Transportation Research Part F 23 (2014) 113–124

Contents lists available at ScienceDirect

Transportation Research Part F

journal homepage: www.elsevier.com/locate/trf

Factors contributing to hit-and-run crashes in China

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ARTICLE INFO

Article history:
Received 12 July 2013
Received in revised form 28 November 2013
Accepted 9 December 2013

Keywords:
Road safety
Hit-and-run
Logistic regression
China

ABSTRACT

Hit-and-run accidents, or those where the perpetrator leaves the crash scene without reporting the event, are a serious concern because they can delay the rescue of victims, thereby increasing the fatality rate and severity of injuries. However, only a few studies exist on the factors that influence hit-and-run behavior, particularly in developing countries. Using data collected from Guangdong Province in China, this study applies a logistic regression model to analyze factors associated with hit-and-run behavior in five categories: crash attributes and human, vehicle, road, and environmental factors. This study finds that the probability of hit-and-run behavior increases with accidents that involve pedestrians, occur in dark driving conditions, and are caused by drivers who are male, middle-aged, and without a valid driver's license, extensive driving experience, or automobile insurance. Therefore, we recommend closer supervision and better public education for different groups of people about traffic laws and regulations.

1. Introduction

Traffic accidents have long been a serious threat to human life and property around the world. Approximately 1.3 million people die each year on the road, and between 20 and 50 million people sustain non-fatal injuries in automobile crashes (World Health Organization, 2009). Among the different types of vehicle crashes, the hit-and-run crash is the most dangerous. While the legal definition of hit-and-run varies from country to country, the hit and run is generally considered a crime in most jurisdictions because it is usually required in statutes that the driver of a vehicle who is involved in a collision with another vehicle, object or human being must stop immediately to provide his or her name, license number and other information required by law to the injured party, a witness or law enforcement officers (Fisher, 1961). Article 70 of Chapter V, Disposition of Traffic Accidents, in the Law of the People's Republic of China on Road Traffic Safety requires that, when a road traffic accident occurs, the driver should immediately stop the vehicle and keep the scene intact; and if the accident causes casualties, the driver should immediately rescue the injured persons and speedily report to the traffic police officer on point duty or to the traffic control department of the public security organization. Otherwise, the case will be considered as hit and run. If the victims die, the offender may be subject to death penalty.

Hit-and-run behavior inevitably delays the notification of authorities and hinders rescue responses, thereby increasing the severity of injuries and fatality rates of victims. In the United States, hit-and-run crashes accounted for 18.1% of

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http://dx.doi.org/10.1016/j.trf.2013.12.009

approximately 48,000 pedestrian fatalities between 1998 and 2007, with wide variation by state, which ranged from 6.6% in Mississippi to 29.8% in the District of Columbia (MacLeod, Griswold, Arnold, & Ragland, 2012). With their severe consequences, hit-and-run crashes have attracted significant public attention. More effective measures should be taken to prevent hit-and-run behavior. However, only a few studies have focused on factors associated with this behavior, and even fewer have focused on the determinants of hit-and-run behavior in developing countries.

Most previous studies have examined hit-and-run crashes in developed countries, although developing countries have higher traffic fatality rates than developed countries (19.5 and 10.3 per 100,000 population, respectively), and developing countries account for 90% of road fatalities with only 48% of registered vehicles in the world. Thus, our study aims to shed light on the determinants of the hit-and-run behavior in developing countries with considerably different social and cultural environments.

The main objective of this study is to identify the factors that influence the decisions of drivers to flee after traffic accidents in China. This paper contributes to the literature in the following aspects. First, our study examines a highly comprehensive set of factors. The detailed data extracted from Guangdong Provincial Security Department covers 30,878 traffic crashes involving 40,373 drivers from 2006 to 2010. A total of 77 variables in 23 categories are examined in this study, and several socioeconomic factors that affect hit-and-run decisions are identified for the first time.

This paper is organized as follows. Section 2 discusses the empirical literature and summarizes the factors that may induce hit-and-run behavior. Section 3 describes the methodology, data, and variables. Section 4 presents the empirical results and discussion. Section 5 concludes the study, as well as indicates its policy implication and research limitation.

2. Literature review

To develop appropriate driver interventions and prevent hit-and-run behavior, two research questions have to be answered: (1) what factors affect the possibility of identifying perpetrators and (2) what factors make the perpetrators of hit-and-run crashes more likely to flee after crashes.[1] Concerning the methods of identifying the involved vehicles and drivers to help apprehend the perpetrators, existing studies find that the color of retrieved paint fragments from crash scenes or from the clothing of victims can be used to identify perpetrators (Baucom, 2006; Karger, Teige, Fuchs, & Brinkmann, 2001; Locke, Cousins, Russell, Jenkins, & Wilkinson, 1987; Locke, Sanger, & Roopnarine, 1982; Locke, Wilkinson, & Hanford, 1988; Taylor, Cousins, Holding, Locke, & Wilkinson, 1989). Other researchers have developed methods based on forensic science to identify the types of vehicles involved in crashes according to the injuries of victims (Karger et al., 2001; Teresinski & Madro, 2001).

As regards the second research question, a study conducted in Singapore by Tay, Rifaat, and Chin (2008) has proposed a cost-benefit analysis framework and argued that the hit-and-run decisions of drivers depend mainly on the likelihood of apprehension, expected benefits of running away, and expected costs of being arrested. Any factor that affects the probability of escaping detection and the driver perception of subsequent economic and legal consequences of the accident significantly contribute to the occurrence of hit-and-run behavior. From an empirical perspective, a logistic regression model has been used as the main analytical method, using "hit-and-run" or "non-hit-and-run" crashes and "perpetrator caught" or "perpetrator not caught" as binary or dichotomous variables, to examine the risk factors related to the hit-and-run crash and the characteristics of the drivers involved (Aidoo, Amoh-Gyimah, & Ackaah, 2013; MacLeod et al., 2012; Solnick & Hemenway, 1995; Tay, Barua, & Kattan, 2009; Tay, Kattan, & Sun, 2010; Tay et al., 2008). These studies find that crash attributes as well as human, vehicle, road, and environmental factors have a significant effect on the hit-and-run decision.

2.1. Crash attributes

The features of the crash itself affect hit-and-run behavior. Drivers are more likely to leave the scene when the collision is with a pedestrian rather than with another vehicle (Tay et al., 2008, 2009). Compared with single-vehicle crashes, crashes that involve two or more vehicles are associated with a significantly higher probability of being hit-and-run cases in fatal crashes (Tay et al., 2008, 2009). Collision type also affects the possibility of hit-and-run behavior in fatal crashes. Compared with head-on and other types of collision, single-vehicle, rear end, angle, and sideswipe collisions are more likely to induce hit-and-run behavior in a fatal crash (Tay et al., 2009).

2.2. Human factors

The characteristics of the victims and perpetrators have a significant effect on hit-and-run behavior and whether the offender will be identified afterwards. Research indicates that when the victim is female, the perpetrator is less likely to flee. However, the association of hit-and-run behavior with victim gender depends entirely on the circumstances of the crash (Solnick & Hemenway, 1995). Although the effect of the victim gender is not obvious, most studies show strong indications

[1] Solnick and Hemenway (1994, 1995) report that in approximately half of the US pedestrian fatality hit-and-run cases, the driver is never apprehended or identified.

that male drivers are more likely to flee from a crash than female drivers (Tay et al., 2010). With regard to identifying who flees the scene of a crash, drivers are more likely to be identified when the victims are female (MacLeod et al., 2012). Age also makes a difference. Drivers are less likely to flee from collisions that involve younger and older pedestrian victims (MacLeod et al., 2012; Solnick & Hemenway, 1995) and are more likely to be identified when the victims are young (MacLeod et al., 2012). Compared with other age groups, middle-aged drivers (between 45 and 69 years old) are more likely to flee (Tay et al., 2008, 2010). Although alcohol involvement is a key factor in the probability of leaving the scene of a crash (MacLeod et al., 2012; Solnick & Hemenway, 1995), testing this factor is difficult because some perpetrators remain at large when the records are made and others are arrested long after the crash when detecting alcohol use at the time of the accident is almost impossible. Thus, prior research has used previous conviction records for "driving while intoxicated" (DWI) to complement analysis, which demonstrates that having an invalid license or previous DWI conviction more than doubles the likelihood that a driver will flee from a pedestrian fatality (MacLeod et al., 2012; Solnick & Hemenway, 1995).

2.3. Vehicle factors

The type, age, and place of registration of the involved vehicles affect the hit-and-run behavior of drivers. If two-wheeled vehicles are involved in the crash or the vehicles are registered in neighboring countries, then perpetrators are more inclined to flee after a crash, whereas collisions that involve buses are less likely to be hit-and-run cases (Tay et al., 2008). Drivers of relatively new cars (5 years old at most) are less likely to flee from a crash.

2.4. Road factors

Road factors refer to roadway conditions, including type of roads, median characteristics, roadway alignments (both horizontal and vertical), speed limitations, and road devices such as signals. Drivers are more likely to flee from a fatal crash scene on interstate highways, as well as on county and municipal roads compared with other road types such as US highways, state highways, frontage roads, and other routes (Tay et al., 2009). Divided highways without traffic barriers and divided highways with median strips and two-way continuous left-turn lanes are believed to reduce hit-and-run behavior in fatal crashes compared with undivided and one-way streets. However, the opposite findings are true in Singapore (Tay et al., 2008, 2010). Roadway alignment also has a major effect on the likelihood of hit-and-run crashes. Studies have found that the probability of hit-and-run behavior in a fatal crash on a straight roadway is significantly higher than that in a crash on a curved roadway. Apart from horizontal alignment, vertical alignment is also observed to have a significant effect on the likelihood of hit-and-run behavior. The probability of hit-and-run crashes tends to increase when a crash occurs on a road with a level profile compared with a roadway with a grade (Tay et al., 2009). The crash location also matters. Drivers are more likely to flee from crashes when the pedestrian is in a location other than the crosswalk or road (MacLeod et al., 2012). Although MacLeod et al. (2012) claim that hit-and-run collisions are less likely to occur in locations with higher speed limits, the effect of speed limit on the likelihood of hit-and-run behavior appears to be nonlinear. According to Tay et al. (2009), collisions on roads with speed limits of 45 mph or less or on roads without speed limit have the highest likelihood of hit-and-run behavior. With regard to the effect of different traffic control devices, hit-and-run behavior is less likely in crashes that occur at intersections with stop signs.

2.5. Environmental factors

Environmental factors, including light conditions, day of the week, time of day, weather conditions, and urban or rural locations, play a major role in the likelihood of hit-and-run crashes. Light conditions are extremely influential in driver decisions about fleeing after a crash. In low light conditions, the perpetrators are more likely to flee (MacLeod et al., 2012; Solnick & Hemenway, 1995; Tay et al., 2008, 2009, 2010). Previous research on the effects of the day of the week and time of day suggests that the probability of hit-and-run behavior in fatal crashes is higher on weekends than weekdays (MacLeod et al., 2012; Solnick & Hemenway, 1995; Tay et al., 2009). However, research in Singapore reveals no significant difference (Tay et al., 2008). The effect of time of day is correlated to light conditions. Compared with day crashes, nighttime crashes are more likely associated with hit-and-run behavior (MacLeod et al., 2012; Tay et al., 2008, 2009). Time of day may affect hit-and-run behavior, but the effect of weather conditions remains ambiguous. According to Tay et al. (2008), the effect of weather conditions is insignificant in Singapore. However, Tay et al. (2010) however find that snow and rain reduce the chance of hit-and-run crashes compared with clear weather conditions in the city of Calgary. A disparity exists between hit-and-run behavior in urban and rural areas. An increased risk of hit-and-run behavior is associated with urban locations (MacLeod et al., 2012; Solnick & Hemenway, 1995), but this factor is not statistically significant when driver characteristics are considered (MacLeod et al., 2012).

Although these studies illuminate the factors that influence driver decisions, they are restricted to developed countries. With the lack of protection and rescue measures and facilities, the losses caused by vehicle collisions, particularly hit-and-run crashes, are actually more serious in developing countries. Thus, research from these countries is crucial. In our study, several new factors in the five categories (crash, human, vehicle, road, and environmental factors) that have not been previously examined, including the driving experience and occupations of motorists, main vehicle attributes, such as insurance status and properties of the vehicles involved, and certain China-specific factors, such as residential registration status (*hukou*[2]), are tested. We expect that these factors will significantly influence hit-and-run behavior. For example, as novice drivers tend to behave differently from experienced drivers in traffic violations (Zhang, Yau, & Chen, 2013), their hit-and-run behavior can also be different from those of experienced drivers. Occupations might also affect the hit-and-run behavior of drivers simply because some occupations such as policemen are believed to enjoy privilege in the traffic management system of China. Whether the involved vehicles have valid insurance also makes a difference. The influence of insurance on traffic safety is a subject of debate because it can lead to a moral hazard by reducing the financial burden of the driver in case of a crash, thereby encouraging risk-taking, which could increase the rate of traffic accidents (Zhang et al., 2013). People with a rural *hukou* tend to behave differently from those with an urban *hukou*, which reflects both the difference between urban and rural as well as local and non-local mindsets. Therefore, analyzing the effects of *hukou* on hit-and-run behavior is necessary.

3. Methodology and data

We analyze our data using a logistic regression model, which is also adopted by most of the previous studies on the factors associated with hit-and-run behavior (MacLeod et al., 2012; Solnick & Hemenway, 1995; Tay et al., 2008, 2009). A logistic regression model is developed to predict a binary dependent variable as a function of predictor variables. Tay et al. (2008) have reviewed various uses of the logistic regression model in road safety studies where the dependent variable is binary. In this model, the logit is the natural logarithm of the odds or the likelihood ratio that the dependent variable is 1 (a hit-and-run crash) as opposed to 0 (not a hit-and-run crash). The probability P of a hit-and-run crash is expressed in:

$$Prob(Y = 1|\boldsymbol{X}) = \frac{\exp(\boldsymbol{X}'\beta)}{1 + \exp(\boldsymbol{X}'\beta)} = \Lambda(\boldsymbol{X}'\beta) \tag{1}$$

where $\Lambda(\cdot)$ denotes the logistic cumulative distribution function. β is a vector of parameters to be estimated and $\boldsymbol{X}$ is a vector of independent variables. When an independent variable X_i increases by one unit as all other factors remain constant, the odds increase by a factor $\exp(\beta_i)$, which is called the odds ratio (*OR*), and ranges from 0 to positive infinity. This ratio indicates the relative amount by which the odds of the outcome (a hit-and-run accident) increase ($OR > 1$) or decrease ($OR < 1$) when the value of the corresponding independent variable increases by one unit (Tay et al., 2008).

One of the core tasks in developing the logistic model is selecting the variables that are expected to influence hit-and-run behavior. This paper selects the variables based on the review of the previous studies (MacLeod et al., 2012; Tay et al., 2008, 2009), which could be grouped into five categories as mentioned: crash attributes, human factors, vehicle factors, road factors, and environmental factors. However, certain amendments and supplements based on the local context and specific characteristics in developing countries have to be examined.

For example, driving experience is selected based on past studies (Zhang, Huang, Roetting, Wang, & Wei, 2006). This paper also considers *hukou* because it incorporates information on the social status, background, medical service, and social welfare status of an individual. The proportion of vehicles without insurance is extremely low in developed countries. By contrast, this research found that 21.4% of hit-and-run vehicles do not have insurance, as shown in Appendix A, which may result in moral hazard and may affect the risk of crashes and hit-and-run. The trend is similar in terms of vehicle safety. Only a few unsafe vehicles are on the road in developed countries because of strict regulations and examination, but based on our data, vehicles in bad safety state comprise about 8% of hit-and-run cases. The ownership of the vehicle is included in the study because this factor significantly affects driver behavior. For example, commercial vehicles have a higher possibility of being overloaded but have a lower likelihood of drunk driving. Moreover, commercial vehicles are usually registered in more detail, making it easier to identify which will reduce drivers' tendency to hit-and-run.

This paper examines 77 variables in 23 categories. The categories are: crash severity, type of collision, gender, age, driving experience, *hukou* (population registration), job, state of driving license, type of vehicle, vehicle maneuver, vehicle safety state, insurance, ownership of the vehicle, lane arrangement, type of road, road surface, type of crash location, type of traffic control device, light condition, weather condition, day of week, time of day, and season of the year. The summary statistics of these variables, including frequency distributions (total, hit-and-run and non-hit-and-run separately), are shown in Appendix A.

For categorical variables, we select one reference category to facilitate comparison and to measure the influence of different variables. Odds ratios against the reference case are used to reflect the effects of the factors.

We analyze the traffic crash data for 2006–2010 in Guangdong Province, China. Guangdong is representative of fast-developing China. Located in the southern part of mainland China, Guangdong Province has experienced the highest annual GDP growth (>10%) of any Chinese province since the economic reform and opening-up policy in 1978. As of 2010, the province had a resident population of over 104 million, making Guangdong the only province with more than 100 million residents. Owing to the rapid economic development and resulting increase in vehicles, the province has the most traffic

[2] *Hukou* is a type of population registration from the era of planned economy in China, which is intended to restrict internal migration. *Hukou* differentiates between people according to two dimensions: region and rural-urban attributes. The purpose of the *hukou* system is to guarantee that urban laborers are prioritized in obtaining employment in urban sectors and to exclude migrants from obtaining equal access to urban social welfare. Thus, a person with a rural *hukou* has difficulty obtaining a local urban *hukou*. Therefore, *hukou* status implies considerable information beyond the difference between urban and rural residences, such as education, occupation, and social status.

crashes among all 31 provinces in China. In 2010, the recorded traffic crashes, deaths, and injuries were 13.84%, 9.51%, and 14.37% (relative to nationwide total), respectively (Zhang, Yau, Gong, & Zhang, 2012). A total of 157 hit-and-run crashes have been recorded in the provincial capital of Guangzhou from January to December 2010, among which perpetrators have been identified in 145 cases; 88 of the hit-and-run crashes were fatal, and, of those, perpetrators were identified in 85 cases (Li, 2012).

Data obtained from the Guangdong Provincial Security Department are extracted from the Traffic Management Sector-Specific Incident Case Data Report covering 30,878 traffic crashes with 40,373 drivers from year 2006 to 2010, which is the only officially available, most detailed, abundant, and reliable source of traffic crash data in China. Data are recorded and reported by the traffic police who conduct on-scene assessments and provide feedback within 24 h to the headquarters of the Traffic Management Department. The information is recorded according to the Code of Traffic Crash Information issued by the Computer and Information Processing Standardization Commission under the Security Department of the country. Each sample includes detailed indexes about demographic information, injury severity, vehicle characteristics, road conditions, crash time, as well as environmental conditions, such as the level, form, and cause of the accident, damage severity of the vehicles, type of the responsibilities of the parties, injury severity of the parties, trip purpose, vehicle status, type of the drivers, and insurance condition (Zhang et al., 2013). Thus, the data are record based, and all victims and perpetrators who could be identified are recorded regardless of whether the case is a hit-and-run. However, the perpetrators in a hit-and-run crash who are not identified are excluded.

Recent studies on road safety in China mainly rely on observational or survey data to assess pedestrian safety (Liu, Huang, Wang, & Xu, 2011; Zhuang & Wu, 2011), helmet and seatbelt usage (Huang, Zhang, Morphy, Shi, & Lin, 2011; Routley, Ozanne-Smith, Li, Yu, Wang, & Zhang et al., 2008; Yu, Ke, Ivers, Du, & Senserrick, 2011), and driver attitudes and behavior toward road safety (Huang, Rau, Zhang, & Roetting, 2008; Zhang et al., 2006). Other studies have adopted regional traffic crash management data (Huang et al., 2008; Kong & Yang, 2010), but not on a large scale. To the best of our knowledge, the current study is the first to use the most comprehensive official database ($N = 40{,}373$) to conduct analysis of traffic crashes in China (Zhang et al., 2013).

The time trends should be considered because the conditions and environment might change significantly in a place that is experiencing a high rate of development, such as Guangdong. The level of related facilities might be completely different at the same place in the span of several years. A study on Singapore reveals a slight increase of the possibility of hit-and-run over time (Tay et al., 2008), whereas in California, trends are not significant (Tay et al., 2009).

Location might also affect the statistical results for hit-and-run crashes, as the regional disparity is significant in Guangdong. The disparity relates to the level of social and economic development, driving conditions and environment, road monitors and devices, government management, enforcement of the traffic laws and regulations, and different local cultural characteristics that people have, which will affect their risk preference and behavior in a hit-and-run crash. All the aforementioned differences might be reflected in the analysis results.

4. Results and discussion

The results of the logistic regression models are presented in Appendix B. The model as a whole fits the data quite well. We have a sufficiently large sample size of 40,373. The logistic regression model yields large Chi-squared statistics (4744.147) and very high area under the receiver operator curve (ROC) (0.795) and percent correctly predicted (92.272).

Our research finds that relative to single-vehicle crashes, drivers are more likely to flee after a crash if pedestrians are involved ($OR = 1.80$). If a collision occurred with a fixed object, the driver is inclined to stay at the scene ($OR = 0.20$), which is consistent with the results of existing research on Singapore and California (Tay et al., 2008, 2009). Drivers tend to flee when they are the offending parties, are involved in a fatal or severe crash, or collide with pedestrians because the driver might anticipate that he or she will receive a more severe punishment when caught in these situations, thus fleeing to avoid penalty.

According to the regression results, male drivers are 28% more likely to leave after a crash than females, which is similar to the results of studies on Singapore and the United States (MacLeod et al., 2012; Solnick & Hemenway, 1995; Tay et al., 2008). Perhaps this finding can be attributed to the fact that men are usually more comfortable with risk than women. Unlike the results in Singapore (Tay et al., 2008), drivers aged 25–44 are the most likely to flee, rather than those aged 45–69. A negative correlation exists between the possibility of hit-and-run crashes and the number of years of driving experience (the OR for those who have driven 0–2 years is 1.52 and the OR for those who have driven 3–5 years is 1.37). The reason might be that an experienced driver has better knowledge of traffic laws and regulations and judge more cautiously between leaving and staying. Most occupations do not have a significant effect on the hit-and-run behavior, except for blue-collar workers, teachers, and migrant workers. It suggests that the drivers from those occupations perceive higher subsequent economic consequences of the crash. Relative to farmers, blue-collar workers ($OR = 0.83$) and migrant workers ($OR = 0.76$) are less likely to flee from crashes, whereas teachers tend to flee after crashes ($OR = 1.77$). The *hukou* attribute of a driver does not have any significant influence on the results. Drivers without a valid driver's license are more likely to flee because they recognize that they will face severe punishment if caught ($OR = 5.49$).

In terms of vehicle factors, type of vehicle, vehicle maneuvers, vehicle safety status, insurance, and ownership of the vehicle are included. Based on the results of our analysis relative to car drivers, motorcycle riders are less likely to hit and run

(*OR* = 0.43), which is opposite to the outcomes of research on Singapore and California (Tay et al., 2008, 2009). Truck drivers do not display a significant tendency. Guangdong drivers are less likely to flee from a crash that occurs while they are turning left, similar to the drivers turning right in the research on Singapore. Furthermore, drivers drive on the left in Singapore, whereas the opposite is true in mainland China. Thus, turning left in China and turning right in Singapore might be perceived as maneuvers that easily cause crashes. Meanwhile, crashes that occur when changing lanes also have a lower hit-and-run possibility (*OR* = 0.52). The influence of vehicle safety status is not significant. Compared with vehicles that have no valid insurance, drivers with valid insurance tend to stay after the crash. A significant finding is that commercial vehicle drivers are less likely to flee because they are easier to identify after running away because their vehicle is usually registered under the name of their company.

Road factors consist of type of road, road surface, type of crash location, and type of traffic control device. Relative to ordinary highways, we find that drivers are less likely to flee crashes when the crash occurs on express roads, whereas they are slightly more likely to flee crashes on urban roads. This result is similar to the existing research on California (Tay et al., 2009). The reason might be that the monitors, such as surveillance videos and photographing, are closer to expressways, such that hit-and-run drivers will be identified more easily. When compared with a dry surface, our research finds that drivers tend to remain at crash sites in poor wet road conditions rather than flee (*OR* = 0.86), although the influence is insignificant in the studies on Singapore and California. The crash location has an evident influence on driver hit-and-run behavior. Relative to intersections, crashes that occur on elevated roads (*OR* = 4.82), merging lanes (*OR* = 3.65), and tunnels (*OR* = 2.94) significantly increase the possibility of hit-and-run crashes. This finding is similar to those in the existing research (MacLeod et al., 2012; Tay et al., 2008, 2009). Crashes that occur on a bridge have a reduced possibility of being hit-and-run crashes (*OR* = 0.65), possibly because such crashes will cause traffic congestion on a bridge, thus making it dangerous or difficult for the driver to flee. The type of traffic control device has no effect on hit-and-run crashes in Guangdong.

Environmental factors involve light conditions, weather conditions, time of day, day of the week, and season of the year. Light is a crucial factor in hit-and-run behavior. Our research indicates that relative to daylight, whether on lighted roads (*OR* = 2.09) or not (*OR* = 2.10), drivers are more likely to flee after crashes that occur at night. This result is similar to previous research, which indicates that the darker the road is, the more likely it is that hit-and-run crashes will occur (MacLeod et al., 2012; Solnick & Hemenway, 1995; Tay et al., 2008, 2009). According to our results, weather conditions have no evident effect on hit-and-run crashes, similar to the results of research on Singapore and California (Tay et al., 2008, 2009). We find that no significant difference exists for hit-and-run crashes between weekdays and weekends, similar to Tay's research on Singapore, but several studies suggest that the probability of hit-and-run behavior in fatal crashes is higher on weekends than weekdays (MacLeod et al., 2012; Solnick & Hemenway, 1995; Tay et al., 2008). We also find that crashes that occur in the early morning hours (0:00–6:59) are more likely to be hit-and-run crashes (*OR* = 1.40), whereas crashes that occur in the peak evening hours (*OR* = 0.85) are less likely to be associated with hit-and-run behavior. Perhaps this finding can be attributed to the fact that in the early morning hours, the traffic flow is minimal, and fewer witnesses will be present to identify the hit-and-run driver. The opposite is true during peak hours. Previous studies find that the effect of time of day is largely correlated to light conditions. Compared with day crashes, nighttime crashes are found to be more likely associated with hit-and-run behavior (MacLeod et al., 2012; Tay et al., 2008, 2009). Guangdong has a shorter fall season with a longer summer than most of China. According to the Bureau of Meteorology, seasons in China are spring (March to May), summer (June to September), fall (October to November), and winter (December to February). Relative to fall, winter has a 14% higher chance of hit-and-run crashes.

According to the regression results, no significant difference exists in Guangdong hit-and-run crashes between 2005 and 2011. The regression results also reveal that an evident disparity exists among cities. Compared those in Guangzhou, drivers in Zhuhai are more than two times as likely to flee after an automobile crash. A greater chance of hit-and-run crashes exists in Shenzhen and Huizhou than in Guangzhou, whereas Jiangmen, Zhanjiang, Maoming, Zhaoqing, Shanwei, Heyuan, Qingyuan, Zhongshan, Chaozhou, and Yunfu display a significantly lower possibility of hit-and-run crashes.

5. Conclusion

Based on the real-world accident data, it was found that the chance of hit-and-run behavior increases with following situations: accidents that involve pedestrians, accidents that occur in darkness, and accidents caused by (a) drivers who are male and middle-aged, (b) drivers who have less driving experience, (c) drivers who have no valid driver's license, and (d) drivers who have no automobile insurance.

Several critical factors are considered under the five-category framework (crash, human, vehicle, road, and environment). A driver is more likely to flee after a crash when pedestrians are involved or when the crash results in a fatality or severe injury. Our research indicates that male drivers aged 25–44 are more likely to flee crashes. A negative relationship exists between driving experience and the possibility of hit-and-run crashes, which indicates that novice drivers are more likely to flee traffic crashes. An extremely high risk exists for drivers without a valid license to flee after a crash. Drivers with insurance or driving a commercial vehicle tend to stay at the scene after crashes. Compared with those on ordinary highways and urban roads, crashes on express roads are less likely to be hit-and-run crashes. Although wet road surfaces might increase the risk of traffic crashes, such roads have a relatively low possibility of hit-and-run crashes compared with dry road surfaces. Compared with intersections and bridges, crashes on merging lanes, elevated roads, and in tunnels have a high possibility of hit-and-run behavior. Light conditions are also a key factor. Crashes that occur in dark conditions are more likely to be hit-and-run crashes, which may be the reason for the relatively increased number of hit-and-run crashes in the late night or at dawn than at afternoon peak hours. In general, our results suggest that the drivers are more likely to flee traffic crashes, if possible, when they perceive higher subsequent economic consequences of the crash. Due to data availability, the paper does not examine whether the drivers under the influence of alcohol may act differently in the traffic crashes. It may be a fruitful direction for future hit-and run research.

Whether a driver exhibits hit-and-run behavior is mainly decided by the specific situation of each crash. However, some measures can be taken to prevent drivers from leaving the scene after a crash. For instance, we should promote vehicle insurance to help to relieve the burden of loss caused by crashes, which will reduce hit-and-run crashes. We should have more quality public education about traffic safety and related laws and statutes. For example, male drivers, new drivers, and non-commercial drivers tend to flee after crashes. Thus, we could target publicity regarding hit-and-run laws on these three groups.

Acknowledgements

This research was supported in part by the National Natural Science Foundation of China 71173244. We would also like to thank Professor Meijin Wang of Sun Yat-Sen University and Haoping Yu of China Guangfa Bank Co., Ltd. for their constructive suggestions and advice.

Appendix A . The means of variables across different samples

Explanatory variables	Description of variables	Full sample	Hit-and-run sample	Non-hit-and-run sample
No. of observations		40,373	3609	36,764
(1) Crash severity				
Killed or serious injured	Fatal or serious injured = 1; otherwise = 0	0.417	0.530	0.406
(2) Type of collision				
Single vehicle	Single vehicles = 1; otherwise = 0	0.025	0.026	0.025
Moving vehicles	Multiple moving vehicles = 1; otherwise = 0	0.865	0.770	0.874
Vehicle and pedestrian	Pedestrian involved = 1; otherwise = 0	0.047	0.101	0.042
Vehicle and object	Bump with fixed objects = 1; otherwise = 0	0.021	0.007	0.022
Moving and stationary vehicles	Bump with stationary vehicles = 1; otherwise = 0	0.014	0.011	0.014
Others	Others = 1; otherwise = 0	0.029	0.085	0.023
(3) Gender				
Male	Male = 1; otherwise = 0	0.940	0.957	0.938
(4) Age				
<25	Younger than 25 = 1; otherwise = 0	0.164	0.162	0.164
25–44	25–44 = 1; otherwise = 0	0.672	0.727	0.666
45–69	45–69 = 1; otherwise = 0	0.162	0.109	0.168
$\geqslant$70	70 or older than 70 = 1; otherwise = 0	0.003	0.003	0.002
(5) Driving experience				
0–2 years	Driving less than 2 years = 1; otherwise = 0	0.132	0.098	0.136
3–5 years	3–5 years = 1; otherwise = 0	0.146	0.104	0.150
$\geqslant$6 years	Driving 6 years or above = 1; otherwise = 0	0.722	0.799	0.714
(6) Hukou (population registration)				
Rural	Rural '*hukou*' = 1; otherwise = 0	0.278	0.295	0.276
(7) Job				
Farmer	Farmer = 1; otherwise = 0	0.175	0.175	0.175
Civil servant	Working in governments = 1; otherwise = 0	0.008	0.004	0.008

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Appendix A (*continued*)

Explanatory variables	Description of variables	Full sample	Hit-and-run sample	Non-hit-and-run sample
Police or in the army	Working in police departments or serve in the army = 1; otherwise = 0	0.005	0.004	0.005
Staff	White collar = 1; otherwise = 0	0.066	0.053	0.067
Worker	Blue collar = 1; otherwise = 0	0.172	0.126	0.176
Boss	Owning a private business = 1; otherwise = 0	0.139	0.101	0.143
Teacher	Teacher in primary school, middle school, high school, college or university = 1; otherwise = 0	0.004	0.005	0.004
Student	Pupil or middle school, high school, college or university student = 1; otherwise = 0	0.007	0.007	0.007
Migrant worker	Workers from other cities or counties = 1; otherwise = 0	0.117	0.117	0.117
Unemployed	Jobless = 1; otherwise = 0	0.028	0.045	0.026
Others	Others = 1; otherwise = 0	0.279	0.364	0.271
(8) License state				
None or not valid	Having no or invalid license = 1; otherwise = 0	0.262	0.536	0.236
(9) Type of vehicle				
Car	Car = 1; otherwise = 0	0.324	0.343	0.322
Truck	Truck = 1; otherwise = 0	0.240	0.202	0.244
Motorcycle	Motorcycle = 1; otherwise = 0	0.436	0.455	0.434
(10) Vehicle maneuver				
Driving ahead	Driving ahead = 1; otherwise = 0	0.792	0.815	0.789
U-turn	Turning round = 1; otherwise = 0	0.010	0.007	0.010
Turning left	Turning left = 1; otherwise = 0	0.080	0.052	0.083
Turning right	Turning right = 1; otherwise = 0	0.030	0.022	0.031
Changing lane	Changing lane = 1; otherwise = 0	0.024	0.012	0.025
Stop/slowing down	Stop or slowing down = 1; otherwise = 0	0.037	0.028	0.038
Others	Others = 1; otherwise = 0	0.027	0.063	0.023
(11) Vehicle safety state				
Bad	Bad = 1; otherwise = 0	0.081	0.109	0.078
(12) Insurance				
Valid	Having an insurance = 1; otherwise = 0	0.786	0.603	0.804
(13) Ownership of the vehicle				
Commercial vehicle	Commercial vehicle = 1; otherwise = 0	0.244	0.169	0.251
(14) Types of traffic lanes				
Shared-lanes	Lanes are not divided = 1; otherwise = 0	0.569	0.589	0.567
(15) Type of road				
Express	Express = 1; otherwise = 0	0.063	0.022	0.067
Ordinary highway	Ordinary highway = 1; otherwise = 0	0.517	0.510	0.518
Urban road	Urban road = 1; otherwise = 0	0.420	0.468	0.415
(16) Road surface				
Dry	Dry = 1; otherwise = 0	0.863	0.875	0.862
Wet	Wet = 1; otherwise = 0	0.119	0.115	0.120
Others	Others = 1; otherwise = 0	0.018	0.010	0.019
(17) Type of crash location				
Intersection	Intersection = 1; otherwise = 0	0.200	0.178	0.202
Ordinary road	Ordinary road = 1; otherwise = 0	0.778	0.796	0.776
Elevated road	Elevated road = 1; otherwise = 0	0.003	0.007	0.003
Merging lanes	Narrowing road = 1; otherwise = 0	0.001	0.003	0.001
Narrow road	Narrow road = 1; otherwise = 0	0.006	0.006	0.006

Appendix A (*continued*)

Explanatory variables	Description of variables	Full sample	Hit-and-run sample	Non-hit-and-run sample
Bridge	Happening on a bridge = 1; otherwise = 0	0.010	0.007	0.010
Tunnel	Happening in a tunnel = 1; otherwise = 0	0.002	0.002	0.002
(18) Types of traffic control device				
None	None = 1; otherwise = 0	0.229	0.247	0.228
Police	Policeman or policewoman = 1; otherwise = 0	0.001	0.001	0.001
Signal	Traffic lights = 1; otherwise = 0	0.067	0.076	0.066
Sign	Warning sign = 1; otherwise = 0	0.657	0.636	0.659
Others	Others = 1; otherwise = 0	0.046	0.039	0.046
(19) Light condition				
Daylight	Daylight = 1; otherwise = 0	0.557	0.351	0.577
Dark but lighted	In the night with street light = 1; otherwise = 0	0.277	0.410	0.265
Dark	In the night without street light = 1; otherwise = 0	0.165	0.239	0.158
(20) Weather condition				
Bad	Bad = 1; otherwise = 0	0.214	0.209	0.215
(21) Day of week				
Weekends	Weekends = 1; otherwise = 0	0.274	0.296	0.271
(22) Time of day				
0:00–6:59	0:00–6:59 = 1; otherwise = 0	0.167	0.520	0.593
7:00–8:59 (a.m. peak hours)	7:00–8:59 = 1; otherwise = 0	0.084	0.261	0.158
17:00–19:59 (p.m. peak hours)	17:00–19:59 = 1; otherwise = 0	0.163	0.054	0.086
Others	Others = 1; otherwise = 0	0.587	0.165	0.163
(23) Season of year				
Spring	From March to May = 1; otherwise = 0	0.244	0.247	0.244
Summer	From June to September = 1; otherwise = 0	0.329	0.314	0.331
Fall	From October to November = 1; otherwise = 0	0.161	0.155	0.161
Winter	From December to February = 1; otherwise = 0	0.266	0.285	0.264

* For brevity, results for the year and location (city) of the crashes are omitted.

Appendix B. Estimation results

Explanatory variables (relative to non-hit-and-run)	Odds ratio	*p*-Value	95% Conf. interval
(1) Crash severity (relative to minor)			
Killed or serious injured	1.46***,[a]	0.000	(1.34, 1.59)
(2) Type of collision (relative to single vehicle)			
Moving vehicles	1.00	−0.973	(0.78, 1.27)
Vehicle and pedestrian	1.80***	0.000	(1.37, 2.34)
Vehicle and object	0.20***	0.000	(0.12, 0.31)
Moving and stationary vehicles	0.70	−0.124	(0.45, 1.10)
Others	3.22***	0.000	(2.42, 4.29)
(3) Gender (relative to female)			
Male	1.28***	−0.007	(1.07, 1.54)
(4) Age (relative to 25–44)			
<25	0.58***	0.000	(0.52, 0.65)
45–69	0.75***	0.000	(0.67, 0.85)

(*continued on next page*)

Appendix B (*continued*)

Explanatory variables (relative to non-hit-and-run)	Odds ratio	*p*-Value	95% Conf. interval
⩾70	0.65	−0.234	(0.31, 1.33)
(5) Driving experience (relative to over 6 years)			
0–2 years	1.52***	0.000	(1.32, 1.74)
3–5 years	1.37***	0.000	(1.20, 1.56)
(6) Hukou (relative to urban)			
Rural	0.94	−0.198	(0.85, 1.03)
(7) Job (relative to farmer)			
Civil servant	0.70	−0.208	(0.41, 1.22)
Police or in the army	0.82	−0.520	(0.45, 1.50)
Staff	1.08	−0.468	(0.88, 1.31)
Worker	0.83**	−0.015	(0.71, 0.96)
Boss	0.91	−0.225	(0.77, 1.06)
Teacher	1.77***	−0.039	(1.03, 3.03)
Student	0.72	−0.151	(0.46, 1.13)
Migrant worker[b]	0.76***	0.000	(0.64, 0.88)
Unemployed	1.10	−0.375	(0.89, 1.36)
Others	1.26***	0.000	(1.11, 1.43)
(8) State of driving license (relative to valid license)			
None or not valid	5.49***	0.000	(4.87, 6.20)
(9) Type of vehicle (relative to car)			
Truck	0.95	−0.432	(0.84, 1.08)
Motorcycle	0.43***	0.000	(0.39, 0.49)
(10) Vehicle maneuver (relative to driving ahead)			
U-turn	0.71	−0.108	(0.46, 1.08)
Turning left	0.57***	0.000	(0.49, 0.68)
Turning right	0.86	−0.223	(0.67, 1.10)
Changing lane	0.52***	0.000	(0.38, 0.72)
Stop/slowing down	0.88	−0.265	(0.69, 1.11)
Others	1.47***	0.000	(1.22, 1.77)
(11) Vehicle safety state (relative to good)			
Bad	1.05	−0.444	(0.92, 1.20)
(12) Insurance (relative to invalid)			
Valid	0.56***	0.000	(0.51, 0.61)
(13) Ownership of the vehicle (relative to non-commercial)			
Commercial vehicle	0.76***	0.000	(0.67, 0.87)
(14) Types of traffic lanes (relative to others)			
Shared-lanes	1.01	−0.766	(0.93, 1.11)
(15) Type of road (relative to ordinary highway)[c]			
Express	0.31***	0.000	(0.24, 0.41)
Urban road	1.09**	−0.047	(1.00, 1.20)
(16) Road surface (relative to dry)			
Wet	0.86**	−0.047	(0.73, 1.00)
Others	0.61***	−0.007	(0.42, 0.88)
(17) Type of crash location (relative to intersection)			
Ordinary road	1.11*	−0.052	(1.00, 1.20)
Elevated road	4.82***	0.000	(2.84, 8.20)
Merging lanes	3.65***	−0.001	(1.65, 8.05)
Narrow road	1.20	−0.511	(0.70, 2.05)
Bridge	0.65*	−0.075	(0.41, 1.04)

Appendix B (*continued*)

Explanatory variables (relative to non-hit-and-run)	Odds ratio	*p*-Value	95% Conf. interval
Tunnel	2.94**	−0.012	(1.27, 6.80)
(18) Types of traffic control device (relative to no device)			
Police	0.99	−0.976	(0.36, 2.71)
Signal	1.12	−0.221	(0.94, 1.33)
Sign	1.04	−0.442	(0.94, 1.15)
Others	0.85	−0.128	(0.69, 1.05)
(19) Light condition (relative to daylight)			
Dark but lighted	2.09***	0.000	(1.89, 2.31)
Dark	2.10***	0.000	(1.87, 2.36)
(20) Weather condition (relative to good)			
Bad	1.07	−0.278	(0.95, 1.21)
(21) Day of week (relative to weekdays)			
Weekends	1.00	−0.939	(0.92, 1.09)
(22) Time of day (relative to others)			
0:00–6:59	1.40***	0.000	(1.27, 1.56)
7:00–8:59 (a.m. peak hours)	1.01	−0.890	(0.85, 1.20)
17:00–19:59 (p.m. peak hours)	0.85***	−0.004	(0.76, 0.95)
(23) Season of year (relative to fall)			
Spring	1.09	−0.185	(0.96, 1.23)
Summer	1.06	−0.326	(0.94, 1.19)
Winter	1.14**	−0.032	(1.01, 1.29)
Model prediction measures			
Percent correct	92.272		
ROC	0.795		
N	40,373		

*For brevity, results for the year and location (city) of the crashes are omitted.

[a] Star "*" correspond to the *p*-value as below: $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$.

[b] The conception of migrant worker relates to the *hukou* system. It refers to the workers who work in non-agricultural industries and spend quite a portion of his/her time living in urban area through the whole year without a local urban *hukou*. Migrant workers come out after the reforming in 1978, which allow people to work out of the region recorded in his/her *hukou*. However, it is still difficult for the non-local workers to get the local urban *hukou*. A particular group gradually forms, who actually has become a resident of the urban area without a local *hukou*, enjoying subordinate social welfare and job opportunities.

[c] According to the People's Republic of China Public Safety Industry Standard (GA 17.1 – 2003), the codes for road traffic accident scene, part1: code of road type, the roads are grouped into three categories, the express, urban road and ordinary highway. Express refers to the highways which reach a certain specification and facility standard, connecting cities to the countryside and industrial or mining bases, etc. The urban road refers to the roads connecting different places through a city. And the ordinary highway refers to the other roads apart from the two categories mentioned above.

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