics may play out in influencing demand, which is the first step toward ensuring more targeted and equitable policy responses (Jacques et al., 2013). However, far too little attention has been paid to the competition between BRT and motorcycle taxis in developing countries, where captive users should be the focus of consideration.

4.2. Data

With the aim of studying the main factors affecting the choice process between BRT and motorcycle taxis, we used a database from a face-to-face survey conducted in Bucaramanga, in October 2014. The survey consisted of the following parts: socioeconomic characterization of users, the rating of effect indicators and discrete choice experiment. In the first place, we are going to put our data in context.

4.2.1. Context

Bucaramanga is the capital city of the department of Santander, Colombia. The metropolitan area of Bucaramanga has the fifth largest economy by gross domestic product in Colombia and has the fifth largest population in the country with about 1.3 million inhabitants. In contrast with Bogotá, which is a predominantly flat and bike-friendly city, Bucaramanga is a city where cycling is very little used because of its topographic characteristics as well as its hot weather.

The BRT system of the city, called locally *Metrolínea*, started operating eight years ago. Its first phase, which consisted of six lines, came into operation with only a few station stops (Jiménez et al., 2015). Along the BRT system, there are several stops without access control, where users can choose between BRT and motorcycle taxis, especially when the BRT service is slow to arrive. According to the local transportation authorities, the main problems facing the BRT system have to do with low-quality service and, consequently, demand reduction. In fact, the current situation indicates that the system serves less than 50% of the expected transportation demand (Administration of Bucaramanga Metropolitan Area, 2011). Consequently, approximately 40,000 captive users are currently riding motorcycle taxis.

During 2014, the BRT service fare was 1,750 COP (about 0.875 dollars) while the motorcycle taxi fare was 2,000 COP on average (approximately 1 dollar). In contrast to the BRT service fare that is flat and paid by card, the motorcycle taxi fare is negotiable and paid in cash.

From interviews to public transportation users, we observed that normally the travel time of the BRT service was greater than the travel time of motorcycle taxis. In addition, we also noted that the access time, i.e. the sum of walking time plus waiting time, was a key attribute in the choice process because users were not willing to wait long for the arrival of the BRT service, preferring in some cases to travel by motorcycle taxis.

In the same year, Bucaramanga exhibited a rate of 10.05 deaths in traffic accidents per 100,000 inhabitants meanwhile the injury rate was 315.10 (Vargas, 2015). When classifying accidents by mode of transportation, motorcycle riders were in first place with 44.28% of deaths and 50.62% of injuries. Transit users were located well below with 11.38% of deaths and 2.43% of injuries (Vargas, 2015), it being clear that the real risk of accidents for motorcycle users was considerably higher.

4.2.2. Profile of the Captive Users

In the same line of Beimborn et al. (2003), our basic definition of captive users referred to those individuals who do not have a driver's license or do not own a car. In addition to not having a car nor driver's license, all of the respondents in our sample reported having used motorcycle taxis at least once during the last year. Taking advantage of the special feature of the stops without access control, we decided that the best method to adopt for this investigation was to take a sample before arriving at the bus stops. The sample consisted of 236 captive users for whom the motorcycle taxi was part of its transportation alternatives.

Figure 7 shows the sample distribution of the main socioeconomic attributes of the respondents. All of the participants were aged between 17 and 64, with an average age of 28. Possibly because of young people are more likely to perform a risk-taking behavior, respondents aged 20-30 represented almost a half of the sample. In this regard, it is important to notice that people who did not use motorcycle taxis were not included in the sample. With 54% of female respondents and 46% of male, our sample exhibited an acceptably balanced gender distribution.

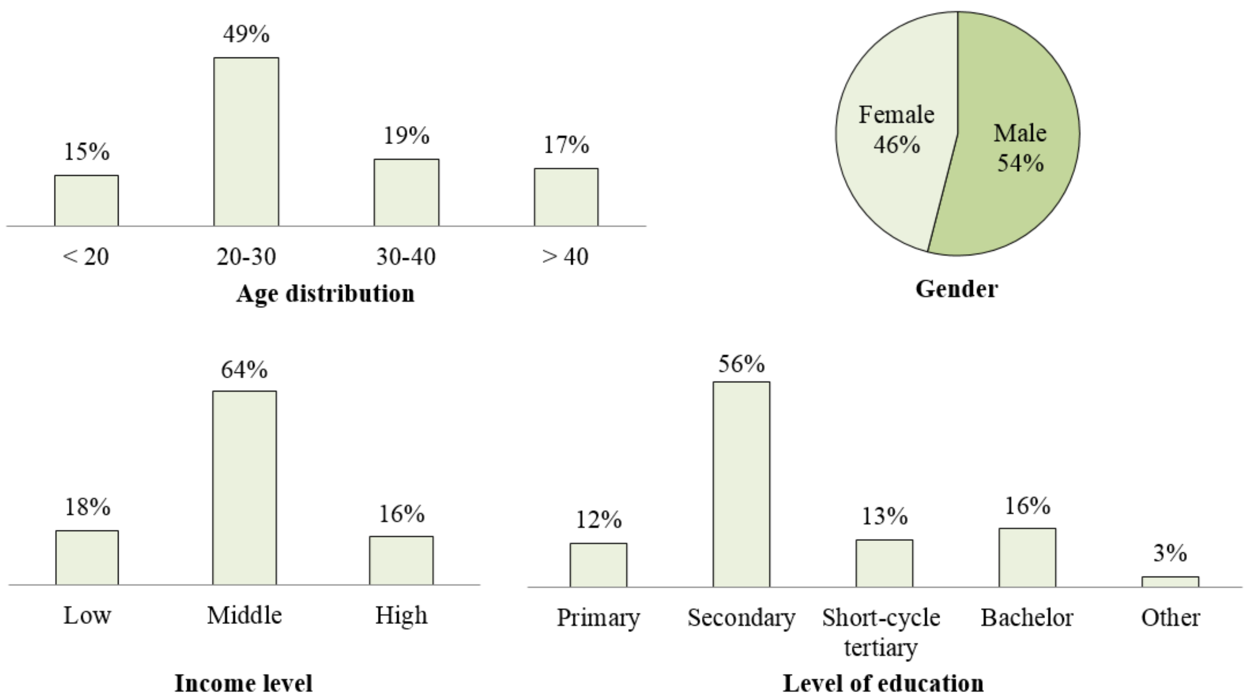

Figure 7. Profile of the Captive Users

Regarding the economic situation of the interviewees, the middle-income group was predominant, which is adequately representative of the studied context, where many poor people are unable to access public transportation services, and the richest people have other transportation alternatives. Finally, regarding the level of education, the majority of respondents had secondary education.

4.2.3. Indicators of Comfort and Safety

We used two set of effect indicators (Bollen, 2002), which emerged in a focus group, to identify the latent variables. We wrote all the statements in Spanish, taking into consideration the main rules regarding indicators design (Johns, 2010).

Respondents rated each indicator on a five-point scale, in which they stated their level of opinion with the given statement. For example, on the indicator "Probability of an accident", we assumed that each respondent had an opinion on how likely it is that an accident occurs when he/she rides a BRT service or a motorcycle taxi. Hence, each respondent picked a relevant Likert point to state such level of opinion. Table 6 summarizes the indicators and their corresponding scales.

Table 6. Indicators of Comfort and Safety for Captive Users

Latent variable	Indicator	Measurement scale				
		1	2	3	4	5
Comfort	I1-Chance to approximate the destination at a planned travel time	Not likely	…	Somewhat likely	…	Very likely
	I2-Passenger comfort	Very poor	…	Fair	…	Very good
	I3-Driver's kindness	Very poor	…	Fair	…	Very good
Safety	I4-Level of compliance with transit rules	Very low	…	Average	…	Very high
	I5-Probability of an accident	Very likely	…	Somewhat likely	…	Not likely
	I6-Probability of injury in case of accident	Very likely	…	Somewhat likely	…	Not likely

4.2.4. Choice Experiment

After rating the indicators, respondents faced a stated preference experiment. According to the study context, the choice experiment assumed that captive users were waiting for public transportation service at bus stops, focusing the study on the three most important observable attributes: access time, travel time and fare. As was evident in the pilot survey, the set of alternatives comprised only two options because users at stops mainly considered the BRT service and motorcycle taxis for commuting (Table 7).

Table 7. Choice Experiment for Captive Users

Attribute	BRT service		Motorcycle taxis	
	Long trips	Short trips	Long trips	Short trips
Access time (minutes)	15	6	5	1
	20	12	10	6
	25	18	15	11
Travel time (minutes)	35	15	25	9
	40	25	30	16
	45	20	35	23
Fare (COP)	1,750		2,000	
			2,250	
			2,500	

In order to present a credible experiment to respondents, the survey provided two scenarios according to the travel time. We pivoted these scenarios based on the user responses regarding their true travel time. Each respondent faced nine choice situations, a number that seems to be optimal in terms of minimizing error variance, thus avoiding an increase of the cognitive burden overload (Caussade et al., 2005). Besides, while the BRT fare remained flat, the motorcycle taxi fare varied into three levels as seen in Table 7.

4.3. Model Specification

To provide a richer explanation of the choice process between BRT and informal services for captive users, we incorporated four alternative-specific latent attributes (Bahamonde-Birke et al., 2015) through structural equations (Ashok et al., 2002):

- Comfort perception of riding a BRT (η_1)
- Safety perception of riding a BRT (η_2)
- Comfort perception of riding motorcycle taxis (η_3)
- Safety perception of riding motorcycle taxis (η_4)

In our case study, since only socioeconomic characteristics explained the latent variables, the structural model allowed for capturing population heterogeneity but no objective changes in the transportation system that might affect perceptions. Although generic estimators may also be considered (Bahamonde-Birke et al., 2015), our specification considered a specific estimator for each of the latent variables.

4.4. Results and Discussion

Our results are based on an empirical chart analysis by diverging stacked bar charts and the modeling results via HDC modeling approach. The empirical chart analysis not only provided us with interesting insights but also helped us to recognize the main socioeconomic characteristics we specified in the structural models.

4.4.1. Empirical Analysis of the Indicators

Figure 8, which omitted the labels for percentages equal to or less than 6%, shows the rating of indicators as diverging stacked bar charts (Heiberger and Robbins, 2014). For each statement, on the right are the percentages of negative opinions, on the left are the percentages of positive views, and split down the middle, in a neutral color, are the percentages of neutral opinions.

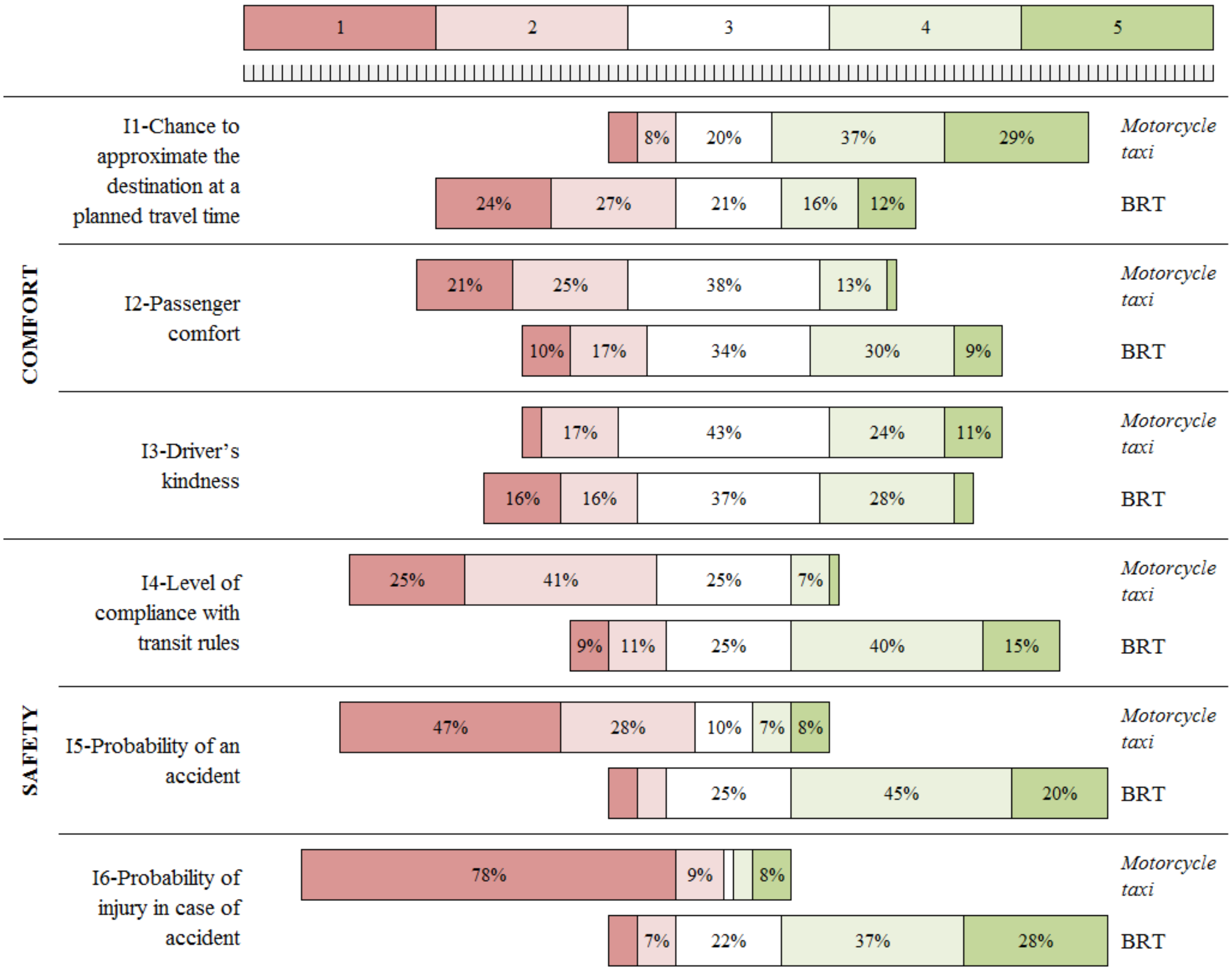

Figure 8. Rating of Indicators for Captive Users

Concerning the first set of indicators, in contrast with the informal service, respondents appeared to have an adverse opinion on the first indicator for the BRT service, thus implying a greater probability of approximating the destination at a planned travel time when they ride motorcycle taxis. Respondents rated the second indicator most favorably toward BRT, stating that, in general, the BRT service seems more comfortable than the motorcycle taxis. Regarding driver's kindness, it seems that individuals are more satisfied with the manners of the motorcycle taxi drivers.

The second set of indicators related safety perception showed very clear positive scores for BRT. This implies that most people are aware of the greater risks of using the motorcycle taxis compared to the BRT service. It is remarkable how many people considered that motorcycle taxis have a high probability of an accident. Likewise, in the case of an accident riding a motorcycle taxi, most of them stated that the probability of being injured was very high.

Figure 9 summarizes the choices according to the main socioeconomic characteristics of respondents. Despite the users perceived BRT being much safer than motorcycle taxi, they chose the alternatives in a balanced way: 48% of respondents chose the BRT service, and 52% of them chose the motorcycle taxis.

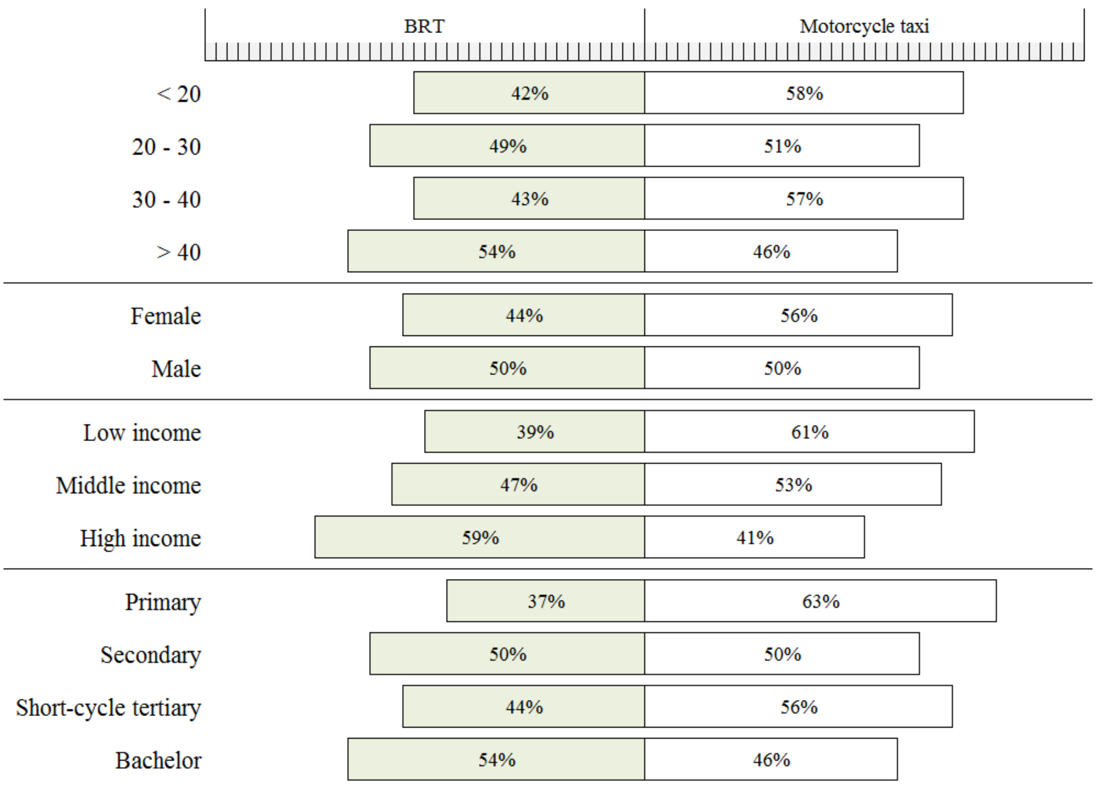

Figure 9. Choices According to Socioeconomic Characteristics

It is apparent that income level is one of the socioeconomic characteristics that most influence the choice. Mainly the high-income people exhibited a greater preference for the BRT service. We observed a similar behavior among individuals over 40 years, who also preferred the BRT service to the motorcycle taxis. Surprisingly, women were more willing to choose the motorcycle taxis than men were. An acceptable explanation of this behavior is that women feel more comfortable than men do when they ride as the pillion behind the motorcycle taxi operator. In general, except persons with secondary education, the data showed that as the level of education increases, the preference of individuals for the BRT service also increases.

Consequently, it is expected that socioeconomic characteristics such as aged over 40, male gender, high income or bachelor studies to emerge as significant variables in modeling.

4.4.2. Model Estimations

Table 8 exhibits the estimates and the robust t-values in round brackets for the structural model. All of the alternative-specific latent attributes only considered socioeconomic characteristics as explanatory variables. The structural model revealed that gender, age, and income are the main socioeconomic characteristics explaining perceptions. Although different model specifications included the level of education as an explanatory variable, this socioeconomic characteristic was not significant in any of the tested specifications.

Table 8. Structural Model Estimates for Captive Users

Latent Variable	Socioeconomic Characteristic	Estimate
Safety perception of riding a BRT	Aged over 40	0.488 (3.50)
	Low income	-0.337 (-2.03)
Comfort perception of riding a BRT	Male gender	0.367 (1.42)
Safety perception of riding motorcycle taxis	Low income	0.332 (2.31)
	High income	-0.202 (-1.13)
Comfort perception of riding motorcycle taxis	High income	-0.938 (-3.77)

The estimated parameters provided interesting insights in line with expectations. Compared with others users, those aged over 40 have more positive safety perception of riding a BRT. Because this service is objectively safer than motorcycle taxis, this behavior coincides with the results of other studies in which older people are usually less willing to take risks (Sullivan et al, 2011; Cantillo et al., 2015). In contrast, low-income people feel the BRT service less safe when compared with other individuals; also, they perceive riding motorcycle taxis to be safer than medium and high-income people are. As was expected, high-income people have a negative safety perception of riding motorcycle taxis. Regarding comfort perception, estimated parameters showed that men are, in average, more comfortable using BRT than women are and high-income people are less comfortable riding motorcycle taxis.

Although the coefficients of measurement equations are not required for evaluating the HDC model in predictive fashion, we examined the overall adequacy of the results. As shown in Table 9, the orientation of indicators is consistent with the expectations. The threshold parameters also being greatly significant, which indicates that the ordered models adequately represented the individuals' opinion on the statements that we captured through the observed responses of indicators.

Table 9. Measurement Model Estimates for Captive Users

Indicator	Estimate	Alternative	Threshold 1	Threshold 2	Threshold 3	Threshold 4
I1	0.980 (5.02)	BRT	-3.289 (-9.15)	-2.325 (-8.18)	-0.977 (-4.89)	0.944 (5.51)
		Motorcycle taxi	-1.171 (-4.93)	0.236 (1.15)	1.311 (5.95)	2.500 (8.82)
I2	0.951 (4.79)	BRT	-1.721 (-7.50)	-0.339 (-2.00)	1.779 (8.32)	3.791 (8.98)
		Motorcycle taxi	-1.748 (-7.59)	-0.526 (-2.53)	1.131 (4.43)	3.079 (7.82)
I3	1.130 (5.28)	BRT	-3.729 (-8.98)	-1.786 (-7.81)	0.639 (3.51)	2.459 (8.39)
		Motorcycle taxi	-1.707 (-6.32)	-0.573 (-2.42)	1.339 (5.34)	3.804 (8.14)
I4	0.676 (5.43)	BRT	-1.079 (-6.08)	0.852 (5.05)	2.644 (10.38)	4.196 (8.88)
		Motorcycle taxi	-2.213 (-9.73)	-1.212 (-7.09)	0.181 (1.20)	2.087 (10.09)
I5	6.818 (1.91)	BRT	0.880 (0.79)	6.473 (1.84)	9.325 (1.95)	11.906 (1.97)
		Motorcycle taxi	-11.279 (-2.36)	-7.967 (-2.46)	-1.933 (-2.21)	6.509 (1.91)
I6	1.670 (7.96)	BRT	2.180 (7.30)	3.075 (9.15)	3.360 (9.48)	3.777 (10.24)
		Motorcycle taxi	-3.543 (-8.49)	-2.424 (-7.76)	-0.554 (-2.53)	1.445 (6.06)

The results of the measurement model revealed that comfort perception was manifested more strongly in the third indicator (Driver's kindness). This finding suggests that, for many captive users, interacting with driver is important. According to information obtained from a focus group, motorcycle taxi users have some kind of greeting before they board and occasionally they will strike up a conversation with the driver during the ride, which makes users feel more comfortable. The measurement model also showed that the fourth indicator (Level of compliance with transit rules) and the sixth one (Probability of injury in case of an accident) manifested more strongly the safety perception.

Table 10 shows the results of the discrete choice models. Both models consider the panel effect produced by having nine different choices per respondent (Cantillo et al. 2007). Unsurprisingly, the HDC model fitted the data better than the mixed logit with panel effect that is a less complex model (Vij and Walker, 2016). All estimated parameters have the expected signs. We found that the BRT-specific constant was positive, suggesting that, *ceteris paribus*, for captive users, the BRT service is preferable than motorcycle taxis. The signs of the coefficients of access time, travel time and fare are in the expected direction: delays, additional travel times or fares that are more expensive reduce the utility of alternatives. Furthermore, the signs of the latent variables indicate that these variables affect utility positively.

Table 10. Discrete Choice Model Estimates for Captive Users

Variable	HDC model	Mixed logit with panel effect
BRT-specific constant	0.388 (1.45)	0.605 (2.26)
Access time	-0.2683 (-14.39)	-0.2656 (-14.21)
Travel time	-0.2045 (-7.75)	-0.2050 (-7.48)
Fare	-0.003784 (-11.68)	-0.003746 (-11.56)
Panel effect	0.869 (2.21)	1.288 (10.70)
Comfort perception of riding a BRT	0.0803 (0.34)	
Safety perception of riding a BRT	0.1182 (2.80)	
Comfort perception of riding motorcycle taxis	0.4642 (2.34)	
Safety perception of riding motorcycle taxis	0.5466 (2.50)	
Log-likelihood	-4,881	
Log-likelihood for the choice component	-1,130	-1,148

We found that safety perception of riding a BRT and both comfort and safety perceptions of riding motorcycle taxis were statistically significant in the HDC model. We also found that when the latent variables are omitted, the BRT-specific constant becomes greater, as shown by results of the mixed logit model. This finding is consistent with the theory because the mode-specific constants capture the omitted information of alternatives (Bahamonde-Birke at al., 2015). Hence, the inclusion of the latent variables improves the explanatory power of the model and the magnitude of the constants decreases.

4.4.3. Policy Implications

Transportation planners are increasingly adopting policies aimed at changing travel choices made by citizens. In this regard, some authors have evaluated a set of policies, ranging from the eradication of the informal services and investment in formal modes, to the complete legalization of such services (Golub et al., 2009). As frequently occurs in other Latin American cities (Hagen et al., 2016), the vulnerability of motorcyclists to traffic injury and death, as well as some cultural aspects of motorcycle use, have forced the authorities to take further measures to make motorcycle taxis safer and improve BRT service. For these reasons, in line with policies adopted in other cities (Qian, 2015), in Colombian cities, motorcycle taxis have become the object of strict state regulation, although in practice the phenomenon is so widespread that its control has become impractical. Within this framework, public transit authorities have considered some measures to reduce the demand for motorcycle taxis and, consequently, decrease the risk of crashes and increasing the demand for BRT.

Unlike other cities throughout the developing world (Sengers and Raven, 2014), in our study context, not many people depend on informal transportation services for their mobility needs. As we have explained, people have formal transportation services, so that the first package of policies could be aimed at restricting the use of motorcycle taxis. However, owing to providing significant benefits to users, such as shorter travel times and greater reliability, informal transportation services are challenging to control by enforcement authorities thus causing serious inconveniences among users that could be transformed into massive social protest and violence.

In some cities, despite protests from some quarters, transportation authorities have banned against people riding as passengers on motorcycles. Depending on the crime levels of cities, this measure is not only aimed at controlling informal transportation services but in some cases also seeks to control delinquency. Nonetheless, because this measure applies to the entire population and not only those who provide informal transportation services, it has a strong negative impact on families using the motorcycle as their main mode of transportation. It is well known that vast majority of people use motorcycles to transport relatives, to work, to go to study or for recreation. Furthermore, regulation banning people riding as passengers on motorcycles would be a useless measurement itself unless authorities implement effective control.

Another possible policy already proposed by national authorities for some cities is to integrate informal services into the BRT systems with the aim to expand the public transportation network in response to growth in population thus ensuring connectivity and easy access to users. In this regard, given that motorcycles taxis are illegal in the whole Colombian territory and authorities have expressed concerns about the users' safety riding them, it would be imperative to consider some alternative vehicle such as the auto-rickshaw, called locally *motocarro*, to feed the trunk BRT service, particularly in low accessibility and demand zones

(Márquez et al., 2017). The idea to use auto-rickshaws as BRT feeders is consistent with using they have had in many developing countries as a form of novelty transportation with low adverse impacts on the environment (Tiwari et al., 2016).

Policies Derived from the Empirical Chart Analysis

Based on the empirical chart analysis, it is possible to suggest some measures aiming at improving the rating of the worst rated indicators of the BRT service. Regarding the first indicator of comfort (Chance to approximate the destination at a planned travel time), we suggest to the authorities to explore the possibilities to establish exclusive lanes for feeder services to reduce the travel time and improve the reliability. Clearly, the BRT service is at a disadvantage with respect to the motorcycle taxi because it has to circulate on infrastructures where the congestion produces a greater effect on the buses than on motorcycles. In our context, exclusive feeder-bus lanes could be of great benefit to supply a fast and convenient access to captive users and make an effective influence on the priority of public transportation even without improving service frequencies.

Regarding the third indicator (Driver's kindness), it is clear that captive users do not perceive BRT drivers to be kindly. Therefore, authorities could train not only BRT drivers but also all the staff for improving communication and customer service, affecting the organizational climate positively for the benefit of users. Besides, authorities should develop and keep effective channels of communication with their users for solving passenger complaints and claims and improving the level of the service delivered to them.

From the data in Figure 9, it is clear that a policy aimed at shifting the use of motorcycle taxis should target young people. It is in this segment of the population that authorities should focus marketing campaigns of the BRT service. For example, authorities could provide transportation allowance for students in public schools and universities by means of the differential reduction of fares through funding from the state, which does not currently occur. Empirical chart analysis suggests that there is also a greater propensity for low-income people to use motorcycle taxis so that this subsidy could also be effectively targeted through the SISBEN (https://www.sisben.gov.co/), which is the Colombian system for the selection of beneficiaries for social programs that classifies the people according to their socio-economic level.

Policies Derived from the Modeling Results

Among observable variables, clearly, access time was the most important factor for captive users. They valuated access time at a level of 1.3 times that of in-vehicle time, which we consider valid in the studied context (see for example Márquez, 2013) although it is relatively low when comparing it with the values reviewed by Diab et al. (2015). It is normal that passengers perceive the access time differently from the actual time because of the exposure to adverse weather conditions and the experience of being stressed by access anxiety (Daskalakis and Stathopoulos, 2008). Although the reduction in access time through improved BRT frequencies is feasible, we also recommend providing passengers with reliable and updated information in real time using information panels (see for example Tavares et al., 2015).

The fare was also an important factor for captive users. Therefore, as we had suggested in the previous section, public transit authorities should consider policy alternatives and strategies for targeting subsidies to low-income users; for example, a targeting scheme that discounts fares for users under a certain income threshold. Obviously, the subsidy should be conditioned to verifiable improvements in the level of service offered. As informal services are less safe than BRT services, when evaluating this strategy, authorities should take into account positive impacts, such as reductions in accidents as well as positive effects on other externalities.

Although fare and travel time are the most significant factors for switching to a motorcycle taxi, it is clear that subjective factors are also important in choosing between motorcycle taxis and BRT service for captive users in Bucaramanga. In this regard, policies should take into account some socioeconomic characteristics such as age, gender, and income level. With the aim of changing the behavior of captive users, authorities should undertake campaigns that emphasize the risks of using motorcycle taxis and highlight the added safety that the BRT service offers. In this line, authorities could focus their efforts on low-income people in order to make them see the benefits of the BRT service, highlighting the added safety that this service offers (see for example Litman, 2014). Furthermore, a campaign of awareness of the risk inherent in the use of motorcycle taxis would be more efficient when focusing on low-income people.

4.5. Conclusions of the Case Study III

This chapter investigated tangible and latent attributes influencing captive user behavior in the face of choice decision between BRT service and motorcycle taxis in Bucaramanga, Colombia. Together with access time, travel time and fare, which are the main attributes traditionally studied, our research considered the perceptions of comfort and safety of riding BRT and motorcycle taxis to provide a better representation of captive user behavior at choosing between these two alternatives.

Our methodology initially supported the formulation of policies to improve the rating of some indicators of the BRT service, such as the chance to approximate the destination at a planned travel time and driver's kindness. Based on an empirical analysis of diverging stacked bar charts we were able to recommend authorities the establishment exclusive lanes for feeder services, driver training programs, development of efficient channels of communication, and transportation allowance for students. Secondly, we used an HDC model to incorporate comfort and safety perceptions through structural equations, finding that gender, age and income are the main socioeconomic characteristics explaining these perceptions.

In our study context, we found that access time and fare were the most important factor for captive users. Regarding latent variables, we found that safety perception of riding a BRT and both comfort and safety perceptions of riding motorcycle taxis were statistically significant in the HDC model. These findings enhance our understanding of captive user behavior and allow us formulating and focusing policies regarding latent variables. As expected, our modeling approach fitted the data better than less complex models that do not consider the effect of latent perceptions.

The only alternative-specific latent variable that was not significant in the choice model was the comfort perception of riding a BRT. Although they emerged in a focus group, the indicators we used to form this latent variable may not have been sufficiently relevant for captive users since perceptions of comfort are usually relevant to BRT users. Further investigation is required into the opportunities for improving the design of indicators. On the other hand, we do not consider the inclusion of tangible attributes linking latent variables, so we were not able to study how changes in alternatives may affect the perceptions of captive users. For that reason, we recommend testing the possibility of including tangible attributes in the latent variable model. The results provided will be the starting point to carry out further investigation to study the influence that policies could have on individual perceptions.

Although vaguely treated in this chapter, an important issue is that captive users are becoming less and less. Mainly because personal income has increased and the motorcycle and car, as private transportation modes, are becoming more affordable. This fact has caused the market share of public transportation (including informal services) to have reduced. Then we consider that the best way to compete and stop the loss of users is to improve the quality of the BRT service so that it is recommended further research to be undertaken in this area, especially in developing countries, where transportation demand must be dealt with in a sustainable manner.

5. Bicycle users: The Influence of Tangible Attributes on Safety Perception

As the three cases previously presented, much research on transportation choices has developed HDC models, in which socioeconomic characteristics normally explain latent variables, capturing in this way the population heterogeneity. In these works, the utility function of the choice model normally captures the effects of changes in the transportation system through the measurable attributes while the model's structural equations only include socioeconomic characteristics. However, few works have studied the effect that tangible attributes have on the latent variables and in consequence, there is still a gap in the use of HDC models for policy evaluation related to latent variables.

To help close that gap, this chapter considers the inclusion of tangible attributes (Bahamonde-Birke et al. 2010) linking latent variables, specifically studying the influence of these attributes on the safety perception of bicycle users. Unlike other studies that have developed structural equation models to analyze safety perceptions of cycling but without considering the effect on choice behavior (see, for example, Chataway et al. 2014), this study develops an HDC model to simultaneously investigate observable factors affecting safety perception and safety perception affecting choice behavior.

5.1. Modeling Cycling Choice Behavior and Safety Perception

Cycling is widely distinguished as an environmentally friendly and healthy mode of transportation (Pucher and Dijkstra 2003). Cycling as an active mode of transportation holds the potential to reduce air pollution and promotes an active lifestyle that in turn improves public health (Mueller et al. 2015). Given the advantages of this mode of transportation, the interest of encouraging its use has been evident, for which it has been essential understanding the behavior of the users. During the last years, growing number of research has focused on studying the behavior of cyclists.

5.1.1. Approaches to Model the Cycling Choices

Discrete choice modeling is a widely used approach to identify and quantify the factors influencing the cycling choice behavior. Using a binary logit model, Ortúzar et al. (2000) studied the use of bicycles in Santiago. They considered the inclusion of a dense network of cycle ways, fully segregated from motorized traffic, and the inclusion of adequate bicycle shelter facilities at Metro, suburban train and selected segregated busway stations. Using a similar approach, Hunt and Abraham (2007) demonstrated that that time spent cycling in mixed traffic, time spent cycling on bike lanes or bike paths, secure parking, and showers at the destination are factors that influence bicycle use in Edmonton, Canada. Tilahun et al. (2007) also estimated a binary logit model to analyze preferences for different cycling facilities using a computer-based adaptive stated preference survey with first person videos. Their results showed that users are willing to pay the highest price for designated bike lanes, followed by the absence of parking on the street and by taking a bike-lane facility off-road.

Wardman et al. (2007) developed a hierarchical logit model for the journey to work with particular emphasis on the propensity to cycle in the United Kingdom. According to their modeling results, the most effective policy would combine improvements in en-route facilities, a daily payment to cycle to work, and complete trip end facilities. Sener et al. (2009) explored the factors influencing the decision to bicycle, using econometric models to evaluate the determinants of bicyclists' perception regarding safety and quality issues, and the frequency of bicycling for commute and non-commute purposes. They specifically used an ordered-response logit model of bicyclists travel perception, and a panel ordered model of the frequency of bicycling. Their study highlighted the importance of a sound understanding of bicyclists' travel perceptions and reasons for bicycling.

Ryley (2006) used a multinomial logit model to determine the propensity to cycle in West Edinburgh, Scotland. The survey included a cycling-based stated preference experiment to choose between cycling and the current mode (e.g. pedestrian, car, bus) for those traveling to work or study. The study considered the population as a whole, instead of focusing on cyclists. Model estimation showed that cyclist facilities, primarily at the destination but also in route, determine the propensity to cycle to work or study. Menghini et al. (2010) also estimated multinomial logit models in a route choice context for bicyclists, demonstrating that it is possible to assess high-quality route choice models for cyclists, from GPS data. Their models captured the heterogeneity of the cyclists through interaction terms with their mean trip characteristics although they did not involve individual perceptions as latent variables.

Recent research has used the HDC modeling approach incorporating the effect of non-observable factors. In their investigation about the willingness to walk or cycle to school in Cyprus, Kamargianni and Polydoropoulou (2013) showed that teenagers' attitudes towards walking and cycling are crucial and significant. They found that active transportation (walking and cycling) is preferred when there are bike paths, bicycle parking places, and wide sidewalks. They also concluded that several facilities could be implemented on sidewalks, elevating the convenience and safety for pedestrians and cyclists, such as bicycle parking places and priority at traffic lights.

Habib et al. (2014) explained some latent variables by socioeconomic characteristics, land use variables, variables related to infrastructure and even other latent variables. They found that it is important to consider the perceptions of people in developing programs to promote cycling and to formulate strategies to maximize the effectiveness of such programs. Specifically, they concluded that greater provision of infrastructure for bike lanes in neighborhoods could increase the perception of safety, resulting in a greater likelihood that residents choose this transportation alternative. Unlike the present work, Habib et al. (2014) did not specifically study the effect of some observable factors related the bike-lanes design on the latent variable. They only explained the latent safety consciousness with infrastructure variables associated with the users' environment, such as the bike-lane density or the proportion of parks in the neighborhood.

Maldonado-Hinarejos et al. (2014) recognized that HDC models have significant potential to consistently predict the impact on the user's behavior like the adoption of certain "soft" policies destined precisely to change the attitudes of people. According to them, one of the potential attractions of HDC models is that they offer a means of controlling for the influence of perceptual and attitudinal factors in model estimation. In addition, they are useful for predicting the impact of policies designed to change the perceptions and attitudes of decision makers on choice behavior (so-called soft measures).

The research conducted by Puello and Geurs (2015) developed a HDC model to analyze cycling as mode choice to access railway stations. They incorporated three latent variables:

perception of connectivity, attitude towards station environment and perceived quality of bicycle facilities. Their results suggest that both observed and unobserved variables are relevant, and show that omitting attitudes tends to lead to overestimation of the probabilities of cycling to the train station. In the same vein, Márquez (2016) also found that conventional choice models overestimate the transportation demand. He did not consider the scenarios with the provision of segregated bike lanes.

Recently, Fernández-Heredia et al. (2016) also proposed an HDC model to study the intention of bicycle use. They grouped the elements that influence bicycle use into users' characteristics, trip characteristics, environmental context, facilities and subjective perceptions. Their structural model comprised four latent variables: convenience, pro-bike, environmental determinants and external restrictions. In their model, thirteen indicators of perception explained those latent variables. As the authors discussed, although these latent variables make sense within the specific case study, they cannot be extrapolated to other cities.

5.1.2. Factors Affecting Cycling Choice Behavior

Table 11 summarizes the most important socioeconomic characteristics and observable factors that influence cycling choice behavior. It shows that personal characteristics (e.g. age, gender, the level of education) affect the use of the bicycle. Other factors related to the household (e.g. income, car and bicycle ownership, and demography), and another set of factors related to the characteristics of the trip and the route (e.g. distance, gradient) are equally determinant. The physical and infrastructure facilities also have a high influence on the willingness to use the bicycle (e.g. existence of segregated lanes, parking places, and shower).

Most studies suggest a positive relationship between aspects of bikeway networks and cycling levels (Buehler and Dill 2016). For example, the interruptions in bicycle facilities at highway interchanges appear to be significant for some users (Stinson and Bhat 2003). Feeder distance for bike users transferring to public transportation also appears significant (Rietveld 2000; Márquez 2016). Moreover, Hunt and Abraham (2007) found that travel time valuation is higher when the cyclist travels in mixed traffic than when travels on bike lanes or bike paths. They also showed that the secure parking has a more positive perception than the presence of showers at the destination.

Table 11. Factors Affecting Cycling Choice Behavior

Factor	Attribute	References
Personal characteristics	Gender	Moudon et al. 2005; Tilahun et al. 2007; Pucher and Buehler 2008; Akar and Clifton 2009; Sener et al. 2009; Pucher et al. 2011
	Age	Ortúzar et al. 2000; Rietveld and Daniel 2004; Moudon et al. 2005; Hunt and Abraham 2007; Tilahun et al. 2007; Sener et al. 2009
	Level of education	Sener et al. 2009
Household related	Income	Dill and Voros 2007; Tilahun et al. 2007; Wardman et al. 2007; Pucher and Buehler 2008
	Car ownership	Ortúzar et al. 2000; Dill and Voros 2007; Sener et al. 2009; Pucher et al. 2011
	Bicycle ownership	Rietveld 2000; Pinjari et al. 2008; Sener et al. 2009
	Household demographics	Tilahun et al. 2007; Sener et al. 2009
Trip characteristics	Distance	Ortúzar et al. 2000; Sener et al. 2009; Menghini et al. 2010
	Travel time	Stinson and Bhat 2003; Tilahun et al. 2007; Wardman et al. 2007; Márquez 2016
	Gradient or hilliness	Ortúzar et al. 2000; Menghini et al. 2010
Physical and infrastructure facilities	Availability and type of cyclist infrastructure	Ryley 2006; Hunt and Abraham 2007; Tilahun et al. 2007; Sener et al. 2009; Menghini et al. 2010; Márquez 2016
	Bicycle facility continuity	Stinson and Bhat 2003
	Safe parking places	Hunt and Abraham 2007
	Showers and other facilities	Hunt and Abraham 2007; Tilahun et al. 2007; Heinen et al. 2010

5.1.3. The Role of Safety Perception

Users' perceptions are key elements to understand bicycle use (Fernández-Heredia et al. 2016) and concerns over safety could be the number one barrier to more people cycling (Fishman 2016; Fishman et al. 2012). Safety is a factor over which transportation policy, particularly investing in cycling facilities, has proved to have a direct and positive influence (Habib et al.

2014; Ortúzar et al. 2000; McClintock and Clearly 1996). For instance, route safety has been identified as the primary factor influencing the decision to bicycle commute (Whannell et al. 2012), and there is consistent evidence that certain facilities improved the perception of safety for people on bicycles (Monsere et al. 2014). However, bike infrastructure-related variables have only been used to endogenously model the safety perception of bicycle users (see, for example, Habib et al. 2014).

Safety is a factor identified by experts to play a major role in the mode choice, and it is a major concern for choosing the bicycle as a mode (Majumdar and Mitra, 2015). For example, while Ortúzar et al. (2000) do not consider the perception of safety, they noticed that safety factor was a recurrent theme in the focus group and in-depth interview surveys and recommended more deeply analyze this variable in subsequent studies. Perception of cycling safety may be more important than objective reality in determining uptake of cycling (Whannell et al., 2012; Heinen et al., 2010). Some authors have stated that a major deterrent to cycling is the perceived level of danger involved (Wardman et al., 2007; Tilahun et al., 2007). Besides, safety perception may be more important for cyclists than the infrastructure itself (Damant-Sirois and El-Geneidy, 2015).

There is evidence that safety perception across cities is different. Heinen et al. (2011) found that the factors “safety” and “awareness” were relevant to the decision to cycle over shorter distances. They also concluded that the importance of such perception might be higher in countries where cycling is less common than the Netherlands, e.g. due to a lacking bicycle infrastructure or a less cycling facilitating attitude of car and truck drivers. In the context of cyclists in mixed traffic between an emerging cycling city and an established cycling city, Chataway et al. (2014) show that safety perception of mixed traffic infrastructure layouts varies among cyclists in Brisbane and Copenhagen. Cyclists in Brisbane feel more fear of traffic and are more likely to adopt cycling avoidance as a coping strategy.

In the Colombian context, Márquez (2016) concluded that safety perception produces a substantial effect on predicting demand for the bike-metro integration. In addition, he demonstrated significant differences in the safety perception of bicycle among users of different modes and, in general, among individuals according to their income level. Modeling results showed that motorcycle users have a higher safety perception of bicycle than car, taxi or public transportation users. However, his study does not investigate observable factors affecting safety perception.

5.1.4. Observable Factors Influencing Safety Perception

Infrastructure is an essential element for improving not only bicycle use and cyclists' safety (Heinen et al. 2010) but also individuals' perceptions of safety while cycling (Carver et al. 2010; Fraser and Lock 2011) and their behavior (Willis et al. 2015). In general, it seems clear that more on-street bike lanes increase a better perception of safety. There is consistent evidence that the protected facilities improve the perception of safety for people on bicycles (Monsere 2014).

Deciding between segregated cycling facilities or shared use paths has been an issue of extensive debate. Although people perceive segregated facilities as safer, encouraging them to cycle (Jacobsen 2015), the literature shows that segregated cycle paths increase accidents where they intersect with roads (Summala et al. 1996; Forsyth and Krizek 2010). People typically indicate a greater likelihood of cycling on various types of separate facilities compared to cycling with motorized traffic (Akar and Clifton 2009; Gossling 2013).

Habib et al. (2014) found that the observable factors with higher statistical significance into the structural model of latent safety consciousness were bike lane density, proportions of residential areas, and the availability of parking zones in the neighborhood. Therefore, bike-infrastructure development programs and policies should focus on increasing bike lanes not only on the main streets but also on the city's overall road network. Specifically, they should concentrate on increasing bike lane density in neighborhoods. They affirmed that increasing on the street and separate bike lanes would have maximum effects on attracting more people to biking in Toronto.

The differences in perceptions of safety are influenced not only by the facilities design, but also by the volume, speed, and behavior of motor vehicle traffic (Monsere 2014). Major streets with shared lanes are associated with greatest perceived risk while shared-use paved paths are considered the safest form of infrastructure (Winters et al. 2012). In general, the use of safety accessories (helmets, high visibility/bright colored clothing and lights/reflective accessories) is not associated with an improvement in the perception of safety but instead is shown to be associated with a decreased safety experience (Lawson et al. 2013).

5.2. Data

We conducted several face-to-face surveys in Bogotá with the aim of studying the main factors affecting the intention to use the public transportation integration on a bike and ride strategy. The instrument comprised the following parts: socioeconomic characteristics, cycling behavior, individual attitudes, safety perception, and discrete choice experiment. The socioeconomic characteristics collected by the survey were the following: Gender, age, neighborhood, income level, car ownership, bicycle ownership, the level of education, and household demographics. Besides, to investigate cycling behavior, we considered some attributes such as frequency of cycling, helmet use, clothing, and use of lights when riding in the dark (Bacchieri et al. 2010; Blaizot et al. 2013; Thornley et al. 2008; Poulos et al. 2012).

5.2.1. Context

The reputation of Bogotá as a bike-friendly city dates to late 1990 when authorities promoted bicycles as an alternative mode of transportation and developed bikeways and other infrastructures. Bicycle use in Bogotá, a predominantly flat city, increased from around 0.5% of daily trips in 1996 to 6% in 2014, after the construction of the first bikeways in 1997. Safety, weather and driver behavior are the main negative factors of biking in the city, while fitness, health, beating car traffic, and environment are the main positive ones. The distribution of different types of bikeways in Bogotá indicates that 62% is on sidewalks, 21% along canal or park, another 11% is in the median of wide roads, and 2% is bike lanes in the road itself (Verma et al. 2015).

In Bogotá, there is one cyclist casualty (injury or death) for every 656,000 kilometers while in Copenhagen, for example, there is one cyclist casualty for every 4.2 million kilometers (City of Copenhagen 2012). Previous studies suggest that improved road safety through bikeway investment, complementary infrastructures, and public awareness campaigns for drivers are needed to improve the perceptions of bicycle users (Verma et al. 2015). The authorities of Bogotá recently discussed infrastructural issues, specifically the city's bikeway network and bicycle integration with Transmilenio, Bogotá's BRT system, concluding that improving and integrating infrastructures and transportation modes should be a central element of bicycle planning (Verma et al. 2015). Regarding infrastructure development, the city policy aim is on adapting existing vehicle infrastructure to increase the length of bike-paths.

5.2.2. Individual Attitudes toward Cycling

The survey considered three individual attitudes toward cycling: risky cycling, pro-bike (Maldonado-Hinajeros et al. 2014), and health beliefs. We required participants to state their level of agreement with the statements in Table 12, using five-point Likert items ranging from "strongly disagree" to "strongly agree."

We measured attitudes towards risky cycling with four items adapted from Iversen's risk-taking attitudes questionnaire (2004) according to the studied context. For example, the item "It is acceptable to drive when traffic lights change from yellow to red" was modified into "It is acceptable to cross even when traffic lights are in the red." Table 2 shows the indicators for individual attitudes toward cycling.

Table 12. Indicators of Individual Attitudes toward Cycling

Variable	Indicator	Statement
Health beliefs	Health01	Cycling improves health
	Health02	Cycling is a good way to get fit
	Health03	Cycling causes other people to adopt a healthy lifestyle
	Health04	Cycling helps reduce stress levels
Pro-bike	ProBike01	Cycling contributes to improving the environment
	ProBike02	I would like to see more bikes than cars on the roads of Bogota
	Probike03	Cycling during rush hour is a good experience
	ProBike04	Cycling is popular in Bogota
Risky cycling	Risky01	Taking some risk does not make me a bad cyclist
	Risky02	Breaking some traffic rules does not make me a bad cyclist
	Risky03	It is acceptable to cross even when traffic lights are in the red
	Risky04	It is acceptable to use the bicycle when I have consumed alcohol

5.2.3. Administration of Tangible Attributes linking Safety Perception

We captured the variability of the observable factors linking the perception of safety through a choice experiment, in which individuals, besides the choice itself, should rate the safety perception related to each choice situation. In the experiment, we varied the tangible attributes and their levels, as follows.

Attribute 1: Buffer type

Buffer, as an extra space separating the bike lane and the standard moving traffic lanes, could influence safety perception. The experiment considered three different buffer types:

- Buffer with planters (see images A, D, G, J in Figure 10)
- Buffer with safe hit posts; that is, plastic posts attached to the street surface (see images B, E, H, K in Figure 10)
- Painted buffer (see images C, F, I, L in Figure 10)

Attribute 2: Vehicle traffic

Additional contexts such as adjacent motor vehicle traffic and facility width might be playing a role in perceptions of safety (Monsere et al. 2014). In this line, the experiment considered two levels for vehicle traffic:

- Only cars (see images B, D, F, H, J, L in Figure 10)
- Buses and trucks (see images A, C, E, G, I, K in Figure 10)

Attribute 3: Bike-lane color

Colored pavement all through the network has been used to give cohesion and homogeneity to the design of bike paths (Marqués et al. 2015). We decided to include this factor in the design because the colored pavement was a recurrent theme in the focus group.

Although some cities have used a green pavement, Bogotá adopted blue pavement within a bike lane to increase the visibility of the facilities and reinforce the priority to bicyclists in potential areas of conflict. The levels of this factor were:

- Non-colored (see images D, E, F, G, H, I in Figure 10)
- Blue pavement (see images A, B, C, J, K, L in Figure 10)

Predetermined attributes

Neighborhood characteristics and certain factors related to infrastructure were predetermined and exhibited no variation during the experimentation. Factors remained fixed, and their levels were:

- Bike two-way width: 3 m

- Buffer width: 1.5 m
- Gradient: 0%
- Parking allowed: no
- Traffic lights: no
- Facility continuity: without interruptions

Administration of the tangible attributes

The literature suggests that use of images for stated preferences choice experiments presents advantages over more traditional representations like text (Hurtubia et al. 2015). Some authors used images (Iglesias et al. 2013; Hurtubia et al. 2015), videos (Tilahun et al. 2007) and cartoons (Duarte et al. 2010) to measure qualitative attributes through stated preference surveys.

In the same line of the mentioned authors, we administrated the tangible attributes in the experiment by constructing images. The combination of all proposed levels for the three variable observable factors produced 12 possible combinations as shown in Figure 10.

5.2.4. Indicators of Safety Perception

The survey involved a set of three statements for each mode to measure the safety perception of the feeder bus and the bicycle (see Table 13). We wrote all statements in Spanish, taking care to use short sentences that were clear and understood by respondents, to obtain information for identification of the latent variable.

Table 13. Indicators of Safety Perception for Bicycle Users

Variable	Indicator	Statement
Feeder bus safety	SafeBus01	Traveling by feeder bus makes me feel safe
	SafeBus02	The interior layout of the feeder bus does a good job at protecting passengers in case of an accident
	SafeBus03	The way as feeder buses are driven makes me feel safe
Bicycle safety	SafeBike01	It is unlikely that a vehicle runs over a cyclist
	SafeBike02	The vehicles could hardly take the bike path
	SafeBike03	I could use this bike path without fear of having an accident

Unlike the indicators proposed for the safety perception of feeder buses that were rated only once; each respondent scored nine times the same three indicators associated with the safety perception of the bike path, according to the orthogonal design showed in the next section. For the bike path case, individuals stated their level of agreement with the statements about the observable factors for the facilities shown in the images in Figure 10.

Figure 10. Images Describing Tangible Attributes Scenarios

The survey also captured information regarding helmet use, clothing, and use of lights when riding in the dark, whose responses allowed for the construction of additional indicators of safety perception of the bicycle. We named these additional indicators as HelmetUse, ClothingUse, and LightsUse.

5.2.5. Discrete Choice Experiment

In addition to tangible attributes already considered, discrete choice experiment further comprised fare and frequency as main factors affecting the intention to use the public transportation integration (Eboli and Mazzula 2008).

We presented fare to respondents as reduced fare promotion to support and encourage intentions to use the bicycle as feeder mode. Frequency was performed as time spent waiting for feeder bus. The choice experiment also involved the influence of distance on cycling as feeder mode (Rietveld 2000; Márquez 2016). We supposed that cyclist infrastructure, bicycle facility continuity, parking, and other facilities were always available. The full orthogonal design is too large to give all choice situations to a single respondent; in consequence, we split the experimental design into four blocks, as shown in Table 14.

5.2.6. Profile of the Bicycle Users

The sample size was 220 people. Table 15 presents the data related to main socioeconomic characteristics of the sample. Although a notable feature of cycling in Bogotá is the disparities of use across demographic categories (Verma et al. 2015), all variables in the sample distributed similarly to the population distributions (National Administrative Department of Statistics 2010). As the sample is wholly representative, it is possible to derive policy implications from modeling results.

Although a helmet and reflective vest must be worn and the bicycle must have reflective panels on the wheels and back, very few people reported using these safety accessories. It is important to note that most individuals stated they had used the bicycle for recreation or sport during the last week, which could be related to the frequency of use of these safety accessories.

Table 14. Experimental Design for Bicycle Users

Block	Image	Buffer	Vehicle Traffic	Bike-lane color	Distance (km)	Travel time difference	Waiting time (min)	Reduced fare (COP)
1	F	Painted	Only cars	Non-colored	1	40%	5	0
1	H	With safe hit posts	Only cars	Non-colored	2	40%	5	0
1	D	With planters	Only cars	Non-colored	3	40%	5	0
1	C	Painted	Buses and Trucks	Blue pavement	2	-40%	5	200
1	K	With safe hit posts	Buses and Trucks	Blue pavement	3	-40%	5	200
1	A	With planters	Buses and Trucks	Blue pavement	1	-40%	5	200
1	E	With safe hit posts	Buses and Trucks	Non-colored	3	40%	15	200
1	G	With planters	Buses and Trucks	Non-colored	1	40%	15	200
1	I	Painted	Buses and Trucks	Non-colored	2	40%	15	200
2	F	Painted	Only cars	Non-colored	3	-40%	15	0
2	H	With safe hit posts	Only cars	Non-colored	1	-40%	15	0
2	D	With planters	Only cars	Non-colored	2	-40%	15	0
2	A	With planters	Buses and Trucks	Blue pavement	2	40%	15	0
2	C	Painted	Buses and Trucks	Blue pavement	3	40%	15	0
2	K	With safe hit posts	Buses and Trucks	Blue pavement	1	40%	15	0
2	L	Painted	Only cars	Blue pavement	1	-40%	5	200
2	B	With safe hit posts	Only cars	Blue pavement	2	-40%	5	200
2	J	With planters	Only cars	Blue pavement	3	-40%	5	200
3	K	With safe hit posts	Buses and Trucks	Blue pavement	3	-40%	15	0
3	A	With planters	Buses and Trucks	Blue pavement	1	-40%	15	0
3	C	Painted	Buses and Trucks	Blue pavement	2	-40%	15	0
3	B	With safe hit posts	Only cars	Blue pavement	2	-40%	15	200
3	J	With planters	Only cars	Blue pavement	3	40%	15	200
3	L	Painted	Only cars	Blue pavement	1	40%	15	200
3	E	With safe hit posts	Buses and Trucks	Non-colored	1	40%	5	200
3	G	With planters	Buses and Trucks	Non-colored	2	40%	5	200
3	I	Painted	Buses and Trucks	Non-colored	3	40%	5	200
4	J	With planters	Only cars	Blue pavement	3	40%	5	0
4	L	Painted	Only cars	Blue pavement	1	40%	5	0
4	B	With safe hit posts	Only cars	Blue pavement	2	40%	5	0
4	D	With planters	Only cars	Non-colored	1	-40%	15	200
4	F	Painted	Only cars	Non-colored	2	-40%	15	200
4	H	With safe hit posts	Only cars	Non-colored	3	-40%	15	200
4	G	With planters	Buses and Trucks	Non-colored	2	-40%	5	0
4	I	Painted	Buses and Trucks	Non-colored	3	-40%	5	0
4	E	With safe hit posts	Buses and Trucks	Non-colored	1	-40%	5	0

Note: In June 2016, when the survey was conducted, the fare of Transmilenio, the Bogotá's BRT system, was 2,000 COP. The exchange rate was 1 USD = 2,800 COP.

Table 15. Profile of the Bicycle Users

Characteristic and variable	Sample	%	Characteristic and variable	Sample	%
Gender			Age		
Male	102	46.4	15-19	30	13.6
Female	118	53.6	20-24	28	12.7
			25-29	27	12.3
			30-34	22	10.0
			35-39	27	12.3
			40-44	30	13.6
			45-49	22	10.0
			50-54	19	8.6
			55-59	14	6.4
			60-64	1	0.5
Size household			Level of Education		
1	24	10.9	Elementary school	17	7.7
2	35	15.9	High school	26	11.8
3	38	17.3	Some college	77	35.0
4	82	37.3	College graduate	83	37.7
5	37	16.8	Advanced degree	4	1.8
6	4	1.8	Other	13	5.9
Income level			Occupation		
Lower	18	8.2	Student	53	24.1
Lower-Middle	96	43.6	Worker	90	40.9
Middle	76	34.5	Self-employed	33	15.0
Upper	30	13.6	Job seeker	31	14.1
			Housewife	3	1.4
			Other	10	4.5
Auto owner			Cycling in the last month		
Yes	53	24.1	Shopping-measures	43	19.5
No	167	75.9	Recreation-sport	148	67.3
			Work-Study	29	13.2
Helmet use			Clothing		
Never	72	32.7	Never	22	10.0
Rarely	86	39.1	Rarely	165	75.0
Sometimes	18	8.2	Sometimes	8	3.6
Very often	31	14.1	Very often	17	7.7
Always	13	5.9	Always	8	3.6
Use of lights in the dark					
Never	196	89.1			
Rarely	9	4.1			
Sometimes	5	2.3			
Very often	6	2.7			
Always	4	1.8			

5.3. Model Formulation

Figure 11 presents the final structure of the selected model. However, we also tested several specifications considering additional socio-economic variables and other combinations of those shown.

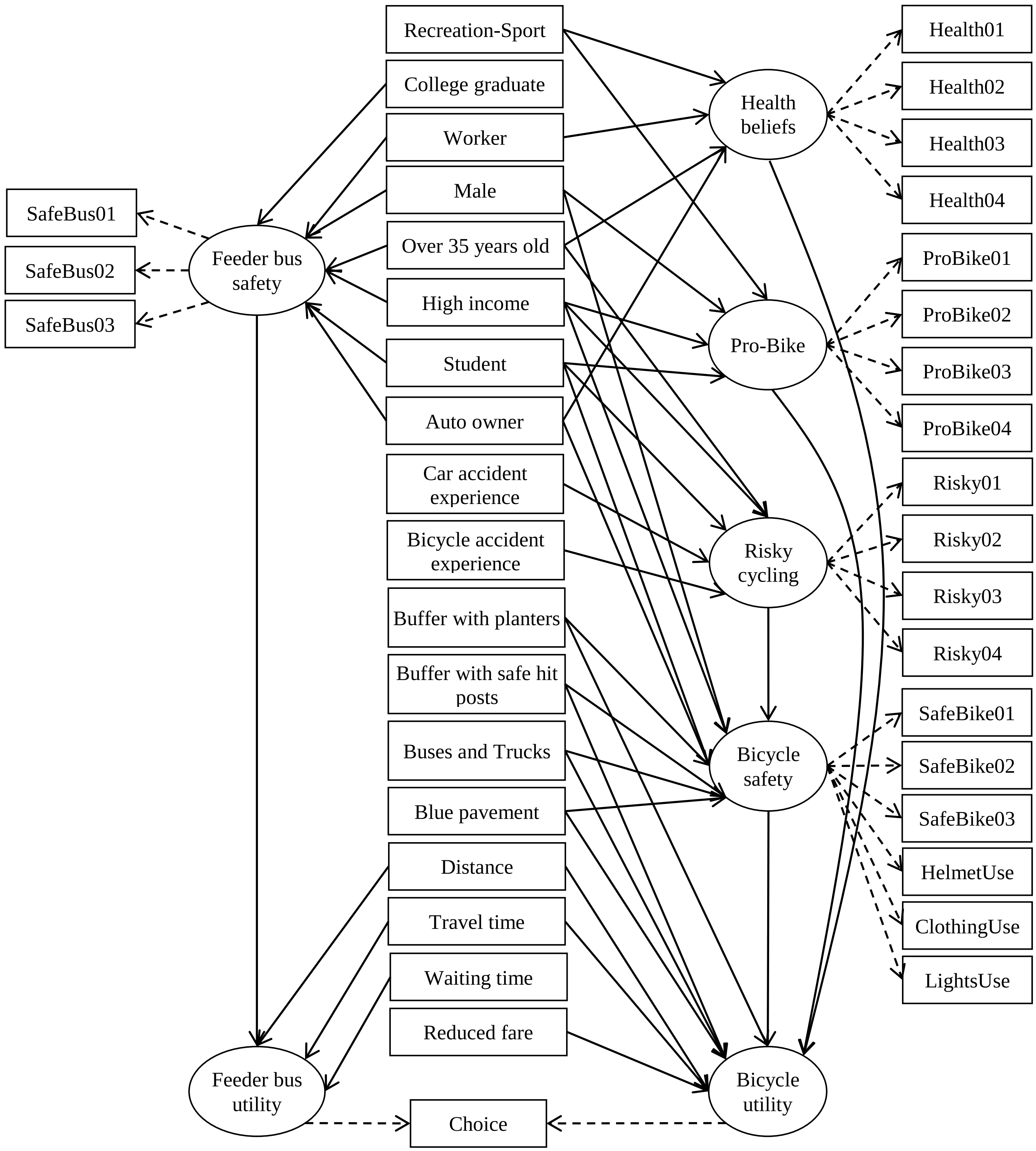

Figure 11. Structure of the HDC Model for Bicycle Users

The first four structural equations defining latent variables (η_l), i.e. Feeder bus safety (η_1), Health beliefs (η_2), Pro-bike (η_3), and Risky cycling (η_4), were specified as a function of observable individual characteristics (S_q) as seen in (1). The specification of the structural equation for Bicycle safety (η_5) is a function of observable individual characteristics (S_q), tangible attributes (B_{htq}), and the fourth variable latent, i.e. Risky cycling (η_4), as seen in (13). In (2), t relates to a choice situation and h to a tangible attribute. The set of parameters $\boldsymbol{\phi}$ must be estimated.

$$\eta_{5q} = \sum_{r} \alpha_{5r} S_{rq} + \alpha_{5r}\eta_{4q} + \sum_{t}\sum_{h} \phi_h B_{htq} + \upsilon_{5q} \tag{13}$$

5.4. Model Estimation and Discussion

We coded the joint likelihood function in OxMetrics (Doornik, 2015), a specialized software for econometric analysis to get the estimation. For simulating the likelihood, we performed 500 drawings for each individual in the sample.

5.4.1. The Structural Equations Model

Table 16 exhibits the estimates and the robust t-values in brackets for the structural model, which was formed by three individual attitudes toward cycling and two alternative-specific latent variables. The individual attitudes toward cycling only considered socioeconomic characteristics as explanatory variables. Instead, the latent variable Bicycle safety, not only examined the characteristics of the individuals as explanatory variables but also some tangible attributes (Buffer with planters, Buffer with safe hit posts, Buses and trucks, and Blue pavement). It is important to notice that the latent variable Feeder bus safety only considered individual characteristics as explanatory variables because the observable factors of this alternative remained fixed for all persons.

The estimation results provided interesting insights. Compared with others, workers over 35, who have own car and using the bicycle for recreation and sport, have more positive beliefs about the benefits of cycling on health. The structural model also revealed that higher-income women who cycle for recreation and sport have a positive attitude pro-bike. It was surprising to find that students have a negative attitude pro-bicycle. Although Maldonado-Hinajeros et al. (2014) had also considered this personal attitude; it was not possible to compare the results of the structural model because they did not report the coefficients in their work. Regarding the latent variable Risky cycling, we found that people under 35 years who have suffered accidents both by car and by bicycle, as well as higher income individuals indicate a less risky cycling attitude. In contrast, students exhibit greater risky cycling attitude.

Table 16. Structural Model Estimates for Bicycle Users

Latent variable	**Explanatory variable**	**Estimate**
Health beliefs	Over 35 years old	1.281 (3.63)
	Auto owner	1.546 (3.62)
	Worker	0.824 (2.45)
	Recreational use	2.705 (5.23)
Pro-bike	Male	-0.835 (-3.12)
	High income	2.859 (5.48)
	Student	-2.891 (-5.88)
	Recreational use	2.793 (5.79)
Risky cycling	Over 35 years old	0.962 (3.11)
	High income	-1.402 (-3.82)
	Student	2.083 (5.93)
	Car accident experience	-2.023 (-5.73)
	Bicycle accident experience	-1.8773 (-7.53)
Bicycle safety	Male	-2.145 (-9.67)
	High income	4.378 (10.36)
	Auto owner	-2.055 (-8.79)
	Student	-1.2167 (-4.41)
	Risky cycling	0.225 (2.17)
	Buffer with planters	0.423 (4.49)
	Buffer with safe hit posts	0.909 (8.63)
	Buses and Trucks	-0.749 (-8.12)
	Blue pavement	1.351 (11.65)
Feeder bus safety	Male	3.204 (4.90)
	Over 35 years old	3.926 (5.82)
	High income	-2.385 (-3.43)
	Auto owner	-2.136 (-5.04)
	College graduate	-3.075 (-4.59)
	Student	1.998 (3.72)
	Worker	5.001 (6.10)

Regarding the latent variable Bicycle safety, both the Risky cycling attitude and the observable factors were found to be statistically significant. The model showed that higher-income women have a greater perception of bicycle safety than other people have. Results suggest that students and auto owners have a lower perception of bicycle safety. Based on the estimated coefficients of the tangible attributes, we found that the blue pavement has the greatest effect on the safety perception of bicycle users. Regarding the space separating the bike lane and the traffic lanes, we found that the buffer with safe hit posts has a greater effect than a buffer with planters or painted buffer, which was taken as the base category. As expected, the traffic of buses and heavy goods vehicles significantly reduces the perception of bicycle safety.

Regarding the safety perception of the feeder bus, the model shows that workers have the greatest perception of the safety of this alternative, followed by men, individuals over 35 years old, and students. In contrast, college graduates, higher-income people, and auto owners have a negative safety perception of the feeder bus.

5.4.2. The Measurement Model

As seen in Table 17, the results of measurement model showed that the individual attitude Health beliefs were manifested more strongly in the indicators Health01 (Cycling improves health) and Health04 (Cycling helps to reduce stress levels). Those indicators are in line with the belief that cycling is a healthy mode of transportation.

Likewise, the attitude Pro-bike was manifested more intensely in the indicators ProBike01 (Cycling contributes to improving the environment) and ProBike02 (I would like to see more bikes than cars on the roads of Bogota) which harmonize with the idea that cycling is an environmentally friendly mode of transportation. The third individual attitude, i.e. Risky cycling, was linked more strongly to the indicators Risky01 (Take some risk does not make me a bad cyclist) and Risky02 (Break some traffic rules does not make a bad cyclist). The above result suggests that some cyclists do have their interpretation of traffic rules leading them to take risky behaviors.

The model shows that the latent variable Bicycle safety was manifested more strongly in the three most important indicators; primarily in the indicator SafeBike03 (I could use this bike path without fear of having an accident). The minus signs of the coefficients of the additional indicators imply that the use of safety accessories is associated with a lower perception of bicycle safety. Because of the methodology used, in which each individual scored nine times, the same three main indicators related to the safety perception of the bike path, the coefficients of the main indicators exhibited greater significance than additional indicators.

Table 17. Measurement Model Estimates for Bicycle Users

Indicator	Estimate	Threshold 1 (τ_{p1})	Threshold 2 (τ_{p2})	Threshold 3 (τ_{p3})	Threshold 4 (τ_{p4})
Health01	0.974 (3.99)	-1.598 (-3.59)	0.280 (0.78)	2.402 (5.41)	6.637 (8.34)
Health02	0.599 (4.13)	-1.391 (-3.91)	-0.148 (-0.51)	1.454 (4.49)	5.197 (10.22)
Health03	0.439 (4.41)	-0.923 (-3.24)	0.077 (0.29)	2.422 (7.57)	4.541 (10.19)
Health04	0.646 (4.42)	-1.217 (-3.30)	0.987 (2.84)	3.476 (7.67)	7.050 (7.88)
ProBike01	1.002 (4.42)	-2.833 (-6.56)	-2.001 (-5.57)	0.247 (0.815)	4.008 (8.55)
ProBike02	0.815 (5.76)	-2.421 (-6.76)	-1.021 (-3.81)	1.013 (3.77)	4.881 (10.45)
ProBike03	0.508 (5.39)	-2.690 (-8.44)	-0.551 (-2.52)	1.448 (6.29)	3.607 (10.94)
ProBike04	0.642 (5.57)	-4.326 (-7.23)	-1.503 (-5.84)	1.222 (4.32)	3.889 (10.06)
Risky01	1.028 (6.67)	-5.016 (-9.13)	-2.297 (-7.49)	-1.392 (-4.94)	1.369 (4.41)
Risky02	1.196 (4.98)	-3.628 (-7.00)	-0.449 (-1.41)	0.265 (0.86)	4.592 (7.87)
Risky03	0.753 (6.63)	-3.531 (-10.27)	-0.715 (-3.18)	-0.158 (-0.70)	2.652 (7.75)
Risky04	0.751 (5.34)	-1.420 (-5.60)	0.865 (3.96)	1.412 (5.85)	4.922 (7.79)
SafeBike01	0.628 (12.30)	-4.566 (-26.18)	-1.085 (-9.19)	-0.355 (-3.03)	3.860 (22.59)
SafeBike02	0.738 (13.62)	-4.407 (-25.12)	-1.181 (-8.58)	-0.416 (-3.10)	3.544 (19.49)
SafeBike03	0.886 (13.98)	-3.925 (-20.22)	-0.413 (-2.56)	0.437 (2.66)	4.977 (22.96)
HelmetUse	-0.136 (-1.32)*	-0.706 (-4.66)	0.967 (6.24)	1.423 (8.08)	2.819 (10.22)
ClothingUse	-0.217 (-2.04)	-2.214 (-9.50)	1.841 (9.10)	2.170 (9.44)	3.410 (9.07)
LightsUse	-0.245 (-1.95)	2.249 (9.19)	2.773 (9.28)	3.207 (9.08)	4.156 (7.89)
SafeBus01	0.454 (5.36)	-1.755 (-4.86)	1.108 (3.83)	1.848 (6.41)	4.476 (11.88)
SafeBus02	0.379 (4.93)	-1.361 (-4.92)	1.138 (4.55)	1.799 (6.97)	4.546 (12.40)
SafeBus03	0.287 (4.74)	-1.065 (-4.38)	1.440 (5.53)	1.839 (6.77)	4.349 (9.98)

* Despite its low significance the indicator was kept in the model, as the sign was consistent with the signs obtained for the other additional indicators

Finally, the results of measurement model also showed that the safety perception of feeder bus was manifested more strongly in the indicator SafeBus01 (Traveling by feeder bus makes me feel safe). In general, all indicators behaved appropriately.

5.4.3. Discrete Choice Model Estimates

Table 18 shows the estimated parameters for the discrete choice model. The numbers in parentheses, next to each variable, indicate the specification of utility functions. The number 1 indicates that the variable was specified in the utility function of Feeder bus, while the number 2 corresponds to the utility function of the Bicycle.

Table 18. Discrete Choice Model Estimates for Bicycle Users

Variable	HDC	MNL
Feeder bus specific constant (1)	1.729 (5.65)	1.973 (6.85)
Buffer with planters (2)	1.146 (6.44)	0.877 (6.35)
Buffer with safe hit posts (2)	1.996 (11.18)	1.824 (12.69)
Buses and Trucks (2)	-1.347 (-9.82)	-1.336 (-11.67)
Blue pavement (2)	1.733 (10.48)	1.486 (12.043)
Distance (2)	-0.307 (-3.48)	-0.238 (-3.46)
Travel time (1, 2)	-0.106 (-5.94)	-0.072 (-3.15)
Waiting time (1)	-0.147 (-10.25)	-0.106 (-8.86)
Reduced fare (2)	0.004 (6.44)	0.003 (5.46)
Safety perception (1, 2)	0.352 (7.50)	
Health beliefs (2)	0.148 (2.60)	
Pro-bike (2)	0.130 (1.94)	
Log-likelihood	-11,537.2	
Log-likelihood for choice component	-877.874	-1,033.5

We found that safety perception and the individual attitudes toward cycling were statistically significant in the HDC model. We also found that, according to expectations, when the latent variables are omitted, the feeder bus specific constant becomes greater, as shown by results of the multinomial logit model (MNL). This finding is consistent with the theory because the mode-specific constants capture the omitted information of alternatives. The inclusion of the latent variables improves the information of alternatives and the magnitude of the constants decreases. However, the specific constant was statistically significant in both models.

All estimated parameters for the discrete choice model have the expected signs. We found that the feeder bus specific constant was positive, suggesting that, *ceteris paribus*, the feeder bus is more preferred than cycling as feeder mode. It is clear that providing blue pavement, buffer with planters, or buffer with safe hit posts, increases the utility of cycling. Instead, the traffic of buses and trucks decrease the utility of this alternative. Likewise, the greater the distance, the lower the probability to choice cycling as feeder mode. The signs of the coefficients of travel time and waiting time are in the expected direction: additional time reduces utility. The positive sign of reduced fare indicates that the higher the fare promotion, the greater the utility. The signs of the latent variables Health beliefs and the Pro-bike attitude as well as the safety perception indicate that these variables affect utility positively.

5.4.4. Discussion: Implications for Policy

Regarding the public policy of adapting infrastructure to increase bike path coverage and its use as a feeder of the BRT system in Bogotá, the model illustrated some relevant aspects. First, buffers with vertical physical objects resulted in considerably higher safety perception levels than buffers created only with paint. Individuals perceive them as an efficient way to real protection from vehicles intrusions. Second, besides giving cohesion and homogeneity to bike paths, colored pavement also increases safety perception. Therefore, using the existing pavement, the authorities can provide an innovative facility for the city, designing the bike lane facilities with these types of buffers and colored pavement. These tangible attributes not only increase the safety perception but also increase the utility of cycling as feeder mode and potentially will increase the number of people cycling. Finally, if the authorities decide to restrict heavy goods vehicles traffic alongside the bicycle lanes, that decision will have a positive effect on the safety perception and possibly increase the use of bike infrastructure.

Authorities should combine new infrastructure design with policy development and promotion to gain new cyclists, encouraging the recreational cyclists to commute and to change attitudes and behavior towards cycling as everyday personal transportation. Therefore, to support and encourage intentions to use the bicycle as a feeder mode, authorities could offer a reduced fare program that allows cyclists to ride BRT for a reduced fare, which may be around 200 COP, as was proposed in the choice experiment. Nevertheless, as cycling is not an option for many disabled and older people, to provide an equitable and inclusive service, we recommend to provide a reduce fare for them as well.

The modeling results showed that individuals who use the bicycle for recreational purposes have a positive pro-bike attitude and have positive beliefs about the benefits of cycling on health. As these two latent variables have a positive effect on the utility of the bicycle as a BRT feeder, we expect that a policy that promotes the recreational use of the bicycle in the city will have a positive impact on the use of bike-BRT integration. While it is important to promote cycling for recreation and sport, there is a specific need to encourage more bicycle as feeder mode. Either through specific cycling-related or comprehensive communication programs, promotion plans that seek to educate, inform and increase awareness on matters concerning cyclists in Bogotá, should be specially targeted to males, students, and auto owners, which have a negative perception of the latent variables pro-bike and safety perception.

5.5. Conclusions

Even though user's perception is a fundamental element to understanding bicycle use, only a few works have modeled the cycling choices by using HDC models. Typically, in these works, simply socioeconomic characteristics link the latent variables to capture the population heterogeneity. Few papers study the effect that tangible attributes of bicycle facilities have on perceptions. In the specific case of safety perception analysis, some authors have explained latent variables via environment variables. Some examples of these variables are bike line density, the proportion of residential area, and the proportion of parks area in the neighborhood. However, due to the insufficient variability exhibited by the observable factors of the bicycle facilities, it is not an easy task to incorporate these factors into the structural equations as explanatory variables. For that reason, rarely HDC models evaluate the influence of tangible attributes on perceptions.

The results clearly showed that while tangible attributes have a significant effect on the utility of the bicycle as feeder mode; it is also true that these factors do have a significant effect on the perception of the safety of individuals. In the case of study, it is clear that the buffer type, the bike lane color of facilities, and the traffic conditions affect the safety perception of individuals. Consequently, the proposed approach allows for the evaluation of policies related to latent variables, being possible study how a certain policy modifies safety perception. Clearly, policies aimed at providing color bike lane will have a substantial positive effect on safety perception of bicycle users. Despite the above, it was also evident that the influence of observable factors on the individual choices comes more strongly to utility than to safety perception. Therefore, depending on the magnitude of the coefficient of the latent variable, it is possible that the effect of tangible attributes through the safety perception is not so crucial for the choice.

6. BRT Feeder Users: Influence of Indicators' Complexity on HDC Model Estimates

One of the most important implications of the experiment we conducted to support the results reported in the previous chapter is that individuals require an additional cognitive effort to rate several times each set of safety indicators. The same applies to a number of papers in which researchers introduce indicators, typically based on Likert items, to allow for the identification of latent variables. It is easy to see how, from one study to another, indicators' complexity, fashioned by the number of indicators for each latent variable, the type of scale and granularity, exhibits remarkable variations.

Dealing with different levels of complexity implies that respondents require different cognitive efforts when choosing a relevant Likert point. This is because regarding the decision process, for each Likert item on a survey, individuals must interpret the statement, recall related facts and memories, interpret the information to form an opinion, and then apply this view to the relevant Likert point. Further, as a Likert item is undoubtedly a set of ordered categories, it is a challenge for modelers to estimate a large number of threshold parameters resulting from greater complexity.

This chapter contributes to the travel behavior modeling literature by being the first to study the influence of indicators' complexity on the HDC models estimation. For this purpose, we designed an experiment that allowed for systematic variations in both the number of indicators and the granularity, which implicitly also determined the type of scale. Hence, for studying the influence of complexity on the error variance of the measurement equations, we specified a heteroscedastic ordered logit model (HOL) in which the scale factor, through an appropriate parameterization, was supposed to be a function of complexity.

6.1. Indicators' Complexity in Transportation Choice Studies

Indicators' complexity, simply named complexity from now on, relates specifically to the number of indicators used to identify each latent variable, the type of scale and the granularity used to measure them. For example, three indicators for each latent variable and a granularity of 5-point correspond to a specific level of complexity. If the granularity used to measure the same three indicators is now 4-point, a different degree of complexity occurs. In this particular case, it does not only change the granularity but also changes the type of scale itself. That is because of 4-point, or any even-numbered Likert scale omits the midpoint, which has significant implications (Garland, 1991; Krosnick et al., 2002; Nowlis et al., 2002; Weijters et al., 2010). Similarly, according to our assumption, the rating of five indicators on a 4-point scale implies a complexity different from the one that would have the measurement of four indicators on a 5-point scale.

In the field of transportation choices, studies based on HDC modeling approach exhibit high differences in their levels of complexity (Table 19). Typically the number of indicators per latent variable varies from two (e.g. Yang et al., 2009; Yáñez et al., 2010; Paulssen et al., 2014) to ten (e.g. Walker, 2001; Soto et al., 2014). Commonly the granularity fluctuates from 4-points (e.g. Di Ciommo et al., 2013) to 10-points (e.g. Duarte et al., 2010; Tsirimpa et al., 2010; Puello and Geurs; 2015; Bahamonde-Birke et al., 2015). Likewise, the most regular practice is to use three indicators per latent variable and 5-point response scales ranging from "Strongly Disagree" on one end to "Strongly Agree" on the other, with "Neither Agree nor Disagree" in the middle. However, there is no consensus on what is the appropriate level of complexity but still choosing a particular level has important implications for respondents and modelers.

6.1.1. Implications for Respondents

From the perspective of the respondents, having to deal with a different number of indicators, types of scales and granularity means that individuals must face several levels of complexity when they rate these indicators. In consequence, they require different cognitive efforts to select a suitable Likert point (Krosnick et al., 2002; Johns, 2005). In terms of the decision process, for each Likert item on a survey, individuals must interpret the statement, recall related facts and memories, interpret the information to form an opinion, and then apply that point of view to the relevant Likert point (Johns, 2005; Krosnick and Presser, 2010). If respondents must face a large number of indicators, they are to become increasingly fatigued as the survey progresses. Furthermore, in some cases, particularly when unmotivated, participants may satisfice and choose the midpoint response (Garland, 1991; Johns, 2005) insofar as the scale used so permits.

Table 19. Complexity in some Transportation Choice Studies

Study	Number of latent variables	Number of indicators	Indicators per latent variable	Granularity
Walker (2001) – Case study 1	2	6	3	5
Walker (2001) – Case study 3	1	10	10	5
Vredin Johansson et al. (2006)	5	20	3 to 5	5
Temme et al. (2007)	3	9	3	5
Yang et al. (2009)	5	13	2 to 3	n.a.
Duarte et al. (2010)	1	8	8	10
Tam et al. (2010)	1	5	5	5
Yáñez et al. (2010)	3	7	2 to 3	7
Tsirimpa et al. (2010)	1	6	6	10
Kamargianni and Polydoropoulou (2013)	2	6	3	7
Di Ciommo et al. (2013)	1	4	4	4
Paulssen et al. (2014)	3	7	2 to 3	5
Comendador et al. (2014)	1	9	9	5
Maldonado-Hinarejos et al. (2014)	4	19	4 to 5	5
Márquez et al. (2014)	2	10	5	5
Soto et al. (2014)	3	22	4 to 10	5
Bahamonde-Birke et al. (2015)	5	17	2 to 7	10
Cantillo et al. (2015)	2	6	3	5
Puello and Geurs (2015)	3	12	4	10
Fernández-Heredia et al. (2016)	4	13	3 to 4	5

When respondents face a Likert item, they first must interpret the statement and deduce its intent. Besides, they must rummage their memories and integrate the information comes to mind into a single judgment to finally translate it into a response, by selecting the relevant Likert point among the responses offered (Krosnick and Presser, 2010). Carrying out this process repeatedly in order to rate several indicators may cause respondents to become increasingly fatigued, disinterested, impatient, and distracted as the survey progresses. Therefore, after having dedicated substantial cognitive effort to rate a certain number of indicators, in accordance with the response behavior called satisficing (Krosnick, 2002), some respondents settle for generating merely satisfactory answers instead of attempting to generate an optimal answer. For example, in the studies of Vredin Johansson et al. (2006) and Soto et al. (2014)

respondents had to rate 20 and 22 indicators respectively, being possible that some of them employed some response strategies to provide a satisfactory answer, such as randomly choosing among the response options offered, among other forms of satisficing.

Another important aspect of Likert items has to do with the type of scale presented to respondents. All odd-numbered scales have a middle option; however, each respondent may have a different interpretation of the midpoint even facing labeled scales. Moreover, when a Likert item confuses respondents and they tend to select the midpoint response, this implies that data will contain a systematic error (Velez and Ashworth, 2007). Nevertheless, when researcher removes the middle option, as in the study by Di Ciommo et al. (2013), respondents are forced to choose either for or against the statement, which eliminates possible misinterpretation of midpoint but respondents could become frustrated, and may not be collecting accurate responses.

In addition to the number of indicators and the type of scale, granularity also has important implications for respondents. From their perspective, the optimal granularity may depend on individuals' cognitive skills and their motivation to provide accurate responses (Krosnick and Presser, 2010). Extra granularity, therefore, becomes hard for respondents to distinguish a relevant Likert point.

6.1.2. Implications for Modelers

When an investigator studies transportation choices through HDC modeling, not only must specify the number of indicators to identify the latent variables but also the statement, the type of scale and its granularity.

When dealing with high complexity, a considerable number of modelers opts for the specification of measurement equations as generalized linear models (e.g. Duarte et al., 2010; Tsirimpa et al., 2010; Puello and Geurs; 2015; Bahamonde-Birke et al., 2015). The standard practice in the literature is to assume that indicators represent continuous response variables (Vij and Walker, 2016). In these cases, the data arising from Likert items are treated as if they were continuous, but these data certainly are not. The issue is that despite being made up of numbers, a Likert item is, in fact, a set of ordered categories, being more natural to think that a couple of cutoffs determines each response option on the basis of respondent's level of opinion (Train, 2009). Consequently, individual responses should be modeled as ordered data because the response levels do have relative position and it is inaccurate to presume that individuals perceive the difference between adjacent levels to be equal, which is a requirement for continuous or interval data.

However, modeling the ordered nature of the data, which in our view is correct, it is a challenge for modelers since the number of threshold parameters to be estimated and computational processing times increase considerably as the complexity grows. The number of thresholds parameters to be estimated (TP) will be equal to the product shown in (1), which depends on the number of alternatives (J), the number of latent variables per alternative ($\bar{L}$), the number of indicators per latent variable ($\bar{P}$) and the granularity (K). For example, in a complex case (5 indicators per latent variable and 10-point scale), the modeler should estimate 45 thresholds per latent variable. Thus, in the typical case of modeling three latent variables, the modeler should estimate 135 threshold parameters per alternative. Finally, considering two transportation modes, the number of threshold parameters to be estimated will be equal to 270, which implies important computational costs.

$$TP = J \times \bar{L} \times \bar{P} \times (K - 1) \tag{14}$$

6.2. Incorporating complexity in the measurement model

According to our definition, complexity involves three dimensions: the number of indicators used as manifestations of the underlying latent variable, the type of scale presented to respondents and the granularity used to rate each indicator. Although it has still not been considered within the framework of HDC modeling, the complexity of experiments do has been studied in discrete choice models applied to transportation (e.g. Arentze et al., 2003; Caussade et al., 2005; Rose et al., 2009; Chen et al., 2016) and other fields (e.g., Swait and Adamowicz, 2001; DeShazo and Fermo, 2002; Dellaert et al., 1999; Dellaert et al. 2012).

In order to incorporate the complexity in the measurement component, unlike practical applications, where the parameter λ is usually normalized to one, we assume that the variance of the random component depends on complexity. In this regard, being λ inversely proportional to the error variance, a more complex rating process will induces higher error rates and thus a lower scale factor. This is because we hypothesize that as responses become more random and independent of the set of parameters in (10), error variance increases. Therefore, through an appropriate parameterization of the scale factor, it is possible to study the influence of complexity on the error variance of the measurement equations. Following the same line of DeShazo and Fermo (2002), our specification considers an exponential functional form for λ to preclude negative scale factors (15).

$$\lambda_q = \exp(\mu_1 P_q + \mu_2 P_q^2 + \mu_3 E_q + \mu_4 K_q + \mu_5 K_q^2 + \mu_6 P_q K_q) \quad (15)$$

Where μ is a set of parameters to be estimated, P is the number of indicators, E is a dummy variable for the even-numbered Likert scales, and K is the granularity.

6.3. Data

We carry out this part of the study considering safety perceptions of riding two alternatives that could become part of a BRT feeder system, which allowed us studying the influence of indicators' complexity on the HDC model estimation. We conducted a survey where respondents were asked to choose between auto-rickshaws and feeder buses in the sector of Soledad, which is part of the metropolitan area of Barranquilla (MAB), Colombia, in November 2015. After data cleaning, the survey yielded 3,780 choice responses corresponding to 420 individuals.

6.3.1. Context

In some Colombian cities, auto-rickshaws, also known locally as *motocarros*, are an important part of urban mobility. Even though they are informal transportation services (Cervero and Golub, 2007), in order to expand the public transportation network in response to growth in population thus ensuring connectivity and easy access to users, national transportation authorities have considered auto-rickshaws to be part of the feeder mode systems, particularly in some marginal urban sectors.

The idea to use auto-rickshaws as BRT feeders is consistent with using they have had in many developing countries as a form of novelty transportation with low adverse impacts on the environment (Tiwari et al., 2016). In our context, national transportation authorities have suggested that the MAB, in which there are about 5000 auto-rickshaws, is the pilot to develop and evaluate this feeder strategy. Although the inhabitants of MAB are familiar with using auto-rickshaws, the authorities have expressed concerns about the safety of the service, reason why it has considered critical to understanding how safety perception affects the choice process.

6.3.2. Description of the Survey

The survey had three parts. In the first place, the survey collected the main socioeconomic characteristics of individuals, such as age, gender, income, relationship to head of household, education level, and vehicle ownership. The survey also asked whether the individual or someone close to him had been in an accident, as well as the most commonly used transportation mode since some studies have shown these aspects to be statistically significant in structural equations explaining safety perception (e.g. Márquez et al., 2015). Then individuals were asked to rate a set of indicators of safety perceptions of riding auto-rickshaws and BRT feeders. Finally, respondents faced a discrete choice experiment between the both alternatives already mentioned.

Socioeconomic Characteristics of Individuals

Figure 12 exhibits the sample distribution of the main socioeconomic characteristics, which conforms sufficiently well to the distribution of public transportation users in the sector of Soledad. Regarding vehicle ownership, 4.5% of respondents owned a car, and 10.1% of them possessed a motorcycle, which showed that most of them were transit-dependent. Reinforcing this idea, 57.0% of individuals stated that transit was the most commonly used transportation mode, followed by informal services (23.9%) and motorcycles (8.3%). The remaining 10.8% represented individuals who stated that they habitually use other modes of transportation. The survey also showed that 19.8% of individuals had been involved in minor accidents, i.e. accidents that just damage to property, and only 1.7% out of the total in serious accidents, i.e. accidents that implicate injuries or deaths.

All of the participants were aged between 15 and 74, with an average age of 36, thus covering a wide range of ages. With 51.4% of male respondents and 48.6% of females, our sample exhibited an acceptably balanced gender distribution. The middle-income group was predominant, which is adequately representative of the studied context, where many people use transit because they do not own cars. The majority of the respondents were household heads and workers since students riding a special school transportation service, which is door-to-door transportation service under the supervision and guidance of a monitor, were not included in the sample. Finally, regarding the level of education, 44.1% of respondents have finished or they are pursuing college studies.

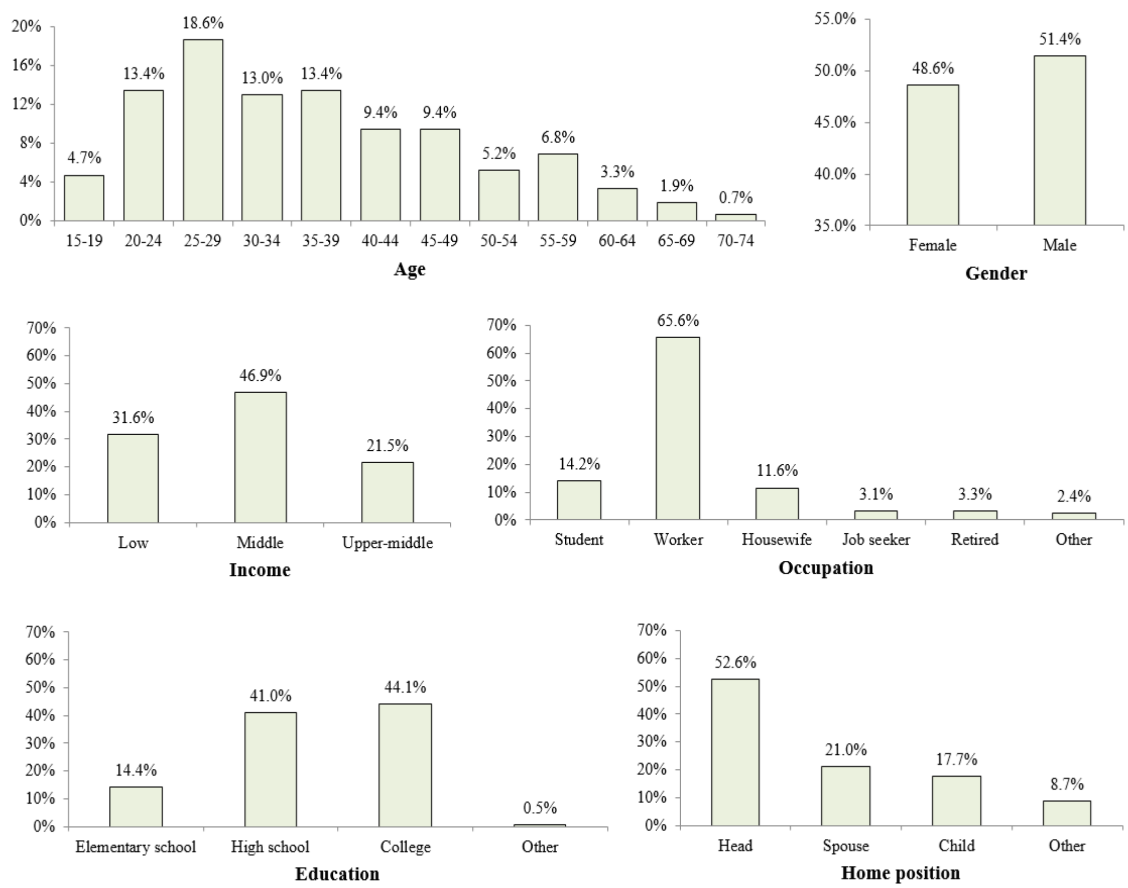

Figure 12. Profile of the BRT Feeder Users

Indicators of Safety Perception of Riding the Alternatives

We defined the safety perceptions of riding the alternatives as *a priori* latent variables (Bollen, 2002). From focus group discussions with users, we selected the effect indicators used to form these latent variables. As a result, the selected indicators involved the three main features in which safety perceptions were manifested: driver behavior, vehicle condition, and interaction between infrastructure and its environment. These features also corresponded to the main factors having influence on bus-involved accidents (Goh et al., 2014). We wrote all the statements in Spanish, taking in consideration the main rules regarding indicators design (Johns, 2010).

We handled the first dimension of complexity, i.e. the number of indicators, at three levels as Table 20 shows. The first level proposed three primary indicators to obtain the manifestations of individuals with regard to drivers, vehicles and interaction between infrastructure and its environment. By dividing each primary indicator into two, the second level proposed six indicators for measuring the level of agreement on the same features but increasing the level of detail. Again dividing each indicator into two, the third level offered to respondents twelve indicators. In this manner, we observed the indicators for each alternative in three different levels of detail, but always measuring the same three features in which we assume safety perception is manifesting.

Table 20. Levels of the Number of Indicators

Level 1	**Level 2**	**Level 3**
3 indicators	6 indicators	12 indicators
I1. [Feeder bus / Auto-rickshaw] drivers drive properly	I1.1. [Feeder bus / Auto-rickshaw] drivers obey traffic rules	I1.1.1. [Feeder bus / Auto-rickshaw] drivers obey traffic lights
		I1.1.2. [Feeder bus / Auto-rickshaw] drivers obey the maximum speed limit
	I1.2. Drivers carefully drive the [Feeder bus / Auto-rickshaw]	I1.2.1. [Feeder bus / Auto-rickshaw] drivers forward to other vehicles dangerously
		I1.2.2. [Feeder bus / Auto-rickshaw] drivers endanger pedestrians
I2. [Feeder buses / Auto-rickshaws] make me feel safe	I2.1. The mechanical condition of [Feeder bus / Auto-rickshaw] makes me feel safe	I2.1.1. The brake system of [Feeder bus / Auto-rickshaw] makes me feel safe
		I2.1.2. The electrical system of [Feeder bus / Auto-rickshaw] makes me feel safe
	I2.2. The design of [Feeder bus / Auto-rickshaw] makes me feel safe	I2.2.1. The interior layout of [Feeder bus / Auto-rickshaw] makes me feel safe
		I2.2.2. The body of [Feeder bus / Auto-rickshaw] makes me feel safe
I3. The neighborhood roads allow for safe circulation of [Feeder bus / Auto-rickshaw]	I3.1. The physical characteristics of neighborhood roads allow for safe circulation of [Feeder bus / Auto-rickshaw]	I3.1.1. The width of neighborhood roads allows for safe circulation of [Feeder bus / Auto-rickshaw]
		I3.1.2. The pavement conditions of neighborhood roads allow for safe circulation of [Feeder bus / Auto-rickshaw]
	I3.2. The traffic flow on neighborhood roads allow for safe circulation of [Feeder bus / Auto-rickshaw]	I3.2.1. The flow of pedestrians on neighborhood roads allows for safe circulation of [Feeder bus / Auto-rickshaw]
		I3.2.2. The flow of motorcyclists on neighborhood roads allows for safe circulation of [Feeder bus / Auto-rickshaw]

As seen in Figure 13, we then varied in four levels the granularity in which respondents rated each indicator. We used the format of a typical Likert item to measure the respondents' level of opinion on a symmetric agree-disagree scale. Taking into account the results of the pilot test and preventing the estimation of a large number of thresholds, the levels of granularity started from the simplest 2-point scale, increasing the number of points until we obtain the most common 5-point scale. In this way, regarding the type of scale presented to respondents, the experiment considered two even-numbered scales that omit the midpoint forcing individuals for choosing among different levels of agreement or disagreement with each statement.

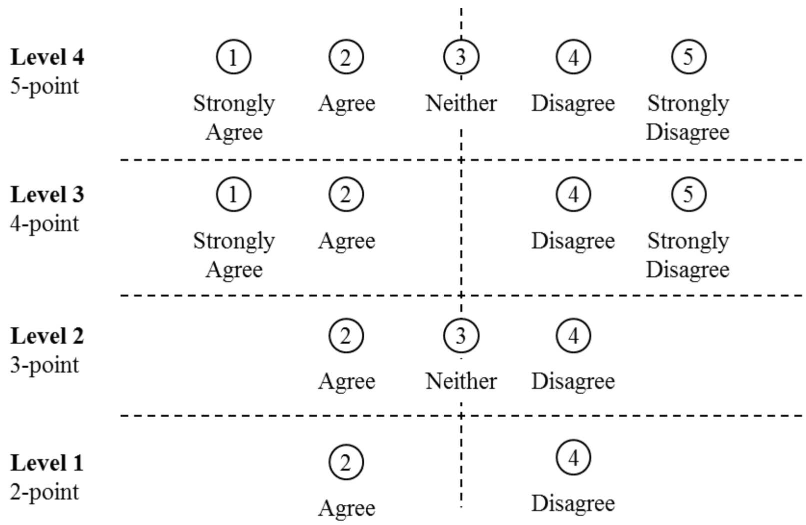

Figure 13. Response Scales for Experimental Design

In order to observe the influence of complexity on the way respondents rated indicators, we used a full factorial experiment design, which allowed us to take on all possible combinations of all levels across all factors, resulting in 12 experimental treatment combinations (Table 21).

Table 21. Experimental Treatment Combinations

Treatment	Number of indicators	Granularity
1	12	5-point
2	12	4-point
3	12	3-point
4	12	2-point
5	6	5-point
6	6	4-point
7	6	3-point
8	6	2-point
9	3	5-point
10	3	4-point
11	3	3-point
12	3	2-point

Implicitly, this experimental design allowed us to observe two even-numbered scales (2-point and 4-point) and two odd-numbered scales (3-point and 5-point). Each respondent faced just one treatment, which was systematically selected to obtain the same number of observations for each treatment. In the most complex case (treatment 1), respondents rated twelve indicators for each alternative on a 5-point scale while in the simplest case (treatment 12), they only rated three indicators for each alternative on a 2-point scale.

Discrete Choice Experiment

After they rated indicators, individuals faced a stated preference discrete choice experiment. Due to the nature of the study, we attempted to design a simple choice experiment. A pilot survey allowed us for the identification of (access + waiting) time and travel time as the most important attributes to include in the choice experiment. We again used a full factorial experiment based on the differences of values of attributes, in which each difference had three levels. As Table 22 shows, the stated preference survey design was finally fashioned by a pattern of nine treatments. Assuming an integrated service into the trunk-and-feeder system, the fare, which would be the same regardless of the feeder service chosen, was not included as an experimental variable. Furthermore, the dimension of the stated choice experiment remained fixed for all individuals to avoid variations related to this part of the survey.

Table 22. Stated Preference Survey Design for BRT Feeder Users

Choice game	Auto-rickshaw		Feeder bus		Differences	
	Access time	Travel time	Access time	Travel time	Access time	Travel time
1	10	20	15	25	5	5
2	10	15	15	15	5	0
3	10	25	15	20	5	-5
4	15	20	15	25	0	5
5	15	15	15	15	0	0
6	15	25	15	20	0	-5
7	20	20	15	25	-5	5
8	20	15	15	15	-5	0
9	20	25	15	20	-5	-5

6.4. Model Estimation

6.4.1. Parameterization of the Scale Factor

Table 23 contains the estimates for the parameterization of the scale factor. The best model considered a linear and a quadratic effect for the granularity, a linear effect for the dummy variable related to even-numbered Likert scales, and an interaction between the granularity and the number of indicators. Note that our best specification did not include either the linear or the quadratic effect of the number of indicators because we were not able to identify them from our data. Nevertheless, this does not imply these effects should not be entered complexity if it is going to be studied in other contexts.

Table 23. Estimates for the Parameterization of λ

Variable	HOL model
Granularity	0.6847 (3.34)
Squared granularity	-0.0854 (-3.07)
Even-numbered Likert scale	-0.1983 (-3.09)
Granularity * number of indicators	-0.01210 (-1.61)

Estimates showed that even-numbered Likert scales had a negative effect on λ, contributing to a higher error variance. This is possibly because even-numbered Likert scales force individuals to exert cognitive effort thus countering participant tendencies to satisfice (Krosnick et al., 2002). We would like to draw attention to some authors claiming that even-numbered Likert scales induce persons to think about their true feelings on the subject without changing their thoughts (Garland, 1991) and they force individuals to use what they perceive to be the most important point of an argument to make a choice (Weijters et al., 2010). However, omitting the midpoint may impair validity, because some people opt for any available option when they have no basis for choosing between agreement and disagreement (Johns, 2005).

Figure 14 illustrates the effect of the variables considered on the scale factor. Despite the number of indicators was not statistically significant, the interaction between the granularity and the number of indicators produced a negative effect on the scale factor. Consequently, given a certain granularity, for example, a 3-point Likert scale, it is possible that a greater number of indicators produce that picking a relevant Likert point becomes more random. In our case study, the use of the three main indicators would be preferable, instead of disaggregating them into 6 or 12 indicators as all the indicators used to refer to the same three main indicators, i.e. driver behavior, vehicle condition, and interaction between infrastructure and its environment. Therefore, it seems unnecessary to increase their level of detail.

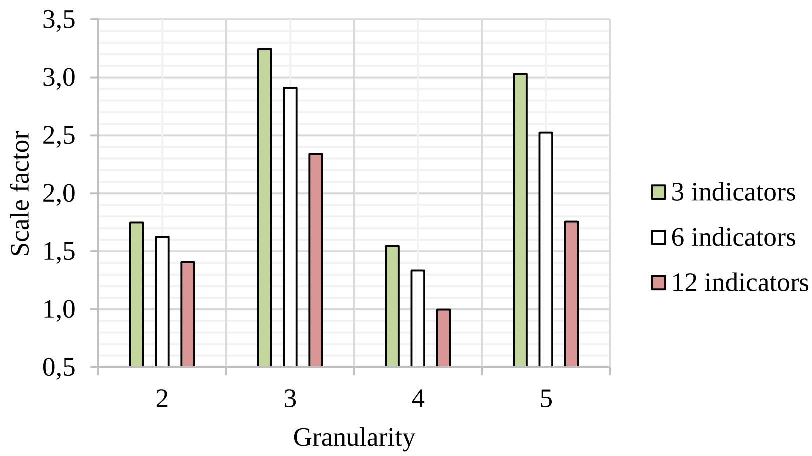

Figure 14. Value of λ versus Number of Indicators and Granularity

It is possible that by introducing a greater level of detail in the indicators, respondents facing a Likert item fail to correctly interpret the statement and deduce their intents. For example, although news reports in MAB, frequently mention accidents caused by electrical failures or in the brake system (e.g. Maintenance of feeder buses in sight, 2014; Feeder bus torched in Soledad, 2015; Feeder bus burned would have been short-circuited, 2015), not all people correctly perceive whether or not these mechanical systems are safe. Instead, a more general indicator related to the mechanical condition of the vehicle would facilitate the statement rating by the respondent, thus avoiding their fatigue, disinterest, impatience or distraction as the survey progresses. Similar arguments could be issued for the other sets of indicators.

6.4.2. Structural Model Components

It is important to note that the structural model, as usual, only specified socioeconomic characteristics as explanatory variables because our experiment did not consider variations on the modal attributes when respondents rated the indicators. Nevertheless, it is clear that, in general, safety perception also depends on the alternatives because any variation in their attributes may lead to a different valuation of perception (Bahamonde-Birke et al., 2015).

Therefore, the results we presented here are valid for the conditions in which the service was provided at the time of the survey.

Several specifications considering additional socioeconomic variables were tested, but Table 24 only presents the estimated parameters of the selected models. The estimates for both the heteroscedastic (HOL) and the homoscedastic components exhibited consistent results and their interpretation leaded to the same deductions. Modeling results showed that the safety perception of riding an auto-rickshaw depends on income while the safety perception of riding a feeder bus depends on education, vehicular possession and the condition of being a regular motorcycle user. Unlike other studies conducted in similar contexts, in which age and gender have been statistically significant (Márquez et al., 2015; Soto et al., 2014), none of these variables significantly explained the variations in safety perceptions in the present study.

Regarding safety perception of riding an auto-rickshaw, the model showed that low and middle-income individuals have a greater safety perception than other people. In other words, the poor people have a greater perception of the safety of riding an auto-rickshaw. With respect to the safety perception of riding a feeder bus, the model showed that elementary-education individuals, car owners, and motorcycle users have a negative perception. That is to say that the most educated individuals, who do not own cars and who are not habitual users of the motorcycle, are those that have a greater safety perception of feeder bus.

Table 24. Structural Model Estimates for BRT Feeder Users

Latent variable	Explanatory variable	HOL measurement component	Homoscedastic measurement component
Safety perception of riding auto-rickshaws	Low income	0.3585 (2.64)	0.6178 (3.77)
	Middle income	0.2675 (2.08)	0.5152 (3.29)
Safety perception of riding feeder buses	Elementary school	-0.2536 (-1.48)	-0.2391 (-1.73)
	Car owner	-0.9614 (-2.44)	-0.4222 (-1.68)
	Motorcycle user	-0.5238 (-3.60)	-0.4390 (-3.75)

Although the coefficients of measurement equations are not required for evaluating the HDC model in predictive fashion, we examined the overall adequacy of the results. We found the orientation of indicators to be consistent with the expectations. The threshold parameters also were greatly significant, which indicated that the ordered models adequately represented the individuals' opinion on the statements that we captured through the observed responses of indicators.

6.4.3. Discrete Choice Model Estimates

Table 25 reports the results of estimating the discrete choice component of the models. Although several interactions between observable attributes and socioeconomic variables were tested, none of them was statistically significant. After presenting the variables included in the models, the following two columns contain the coefficients of the estimated HDC models and the last column contains the results of a multinomial logit model, usually estimated as a reference. All estimated parameters for the discrete choice models have the expected *a priori* signs.

The feeder bus specific constant, which captures the average effect on the utility of all factors that are not included in the model, was found to be positive, suggesting that, *ceteris paribus,* the feeder bus is more preferred than auto-rickshaws as feeder mode. The estimates for observable attributes, all of them specified as generic variables, show that increasing any component of time decreasing the utility of the alternatives. As expected, passengers do perceive access and waiting time to be more important than travel time. Although the values of walking or waiting time on transit trips are considerably larger than that of in-vehicle time, by ratios from two to three (Small, 2012), in our case, the ratio was only 1.7, as in Abrantes and Wardman (2011).

Table 25. Discrete Choice Model Estimates for BRT Feeder Users

Variable	HDC models		MNL
	HOL component	Homoscedastic measurement component	
Feeder bus specific constant	0.6447 (4.05)	1.4839 (6.12)	0.8464 (9.54)
Access + Waiting time	-0.5098 (-15.87)	-0.4809 (-16.55)	-0.4052 (-19.61)
Travel time	-0.3096 (-14.17)	-0.2875 (-14.91)	-0.2410 (-16.73)
Safety perception of feeder bus	1.0606 (7.19)	1.3055 (4.44)	n/a
Safety perception of auto-rickshaw	0.4416 (3.98)	0.6307 (1.68)	n/a
Log-likelihood	-7,213.6	-7,215.2	n/a
Log-likelihood for choice component	-1,579.7	-1,612.6	-1658.51

The safety perceptions entered utility as alternative-specific latent attributes, thus estimating a different coefficient for each of them. Modeling results showed the latent variables we specified to be statistically significant, which means that safety perception of riding an auto-rickshaw and safety perception of riding a feeder bus affect positively the utility of the alternatives. In general, the latent variables appears to explain a significant portion of the variability captured by the alternative specific constant, improving the goodness-of-fit of the model. It is not surprising that estimates of latent variables were smaller when we estimated the heteroscedastic model. According to (6), this just goes to show that these estimates are directly affected by the scale factor.

Notwithstanding the two discrete choice sub-models were equivalent for the two estimated HDC models, i.e. the both had identical specification and the same explanatory variables included, it is remarkable that the choice sub-model fitted the choice data better when we parameterized the scale factor in the measurement component. This empirical evidence suggests that complexity not only affects the measurement component, which was already obvious, but also it has an important effect on the goodness-of-fit of the discrete choice sub-model. These empirical findings add substantially to our understanding of the influence of indicators' complexity on HDC model estimates.

6.5. Conclusions

In addition to the usual requirements of stated and revealed preference data, the estimation of HDC models requires observing indicators to allow for the identification of latent variables. The common practice is to design certain number of indicators, usually based on Likert items, which are conformed by a statement and a response scale. Although the modelers mostly ignore the implications of the indicators' complexity on the estimation of HDC models, it is clear that the number of indicators per latent variable, the type of scale and the granularity used to measure them do affect the error variance of the measurement component as well as the other model estimates. The lack of attention on this issue is due in part to the decision to model the individual responses as if they were continuous when a Likert item is, in fact, a set of ordered categories, which considerably reduces the number of parameters to be estimated. However, given that complexity has important implications for respondents and affects the estimates of the discrete choice sub-model, the modelers should guide their efforts to design the indicators in the best way possible.

Our approach is consistent with the respondents' decision process facing a Likert item, according to which they must interpret the statement and deduce its intent, then remember any relevant information, integrate it into a single judgment, and translate that judgment into a response by picking a relevant Likert point. As respondents must repeat this process many times as necessary, depending on the number of indicators to rate, our specification assumed that if complexity increases, then responses become more random and independent of the set of parameters in measurement models and the latent variable itself. Therefore, our specification reflects that a more complex rating process induces higher error rates and thus lower scale factor. Although this study focused on the safety perceptions of riding auto-rickshaws and bus feeders, our approach can be generalized to study other contexts of choice on the HDC modeling framework.

Our findings revealed that the type of the scale, the granularity and its quadratic effect as well as the interaction between the granularity, and the number of indicators, affect the error variance of the measurement component. Although the number of indicators was not statistically significant, its interaction with granularity suggests that, given a certain granularity, a greater number of indicators may cause responses to be more random. One of the more significant findings to emerge from this study is that odd-numbered Likert scales, which are widely used in transportation choice studies, appear to have an incremental effect on scale factor, contributing to a lower error variance. However, based on the information gathered and the calibrated models, it is possible to conclude that using 3-point response scales seems more advisable than 5-point ones.

Properly understanding safety perception is a crucial step toward creating programs and information campaigns to raise awareness and make transportation systems safer. Although vaguely treated in this chapter, there may be a relationship between news media exposure and safety perception. It is perhaps not surprising then that some individuals become to feel unsafe using a feeder bus, for example, after reading a negative news in the local media concerning a traffic accident involving that transportation mode. Therefore, it seems reasonable to add one more dimension to the construction of the latent variable model to further study the impact of news media exposure, also as a latent variable, on the safety perception. From the perspective of decision makers, adding this new dimension to latent variable model is also interesting for studying the effect of campaigns via TV commercials and advertisements in newspapers, on the safety perception. These issues should also be considered in further research.

7. Conclusion

Although we outlined the specific conclusions in each chapter, we believe it is appropriate to present a summary of them in an integrated form and even in connection with the extensions of the study.

7.1. Overall Conclusions

According to our guiding philosophy, this dissertation has given an account of the influence of safety perceptions in travelers' behavior, in five choice contexts. In the first place, we studied the drivers' behavior in a choice context in which they were to decide whether they would use their cell phone while driving. Subsequently, we considered not only the safety perception but also the comfort perception and their influence on inland waterway transportation users' behavior. In the third place, our study focused on the safety and comfort perceptions in the competition of the BRT service and motorcycle taxis. We then investigated the bicycle users' behavior in a context of integration as feeder mode in a BRT system, incorporating individual attitudes toward cycling in addition to safety perception. Finally, we studied safety perceptions of riding both feeder buses and auto-rickshaws as alternatives that could become part of a BRT feeder system.

We corroborated the basic hypothesis of the investigation, finding that safety perceptions influence travelers' behavior in a broad array of choice contexts. Except for the first case, in all other ones, we found, as expected, a vast improvement in the goodness-of-fit thanks to the incorporation of latent variables. In the first case concerned the mobile phone use while driving, we just found a slight improvement in the goodness-of-fit of the HDC model. However, the study has shown that the incorporation of the latent variable improve the representation of the individual behavior reflecting the effect of the safety perception on the choices made, which allow us to propose policies aimed to shift the use of less safe transportation modes.

In contrast to the standard practice in the literature, we considered the ordered nature of the data and simulated the likelihood in a simultaneous way by using the OxMetrics software package. Owing to the computational costs, when dealing with simpler cases, we employed

1,000 random draws to depict the probability distributions associated with the latent variables while, for more complex cases, we used 500 random draws. This was a challenge for us, in particular because in the most complex cases we had to estimate a considerable number of parameters, estimating the models multiple times to deal empirically with the identifiability issues of them. Depending on the case, the estimation time varied significantly about either hours or days. Notwithstanding the above, we believe this effort is justified in having obtained consistent and unbiased estimators.

We demonstrated that safety perception can be modeled in the traditional way but also modifying the original specification of the HDC model in many ways, deeming them more appropriate for certain specific contexts. In the first case, the latent variable entered the utility function of a mixed logit model, in which the fine was supposed to be normally distributed. The first variation we considered was to estimate the model with interactions between safety perception and observable explanatory variables in the utility specification and to include a non-linear specification for the safety perception, as shown in the second case study. In the third case, we incorporated safety perceptions as alternative-specific latent attributes in the traditional way. Further, we estimated an HDC model with hierarchical relationships between the latent variables, such as the fourth case in which the structural equation for the safety perception included another latent variable as an explanatory variable. Finally, we specified a heteroscedastic model in which the scale factor, through an appropriate parameterization, was supposed to be a function of the indicators' complexity.

The modeling results of the different case studies showed that several socioeconomic characteristics affect safety perceptions. In general, gender, age, income level, educational attainment, and occupation of the people, are the main socioeconomic characteristics explaining safety perceptions. In some cases, in which the income level was not significant, car ownership emerged as a significant variable explaining safety perceptions. Individual experiences also appeared to explain safety perceptions. For example, if the individual has been fined, if he/she has been or almost been in an accident, or if he/she has some experience riding a specific type of vehicle, are variables influencing safety perceptions. All these variables should be considered when taking data to study safety perceptions. We also demonstrated that some tangible attributes related to alternatives explain safety perceptions.

The work suggests that stated preference experiments can be extended to analyze how certain combinations of observable factors may affect individuals' perception. Results show that it is possible to model the influence of tangible attributes on the safety perception of users if the observable factors are properly administrated in the survey. In this regard, it is important to try to identify a priori which observable factors are relevant to the perception and treat them properly. Additionally, with the aim of exploiting the advantages of images over traditional representations like text, we strongly recommend their use to administrate the tangible attributes. However, as these observable factors make sense within the specific case study, they cannot be generalized to other systems, being recommended to take into account the conditions of the context studied before replicating the experiment.

Throughout the case studies, we used a broad range of effect indicators. In the first case study, we formed the latent variable by measuring three indicators in different response scales, two of these on a 3-point scale, and the other one on a 2-point scale. In the analysis of inland waterway transportation, we used two indicators per latent variable, which initially were rated on a 5-point scale but finally aggregated into a 3-point scale to enhance the significance of estimates. In the following two cases, by using a 5-point scale, we used three indicators per latent variable to analyze captive users' behavior as well as the safety perception for bicycle users. At the end, self-motivated by the wide range of the number of indicators per latent variable and response options used in transportation choice studies as well as in our case studies based on existing databases, we conducted an experiment to examine the influence of indicators' complexity on model estimates.

In this regard, based on an experiment that allowed systematic variations in the number of indicators and the granularity, which at the same time implicitly determined the type of scale, we modeled the indicators' complexity via the parameterization of the scale factor of the measurement component. We found that the type of the scale, the granularity and the number of indicators per latent variable, affect the error variance of the measurement component. Our findings suggest that odd-numbered Likert scales contribute to a lower error variance so that we strongly recommend the use of this type of response scales instead of the even-numbered ones. Although our findings require further research, based on our analysis we consider that using 3-point scales seems more advisable than 5-point ones. Likewise, our experimentation suggests that the use of three indicators per latent variable is preferable, instead of using a further level of detail to form the latent variable.

7.2. Future Research

In every case study, we identified issues and suggestions for future research. In the first case study, for instance, we proposed a new experiment including an additional option and an additional latent variable to better explain the behavior of individuals by phoning while driving. In the second case, we considered that it is important to evaluate the impact of the infrastructure on the perceptions of inland waterway transportation users. To that end, we recommend designing an experiment based on images in a similar way we administrated the tangible attributes linking safety perceptions we presented in Chapter 5.

We also recommended further research to be undertaken in the perceptions regarding the BRT services, especially in developing countries, where the market share of public transportation to have reduced. An important issue we highlighted is that captive users are becoming less and less, being necessary to improve the quality of the BRT services hence, it requires further research into the effectiveness of policies affecting perceptions. In this case, we also recommend testing the possibility of including tangible attributes to study how changes in alternatives may affect the perceptions of captive users.

Finally, we considered reasonable to add one more dimension to the construction of the latent variable model to further study, for instance, the impact of news media exposure, also as a latent variable, on the safety perception. Clearly, individuals are more likely to protect themselves when they anticipate negative consequences, have the desire to avoid them and feel they have the ability to take preventive measures. Therefore, safety perception could be a function of many factors such as anticipated consequences, past experiences, and confidence, among others, that could be treated as latent variables linking safety perceptions.

Overall, our results show that it is necessary to further investigation into numerous issues, including the following.

7.2.1. Applications

The first issue is simply that more experience with applications is necessary to uncover related issues and to better understand the analysis of the influence of safety perceptions in travelers' behavior. Further research may include the specific consideration of motorcycle drivers take into account their growing rate in Colombia. In fact, the number of motorcycles today exceeds the number of autos and exhibits the highest accident rates, yet there are few studies regarding this kind of vehicles.

We also recommend investigating the use of pedicabs that although they are not regulated in any Colombian city, travel with passengers in the streets of large cities such as Bogota. Many of these vehicles supply the demand for transportation in neighborhoods, especially as BRT feeders. However, the question is whether citizens feel safe in them and if people are in favor of these vehicles are regulated.

7.2.2. Data

One of the key issues of the analysis of safety perception is to make use of the indicators that can form adequately the latent variable. We found that modelers mostly ignore the implications of the indicators' design on the analysis of latent variables and we demonstrated that the number of indicators, the type of the scale and the granularity affect the error variance of the measurement component. Specifically, we showed that odd-numbered Likert scales contribute to a lower error variance and we conclude that using 3-point response scales would be advisable. However, we are aware that the implementation of our findings requires further research.

We consider that some aspects of the experiment we used to study indicators' complexity could be improved. In the first place, it is unnecessary to use 12 indicators to form the latent variable so that any new experiment should vary the number of levels only in the range of 2 to 5. Concerning the granularity of the response scale, we recommend the removal of the 2-point option in order to reduce the number of experimental combinations.

8. References

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