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Wrecked by Work? Examining Work-Related Motorcycle Crashes in Colombia

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Examining Work-Related Motorcycle Crashes in Colombia

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Master of Urban and Regional Planning

by

Manuel Santana Palacios

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ABSTRACT OF THE THESIS

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Master of Urban and Regional Planning

University of California, Los Angeles, 2015

Professor Paavo Monkkonen, Chair

In many developing countries motorcycles are used not only for personal travel (commuting, leisure, etc.) but also to deliver documents and small commodities (e.g., food) or to provide taxi services. Incomes of these commercial motorcyclists are generally based on the number of services they are able to provide within a given amount of time. Some have suggested that this incentive might induce commercial motorcyclists to engage in risky behaviors – that is they might be more likely to drive fast and break traffic laws in order to maximize income. To empirically test for differences between commercial and non-commercial motorcyclists, I estimated a logistic regression model using data from a survey conducted by the Development

Bank of Latin America (CAF) between 2012 and 2013 in Bogota and Barranquilla, Colombia.[1] My results support the hypothesis that motorcycles used for commercial activities and whose income is generally based on the number of services they are able to provide are at a higher risk of being involved in a crash. The probability of being involved in a crash is higher when using motorcycles for taxi services than when using motorcycles for non-commercial purposes or for commercial activities other than courier or taxi services (after controlling for exposure, demographic characterizes, vehicle features, and other possible explanatory variables, though this finding may be affected by a possible reporting bias by those providing (illegal) taxi services). By contrast, motorcyclists who provide courier services have neither a higher nor lower probability of being involved in a crash compared to those riding motorcycles for non-commercial purposes or for commercial activities other than courier or taxi services. Other variables associated with crash occurrence include age, owning the motorcycle, and riding in Bogota. While I see evidence that the financial incentives of being paid per job motivate risky driving behaviors among commercial motorcyclists, better data and further research are needed to fully understand the causes of differential crash risks among types of motorcyclists.

[1] The findings, interpretations, and conclusions expressed herein are those of the author and do not necessarily reflect the views of the Development Bank of Latin America (CAF)

The thesis of Manuel Santana Palacios is approved.

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Martin Wachs

Paavo Monkkonen, Committee Chair

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2015

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1. Introduction

Motorcycle use is growing at a fast pace worldwide. It is estimated that there are 313 million motorcycles in the world, 77 percent of which are in Asia, 16 percent in North America and Europe and 5 percent in Latin America (Haworth, 2012). According to the World Bank, in 2002 Latin America had approximately 7,810,500 mopeds and motorcycles, equivalent to about 18 motorcycles per 1000 inhabitants. In Colombia, in 2003 nearly 50,000 new motorcycles were sold, sales rose to 450,000 in 2008 ("CFPV," 2012). While some might view this increase in motorization as an expression of freedom and economic development, there are also some important negative outcomes such as pollution, traffic congestion, and safety.

One of the most important negative consequences of the rise in motorcycle use is the high rate of crashes, and high mortality rates compared with other transportation modes. Mortality rates per distance traveled among motorcyclists are 35 to 40 times higher than those of automobile occupants (Jamson, 2009; NHTSA, 2009). Road safety improvements have been hailed as one of great public health achievements of the twentieth century in the United States, but between 1997 and 2005 the total number of fatalities for motorcycle crashes doubled, from 2,116 to 4,553 fatalities (Dee, 2009). According to Ecola, Collins, & Eiseman (2010), over the past 10 years, the number of registered motorcycles and fatalities in the United States has increased at similar rates while the vehicle miles traveled (VMT) on motorcycles has remained unchanged, suggesting that riding a motorcycle is riskier now than it was a decade ago. Motorcyclists' deaths from traffic crashes in Brazil declined from 50 per 10,000 inhabitants in 1996 to 32 per 10,000 inhabitants in 2005, but death rates remain high if compared to the national rate of deaths from all motorized vehicle traffic crashes (225 per 10,000 inhabitants in 2010) (Holtz & Lindau, 2009). In

Colombia, although the number of fatalities from traffic crashes declined 60 percent between 1996 and 2009, motorcyclist deaths increased from 25 percent of the fatalities in 1996 to 44 percent in 2009 ("CFPV," 2012).

Besides being a popular transportation mode among mid-to-low income population groups, motorcycles also represent a source of income for those in urban areas in the developing world who do not have well paid work opportunities (Montezuma, 2010; Sanchez, 2011). According to a study in Sincelejo, Colombia, 38 percent of new motorcycle buyers stated that they planned to use their vehicle for commercial purposes in order to increase their income (Sanchez, 2011). Courier or taxi services are two examples of the jobs people with two-wheelers are able to access, and the incomes from these jobs can double the minimum wage (Sanchez, 2011).

The use of motorcycle-taxis has been encouraged in some cities around the world, such as Madrid, Caracas, and Bangkok, where such services have been allowed and regulated. In 2005, the government of Thailand established the first policy on mototaxis by creating additional safety regulations and establishing fares, among other provisions. These policies benefited drivers as their income increased due to the higher fares (Oshima et al., 2007). In Colombia, the demand for this service is example of the increasing trend where travelers prefer the motorcycle-taxi's low fares and reduced travel times when compared with other modes such as buses or regular taxis (Sanchez, 2011). In Sao Paulo the "motoboys" as they are called offer goods delivery for a lower rate and faster delivery time than traditional services. In Sao Paulo, motorcycle sales increased in part because of the increase in the demand for motorcycle delivery services. Between 1985 and 1997, 65 percent of new motorcycles in Sao Paulo were used for work (Vasconcellos, 2005). In Bogota and Barranquilla two-wheelers that are used for commercial

purposes represent approximately 40 percent of the motorcycles fleet.

In Latin America, motorcyclists who use their vehicles for commercial purposes generally do not get paid by the hour, instead their income is based on the number of services they are able to provide in certain amount of time (Development of Latin America, 2013; Domecq & Sarmiento, 2015). For example, motorcycle-taxi drivers' income depends on how many passengers they carry each day. At first glance it seems logical that this race against the clock will incentivize motorcyclists to speed and perform risky maneuvers in order to maximize their income. In fact, some blame motorcyclists who use the vehicle for commercial purposes for the high crash rates in Latin America (Domecq & Sarmiento, 2015; Kieling et al., 2011; "Las motos y su más grave pecado," n.d.; Petersson, 2010). However, this is speculative, as no rigorous research on this topic has been done. Commercial motorcyclists might potentially be more skillful than private motorcyclists in riding motorcycles through crowded urban environments because they have more riding experience. Additionally, because the vehicle is as an income-generating asset for these workers, we can also hypothesize that that motorcyclists who offer delivery or taxi services will avoid risky behaviors so as to not crash and damage their source of income.

To provide empirical evidence for the possible differences between these two groups of motorcyclists (commercial and non-commercial), I estimated a logistic regression model using data from a survey conducted by the Development Bank of Latin America between 2012 and 2013 in Bogota and Barranquilla, Colombia ("CAF," 2015).[2] The survey contains information regarding motorcycle usage (taxi and courier services, or non-commercial uses such as commuting or recreational trips), vehicle characteristics, crashes and perception of safety, among

[2] CAF also conducted surveys in Buenos Aires, Caracas and Sao Paulo. Only surveys conducted in Barranquilla's Metropolitan Area and the city of Bogota were used in this research.

others.[3] A logistic regression using sampling weights and controlling for different factors (exposure, age, gender, motorcycle's engine size, license, training, automobile and motorcycle ownership, insurance, cost and safety perception, etc.) was used to test the hypothesis that motorcyclist who use the two wheeler for commercial purposes have a higher probability of crash occurrence.

In support of my hypothesis, the results obtained in this study suggest that the probability of being involved in a crash when using the motorcycle to provide taxi services is higher than those who use the motorcycle for non-commercial purposes or for commercial activities other than courier or taxi services (after controlling for exposure, demographic characterizes, vehicle features, and other possible explanatory variables). Motorcyclists who use their vehicles to provide courier services do not have a higher or lower probability of being involved in a crash when compared to those that use their motorcycles for non-commercial purposes or for economic activities different than providing courier or taxi services. It could be possible that there was a crash reporting bias on the part of this group of motorcyclists vis-à-vis private riders. Additionally, young motorcyclists (17-25 years) have a higher likelihood of getting involved in a motorcycle crash when compared with motorcyclists more than 25 years old. Motorcycle ownership is associated with a higher likelihood of getting involved in a crash when compared with those who were using a two-wheeler borrowed from a friend, relative or provided by the employer. As in the case of motorcycle couriers, it might be possible that non-owners underreported crashes. Finally, riding in Bogotá, versus riding in Barranquilla, is associated with a higher probability of being involved in a crash. More research is needed to better understand

[3] Although users of other transportation modes were surveyed (transit and automobile users, bicyclists, etc.), I used only those surveys applied to motorcyclists for the purpose of this research.

the reasons of the differences in the probability in crash occurrence between commercial and non-commercial motorcycle users, in order to design better policies that reduce crash rates among motorcyclists. The results obtained here are an important starting point.

2. Description of survey venues

2.1. Bogota

Bogotá is the capital and largest city of Colombia with approximately 6,800,000 inhabitants as of 2005 ("Censo General 2005," n.d.). The city lies is s 8,660 feet above sea level on a mountain plateau in the eastern mountains of the Andes. Bogotá has a subtropical highland climate, with average temperatures of 43 to 66 °F on fair skies days, to 50 to 64 °F on heavy rain. The rainiest months are April, May, October and November; the average precipitation in those months is 5.3, 4.7, 5.4 and 5.0 respectively ("Promedios Cifras Meteorologicas," n.d.). Trips by public transportation account for 40 percent of total daily person trips (28% in collective buses and 12% on TransMilenio bus rapid transit). Approximately 28 percent of daily trips are by foot, followed by automobile (15%), taxi (5%), bicycle (4%) and motorcycle (3%) (CCB, 2014). Average travel time is approximately 60 minutes on public transit and 30 minutes by car (CCB, 2014). Average speed for automobiles and collective buses is approximately 12 mph ("Bogotá pierde siete millones de horas al año en trancones," 2015).

2.2. Barranquilla

Barranquilla's Metropolitan Area[4] is located in the northern Caribbean Coast region of Colombia and had approximately 1,800,000 inhabitants as of 2005 ("Censo General 2005," n.d.). Much warmer than Bogota, the city's average daytime high temperature is 80 to 83°F. The warmest

[4] Hereinafter Barranquilla

months are July and October, and the rainiest are May, September, and October, with average precipitation of 3.5, 5.0 and 5.7 inches respectively ("Promedios Cifras Meteorologicas," n.d.). The comparatively wet weather in Bogota and Barranquilla and correspondingly slick streets can be treacherous for motorcyclists. Trips by public transportation represent 49 percent of total daily trips. Approximately 16 percent are by informal transportation (e.g. motorcycle taxi or pedicab), followed by foot (13%), in automobile (11%), taxi (5%), motorcycle (3%), and bicycle (1%) (Unviersidad del Norte, 2009).

3. What do we know about motorcycle crashes?

The motorcycle safety literature has evolved since the early studies published more than five decades ago. The focus of studying the effects of safety elements such as helmets or headlamps has changed towards research related to risk perception. An important part of the recent literature is dedicated to identifying relationships between demographic characteristics and risk perception as well as the effectiveness of training to modify risky driving behaviors. Researchers have also studied differences in crash rates between motorcycle riders and drivers of other motor vehicles and factors associated with crashes among motorcyclists that use the vehicle form commercial purposes. Despite that, there is no evidence that using the motorcycle for commercial purposes is associated with a higher likelihood of crash occurrence than non-commercial users.

3.1. More than three decades of research in motorcycling safety: shifting of approaches and main theories

Motorcycles are proven to be dangerous for occupants as well as for other road users. After the boom in motorcycling in the Western world in the 1960's, several researchers have tried to understand the causes of motorcycle crashes (Chesham, Rutter, & Quine, 1993). Based on peer reviewed literature from the 1940s to the 1990s, Chesham et al., (1993) divided motorcycling safety research in three periods based on the type of analysis conducted: the period of crash analysis, the period of riding analysis, and the period of motorcyclist behavior analysis.

3.1.1. The period of crash analysis

The first period of research about motorcyclist, spanning the 1970s, was dominated by crash analysis. Crash analysis' focus was to understand what factors are associated to crash outcomes, generally physical elements such as use of safety helmets. Robertson (1976) compared crash

statistics from eight American States that had legislated compulsory helmet use for motorcyclists with eight that had not. He found that the "average fatal involvement rate" for those states that required helmet use declined approximately 30 percent after the year the legislation was enacted, whilst there was no decline of this rate from states without helmet laws. Subsequent studies have concluded that safety helmets contribute significantly to reducing the risk serious injuries (Dee, 2009; Hurt & Dupont, 1977; Newman, 1973). Other factors associated with motorcycle crashes found in research conducted in the 1970's include: daytime use of headlamps (Andersson, Nilsson, & Salusjarvi, 1976; Janoff & Cassel, 1971; Waller & Griffin, 1977; Williams, 1976), and drink-riding (Baker & Fisher, 1977; J. W. Graham, 1969; Williams & Hoffmann, 1979).

3.1.2. The period of riding analysis

By the late 1970s research moved away from identifying what physical elements are associated with crashes to "riding analysis," which take into account the actions and performances of the motorcyclist (Chesham et al., 1993). Most of the research identified as "riding analysis" during the 1980s was focused on skills testing and training evaluation (Chesham et al., 1993). Effectiveness of riding training is discussed below

3.1.3. The period of motorcyclist behavior analysis

As a result of the controversial findings regarding the effectiveness of motorcycling training during the 1980s and 1990s, a period in which the rider begun to be seen as an 'active agent' emerged. A considerable body of research about risk perception and modification of risk taking levels have been developed since then. Much of the recent body of research has its origins in the social psychological literature on the role of beliefs and attitudes in human action (Chesham et al., 1993). Inputs such as age and experience have proven to be primary demographic predictors

of unsafe or risky riding behaviour and crash involvement, suggesting that "social psychological variables are best seen as mediators" (Chesham et al., 1993, p. 427). Results of previous research have found explanations in theories such as risk homeostasis and self-selection.

3.1.4. Self-selection and risk compensation

Because most training programs are not mandatory, people who choose to take motorcycle training might not be representative of the entire population of riders (Daniello, Gabler, & Mehta, 2009). It is possible that people who seek training are not as good at motorcycling than those who do not – a clear example of self-selection (Daniello et al., 2009). Savolainen & Mannering (2007) found that people who said that they saw no need to take a training course were approximately 50 percent less likely to be involved in a crash than those who expressed the need the course. In places where formal training is mandatory by law to obtain a license, but enforcement is weak, motorcyclists might find ways to obtain licenses without taking courses. Seeking training may then be a result of a lesser skill level, supporting the notion that those who are trained have a higher chance to be involved in an traffic crash (Daniello et al., 2009).

One possible explanation for some of the unexpected results in research about traffic safety (e.g. ineffectiveness of training) is found in the theory of risk compensation. Risk compensation effects occur when modifications in risk-related factors lead to offsetting or reinforcing behaviors - becoming more careful where they perceive greater risk and less careful if they feel more protected (Hedlund, 2000). According to Chesham et al. (1993, p. 425) "[w]hen new safety measures are introduced , it is argued, the human operator adjusts his or her behaviour to maintain all or part of a previous level of acceptable risk." Chesham et al., (1993) argue that a

"real" reduction in motorcycle crashes can be achieved only by changing the riders' level of acceptable risk.

A study of Munich taxicabs found that drivers with antilock brakes changed their behavior by driving faster and braking harder than before the antilock brakes were installed, suggesting that risk compensation occurred (J. D. Graham, 1998). Similarly, if a person's salary depends on his or her output; his or her goal will be to maximize production while keeping injury risk below an acceptable level (Hedlund, 2000). Consequently, if more output is possible to generate, a person might be able increase his or her risk level threshold. Based on the theory of compensation, motorcyclists who depend on the vehicle to work and whose salary depend on their outcome, might accept higher levels of risk on the road in order to maximize income.

3.2. Risky riding behaviour, impulsivity and crashes

In order to better understand motorcycle crashes, Chang & Yeh (2007) classified risky riding behaviour in three categories: negligence of potential risk, negligence of motorcycle examination, and deliberate risk-taking. Negligence of the potential risk occurs when motorcyclists are unaware that their potentially dangerous behaviors might lead to a crash. Negligence of potential risk can also be described (or interpreted) as "driving mistakes or errors" (Parker, West, Stradling, & Manstead, 1995). Examples of such as errors include squeezing though narrow spaces between heavy vehicles that might not see the motorcycle approaching in their mirrors, accelerating at high speed from a green light, or driving without using turn signals. The second type of risky behaviour defined by Chang & Yeh (2007) is negligence of motorcycle inspection. This means lack of routine examination of vital elements of the vehicle such as brakes, lights and tires (Chang & Yeh, 2007).

Deliberate risk-taking is where motorcyclists are aware that their actions or behaviors may be dangerous (or illegal), but they still perform such actions (Chang & Yeh, 2007). Deliberate risk-taking behavior can be also classified as "violations," including risky practices such as speeding and riding under the influence of alcohol. Studies have suggested that there is an association between driving violations and traffic crashes (Lucidi et al., 2010). According to Jiménez et al. (2014) among the most recurrent factors contributing to motorcycle crashes in Bogota are speeding and risky overtaking maneuvers.

Risky driving has been associated to sensation-seeking (e.g. Jonah, 1997; Schwebel, Severson, Ball, & Rizzo, 2006; Zuckerman, 2007). Sensation-seekers thrive on exciting experiences, such as speeding, not because they do not understand the risk, but because they like going fast (Ecola et al., 2010). According to Jonah (1997, cited in Ecola et al., 2010), sensation-seeking personality can account for a up to 16 percent of the variation in drivers' risky behavior. Similarly, several studies have also linked impulsivity to crashes (e.g. Araujo, Malloy-Diniz, & Lopes, 2009; Cheng & Lee, 2012; Ryb, Dischinger, Kufera, & Read, 2006). Chen & Lee (2012) studied relationships between risk-taking behavior, response inhibition, and risky motorcycle riding behavior of commuter motorcyclists with different levels of impulsivity[5] as well as how these behaviors contribute to motorcycle crashes in China. They found that "highly impulsive motorcyclists carry out more risk-taking behaviors and are less able to inhibit responses than those with low impulsivity." The authors determined also that motorcyclists with high impulsivity were about 5 times more likely to be involved in traffic crashes than those with low impulsivity.

[5] Inability to wait, tendency to act without forethought, or insensitivity to consequences (Cheng & Lee, 2012).

However, risk perception might not necessarily predict behavior. Several studies have concluded that those who drive less safely also rate the risks of this behavior as low (e.g. Ivers et al., 2009; Ryb et al., 2006; Ulleberg & Rundmo, 2003). This phenomenon can be explained with Festinger's theory of cognitive dissonance. According to Festinger (1962), people who experiences inconsistencies between beliefs and behavior might seek internal consistency – that is, people adjust their attitudes to reduce dissonance between their attitudes and their behavior. Consequently, individuals who engage in risky driving behaviors, and experience inconsistencies between beliefs and behaviors, will report that the risks of their actions are minimal in order to bring their stated attitudes into agreement with their behavior.

3.3. Demographic factors and vehicle characteristics as predictors of crashes

Age and gender are strongly associated with crashes. The relationship between driver age and car crash involvement follows a U-shaped function - rates are higher for older and younger drivers (Massie, Campbell, & Williams, 1995; J., Gerald McGwin & Brown, 1999). For example, fatal crash rates per mile traveled is high for drivers aged 15‑24 years; declines until approximately age 55, where begin to increase (J., Gerald McGwin & Brown, 1999). The crash rate for females is higher than that for males and the relationship follows the same u-shaped pattern (J., Gerald McGwin & Brown, 1999).

As with automobiles, age and gender are associated with crashes for motorcyclists. The age at which the rate of fatal crashes for motorcyclist reaches it minimum point is at approximately 40 years old – compared to 55 years old for automobiles (Ecola et al., 2010). Motorcyclists under 25 years old and who drive less than three days a week are more likely to crash (Jamson & Chorlton, 2009). Rutter & Quine (1996) identified that young and male motorcycle riders have a

higher propensity for risky driving behaviors, which also are associated with a higher likelihood of crashes occurrence. The higher number of fatalities in motorcyclists over the age of 40 may be due in part to increased ownership and licensing of these vehicles (Haworth and Mulvihill, 2005; Creaser et al., 2007). Nevertheless, there is no enough evidence to conclude that motorcyclists over the age of 40 are taking more risks.

Rutter and Quine (1996) identified particular patterns of youth behaviors associated to their higher probability of being involved in crashes, such as a willingness to break the law and to violate the rules of safe riding. These particular behaviors had a much greater role in accident involvement than inexperience, although experience has being demonstrated to be also relevant in predicting accident occurrence and severity (Chang & Yeh, 2007; Mullin, Jackson, Langley, & Norton, 2000). Chang & Yeh (2007) concluded that male riders of 29 years of less age were more likely to disobey traffic regulations (deliberate risk-taking), have a higher propensity towards negligence of potential risk, and avoid motorcycle safety checks. Cheng and Lee, (2012) argued that as we age we become more psychosocially mature, and thus more likely to avoid risky behaviors. According to Laapotti et al. (2001), young novice riders, and especially young males, demonstrated more problems related to self-control, motives, and emotions; but female riders presented more problems associated to vehicle maneuvering and mastering traffic situations. The authors argued that this lack of skills of female riders was associated to lower driving kilometers (i.e. less experience).

Motorcycle type has been also associated to accident occurrence and severity. Namdaran & Elton, (1988) and Quddus et al. (2002) suggest that one of the most important risk factors in accident occurrence is increased cubic capacity (e.g. supersports bikes). Similarly, Broughton,

(1988) found that people who ride motorcycles with bigger engines have higher accident-involvement rates per kilometre travelled. Mattsson & Summala (2010) found that the risk of being involved in a fatal accident is higher among the riders of more powerful motorcycles (>.75 kW). Mattsson & Summala (2010) recognize that it is not clear whether this result is related to riding behaviour of motorcyclist that choose the most powerful vehicles or whether the high risk is due to the characteristics of the bikes themselves.

3.4. Lack of driving experience as predictor of crashes

Previous research has shown that the lack of riding experience is associated with poor driving skills for young automobile drivers (Benda & Hoyos, 1983; Matthews & Moran, 1986). Several traffic safety researchers have concluded that crash risk is reduced with experience (Blom, Pokorny, & Leeuwen, 1987; Chipman, 1982; Dorn & Af Wåhlberg, 2008; Ferdun, Peck, & Coppin, 1967; Kaneko & Jovanis, 1992). One of the most recurrent factors contributing to motorcycle crashes in Bogota is riding inexperience (Jimenez et al., 2014).

A number of studies have demonstrated that the likelihood of a motorcyclist having a crash increases with exposure but falls with riding experience (Lin et al., 2003a, Lin et al., 2003b and Taylor and Lockwood, 1990). Chipman (1982) argues that "experience is an important benefit of high exposure drivers and may protect them from collisions in some circumstances." As riding experience increases, risk perception improves as well as the risk of being involved in an crash should decrease (Deery, 1999). Thus, training and testing that includes awareness programs to improve risk perception in addition to improving riding skills, has been suggested as an important means to reduce motorcycle traffic crashes (Cheng & Lee, 2012).

3.5. The road environment and its relationship with motorcycle crashes

Other causes of motorcycles crashes are associated with how the road environment and other vehicles, especially automobiles, interact with the motorcycles. Crashes that involved at least one motorcycle and one automobile are generally attributed to lack of visibility of the motorcycle, and the failure to calculate speed and distance of the approaching automobile at intersections (Pai, 2011).

Other factors explaining high crash rates include lack of visibility given road geometry or the natural environment (e.g. trees) that lead to miss road elements and even automobiles or other vehicles on the road (Pai, 2011). According to Jimenez et al. (2014) factors related to the road environment contributing to motorcycle crashes in Bogota include wide roads, which motivate speeding and risky overtaking maneuvers; non-congested arterial streets, which encourage speeding; and lack of infrastructure maintenance. However, it can be hypothesized that risk perception of hazards plays a more important role on crash occurrence than the quality of the infrastructure itself.

3.6. Prior crashes as possible modifier of risk perception

Drivers might be expected to learn from their crashes, especially if they feel they have caused them, and change their driving/riding behaviour as consequence (Wahlberg, 2012). For example, Lucas (2003) found that drivers reporting that they had had a traffic crash in the past five years also reported more fears and worries when driving. However, some researchers have found that past crash experiences do not modify risk perception or driving behavior (e.g. Af Wåhlberg, 2012; Dorn & Af Wåhlberg, 2008; Lin, Huang, Hwang, Wu, & Yen, 2004).

Lin et al. (2004) conducted a study to explore the effect of motorcycle crash experience on changes in risk taking among students in Taiwan. The authors concluded that crash experience did not significantly change the risk-taking among the population studied. These results are in accordance with those Af Wåhlberg (2012) who studied the effects on crash occurrence in changing driving behaviors over a period of three years, more especially acceleration (speed change) among bus drivers in Sweden. He concluded that past experiences did not affect driver's acceleration patterns.

3.7. Effectiveness of riding training and licensing systems

Evidence about the effectiveness of riding training is mixed – researchers have found positive impact, no impact, or even a negative impact. A considerable body research developed in this area has concluded that training courses are not associated with reduction in traffic violations and accident involvement (Haworth, Smith, & Kowadlo, 2000; Mortimer, 1984; Prem & Good, 1984). In contrasts, some studies (e.g. Billheimer, 1998) have concluded that training has been effective in reducing motorcycle crashes. Haworth, Smith, and Kowadlo, (2000) conducted a review of the literature published in the United States from 1980 to 1995 looking at training using the Motorcycle Safety Foundation (MSF) curriculum found that, only one study (out of nine) concluded that untrained riders had higher percent more crashes than those who took the MSF course.

McDavid, Lohrmann, & Lohrmann (1989) suggest that the difficulty finding positive effects of formal training in previous research may be due "the lack of similarity between persons who seek motorcycle training and those who do not." Lin and Kraus (2009) and Kardamanidis et al. (2010) concluded that the effectiveness of rider's education and training programs needs to be

examined using better research designs, including randomized controlled studies, identifying better sources of data - most of the studies rely on police records or self-reported data that generally omit information, including underreporting crashes.

Similarly, studies of various licensing systems have found mixed results. McGwin et al (2004) found that states which required skill tests for obtaining a motorcycling learner's permit, had longer durations for learner's permits, or placed three or more restrictions on the learner's permit presented lower mortality rates.[6] However, graduated driver licensing and tiered licensing were not associated with lower mortality rates. In contrast, Reeder et al. (1999) found that the introduction of the graduated driver licensing in New Zealand was associated to reduction of 22% in traffic crash hospitalizations for motorcyclist 15–19 years old. The authors suggest that this decline may be attributable to an overall reduction in exposure to motorcycle riding.

3.8. The Motorcycle and work

In developing countries, motorcycles are used not only for travel or leisure, but also to deliver documents and small commodities as well as to provide taxi services (Cervero, 2000; da Silva et al., 2012; Kieling et al., 2011). Tuan & Mateo-Babiano (2013) contended that since motorcycle taxi drivers usually drive at high speed to save time, more severe crashes may result. Similarly, Domecq & Sarmiento (2015) hypothesize that the fact that rider who uses his or her motorcycle to provide courier services, and who drive for at least eight hours per day, have a higher probability of being involved in an crash. Kieling et al. (2011) argue that delivery motorcycles

[6] "A learner's permit is a restricted license issued to novice riders and is required for on-street operation of a motorcycle […] The graduated driver licensing usually has three stages—a learner's permit, an intermediate (sometimes called provisional) license, and a full license […] An intermediate license provides novice riders with additional time to gain practical experience and develop skills and behaviors associated with safe riding. The intermediate license still imposes several restrictions but allows unsupervised driving under certain restrictions" (Ecola, Collins, & Eiseman, 2010, p. 68).

(known as “motoboys”) in Brazil are perceived responsible for a high number of traffic crashes. While some researchers have tried to understand the factors associated with crash occurrence among motorcyclists who use their vehicle for commercial purposes, there is no evidence that performing these activities is associated with a higher likelihood of crash occurrence than non-commercial users after controlling for demographic factors, experience and exposure.

Tuan & Mateo-Babiano (2013) conducted a survey of motorcycle taxi drivers and passengers in order to understand the main characteristics of this activity. They found that almost half of motorcycle taxi drivers reported they were accused of violating traffic laws including speeding, red light running, wrong lane encroachment, or carrying two or more passengers; about 80 percent stated that they violated these same laws more than twice. Among the possible explanations for this behavior is that about 90 percent of the motorcycle taxi drivers surveyed perceived the vehicle and job as safe or very safe. Da Silva et al. (2012) studied the factors associated with crashes among motorcycle couriers. They found young age (18 to 24 years), speeding, and using cell phones while driving were factors independently associated with crash occurrence. Kieling et al. (2011) concluded that attention-deficit/hyperactivity disorder was associated with a higher number of traffic crashes and antisocial personality disorder was associated with a greater number of traffic violations among “motoboys” in Porto Alegre, Brazil.

In conclusion, the motorcycle safety literature has evolved since the early studies published more than five decades ago. Much of the recent body of research has its origins in the social psychological literature on the role of beliefs about and attitudes toward human action (Chesham et al., 1993). Inputs such as age and experience have proven to be primary demographic predictors of unsafe or risky riding behaviour and crash involvement, suggesting that “social

psychological variables are best seen as mediators" (Chesham et al., 1993, p. 427). For example, young male riders have a higher probability of being involved in crashes, such as a willingness to break traffic laws and to violate the rules of safe riding (Rutter and Quine, 1996).

Additionally the likelihood of a motorcyclist having a crash increases with exposure but falls with riding experience (Lin et al., 2003a, Lin et al., 2003b and Taylor and Lockwood, 1990). Other factors associated with high crash rates are associated with lack of visibility of the motorcycle; wider roads, which encourage speeding and risky overtaking maneuvers; uncongested arterial streets, which encourage speeding; and lack of infrastructure maintenance causing potholes and the like (e.g. Pai, 2011, Jimenez et al. 2014). Evidence about the effectiveness of rider training is mixed – researchers have found positive impact, no impact, or even a negative impact. Similarly, studies of various licensing systems have found mixed results. Despite the all these efforts to understand motorcycle crashes, there has been little research on whether using the motorcycle for commercial purposes is associated with a higher likelihood of crash occurrence than non-commercial users. This thesis is an attempt to fill that gap in the literature.

4. Methods

4.1. Data sources and sampling methodology

As part of a study developed in 2012 to understand the rapid increase in motorcycle usage in Latin America, the Development Bank of Latin America (CAF) conducted surveys in two cities in Colombia: Barranquilla and Bogota ("CAF," 2015).[7] Survey questions included (when applicable): whether the motorcycle is used as a private transportation mode (i.e. for non-commercial purposes) or for commercial purposes (delivery, taxi services or other economic activity), the vehicle characteristics, other modes used (before and if motorcycle not available), insurance, and perception of vehicle safety and costs, among others (Appendix A). The survey also asked whether the motorcyclist had a crash in the previous year, to which the options for answers were "yes" or "no."

"Since motorcycle usage remains as a low prevalence event in statistical terms (< 10% of trips) in some Latin American cities, it is unlikely that some origin-destination surveys capture adequately the prevalence of this mode and its spatial characteristics. Surveys attempting to collect this information should use innovative research designs to collect information such as distance travelled, frequency, out of pocket cost, travel time, trip purpose, and work conditions (for those who offer it as for hire transportation service)" (Rodriguez et al., 2012). Because of the low frequency and spatial asymmetry of motorcycle usage, a multi-stage cluster sampling was employed by the CAF to create the sample. As a proxy for number of motorcyclists in a given area (or cluster), the unit of analysis chosen by CAF was number of trips attracted during the morning peak period at different geographical levels. To determine the number of motorcyclists

[7] CAF also conducted surveys in Buenos Aires, Caracas and Sao Paulo. CAF also surveyed non-motorcycle users (transit and automobile users, bicyclists, etc.). Only surveys conducted in Barranquilla and Bogota to motorcyclists were used in this research.

in each city CAF used Bogota's 2005 Origin & Destination Trip Survey and Barranquilla's 2007 Origin & Destination Trip Survey (ODT).

In the first stage, eight macro-zones were selected in each city.[8] Four macro-zones that attract the highest number of motorcycle trips were selected for convenience; other four macro-zones were selected randomly. In the second stage two Transportation Analysis Zones (TAZ) were randomly selected within each of the eight macro-zones previously selected in Stage One. In stage three clusters of motorcyclists (parking lots) were randomly selected within each TAZ. An inventory of motorcycle parking lots/areas was conducted previous to the stage three. In the stage four, motorcyclists within each parking lot/area were asked to answer the survey questions. A minimum of 6 surveys were completed in each parking lot/area for a total of 288 surveys per city.

4.2. Data limitations

It is important to note that the data used in this study present some limitations. Because the data are self-reported, only non-fatal crashes are analyzed. It is possible that the results might change considerably if fatal crashes are included in the analysis - in 2012 there were 125 fatal crashes and 1002 crashes in which motorcyclists were injured ("CFPV," 2012). In addition, using self-reported surveys might also lead to underreporting of crashes of certain individuals that ultimately would affect the magnitude of the coefficients and their direction (or sign). Additionally crash occurrence (coded as 0 or 1) is studied rather than the number of crashes and their severity. If number of crashes and their severity were studied, the results of the analysis might change. Imagine that you are comparing two groups (e.g. motorcycle taxi drivers and

[8] Macro-zones in both cities contain at least 4 Transportation Analysis Zones (TAZ).

commuters). The first has a lower proportion of people who had a motorcycle crash the previous year, but a higher average crash rate compared to other group(s). In this case coefficients in a regression model using crash occurrence as a dependent variable have a different magnitude, direction, or even level of significance than if one used crash rate as the dependent variable.

There are also limitations regarding the sampling method. Because cluster sampling was used in the first three stages and surveys were conducted only during the morning peak period, it is possible that the sample captures more motorcyclists who use the vehicle for commuting or for commercial purposes than is the case among the universe of motorcyclists in these cities. Those who ride a motorcycle for recreational purposes only or who work on a schedule that does not match the period of data collection might be underrepresented in the sample.

Additionally, because the CAF survey's purpose was not only to examine safety issues but also to understand the reasons that motivate people to buy and use motorcycles, the survey was broad in scope and large in terms of number of questions. While the former issue limits the scope of my analysis since the number of questions regarding traffic safety asked was limited, the latter might compromise the quality of the information provided by survey respondents because respondents might have preferred to not respond all the questions or hastily (and inaccurately) complete a very long survey. Another possible problem is that because people voluntary accepted to answer the questions, there might be a sampling bias.

4.3. Descriptive statistical analysis

Initial descriptive statistical analysis was conducted in Stata in order to understand the characteristics of the motorcyclists' population, including socioeconomic factors, perception of safety, vehicle features and other factors, all selected based on the explanatory variables used in

the reviewed literature. The data were analyzed classifying the motorcyclists and their vehicles by city and by purpose of use (commercial or non-commercial use). No evidence of multicollinearity was identified among the possible explanatory variables (Appendix B).

The descriptive statistics of variables in the database potentially associated with crash occurrence were divided into three different groups as follows: 1) motorcyclists' characteristics, 2) vehicle related variables; and 3) experience and exposure. Motorcyclists' characteristics analyzed include age, gender and whether the motorcyclist was formally trained for riding the vehicle; vehicle related variables include automobile and/or motorcycle ownership, motorcycle's cylinder displacement, and possession of motorcycle driving license, third party insurance for the vehicle the respondent was riding; experience and exposure variables are number years driving the motorcycle and number of times the motorcycles put gas in the motorcycle (as a proxy for vehicle kilometers of travel) respectively.[9]

4.4. Regression analysis

Descriptive statistics provide an idea of the magnitude and variability of the data of interest (such as socio-economic difference and similarities between motorcycle users or differences in engine size), while cross-tabulations helped to reveal potential associations such as age and the occurrence of crashes. However, in many cases the associations can be caused by other variables shared in common (i.e. spurious relationship). Therefore, regression analysis was used to

[9] Because controlling by exposure is important in traffic safety studies I included number of times the motorcyclist fuel the vehicle monthly as a proxy for Vehicle Kilometers of Travel – the latter information (VKT) was not available in the data provided by CAF. Using number of times the motorcyclist fuel the vehicle monthly as a proxy for exposure might present the following issues: [1] Not all motorcyclists add the same amount of gasoline per time, [2] Fueling frequency per month might not be a constant number for some motorcyclists – that is not all the months they visit the gas stations the same number of times.

simultaneously examine functional relationships among different possible explanatory variables of crash occurrence – the dependent variable.

Since crash occurrence is a dichotomous variable, a logistic regression model with sampling weights and robust standard errors was estimated (Equation 1). The variable Crash takes the value of 1 if the respondent had a crash during the year prior to the survey; else it takes the form of 0. Some dependent categorical variables such as gender, vehicle ownership, young motorcycle riders (17-25 years old) and training were also recoded as (0, 1) dummy variables. Continuous variables (e.g. cylinder displacement) were included without any transformation assuming initially linearity with the dependent variable - crash occurrence.

However, some continuous variables do not always have a uniform effect across the entire range of the variable. Some authors suggests that only young motorcyclists have a higher likelihood of being involved in a crash (cite). Others suggest the variable Age might have a curvilinear relationship with the logit of crash occurrence. A squared version of the age variable was introduced to the model to test for curvilinear effect. The model that included the variable Young rider, instead of the squared version of Age, provides a better goodness of fitness.

Other variables that should not have a linear relationship with the logit of crash occurrence are the time the driver has been driving the vehicle (i.e. experience). As driving experience increases, the marginal effect on the likelihood of being involved in a crash may decrease. A logarithmic version of the Time usage variable was also introduced to the model to test for curvilinear effect. The transformation of the variable Time usage increased the explanatory power of the model.

Lastly, the regression analysis was limited only to those motorcyclists who reported having a Motorcycle Driver's License. While individuals with no motorcycle drivers' license might be more prone to underreport crashes (out of fear of detection by authorities), they represent only three percent of the sample. In fact, a logistic regression model that includes that variable resulted in a negative coefficient, suggesting that those with license have a higher likelihood of being involved in a crash (Appendix C). However, this apparently counter-intuitive result might simply reflect an underreporting bias by motorcyclists with no license. Other combinations of variables were examined (Appendix C); the model with the highest explanatory power is reported in the next section.

Equation 1 Model specification

$$\Pr(\text{Accident} = 1 \mid X = x) = \frac{e^{\beta_0+\beta_1 X_1+\beta_2 X_2+\cdots\beta_n X_n}}{1 + e^{\beta_0+\beta_1 X_1+\beta_2 X_2+\cdots\beta_n X_n}}$$

Where independent variables take the following values:

Motorcycle_taxi	=	1 if the respondent uses the motorcycle to provide taxi services, 0 otherwise
Motorcycle-courier	=	1 if the respondent uses the motorcycle to provide courier services, 0 otherwise
Male	=	1 if respondent is male, 0 otherwise
Young	=	1 if responded is between 17 and 25 years old
Automobile_ownership	=	1 if respondent owns an automobile, 0 otherwise
Motorcycle_ownership	=	1 if respondent owns the motorcycle, 0 otherwise
Formal_Training	=	1 if respondent took a driving course/exam to obtain the license, 0 otherwise
ln_Time_usage	=	Natural logarithm of the time the motorcyclist has being driving the vehicle (in years).
Insurance	=	1 if respondent has insurance to cover third party damages, 0 otherwise
Fuel_Freq	=	Motorcycle fuel purchases per month
Cylinder_displacement	=	Engine size in cubic centimeters
Bogotá	=	1 if the survey was conducted in Bogotá, 0 otherwise

Because logistic models must be estimated using non-linear methods, there is not a direct interpretation of the coefficients besides their statistical significance and direction. In order to better interpret the coefficients obtained in the logistic model, marginal effects were calculated. The variables that were statistically significant at the 95 and 99 percent confidence level are discussed in the results section.

5. Results

5.1. Descriptive statistics

Demographic characteristics of motorcyclists and their vehicles were identified. The data were disaggregated by city and usage type (commercial and non-commercial) to better understand the differences and similarities between motorcyclists in different geographies and groups.

5.1.1. Using the motorcycle for commercial purposes

Motorcyclists who use a vehicle for commercial purposes represent approximately 53 percent of the sample. This proportion in Bogota is 48 percent and in Barranquilla 61 percent. Motorcycle taxi drivers represent four percent of the survey respondents in Bogota and 42 percent in Barranquilla. Motorcycle couriers represent 36 percent of the survey respondents in Bogota and seven percent in Barranquilla (Table 2).

5.1.2. Crash occurrence

Approximately 20 percent of survey respondents reported having at least one crash the year prior to the survey. This proportion is similar in both cities; 20 percent in Bogotá and 18 percent in Barranquilla had been in a motorcycle crash in the previous year (Table 2).

Of the total number of motorcyclists who used the vehicle for commercial purposes, 20 percent had at least one accident in the previous year – the number was 1 percentage point higher for the group of motorcyclists who use the vehicle only for non-commercial purposes. Approximately14 percent of motorcycle couriers reported having at least one motorcycle crash in the previous year– this figure is 14 percent points higher for motorcycle taxi. The latter difference is statistically significant (Figure 1).

5.1.3. Gender and age

Motorcyclists in both cities are mostly young males. Males represent 96 percent of survey respondents – figures in Bogota and Barranquilla are similar. Motorcyclists are on average 34 years old. The minimum age of survey respondent was 17 and the maximum was 79. The average age of survey respondents in Bogota is 33 and in Barranquilla is 37 (Table 1).

While 26 percent of female motorcyclists were involved in a crash, the proportion of males involved in a crash in the previous year is seven percentage points lower (19 percent). Within the group of young motorcyclists (from 17 to 25 years old), 28 percent were in at least one crash in the past year. This figure is 11 percentage points higher than the group of motorcyclists who are over 25 years (Figure 2).

5.1.4. Vehicle characteristics, ownership, training and driving license

Most motorcyclists are owners of their vehicle,[10] approximately 89 percent in Bogota are owners, and 81 percent in Barranquilla. In contrast, only 11 percent own at least one automobile (Table 2). Within the group of motorcycle owners, 20 percent reported a crash during the previous year – this figure is five percentage points lower for non-owners. Among motorcyclists who own at least one automobile, 20 percent had an accident the previous year, which was four percentage points lower than those motorcyclists who did not own at least one automobile (Figure 2).

The average cylinder displacement of the motorcycles ridden by survey respondents was approximately 140 cubic centimeters (cc). This number in Bogota was approximately 150 cc and

[10] Non owners reported that the vehicle was borrowed by a friend, relative, or provided by the employer or other person.

in Barranquilla 120 cc (Table 1). Only four percent had sportbikes (motorcycles with engine of 500 or more cc) (Table 2). Among those who had sportbikes, the 23 percent reported in the survey having at least a crash during the past year – this figure is four percentage points higher that the group of users of non-sportbikes (Figure 2).

A small number (about 3%) of motorcyclists do not have motorcycle driver's license. Two percent of motorcyclists in the Bogota sample reported not having a motorcycle driver's license, and four percent in Barranquilla (Table 2). Among motorcyclists with no license, 33 percent had a crash in the year prior, which was 14 percentage points higher than among motorcyclists who had licenses (Figure 2).

A substantial percentage of motorcyclists had not taken any formal driving course or exam in order to obtain their driver's license.[11] In Bogota 14 percent of the motorcyclists did not take any formal training to obtain the motorcycle driver license; the figure in Barranquilla was considerably higher – 32 percent (Table 2). Within the group of motorcyclists who did not have any formal training to ride a motorcycle, 26 percent had at least one crash during the previous year to the survey – this number is 8 percentage points higher than the group of motorcyclists who received formal training (Table 1).

A large percentage of motorcyclists do not have third-party liability vehicle insurance.[12] In Bogota, 67 percent of the motorcyclists did not have third-party liability insurance, while in

[11] Requirements for obtaining any driver's license for the first time in Colombia include being at least 16 years of age, passing a written test and on-road driving exam (or provide a driving skills certificate awarded by a private driving school), and providing a certificate of physical and mental capabilities to drive a motorcycle.

[12] Only traffic accident insurance (SOAT is its acronym in Spanish) is mandatory. The SOAT covers exclusively costs related to injury or death of the people involved in an accident. Costs related to material damages are covered by third-party liability insurance. It is also important to mention that both the SOAT and third-party liability insurance are issued to the vehicle and not by driver.

Barranquilla the number was even higher – 87 percent (Table 2). Among those who did not have third-party liability vehicle insurance, 18 percent reported in the survey having at least a crash during the past year – this figure is six percentage points lower that the group of users that have third-party liability insurance.

5.1.5. Experience and exposure

A large number of motorcyclists surveyed had been driving their vehicles for less than one year, about one-third in Bogota and 21 percent in Barranquilla (Table 2). Among those who have been riding the motorcycle for less than one year, 20 percent had a crash the previous year. This figure is just one percentage point higher than those with more experience riding the motorcycle (Figure 2).

Motorcyclists who use the two-wheeler for commercial purposes purchase fuel more frequently, on average, than those who use the vehicle for non-commercial purposes – suggesting both more riding experience (thought to lower crash risk) and higher levels of exposure (thought to increase the likelihood of a crash). Consequently, the former group ride more kilometers.[13] In Bogotá, commercial users add fuel to the vehicle an average of 9.3 times per month, while non-commercial users fuel up 7.8 times per month. In Barranquilla motorcyclists add fuel more frequently. Commercial users purchase fuel 17.0 times per month and non-commercial motorcyclists fuel up 16.6 times per month.

[13] Fueling frequency is used as a proxy for kilometers driven.

Table 1 Descriptive Statistics – Continuous Variables Categorical variables

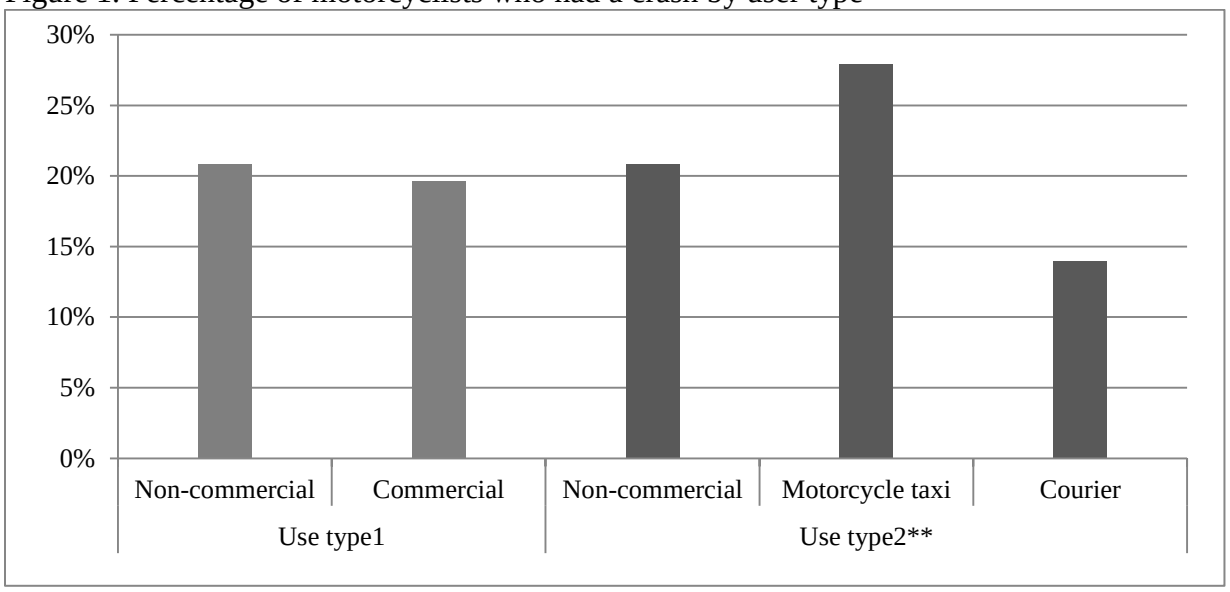
Variables		Mean	Std. Dev.	Min	Max
Age	Both Cities	34.4	9.2	17.0	79.0
	Bogota	33.1	8.6	17.0	79.0
	Barranquilla	36.7	9.6	19.0	65.0
Time_usage	Both Cities	3.1	6.2	0.0	107.2
	Bogota	2.8	7.0	0.0	107.2
	Barranquilla	3.8	3.8	0.0	24.1
Cylinder_displacement	Both Cities	138.3	74.4	70.0	1000.0
	Bogota	150.0	77.0	70.0	1000.0
	Barranquilla	117.7	64.9	80.0	1000.0
Fuel_Freq	Both Cities	11.5	9.7	1.0	30.0
	Bogota	8.7	7.5	1.0	30.0
	Barranquilla	16.3	11.2	1.0	30.0

Table 2 Descriptive Statistics – Categorical variables

Variables	Geography	Observations	Percent of Sample
Crashes	Both Cities	150	19.3%
	Bogota	96	19.6%
	Barranquilla	54	18.8%
Commercial_Usage[1]	Both Cities	435	52.8%
	Bogota	254	48.0%
	Barranquilla	181	61.4%
Motorcycle-taxi	Both Cities	142	17.2%
	Bogota	19	3.6%
	Barranquilla	123	41.7%
Motorcycle-courier	Both Cities	213	25.8%
	Bogota	192	36.3%
	Barranquilla	21	7.1%
Male	Both Cities	752	96.2%
	Bogota	505	96.0%
	Barranquilla	247	96.5%
Auto_ownership	Both Cities	91	11.2%
	Bogota	81	15.5%
	Barranquilla	10	3.4%
Moto_ownership	Both Cities	707	85.8%
	Bogota	469	88.7%
	Barranquilla	238	80.7%
Sportbike	Both Cities	29	3.5%
	Bogota	25	4.7%
	Barranquilla	4	1.4%
Motorcycle Driver's License	Both Cities	786	97.0%
	Bogota	506	97.9%
	Barranquilla	280	95.6%
Formal_Training	Both Cities	639	80.0%
	Bogota	444	86.4%
	Barranquilla	195	68.4%
Insurance	Both Cities	197	24.3%
	Bogota	160	30.9%
	Barranquilla	37	12.6%
TIme_usage<1year	Both Cities	234	28.4%
	Bogota	170	32.1%
	Barranquilla	64	21.7%

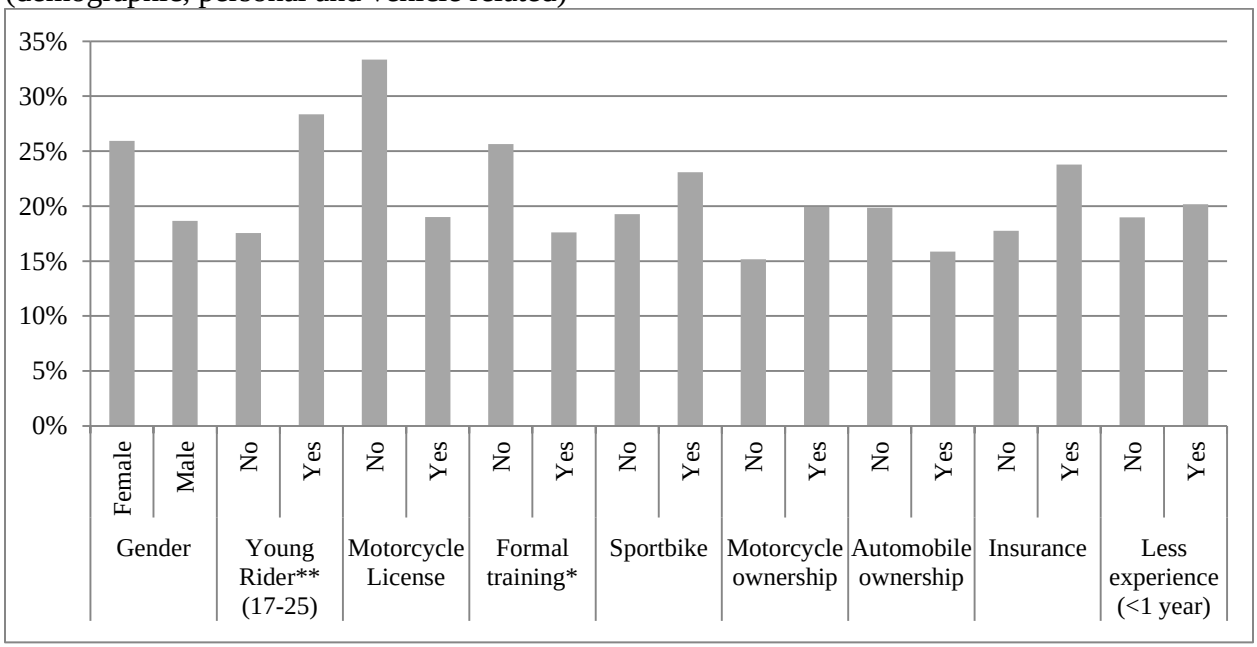
Notes: [1] The variable Commercial_Usage includes both Motorcycle taxi drivers and Motorcycle couriers

Figure 1. Percentage of motorcyclists who had a crash by user type



Notes: [1] Cross tabulations were created and Chi-square tests were conducted to determine with there was an association between User type 1 and Crash Occurrence, and between User type 2 and Crash Occurrence. Significance levels are denoted as follows: *** p<0.01, ** p<0.05, * p<0.1.

Figure 2. Percentage of motorcyclists who had a crash by possible explanatory variables (demographic, personal and vehicle related)



Notes: [1] To test for association between each possible control variable and Crash Occurrence, a cross tabulations was created and Chi-square test was conducted for each variable. [2] Significance levels are denoted as follows: *** p<0.01, ** p<0.05, * p<0.1. [3] The difference in percentages between those who did not had a motorcycle driver's license and those who had one is not statistically significant probably because the low number of respondents within the former group (3%). This might be also the case for Female vs. Male.

5.2. Model results

The variables included in the logistic regression model are statistically significant together (Chi-squared: 30.04, p-value: 0.003) and the goodness of fitness is acceptable (pseudo r-square: 0.16) Table 3). In addition, the model correctly predicts approximately 81 percent of the observations. Because logistic models must be estimated using non-linear methods, there is not a direct interpretation of the coefficients beyond their statistical significance and direction. In order to better interpret the model results, marginal effects were calculated (Table 3).

Marginal effects of the statistically significant variables suggest that the probability of being involved in a crash when using the motorcycle to provide taxi services is 12 percentage points higher when using motorcycles for taxi services than when using motorcycles for non-commercial purposes or for other motorcycle-dependent commercial activities other than courier or taxi services (Table 3). This result supports my hypothesis that motorcycles used for commercial activities and whose income is generally based on the number of services they are able to provide are at a higher risk of being involved in a crash.. However, motorcyclists who use the vehicle to provide courier services do not have a higher or lower probability of being involved in a crash when compared to those that use the motorcycle for non-commercial purposes or for other activities different than providing courier or taxi services (Table 3).

The latter finding is counter to my hypothesis and may suggest that the added risks of risk-taking behavior, increased exposure, and increased skill that comes from frequent riding may be fully accounted for in the model by factors unrelated to commercial status. Or this result may simply reflect a crash reporting bias on the part of motorcycle couriers. Possible reasons for a reporting bias include fear of self-incrimination that could potentially put their jobs at risk (Morrow &

Crum, 2004). Another possibility is that both types of users (motorcycle couriers and the group of non-commercial motorcyclists and motorcycles that use the vehicle for commercial activities other than courier or taxi services) take similar risks on the road (after controlling for risk-related variables such as age and gender).

Young motorcyclists (17-25 years) have a probability 15 percentage points higher of getting involved in a motorcycle crash when compared with motorcyclists over 25 years of age (Table 3). This result is consistent with findings of Rutter & Quine (1996) and Jamson & Chorlton (2009); they suggest that young motorcyclists are more likely to crash because they have a higher propensity for risky driving behaviors.

The number of times a motorcyclist adds gasoline to the vehicle is also associated with crash occurrence (Table 3). Each additional fueling stop is associated with an increase of one percentage point in the probability of being involved in a crash. This supports the obvious conclusion that the more a motorcyclist rides the vehicle, the more gasoline they use, the more they are exposed to the risk of being involved in a crash (Table 3).

Motorcycle ownership is also associated with a higher likelihood of being involved in a crash when compared with those who were using a two-wheeler borrowed from a friend, relative or provided by their employer (Table 3). As in the case of motorcycle couriers, it might be possible that non-owners underreported crashes.

Finally, riding in Bogotá, versus riding in Barranquilla, is associated with a higher probability of being involved in a crash (15 percentage points) (Table 3). This difference might be due to the differences in cities' intrinsic characteristics such as weather conditions (Bogota has more

precipitation than Barranquilla), and differences in driving behavior among road users influenced by heavier congestion and longer average trip distances in Bogota.

Motorcyclists who received formal training prior to riding have neither a higher nor lower probability of being involved in a crash compared with those who did not have any formal training (Table 3). This result is consistent with results obtained in several other studies (Haworth, Smith, & Kowadlo, 2000; Mortimer, 1984; Prem & Good, 1984). Assuming that there was not a crash reporting or sample bias, the fact that the variable Formal Training was not statistically significant might suggest training is not effectively improving riding skills and behavior.

Table 3. Model results

Variables	Coefficients	Marginal Effects
Motorcycle-taxi	1.01**	0.12
	(0.50)	
Motorcycle-courier	-0.55	-0.07
	(0.45)	
Male	-0.76	-0.09
	(0.67)	
Young (17-25)	1.23**	0.15
	(0.55)	
Formal_Training	0.02	0.00
	(0.43)	
ln_Usage_time	-0.18	-0.02
	(0.16)	
Fuel_Freq	0.07***	0.01
	(0.02)	
Insurance	0.20	0.02
	(0.39)	
Auto_ownership	0.19	0.02
	(0.54)	
Moto_ownership	2.01**	0.24
	(0.84)	
Cylinder_displacement	-0.01	0.00
	(0.01)	
Bogota	1.45***	0.17
	(0.43)	
Constant	-3.95***	-
	(1.47)	
Observations	627	
Pseudo R-squared	0.163	
F test	0.003	
Chi-Squared	30.16	

Notes: [1] Significance levels are denoted as follows: *** p<0.01, ** p<0.05, * p<0.1.
[2] Robust standard errors in parentheses

6. Conclusions

In developing countries, like Colombia, motorcycles are used for personal travel (commuting, leisure, etc.) but also to deliver documents and small commodities (e.g., food) or to provide taxi services. Commercial motorcyclists' income is generally based on the number of services they are able to provide within a certain amount of time. Although there are no official statistics, commercial motorcyclists are perceived by many observers to be responsible for a proportionally high number of crashes.

In this research I analyzed a unique dataset on motorcycle crashes in two Colombian cities to better understand the factors associated with crash risk. While rich in many ways, the data are problematic in some respect, an issue all too common in traffic safety research (e.g. Kardamanidis et al., 2010; Lin & Kraus, 2009; Yamamoto, Hashiji, & Shankar, 2008). The results obtained in this study support the hypothesis that motorcycles used for commercial purposes are at higher risk of crashing. The probability of being involved in a crash is higher when using motorcycles for taxi services than when using motorcycles for non-commercial purposes or for commercial activities other than courier or taxi services (after controlling for exposure, demographic characterizes, vehicle features, and other possible explanatory variables).

Motorcyclists who use the vehicle to provide courier services have neither a higher nor lower probability of being involved in a crash when compared to those that use the motorcycle for non-commercial purposes or for other motorcycle-dependent commercial activities other than courier or taxi services. This apparently counter-intuitive finding could reflect a crash reporting bias on the part of this group of motorcyclists. One possible reason for a reporting bias is fear of self-incrimination that could potentially put their jobs at risk. Assuming there is no crash reporting

bias, one possibility that explains the no apparently elevated risk among couriers is that these two groups actually take similar risks on the road (after controlling for risk-related variables such as age and gender).

Other variables associated with crash occurrence include age, being owner of the motorcycle and riding the vehicle in Bogota. Young motorcyclists (17-25 years) have a higher likelihood of getting involved in a crash when compared with motorcyclists more than 25 years old. The literature suggests that young motorcyclists are more likely to crash because they have a higher propensity for risky driving behaviors (e.g. Rutter & Quine, 1996; Jamson & Chorlton, 2009).

Motorcycle ownership is associated with a higher likelihood of getting involved in a crash when compared with those who used a two-wheeler borrowed from a friend or relative, or one provided by the employer. As in the case of motorcycle couriers, it might be possible that non-owners underreported crashes. Finally, riding in Bogotá, versus riding in Barranquilla, is associated with a higher probability of being involved in a crash (15 percentage points). This difference might be due to the differences in cities' intrinsic characteristics such as weather conditions (it rains more in Bogota than in Barranquilla), and differences in driving behavior among road users influenced by higher levels of congestion and longer trip distances in Bogota.

Further research is needed in order to understand the reasons of why motorcycle taxi drivers have a higher probability of having a crash compared with those who use the vehicle for non-commercial purposes. One of the hypotheses to be tested is that they engage in risker driving behaviors in order to maximize their income. Another is that those who choose this profession tend to be risk-takers regardless whether or not there is a monetary incentive to drive faster. If the former hypothesis is supported empirically, government authorities might invest more in

regulating jobs that involved motorcycling. These regulations could include hourly pay (rather than payments per delivery), regular training, and frequent checking of traffic violations. Media campaigns targeted to motorcyclists at higher risk could potentially help to decrease crash rates (Ecola, Collins, & Eiseman, 2010). Other promising interventions include high-visibility enforcement campaigns, which combine stepped-up enforcement of laws with publicity about enforcement, and "fear appeal" campaigns, which tries to frighten riders into changing their behavior by emphasizing the risks and consequences (Ecola, Collins, & Eiseman, 2010). This type of campaigns have proven to be successful in reducing crashes in the United States (Ecola, Collins, & Eiseman, 2010)

Appendices

Appendix A: Survey questionnaires[14]

A1. Survey for Non-Commercial Motorcyclists

A. Surveyor, date and address:

Name: _____

Date (day/month/year): ___ / _____ / _____

Address of the parking lot/area assigned: _____ TAZ No. _____

# of motorcycles at the time of the survey in the parking lot/area: _____

B. Demographic characteristics

1. Age: ____ Gender: Male ❑ Female ❑
2. ¿Do you own an automobile? No ❑ Yes❑ ➔How many? _____
3. ¿Do you have automobile driver's license? No❑
   Yes❑ ¿Have you taken driving classes to obtain this license? No❑ Yes❑
4. ¿Do you own a motorcycle? No ❑ Yes❑ ➔How many? _____
5. ¿ Do you have motorcycle driver's license? No❑
   Yes❑ ¿Have you taken riding classes to obtain this license? No❑ Yes❑
6. ¿Do you own a bicycle? No ❑ Yes❑
7. ¿What is your monthly income level?

$ 0-200.000	❑	$ 1.000.001-3.000.000	❑	More than $ 10.000.000	❑
$ 200.001-500.000	❑	$ 3.000.001-5.000.000	❑		
$ 500.001-1.000.000	❑	$ 5.000.001-10.000.000	❑		

8. ¿What is your maximum level of education?

Elementary school incomplete	❑	Vocational training incomplete	❑	Master's professional degree incomplete	❑
Elementary school complete	❑	Vocational training incomplete	❑	Master's professional degree complete	❑
High school incomplete	❑	Associate and/or Bachelor's degree incomplete	❑	Other	❑
High school complete	❑	Associate and/or Bachelor's degree complete	❑		

C. Information about the motorcycle and its use

9. ¿Who is the owner of the vehicle?

Myself	❑	A friend	❑	A relative	❑	The company/employer	❑
Other	❑						

[14] Translated from Spanish by the author

10. **If the surveyed is the owner or the motorcycle:** ¿Do you have any debt on the vehicle? No❑ Yes❑
11. Brand:_____ Model (year):_____Cylinder capacity (cc):_____
12. **If the surveyed is the owner or the motorcycle:** ¿When did you buy it? (month/year): _____/____
13. Since when do you use the vehicle? (month/year): _____ /_____
14. ¿How many days per week do you use the vehicle? (0-7): _____
15. ¿How often (in days) you add fuel? _____
16. ¿How much gasoline do you buy each time you add fuel? (Colombian Pesos)_____
17. ¿Do you have parking problems in your destination? Yes❑ No❑ Some times ❑
18. ¿Have you had crashes over the last year on the motorcycle? No ❑ Yes ❑ ¿ Did you have any injury?: No❑ Yes❑
19. ¿Do you have third party liability insurance?: No❑ Yes❑

D. Information about the previous an substitute transportation mode

20. ¿ If you had not had the bike available, in which of the following modes of transport would have made the trip?

Bus	❑	BRT	❑	Automobile as a driver	❑	Walking	❑
Taxi	❑	Bicycle	❑	Automobile as a passenger	❑	Motorcycle taxi	❑
						I had not travelled	❑

21. What transportation modes were the most used before using the motorcycle?

Bus	❑	BRT	❑	Automobile as a driver	❑	Walking	❑
Taxi	❑	Bicycle	❑	Automobile as a passenger	❑	Motorcycle taxi	❑
Other	❑	→ Which one? _____					

E. Current trip information

22. Where did you start this trip? (address):_____
23. Location indicating the origin of the trip (if any): _____
24. Where are you going on this trip? (address or nearest corner):_____
25. Location indicating the destination of the trip (if any): _____
26. Departing time: _____ Arrival time:_____
27. Purpose of the trip:

Work	❑	Study	❑	Recreational	❑	Way home	❑
Job search	❑	Shopping	❑	Other personal matters	❑		

F. Trip information of a typical workweek day

28. ¿How many trips (transfers do not count as trips) do you take on a typical workweek day? ____
29. ¿Of all the trips made on a typical workweek day, how many where made by **Bus**? ____
30. How many where made by **Taxi**? (Indicate quantity) ____
31. How many where made by **Motorcycle-taxi, you being the passenger**? ____
32. How many where made by **Motorcycle** (driver/passenger)? ____
33. How many where made by **Automobile, you being the driver**? ____

34. How many where made by **Automobile, you being the passenger**? ____
35. How many where made by **Bicycle**? ____
36. How many where made **Walking**? ____

G. Use/Adoption factors

37. Indicate your level of agreement or disagreement with the following statements:

Affirmations	Disagree	Neither Agree nor Disagree	Agree
The **cost** of buying a motorcycle is **high**	❑	❑	❑
The **quickest** way to get to where I'm going during peak hour, is using the **motorcycle**	❑	❑	❑
The **cost** of using the motorcycle is **less** than the cost of taking the Bus	❑	❑	❑
The **cost** of using the motorcycle is **less** than the cost of taking BRT	❑	❑	❑
The **cost** of using motorcycle is **less** than the cost of taking Taxi	❑	❑	❑
The **cost** of using motorcycle is **less** than the cost of taking Motorcycle-taxi	❑	❑	❑
The **cost** of using motorcycle is **less** than the cost of using the Automobile	❑	❑	❑
The **motorcycle** is a very **safe** vehicle	❑	❑	❑
Many **friends and relatives** use motorcycle	❑	❑	❑
If traveling by **motorcycle** between two points of the city, **travel time** is almost the **same** regardless of time of day or congestion	❑	❑	❑

A.2. Survey for Commercial Motorcyclists

A. Surveyor, date and address:

Name: _____

Date (day/month/year): ___ / _____ / _____

Address of the parking lot/area assigned: _____ TAZ No. _____

# of motorcycles at the time of the survey in the parking lot/area: _____

B. Datos sociodemográficos del encuestado/tipo de usuario

1. Occupation:
   Motorcycle-taxi driver:❑Courier:❑ Other:❑ → Which one?_____
   Age: _____ Gender: Male ❑Female❑
2. ¿Do you own an automobile? No ❑ Yes❑ →How many? _____
3. ¿Do you have automobile driver's license? No❑
   Yes❑ ¿Have you taken driving classes to obtain this license? No❑ Yes❑
4. ¿Do you own a motorcycle? No ❑ Yes❑ →How many? _____
5. ¿ Do you have motorcycle driver's license? No❑
   Yes❑ ¿Have you taken riding classes to obtain this license? No❑ Yes❑
6. ¿What is your monthly income level?

$ 0-200.000	❑	$ 1.000.001-3.000.000	❑	More than $ 10.000.000	❑
$ 200.001-500.000	❑	$ 3.000.001-5.000.000	❑		
$ 500.001-1.000.000	❑	$ 5.000.001-10.000.000	❑		

7. ¿What is your maximum level of education?

Elementary school incomplete	❑	Vocational training incomplete	❑	Master's professional degree incomplete	❑
Elementary school complete	❑	Vocational training incomplete	❑	Master's professional degree complete	❑
High school incomplete	❑	Associate and/or Bachelor's degree incomplete	❑	Other	❑
High school complete	❑	Associate and/or Bachelor's degree complete	❑		

C. Information about the motorcycle and its use

8. ¿Who is the owner of the vehicle?

Myself	❑	A friend	❑	A relative	❑	The company/employer	❑
Other	❑						

9. Brand: _____Modelo (año): _____Cilindraje(cc):_____
10. **If the surveyed is the owner or the motorcycle:** ¿When did you buy it? (month/year): _____/____
11. Since when do you use the vehicle? (month/year): _____ /_____
12. ¿ Have you had crashes over the last year on the motorcycle? No ❑
    Yes ❑ ¿ Did you have any injury?: No❑ Yes❑
13. ¿Is the motorcycle your only source of income? No❑ Yes❑

14. ¿Prior source of income?

Construction worker	❑	Independent Contractor	❑
Employee	❑	Employer	❑
Industrial Operator	❑	Non-remunerated worker (family)	❑
Contractor (professional services)	❑	Bus, Truck or Automobile driver	❑
House keeping	❑	Courier	❑
Freelancer	❑	Motorcycle-taxi driver	❑
Other	❑	→¿Other, Which one? _____	

15. ¿Do you have third party liability insurance?: No❑ Yes❑
16. ¿Do you have parking issues/problems with the motorcycle? No❑ Yes❑ Sometimes❑
17. ¿How often (in days) you add fuel? _____
18. ¿How much gasoline do you buy each time you add fuel? (Colombian Pesos)_____
19. ¿Do you operate a fixed route? No❑ Yes❑ Sometimes❑
20. ¿Have you had any problems with the police while using the motorcycle? No❑ Yes❑
21. **If you are Motorcycle-taxi driver:** ¿Have you had any problem with your passengers? No❑ Yes❑

D. Trip information of a typical workweek day

22. ¿How many trips (transfers do not count as trips) do you take on a typical workweek day? ____

E. Use/Adoption factors

23. Indicate your level of agreement or disagreement with the following statements:

Affirmations	Disagree	Neither Agree nor Disagree	Agree
The **cost** of buying a motorcycle is **high**	❑	❑	❑
The **quickest** way to get to where I'm going during peak hour, is using the **motorcycle**	❑	❑	❑
The **cost** of using the motorcycle is **less** than the cost of taking the Bus	❑	❑	❑
The **cost** of using the motorcycle is **less** than the cost of taking BRT	❑	❑	❑
The **cost** of using motorcycle is **less** than the cost of taking Taxi	❑	❑	❑
The **cost** of using motorcycle is **less** than the cost of using the Automobile	❑	❑	❑
The **motorcycle** is a very **safe** vehicle	❑	❑	❑
Many **friends and relatives** use motorcycle	❑	❑	❑
If traveling by **motorcycle** between two points of the city, **travel time** is almost the **same** regardless of time of day or congestion	❑	❑	❑
I would be able to work if I did not have access to the Motorcycle	❑	❑	❑
My current job is highly fulfilling	❑	❑	❑

Appendix B: Correlation matrix

Correlation	Crashes	Commercial	Motorc .-taxi	Motorc.-courier	Male	Young	Formal_ Training	Usage _time	Fuel _Freq	Insurance	Auto._ ownership	Motorc._ ownership	Cylinder_ displace-ment
Crashes	1.0												
Commercial	0.0	1.0											
Motorcycle-taxi	0.1	0.4	1.0										
Motorcycle-courier	-0.1	0.6	-0.2	1.0									
Male	0.0	0.1	0.0	0.1	1.0								
Young	0.1	-0.1	-0.1	0.0	0.0	1.0							
Formal_ Training	0.0	0.0	-0.1	0.1	-0.1	0.1	1.0						
Usage_time	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0					
Fuel_Freq	0.1	0.1	0.3	-0.1	0.0	-0.1	-0.2	0.0	1.0				
Insurance	0.1	0.0	-0.1	0.1	0.0	0.1	0.1	-0.1	-0.1	1.0			
Automobile_ ownership	0.0	0.0	-0.1	0.1	0.0	0.0	0.0	0.1	-0.1	0.1	1.0		
Motorcycle_ ownership	0.1	-0.2	-0.2	-0.1	0.0	0.0	0.0	0.1	-0.2	-0.1	0.1	1.0	
Cylinder_ displacement	0.0	-0.1	-0.2	0.1	0.0	0.0	0.0	-0.1	-0.1	0.1	0.3	0.0	1.0

Appendix C: Models tested with different combination of variables

Variables	(1)	(2)	(3)	(4)
Commercial-motorcyclist			0.20	
			(0.40)	
Motorcycle-taxi	1.01**	0.90*		0.96*
	(0.50)	(0.48)		(0.50)
Motorcycle-courier	-0.547	-1.03*		-0.56
	(0.45)	(0.60)		(0.45)
Male	-0.761	-0.97	-0.574	-0.54
	(0.67)	(0.66)	(0.712)	(0.67)
Young	1.23**	1.52***	1.057**	
	(0.55)	(0.54)	(0.518)	
Age				-0.20
				(0.13)
Sqr_age				0.00
				(0.00)
Motorcycle_Driver's_License		-2.35***		
		(0.73)		
Formal_Training	0.02	0.039	-0.025	0.06
	(0.43)	(0.43)	(0.42)	(0.43)
ln_Usage_time	-0.18	-0.07	-0.20	-0.20
	(0.16)	(0.17)	(0.16)	(0.14)
Fuel_Freq	0.07***	0.06***	0.07***	0.07***
	(0.02)	(0.02)	(0.02)	(0.02)
Insurance	0.20	0.34	0.20	0.26
	(0.39)	(0.43)	(0.41)	(0.39)
Auto_ownership	0.19	-0.17	0.06	0.30
	(0.54)	(0.68)	(0.51)	(0.55)
Moto_ownership	2.00**	1.29*	1.99**	1.90**
	(0.84)	(0.68)	(0.90)	(0.82)
Cylinder_displacement	-0.01	-0.00	-0.01	-0.01
	(0.01)	(0.00)	(0.01)	(0.01)
Bogota	1.45***	1.14**	1.09***	1.48***
	(0.43)	(0.44)	(0.41)	(0.42)
Constant	-3.94***	-1.27	-3.66**	-0.11
	(1.47)	(1.26)	(1.57)	(2.45)
Observations	626	645	626	623
Pseudo R-squared	**0.161**	**0.163**	**0.135**	**0.146**
F test	0.003	0.003	0.012	0.002
Chi-Squared	30.04	31.31	24.31	32.42

Notes: [1]*** p<0.01, ** p<0.05, * p<0.1. [2] Robust standard errors in parentheses. [3] Models (1), (3) and (4) only include respondents with motorcycle driver's license [4] Model (1) is the one discussed in the Results section.

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