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### What is the problem?

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#### DOI

[10.1080/15389588.2023.2238862](https://doi.org/10.1080/15389588.2023.2238862)

#### Publication date

2023

#### Document Version

Final published version

#### Published in

Traffic Injury Prevention

#### Citation (APA)

Nguyen, M. H., Nguyen-Phuoc, D. Q., & Oviedo-Trespalacios, O. (2023). Non-fatal traffic crashes among food delivery riders in Vietnam: What is the problem? *Traffic Injury Prevention*, 24(8), 686-692.  
<https://doi.org/10.1080/15389588.2023.2238862>

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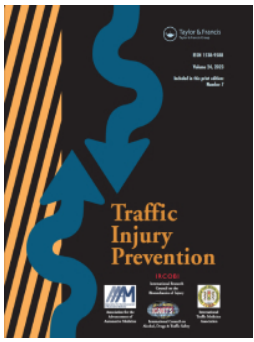
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To cite this article: Minh Hieu Nguyen, Duy Quy Nguyen-Phuoc & Oscar Oviedo-Trespalacios (2023): Non-fatal traffic crashes among food delivery riders in Vietnam: What is the problem?, Traffic Injury Prevention, DOI: [10.1080/15389588.2023.2238862](https://doi.org/10.1080/15389588.2023.2238862)

To link to this article: <https://doi.org/10.1080/15389588.2023.2238862>



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# Non-fatal traffic crashes among food delivery riders in Vietnam: What is the problem?

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## ABSTRACT

**Objective:** The rapid development of information technologies and the COVID-19 pandemic have resulted in the proliferation of online food shopping and food delivery motorcyclists. In contrast to the relatively ample literature on factors influencing fatalities and risky riding behaviors of food delivery motorcyclists, little is known about the determinants of non-fatal crashes involving online food delivery riders. The present study examines the prevalence and factors of non-fatal crashes among food delivery riders.

**Methods:** The self-reported data of 393 online food delivery riders were collected in Hanoi and Hochiminh city, Vietnam. Binary logit regression was used to investigate the factors associated with non-fatal crashes.

**Results:** The findings showed that more than half of riders (54%) reported being involved in at least one crash in the last 12 months. The most common risky riding behaviors associated with the crashes included using a mobile phone while riding, neglecting turn signals, red-light running, riding when tired/sleepy, and speeding. The riders who were national migrants, married, and worked on planned delivery routes mainly alone were more likely to experience crashes. At the same time, adequate perceived rewards for their work prevent crash involvement. Perceived risk was not a significant predictor of self-reported crashes.

**Conclusions:** Ensuring road safety for delivery riders requires a systemic effort involving multiple stakeholders, and the private sector plays a crucial role in discouraging risky riding behaviors. It is imperative for the government and regulatory bodies to redefine the delivery job to alleviate the strain on riders and provide resources such as rewards. Specifically, riders should be considered employees rather than partners. Furthermore, it is crucial for the police to take a more active role in preventing dangerous behaviors among delivery riders, such as running red lights. At the same time, supporting financial strategies should be implemented for delivery riders, particularly for those who are migrants or married and may face additional challenges.

## ARTICLE HISTORY

Received 8 June 2022  
Accepted 14 July 2023

## KEYWORDS

Accident; food delivery; risky riding behavior; non-fatal crashes; binary logistic regression; workload

## Background

The rapid development of information technologies and digital innovations has increased the profound growth in online shopping over the last several decades. Recently, the outbreak of COVID-19 has influenced the expansion of e-purchasing services, particularly for food (UNCTAD 2020). To complete the online-to-offline process, online shopping needs delivery services, wherein couriers are notified online to pick up orders and send them to the customers quickly. Therefore, the proliferation of food e-shopping has placed substantial demands on delivery riders. In 2018, Ele.me and Meituan<sup>1</sup> hired over 3 million and 0.5 million food delivery riders in China (Chen and Sun 2020). Riders can carry

meals to customers by car in industrialized countries. Motorcycles/scooters, which are more flexible and accessible to busy and narrow streets than four-wheeled vehicles, are used the most in low- and middle-income countries (LMICs). However, the increase in delivery motorcyclists has resulted in significant adverse safety outcomes (Nguyen et al. 2021).

Delivery riders are among the most vulnerable road users. Existing studies have emphasized that food delivery in LMICs is a notoriously informal, precarious, and dangerous occupation (Nguyen-Phuoc et al. 2022). It is characterized by job insecurity and irregular working time (Huang 2021). Analyses in China (Zheng et al. 2019) and Malaysia (Kulanthayan et al. 2012) show that riders experience

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Associate Editor Richard Frampton oversaw the review of this article.

 Supplemental data for this article can be accessed online at <https://doi.org/10.1080/15389588.2023.2238862>.

<sup>1</sup>Ele.me founded in 2008 is a food delivery platform whose name means 'Hungry now?'. Meituan founded in 2009 is a shopping platform. Ele.me and Meituan formulate a duopoly in China, accounting for about 90% of the online food delivery market.

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extreme workloads with insufficient resting time, high-stress levels, and a lack of protective equipment. Regarding safety, in the UAE, there are reports of nearly 70 delivery riders being hospitalized, of which 24 died in 2020 (VOA 2021). From March to June 2020, more than 150 crashes involving food delivery motorcyclists were reported in Malaysia (Bernama 2021). As for the reasons, much research has also reported that delivery riders engage more than private riders in risky behaviors such as phone use while riding, thus leading to more involvement in crashes (Choi et al. 2022; Oviedo-Trespacios et al. 2022; Zheng et al. 2019). Several studies have presented a socio-demographics-based picture of crashes among delivery riders. In a study based in Malaysia, Rusli et al. (2022) found that the likelihood of crashing was significantly higher for young workers. Another analysis set in the Republic of Korea indicated that roughly 99% of crash-related delivery riders were male (Byun et al. 2017). The relationship between educational degree and crashes for e-bike riders in Shanghai was investigated by Wang et al. (2021).

While food delivery rider-related traffic crashes are severe, little is known about the determinants of crash involvement. Using a national dataset of 1,317 crashes involving food delivery motorcyclists in South Korea, Byun et al. (2020) reported that most injured riders are temporary workers working in small companies, riding at night, and less than one month on the job. Fewer rests, a higher frequency of risky riding behaviors, and more daily orders are demonstrated to significantly increase the probability of crash involvement for delivery riders in Shanghai and Nanjing, China (Zheng et al. 2019). Based on these findings, it is clear that there is a connection between the job design (including training) and the safety outcomes of food delivery riders.

Preliminary research has analyzed the predictors of traffic crashes involving commercial riders (mainly motorcycle taxi drivers) (e.g., Nguyen-Phuoc et al. 2019a; Wankie et al. 2021). However, the results from these studies have partial transferability to food delivery riding safety. This is mainly because transporting a passenger has been consistently identified in the literature as a protective factor against risky riding behaviors (Nguyen-Phuoc et al. 2019b). As such, research looking at solo-rider workers is necessary.

In the current paper, the investigation analyses self-reported non-fatal crashes of food delivery riders (i.e., crashes not resulting in the deaths of riders). This is significant because non-fatal crashes are more frequent and have more significant financial and social costs than fatal crashes. Moreover, there is a direct correlation between non-fatal crashes and fatal crashes. When there are a greater number of non-fatal crashes, it is more likely to result in an increased frequency of fatal crashes (Bellamy 2015). This study contributes to the literature in several ways. Firstly, it investigates the prevalence of non-fatal traffic crashes among food delivery riders in a motorcycle-dependent country. Secondly, it provides an in-depth analysis of the relationship between non-fatal crashes and risky riding behaviors. Third, it provides a comprehensive model associating socio-demographic and job design factors with non-fatal crashes. This study was conducted in Vietnam, a typical

motorcycle-dependent country in Southeast Asia, with the highest rate (43%) of fatalities in motorcycle-related crashes worldwide (World Health Organization 2018). The country has witnessed the rapid growth of food delivery services, especially during the COVID-19 era, with a value of about 38\$ million (2020) and an expected annual growth rate of the next five years at 11%. This trend raises concerns about increased motorcycle use and traffic safety in urban areas (VietnamCredit 2020). In 2021, ShopeeFood and GrabFood were Vietnam's leading food delivery services (41% of the market share). The findings of this study can be used to increase the safety of food delivery riders in LMICs.

## Data and methods

### Research settings

This study was carried out in Hanoi and Hochiminh City - the two largest cities of Vietnam and typical megacities in the Global South contexts (see Figure 1). Among Vietnamese cities and provinces, Hanoi and Hochiminh City are the busiest and most developed markets for online food delivery services, with many prominent brands, such as GrabFood, Baemin, Gojek, and Now. It is essential to highlight that cars are expensive in Vietnam. Also, a lack of cycling infrastructure reduces the feasibility of bicycle-based food delivery. Consequently, motorcycles are chosen by almost all delivery riders.

### Data collection

The survey of this study was conducted between 10 April and 9 May 2021. During this period, COVID-19 was stamped out successfully in Hanoi and Hochiminh City; therefore, a face-to-face interview was employed. Ten trained undergraduate students (five in Hanoi and five in Hochiminh City) accessed public places where food delivery riders usually gathered to take a rest and wait for missions, such as lakes, parks, and department stores. For recruitment, the surveyors directly approached riders during non-business hours (before 10:30, 14:00 - 17:00 on both weekdays and weekends) to give participation invitations. It is noted that research ethics approval for carrying out a survey is not required in Vietnam. However, to mitigate any potential risks to the surveyed riders, the surveyors were required to clearly explain the main aim and objectives of the research for all riders approached. The surveyors also highlighted that the survey was confidential and their responses were anonymous. The delivery riders were also informed that their participation in the survey was completely voluntary and they would receive an incentive of approximately 1.5\$ as compensation for their time. On average, about 75% of invited riders took part in and completed the survey. It took around 12–15 min to complete the entire questionnaire. There were over 25 riders who decided to stop the interview mid-way through since they received work-orders. Finally, among 561 completed forms, only 393 (70%) of delivery riders working at least 12 months were

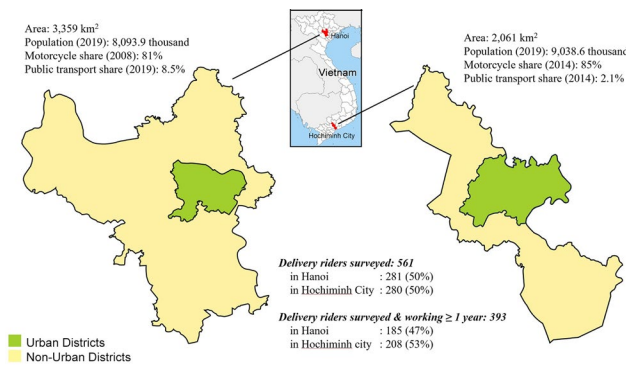


Figure 1. Research areas and survey profile.

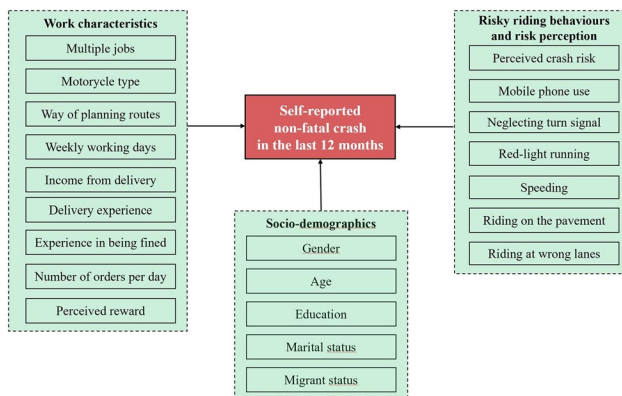


Figure 2. Considered factors to model the self-reported non-fatal crash prevalence among food delivery riders.

eligible for further analyses of the prevalence and determinants of traffic crashes.

### Questionnaire

Based on previous research on non-fatal crashes among taxi motorcyclists conducted by (Nguyen-Phuoc et al. 2020b, 2019a, Rusli et al. 2020), this study adopted three groups of independent variables: socio-demographics, working characteristics, risk perception and six risky riding behaviors – which are common among motorcyclists (Figure 2). The six considered risky riding behaviors were the most frequent violations for commercial riders based on our practical observations and previous relevant studies (Nguyen-Phuoc et al. 2020; Oviedo-Trespalacios et al. 2022; Shen et al. 2020; Zheng et al. 2019). Some new variables were added to adapt to the context of the delivery job, following proven relationships between them and working safety.

A structured questionnaire was designed following the proposed framework to collect the data for this study. First, the cover page introduced the survey objectives and emphasized that each rider should participate once. The second part requested socio-demographic information on gender, age, education, marital status, and internal migrant status. The following section gathered data on the availability of other jobs besides delivery worker (e.g., students or others), the motorcycle type used, planning routes, the average number of working days, the

average number of orders per day, the income from delivery, working experience, the history of being fined in the last year, perceived risk of crash (*'I am at a high risk of crashes due to riding in various road and weather conditions'*), and perceived reward (*'My performance is rewarded properly'*) – adapted from (Demerouti et al. 2001). The measurement of perceived risk and perceived crashes were achieved using a 7-point Likert scale.<sup>2</sup> In the fourth part, the frequencies of various violations (i.e., riding on the pavement, speeding, neglecting turn signal, mobile phone use, red-light running, riding in wrong lanes) were asked using a 7-point Likert scale.<sup>3</sup> The last part, which was applied only for riders working at least 12 months, encompassed whether the respondent was involved in at least one traffic crash in the previous 12 months. If the respondent declared to have been involved in crashes, (s)he was then asked to choose all the risky behaviors related to such crashes from a list provided (Figure 3).

### Analytical methods

Descriptive statistics were carried out to describe the characteristics of the sample used. Subsequently, the prevalence of non-fatal crashes and associated risky riding behaviors were analyzed. Binary logistic regression was undertaken to better understand the critical factors of crashes. The dependent variable was whether a respondent had been involved in a crash in the past 12 months (crash involvement = 1; non-crash involvement = 0). Independent variables were categorized into three groups, as illustrated in Figure 2. The authors first fitted a full model that includes all the independent variables to choose the most important predictors of crash prevalence. Then, the final model, which is the most parsimonious, consisted of only significant variables in the model. The chosen statistical threshold of significance for  $p$ -value was 0.05.

For a regression model, multicollinearity can result in biased standard errors, thus unstable the values of  $p$ . Therefore, Variance Inflation Factors (VIFs) for predictors were estimated. VIF of each independent variable should be under 4 to be safely kept with no concern about the effect of multicollinearity (O'Brien 2007). Stata 15.0 was used to implement statistical analyses.

## Results

### Characteristics of the sample and crashes

The profiles of food delivery riders surveyed in connection with their engagement in traffic crashes in the last 12 months are provided in Appendix 1. Among 393 delivery riders questioned, the majority (88%) were male. The sample was relatively young, with an average age of 27.15 (std = 5.682). Most workers were single (65%), internal migrants (57%), and did not hold a university degree (63%). While working as a delivery rider was the only occupation for 61% of the respondents, 28% were students. Manual motorcycles were

<sup>2</sup>Ranging from 'strongly disagree' to 'strongly agree'

<sup>3</sup>1: Never; 2: Seldom ( $\leq 10\%$  of trips); 3: Occasionally ( $\leq 30\%$  of trips); 4: Sometimes ( $\leq 50\%$  of trips); 5: Frequently ( $\leq 70\%$  of trips); 6: Regularly ( $\leq 90\%$  of trips); 7: Always (over 90% of trips).



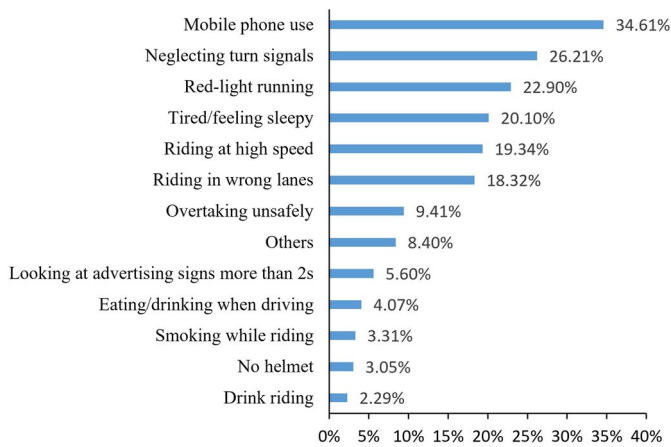


Figure 3. Risky riding behaviors associated with crashes.

used much more than automatic ones (68% vs. 32%). The planning of delivery routes relied entirely and mostly on applications for 43% and 41% of the interviewed riders. A high number of respondents (246 or 63%) had no day off, while a quarter worked six days per week. Roughly 27% got fined while working. On average, a rider worked 17.85 months (std = 8.270) and earned 9.72 million VND (std = 4.528) from delivering orders, which was higher than Vietnam average monthly income in 2020 (around 4.2 million VND).

The prevalence of non-fatal traffic crashes among food delivery riders interviewed was 53.94% (95% CI: 48.87–58.95). The rates of female and male involving crashes were close at around 54%. Higher crash prevalence was reported for less-educated riders (59.27%; 95% CI: 52.88–65.45) compared to those holding a university degree (44.83%; 95% CI: 36.57–53.30). The proportion of married riders engaging in crashes (65.69%; 95% CI: 57.10–73.59) was much greater than that for single counterparts (47.66%; 95% CI: 41.40–53.97). A similar pattern of the prevalence was seen for internal migrant riders (59.56%; 95% CI: 52.83–66.03) against non-migrant ones (46.43%; 95% CI: 38.71–54.27). Automatic ones made up a smaller number than manual motorcycles but had a greater prevalence of non-fatal crashes (61.29% vs. 50.56%). The crash-involved rate for riders who relied mainly on themselves and sometimes on the app for navigation (84.61%; 71.92–93.12) was far higher than other rider groups. Regarding the number of working days per week, crash prevalence increased. Generally speaking, the crash rate of delivery riders who never adopted risky behaviors (e.g., red light running and using mobile phones while riding) was lower than those of riders who seldom, occasionally, sometimes, frequently, regularly, and always engage in these activities. As regards perceived reward, the highest (80%, 95% CI: 44.39–97.47) and lowest (39.47%, 95% CI: 28.44–51.35) crash prevalence was seen for respondents who strongly disagreed and strongly agreed with ‘My performance is rewarded properly’, respectively. Surprisingly, the lowest prevalence of crashes (42.85%, 95% CI: 9.89–81.59) was involved in the lowest level of perceived risk (i.e., strongly disagree), while the figure for participants having the highest level of perceived risk was 47.36%, 95% CI: 35.79–59.15.

The tests of analysis of variance (ANOVA) indicated that the age differences (df: 1,  $F$ : 1.82,  $\text{Prob} > F$ : 0.1779), delivery income (df: 1,  $F$ : 1.14,  $\text{Prob} > F$ : 0.2853), and the number of orders per day (df: 1,  $F$ : 0.1,  $\text{Prob} > F$ : 0.7501) between riders involving crashes and those experiencing no crashes were insignificant. However, the ANOVA test is significant for working experience (df: 1,  $F$ : 8.54,  $\text{Prob} > F$ : 0.0037). Specifically, delivery riders involving crashes had a significantly higher mean of working months (18.4 vs. 15.8).

Regarding the relationships between self-reported crashes and risky riding behaviors (Figure 3), mobile phone use while riding for work was selected as the top cause of crashes. Nearly 35% of riders declared engaging in this behavior when experiencing crashes in the past 12 months. The next common unsafe riding behaviors conducted when crashes occurred included neglecting turn signals (26%), red light violation (23%), feeling tired or sleepy (20%), speeding (19%), and riding in the wrong lanes (18%). Other dangerous riding behaviors were much less frequently involved in crashes, with less than 10% of riders reporting them.

### Factors influencing crashes

A parsimonious model was fitted, as shown in Table 1. The final model showed that reporting a crash among food delivery riders was associated with socio-demographics (marital status and migrant status), work characteristics (way of planning routes and perceived reward), and risky riding behaviors (frequency of red-light running). Since all estimated VIFs for independent variables were smaller than 2 (Appendix 2), the risk of multicollinearity was eliminated. The odds ratio presents the change in the odds resulting from a unit change in the independent variable. The odds ratio greater than 1 indicates a positive relationship wherein an increase in the predictor coincides with increased odds of reporting a crash. By contrast, the odds ratio of less than 1 suggests a negative correlation.

Relative to single riders, married ones were more likely to experience a crash last year (OR = 2.193). Internal migrant riders (OR = 0.405) were more likely to report a crash. The riders relying on themselves mostly and on the app sometimes when selecting delivery routes had a higher likelihood of crash involvement (OR = 6.608) than those depending entirely on the app. Respondents with a strong disagreement with the receipt of a reward commensurate with working performance were more inclined to experience a crash compared to others who agreed (OR = 0.183) or strongly agreed (OR = 0.098) with receiving a proper reward. Delivery riders who seldom (OR = 2.153), occasionally (OR = 3.282), sometimes (OR = 3.125) or frequently (OR = 3.428) run through red lights were more likely to report having been involved in a crash.

### Discussion

The outbreak of COVID-19 and the rapid advances in information communication technologies have accelerated the growth of virtual shopping for food, thereby imposing

heavier working demands on delivery riders. This paper investigated non-fatal crashes among food delivery riders in Vietnam. The main aspects are discussed and interpreted as follows: (1) the prevalence of non-fatal traffic crashes among the respondents; (2) the risky riding behaviors that were performed when crashes occurred; (3) the factors associated with the crash prevalence based on binary logistic regression; and (4) the proposed practical implications.

(1) *Regarding the prevalence of non-fatal traffic crashes*, 54% of all participants reported being involved in at least one crash in the last 12 months. The proportion seems to be higher than that of taxi riders in Rwanda (39% - considering the whole lifetime of riders [Nickenig Vissoci et al. 2020]), Cameroon (22% - considering crashes within the last year [Wankie et al. 2021]), and Vietnam (30% - considering crashes within the last 12 months [Nguyen-Phuoc et al. 2019a]). The high number of food delivery riders involved in non-fatal crashes may be a consequence of the stricter time-related demands that they experience compared to taxi riders, i.e., delivery riders' income is negatively affected by delays. Additionally, taxi riders also need to keep in mind the safety of their passengers, which becomes a protective factor (Nguyen-Phuoc et al. 2019b). The COVID-19 pandemic could have contributed to many traffic crashes reported by food delivery workers in Vietnam, i.e., disruption in the training, safety checks, and maintenance of vehicles. In an analysis set in Hochiminh city (Vietnam) during the lockdown time, 74% of 806 delivery riders reported engaging in risky riding behaviors (Tran et al. 2022). Another factor is that the absence of several riders due to fear of

COVID-19 infection could have resulted in a heavier workload for those remaining, leading to greater collision risk (Huang 2021). Based on these findings, it is clear that the private sector is not doing enough to prevent crashes, which is consistent with previous studies (Papakostopoulos and Nathanael 2021). Arguably, the fact that taxi riders are safer suggests that job-specific factors of the food delivery industry need to be modified. It is important to remember that both economic activities, taxi and delivery riders, occur in similar vehicles and the same road traffic environment. The nature of the work is the main difference.

(2) *Regarding the risky behaviors conducted when crashes took place*, using a mobile phone for tasks such as confirming orders, checking addresses and contacting customers is essential to food delivery riding. Nonetheless, phone use while on the road is a source of distraction when riding (Nguyen-Phuoc et al. 2020). Thus, food delivery companies need to work to develop strategies to prevent distraction. And the government need to establish a process that protects riders from the current inherently risky job design of food delivery riding. Notably, riders should not be blamed for this behavior because it is the product of poor job design. This research is consistent with the trend in the literature highlighting that the use of the phone-based platform for gig-economy work results in distraction and safety risks (Oviedo-Trespalacios et al. 2022). Another characteristic of the food delivery riding process that influences the behavior of the riders is the time pressure associated with completing the delivery on the expected calculations made by the app. When in a hurry, food delivery riders neglect

**Table 1.** Factors associated with crash involvement.

| Exploratory variables                      |                                                               | Odds Ratio | Std.  | p> z   |
|--------------------------------------------|---------------------------------------------------------------|------------|-------|--------|
| Socio-demographics                         | <i>Marital status</i>                                         |            |       |        |
|                                            | single                                                        | ref        | ref   | ref    |
|                                            | married                                                       | 2.193      | 0.540 | 0.001  |
|                                            | <i>Internal migrant status</i>                                |            |       |        |
| Work characteristics                       | no                                                            | ref        |       |        |
|                                            | yes                                                           | 0.405      | 0.102 | <0.001 |
|                                            | <i>Way of planning routes</i>                                 |            |       |        |
|                                            | depend on the app completely                                  | ref        | ref   | ref    |
| Risky riding behaviors and risk perception | depend on the app mostly and on yourselves sometimes          | 1.389      | 0.357 | 0.201  |
|                                            | depend on yourselves mostly and on the app sometimes          | 6.608      | 2.971 | <0.001 |
|                                            | depend on yourselves entirely                                 | 2.692      | 1.885 | 0.157  |
|                                            | <i>Perceived reward (My performance is rewarded properly)</i> |            |       |        |
|                                            | strongly disagree                                             | ref        | ref   | ref    |
|                                            | disagree                                                      | 0.620      | 0.596 | 0.620  |
|                                            | relatively disagree                                           | 0.435      | 0.442 | 0.413  |
|                                            | neutral                                                       | 0.242      | 0.219 | 0.117  |
|                                            | relatively agree                                              | 0.268      | 0.236 | 0.135  |
|                                            | agree                                                         | 0.183      | 0.164 | 0.048  |
|                                            | strongly agree                                                | 0.098      | 0.088 | 0.010  |
|                                            | <i>Frequency of red light running</i>                         |            |       |        |
|                                            | never                                                         | ref        | ref   | ref    |
|                                            | seldom (up to 10% of trips)                                   | 2.153      | 0.668 | 0.013  |
|                                            | occasionally (up to 30% of trips)                             | 3.282      | 1.180 | 0.001  |
|                                            | sometimes (up to 50% of trips)                                | 3.125      | 1.209 | 0.003  |
|                                            | frequently (up to 70% of trips)                               | 3.428      | 1.800 | 0.019  |
|                                            | regularly (up to 90% of trips)                                | 1.668      | 1.238 | 0.490  |
|                                            | always (over 90% trips)                                       | 1.199      | 1.585 | 0.890  |
|                                            | Intercept                                                     | 1.961      | 1.783 | 0.459  |

Note: Dependent variable: whether experiencing crashes in the last 12 months (1=yes; 0=no).

To explore the potential difference in the effects of exploratory variables on the prevalence of crashes between Hanoi and Hochiminh City, interactions between the city (0 = 'Hanoi', 1 = 'Hochiminh City') and exploratory variables were modeled. However, since all the interactions were insignificant, Table 1 only presents the results of the model without considering interactions.

Log-likelihood: -229.3576, LR  $\chi^2(17)$ : 83.65, Pseudo R<sup>2</sup>: 0.1542, Number of observations: 393.



turn signals, disregard red lights, ride faster and ride in the wrong lanes (Zheng et al. 2019). Targeted enforcement and more severe penalties for such illegal riding behaviors are highly recommended to prevent crashes (Nguyen-Phuoc et al. 2020). Finally, the present study found that 60% of respondents reported working the whole week with no rest days. As insufficient rest and sleep disorders are common among riders (Huang 2021; Zheng et al. 2019), limiting working time and guaranteeing a livable wage should be considered to improve the safety and well-being of the riders.

(3) *Regarding the influential risky factors*, the logistic regression analysis revealed marital status, internal migrant status, way of planning routes, perceived reward and frequency of red light running. The significantly positive association between married status and crash involvement can be explained on financial grounds. In Vietnamese culture, the man is usually the breadwinner in his family, particularly for low(er)-income households (Hoang 2011). Therefore, married (male) riders are probably under a more considerable financial burden. As for marital status, the significantly higher odds of involving a crash for internal migrant riders can stem from a more significant financial obligation relative to local peers, possibly pushing them to engage in more traffic violations to earn more.

Planning an optimal delivery route to reduce riding time is vital for riders. In most cases, experienced riders can plan routes by themselves and sometimes consider the routes recommended by the app. However, this routing approach was more likely to involve crashes than depending entirely on the apps, as riders would choose (often illegal) shortcuts to arrive at destinations faster. For instance, they might ride illegally on one-way roads and narrow alleys, which might not be available on the apps' maps.

Red-light running was the top three risky riding behavior associated with traffic crashes. Furthermore, the binary regression confirmed the significant association between the prevalence of crashes and the frequency of red light violations (Zheng et al. 2019). Notably, the likelihood of crash involvement for those regularly or always running through the red lights compared to that for those never doing so was insignificantly different. Perhaps due to the familiarity with the potential risks possibly occurring due to the red-light running, the respondents can avoid the crashes. However, it is important to emphasize that their violation can pose threats to many other riders who strictly adhere to the traffic lights at intersections. In Asia, running through red lights is a prevalent behavior among motorcyclists. The observational survey in Malaysia reported that 9,280 (12.8%) of 72,377 motorcyclists engage in this behavior (Rusli et al. 2020). Of over 15.57 million violations recorded by the police in Vietnam from 2016 to 2020, about 2.2% are illegal riding behaviors at intersections (NTSCV 2021). In megacities like Hanoi and Hochiminh city, road policing is usually neglected in rush hours as the police are busy guiding traffic (Nguyen et al. 2019; Tien 2021). In addition, anecdotal evidence suggests that the police focus more on violations of conventional riders at intersections rather than commercial ones due to the known vulnerabilities of this group of riders. For example, online food delivery riders will confront

severe difficulties with their companies. This phenomenon partly explains why the rate of riders being fined was relatively low (27%) compared to 49% of respondents reporting engaging in red light running for at least 30% of delivery trips.

A rider who perceived their performance was appropriately rewarded was less likely to report crashes. This finding is consistent with the Job Demands-Resources model that explains the behavioral responses of individuals in work settings. The analyses of Nahrgang et al. (2011) demonstrated that a demanding job causes prolonged stress, depression, and physical and mental exhaustion (i.e., job burnout), triggering unsafe behaviors. However, resources, such as rewards, can relieve job burnout and subsequently reduce the extent and likelihood of performing risky behaviors (Demerouti et al. 2001; Tran et al. 2022). In this sense, platforms should (re-)formulate compensation methods that prioritize riders' well-being. Indeed, appropriate rewards for riders with good safety records would reduce burnout and encourage safe riding.

(4) *In terms of managerial implications*, this study has highlighted the significant responsibility of motorcycle-based couriers in developing countries to adopt safe riding behaviors, as well as the pressure of the delivery job, which can lead to non-fatal crashes. It is critical for the government and regulatory bodies to redefine the delivery job to alleviate the strain on riders and provide resources such as rewards for delivery riders. Specifically, riders should be considered as employees (rather than partners) and be eligible to receive more benefits from the platforms/companies they work for. However, this may require a significant amount of effort and time due to opposition from delivery enterprises. Therefore, it is essential for the police to be more active in preventing dangerous behaviors among delivery riders, such as red-light running. Additionally, there is a pressing need to implement financial support strategies for delivery riders, especially for those who are migrants or married and may face additional challenges.

Several limitations need to be highlighted. Firstly, the crash rate reported in this paper is likely to be underestimated because of the absence of riders who experienced severe crashes and did not return to work in the industry. Secondly, this study relies on the willingness to take part in the survey of riders. Although incentives were provided to encourage participation, nearly 25% of potential participants decided not to participate. Thirdly, this study did not adopt a conceptual framework based on a well-established theory (e.g., the theory of planned behavior). As such, many latent psychological factors, which are critical determinants of performing risky riding behaviors and thus experiencing crashes, were disregarded in this study. Fourth, our study found that the number of weekly working days and the average number of orders per day in the prevalence of crashes. There is a need to explore the reason behind this finding as it has been widely reported in previous research (Nguyen-Phuoc et al. 2019a; Zheng et al. 2019). Perhaps, if we had considered the interaction between working days and working hours, the effects of workload on crash rates would have been obvious. Future research should better

address the limitations of this current analysis when investigating the factors contributing to traffic crashes among delivery riders in different contexts. In addition, gathering and analyzing more detailed characteristics of crashes, such as the severity and the vehicles involved can lead to a better understanding of the safety outcomes of food delivery riders.

## Funding

The author(s) reported there is no funding associated with the work featured in this article.

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