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Non-conforming behaviors of motorcyclists at signalized intersections in Fortaleza

Comportamento não conforme de motociclistas em interseções semaforizadas de Fortaleza

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ABSTRACT
In Brazilian cities, motorcycles are increasingly popular due to their ease of acquisition, usefulness, maneuverability and low-cost maintenance. However, with motorcycle crashes on the rise, research on the association between motorcyclist behavior and road crashes has become highly relevant. In this quantitative study we correlated non-conforming behaviors, traffic and environmental variables, and data on crashes based on 124 hours of manually processed traffic surveillance camera footage of 24 signalized intersections (31 approaches). Non-conforming behaviors included zigzagging, red light running, sidewalk riding, speeding and wrong-way riding. Our results show that a proportional increase in heavy vehicle traffic volume can reduce zigzagging by up to 22%. The presence of traffic enforcement cameras efficiently inhibited red light running. Using 85th percentile speed in our analysis, motorcycles were found to travel 11% faster than cars. The difference in speed between motorcycles and cars and the number of lanes were significant in the crash model. In conclusion, the presence of physical separations and traffic enforcement cameras and the number of lanes significantly influenced motorcyclist behavior. In addition to speed control, these factors should be taken into account when implementing road safety measures.

RESUMO
Os acidentes no Brasil envolvendo motociclistas tem crescido nos últimos anos, motivando mais estudos que permitam compreender a relação entre o comportamento de condução e os acidentes de trânsito. Nesta linha, utilizou-se o conceito de Comportamentos Não Conforme dos motociclistas juntamente com características do ambiente de circulação e acidentes de trânsito para representar quantitativamente esse fenômeno. Neste trabalho foram coletadas e analisadas de forma manual, 124 horas de vídeo de 31 aproximações de interseções semaforizadas. Os comportamentos em não conformidade analisados foram mudança de faixa, avanço semafórico, trânsito sobre a calçada e em sentido proibido e velocidade inadequada, os quais foram relacionados ao ambiente de circulação e posteriormente com os acidentes. Os resultados mostraram que o aumento proporcional do fluxo de veículos pesados pode reduzir em até 22% a frequência de mudança de faixas das motocicletas. A fiscalização eletrônica mostrou-se eficiente em coibir o avanço semafórico. Os motociclistas desenvolvem velocidades 11% maiores que os carros. A diferença de velocidade do 85º percentil entre motos e carros e o número de faixas foram identificadas como variáveis significativas na modelagem dos acidentes. Encontrou-se indícios de que canteiro central, número de faixas e fiscalização eletrônica apresentam influência sobre o comportamento dos motociclistas.

1. INTRODUCTION

Between 2001 and 2016, the number of motorcycles circulating in Brazil increased almost six-fold, compared to a three-fold increase in the number of cars, leading to a profound change in traffic dynamics. According to traffic authorities (Denatran, 2017), the representation of motorcycles in the overall vehicle mix rose from 15% in 2001 to 27% in 2016. The increasing popularity of motorcycles is due to two major factors (Vasconcellos, 2008): government incentives to manufacturers through tax cuts and regulations, and changes in user profile. Motorcycles were mostly used for leisure until the mid-nineties and are now primarily employed in commuting and for work, such as delivery service.

The greater proportion of motorcycles in the vehicle mix is reflected in an increasing number of crashes involving motorcyclists. According to the 2015 Global Status Report on Road Safety issued by the World Health Organization, the proportion of deaths of motorcyclists in relation to all road traffic deaths in the Americas rose from 15% to 20% in the period 2010-2013. In Brazil, the number of deaths of motorcyclists increased by 140% from 2001 to 2012, corresponding to a change from 15% to 36% of all road traffic deaths (DATASUS; IBGE, 2012). In 2016, according to Líder-DPVAT (a mandatory nationwide insurance for the compensation of victims of crashes), 76% of payouts per type of vehicle were made to motorcyclists.

The risk behaviors of motorcyclists have been extensively evaluated based on questionnaires including a range of variables such as helmet use, speeding, age, level of schooling and vehicle use (Susilo *et al.*, 2015; Wong *et al.*, 2010). Interestingly, Sukor *et al*. (2017) found speeding to be significantly correlated with street design in that the presence of exclusive motorcycle lanes had a negative impact on road safety.

Supporting the findings of Sukor *et al*. (2017), several authors have concluded that motorcyclists are more likely to speed when riding on well-paved, wide and straight lanes segregated from the common traffic (Abdul Manan & Várhelyi, 2012; Goldenbeld & van Schagen, 2007; Lewis-Evans & Charlton, 2006; Pau & Angius, 2001). Thus, evidence points to an association between street design and risk behavior among motorcyclists, especially in view of the greater maneuverability of two-wheeled vehicles. If environmental elements can induce speeding, it is reasonable to assume they are correlated with other risk behaviors, such as wrong-way riding, red light running, lane splitting and sidewalk riding.

The factors contributing to crashes involving motorcyclists have been investigated by many scholars, but little has been published on the influence of the environment (site, geometric components, flow, vehicle mix) on the likelihood of motorcycle riders to engage in risky and non-conforming behaviors. More in-depth research is necessary to fill the gaps in our understanding of motorcycle crashes in urban environments where motorcyclists often display behaviors atypical for other categories of vehicles. Thus, the main purpose of this study was to evaluate the effect of traffic and environmental factors on motorcyclists' non-conforming behaviors and their association with road safety at signalized intersections in Fortaleza, a state capital in Northeastern Brazil.

2. NON-CONFORMING BEHAVIORS AND ROAD SAFETY

Motorcyclist behavior has historically been studied from one of two major perspectives: one based on the definition and classification of observed vehicle displacement patterns (Puscar *et al.*, 2018), the other based on questionnaires administered to riders (Sukor *et al.*, 2017). In this study, the term 'non-conforming behaviors' covers both actual traffic violations, such as red light running and speeding, and allowable but risky behaviors compromising the safety of others, such as zigzagging in and out between larger vehicles (Sethi & Brillhart, 1991).

Motorcycles in our region tend to be small and easy to maneuver, making it possible and even attractive for motorcyclists to make use of the space between cars (lane splitting or stripe riding), especially during rush hour. Referred to by Bonte *et al.* (2007) as 'virtual lanes', this space may be between lanes or along the curb. Lane splitting is a common practice on the streets of large Brazilian cities and is most evident when traffic is heavily congested.

Using traffic surveillance camera footage, Holz (2014) analyzed the width of virtual lanes and the speed, acceleration and deceleration of motorcyclists in Porto Alegre (capital of the state of Rio Grande do Sul). Although zigzagging between lanes and cars is usually done when the cars are not moving, the practice poses risks to motorcyclists as they become partly concealed by other vehicles, increasing the likelihood of crashes (Nguyen *et al.*, 2014).

Puscar *et al*. (2018) performed a spatial and temporal analysis of non-conforming behaviors in order to find patterns associated with road safety. The study site was a video-monitored intersection, and a computer software was employed to identify conflicts between different types of vehicles. The behaviors most conducive to conflict were right-of-way violations, red light running, and stop line trespassing.

A study from Guangdong, China, analyzing risk factors for crashes in the period 2006-2010 found a strong correlation between non-conforming behaviors (traffic violations) and crashes (Zhang *et al.*, 2013). Non-conforming behaviors included speeding, driving under the influence of alcohol or fatigue, and right-of-way violations. Using logistic regression analysis, the authors identified gender, urban environment, vehicle use (work vs. private), street lighting, weather conditions, visibility, and weekday as significant determinants of traffic violations.

The effect of speeding on road safety is a recurring topic in the literature. Thus, Hirst *et al.* (2005) found reductions in speed limits to be significantly associated with reductions in crashes. Among motorcyclists, speeding is a major contributing factor to crashes (Teoh & Campbell, 2010), especially severe crashes (Cunto & Ferreira, 2016). In a study on intersections in New Zealand renowned for crashes involving motorcyclists, Walton and Buchanan (2012) observed that motorcyclists were 3.4 times more likely to speed than drivers and on the average traveled 10% faster than the surrounding cars. Among other things, the authors concluded that relative speed is an important factor in the analysis of relative risk for motorcycles vs. other vehicles.

A study from Thailand by Jensupakarn and Kanitpong (2018) showed that red light running by motorcyclists is not only determined by rider characteristics but also by local environmental factors, such as the number of lanes, lane width, pavement friction, the existence of turn lanes, driving direction and time of the day. The type of traffic light, the approach velocity and the presence of advance warning signs also had a significant influence on the frequency of red light running.

Covering the period 2010-2014, Das *et al*. (2018) analyzed crashes in the State of Louisiana caused, among other things, by wrong-way driving. Using multiple correspondence analysis, the authors found higher speed limits, inadequate street lighting and lack of physical separations between opposing lanes to increase the likelihood of this type of behavior. As a simple and efficient measure, the authors recommended installing physical separations between opposing lanes.

3. METHODS

The method employed in this study included the following steps: definition of study locations (signalized intersections), video acquisition, image processing for the estimation of variables of non-conforming behavior, collection of traffic and environmental variables and analysis of potential associations between non-conforming behavior, traffic environment and crashes (Figure 1).

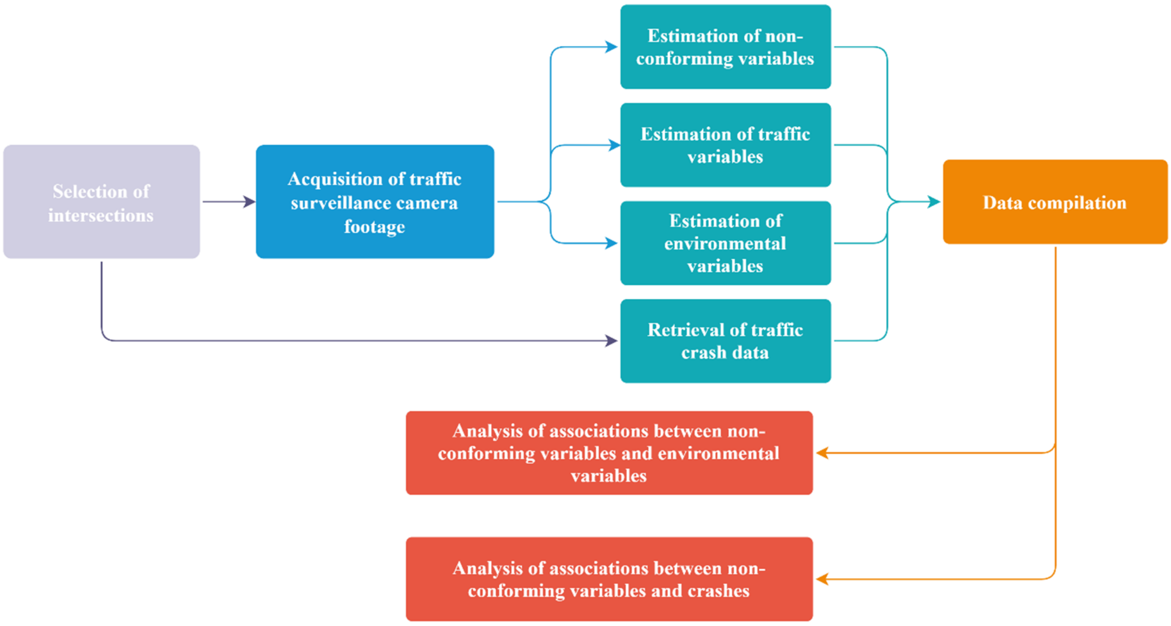

Figure 1. Study methodology

The study locations were restricted by the availability of fixed traffic surveillance cameras operated by the city's traffic control authorities (CTAFOR). The selected cameras allowed to view beyond the stop line at a distance of at least 50 m. The presence of these surveillance cameras, installed two decades earlier, is unlikely to have affected driving behavior. Two or more clearly identified points on the ground, separated by at least 30 m, were used to calculate speed.

The position of surveillance cameras can be changed to focus on different angles or approaches of an intersection (Figure 2). In some of the intersections included in our sample, more than one approach was filmed. Each video sample consisted of 2 hours of continuous recording, and each intersection was filmed in both peak and off-peak periods on weekdays, in the absence of rain, crashes or other events disrupting the normal traffic flow. The final sample included 124 hours of video covering 24 intersections and 31 different approaches.

Figure 2. Image of intersection from a traffic surveillance camera

Three categories of variables were collected from the videos:

a. Non-conforming behaviors of motorcyclists (zigzagging, speeding, red light running, wrong-way riding, sidewalk riding)
b. Traffic conditions (flow volume, vehicle mix)
c. Geometric and physical elements of the environment (traffic enforcement cameras, raised curbs, street width, number of lanes, physical separations, pavement markers).

Information was retrieved from the videos in three stages. First, the traffic volume and vehicle mix were quantified using manual counters, covering the first 15 min of the first hour and the last 15 min of the second hour of each video.

Second, the videos were carefully reviewed to observe non-conforming behaviors such as zigzagging, wrong-way riding, red light running and sidewalk riding. The variables were quantified per 15min segment of video.

Zigzagging was defined as lane filtering in and out between stationary vehicles. Each movement was counted, even when performed by the same rider, but only while the traffic flow was interrupted. Changing lanes during moving traffic was considered overtaking and was not counted.

Third, the speed of each vehicle was determined. To do so, two easily identifiable markers were chosen and the distance between them measured *in loco* for greater accuracy. The time elapsed between the two markers was used to calculate the speed, but only when the traffic was flowing freely. This usually coincided with the crossing of the stop line by the fourth of fifth vehicle after the light had turned green. For each scenario (peak and off-peak), we measured the speed of 50-60 vehicles, totaling 3,459 cars and 3,325 motorcycles.

Table 1 – Non-conforming, environmental and traffic variables

Category	Code	Variable	Unit	Description
Non-conforming behaviors	*zigzag*	Zigzagging	n/hour	Lane changes per hour, counted only during interrupted flow
	sidewalk	Sidewalk riding	n/hour	Motorcycles per hour riding on pedestrian sidewalks
	red_light	Red light running	n/hour	Motorcycles per hour going through a red light
	wrong_way	Wrong-way riding	n/hour	Motorcycles per hour riding the wrong way
	ΔSpd85	Speed difference between motorcycles and cars	Km/h	Difference in 85th percentile speed between motorcycles and cars
Environment	*TW*	Total street width	m	Lateral space available for vehicles
	NL	Number of lanes	n	Number of lanes destined for motor vehicles
	Curb	Curb	yes/no	Raised divider between street and sidewalk
	TEC	Traffic enforcement camera	yes/no	Cameras triggered by underground sensors, used to register traffic violations
	PhySep	Physical separation	yes/no	Elevated strip separating opposing lanes of traffic
	Markers	Raised markers	yes/no	Raised blocks used to inhibit lane changes and overtaking
Traffic	*Flow*	Vehicle flow volume	n/hour	Number of vehicles traversing the observed intersection
		Vehicle mix	n/hour	Proportion of each type of vehicle traversing the intersection

Since the volume of motorcycle traffic affected the frequency of the observed behaviors, we estimated rates of occurrence expressed as the number a given behavior per hour per 1,000 vehicles.

Differences in 85th percentile speed between cars and motorcycles and between peak and off-peak periods were also evaluated in order to estimate the potential risk of conflicts between the two types of vehicles. Table 1 displays the variables employed in the analysis of motorcyclist behavior.

The environmental variables were also obtained from the videos, except lane width which was measured *in loco* using a measuring wheel.

Geo-referenced data of all crashes involving motorcycles at the selected intersections were retrieved from a municipal database (integrated system of information on crashes in Fortaleza, SIAT-FOR), covering the years 2015, 2016 and 2017. Accidents occurring within 50 m of the stop line or inside the intersection were included in the analysis, as long as they occurred during the day, on weekdays, i.e., under circumstances comparable to the footage evaluated in the study. Accidents occurring after dark were excluded due to the additional variables involved.

Initially, the variables were submitted to exploratory analysis with correlation coefficients and scatter plots in order to test for potential associations between the study variables. Our initial results were then tested with generalized linear models with Poisson or negative binomial distribution since the primary dependent variables were frequencies, most of which had high coefficients of variance, except for speed which was analyzed with multiple linear regression. The models allowed to identify variables significantly associated with non-conforming behaviors, but the relative weight of each significant variable was not explored in this study.

The parameters were calibrated by stepwise forward selection, i.e., by testing the variables one by one and leaving the most significant variables in the model. The quality of the models was assessed using root-mean-square deviation, the cumulative residuals of the generalized linear models, and the determination coefficient (R^2) of the linear regression models.

4. RESULTS

The categorical environmental variables at the 31 approaches were as follows: The curb was raised (in good condition) in 74% and lowered (absent or in poor condition) in 26%, physical separations were present in 95%, and 52% had traffic enforcement cameras. In addition, the lanes were separated by raised markers in 58% of the approaches. Twenty approaches (65%) had two lanes in each direction, 10 (32%) had three lanes, and one (3%) had five.

Table 2 shows the descriptive statistics of the collected variables. Zigzagging was the non-conforming behavior displaying the greatest variation from one intersection to another, being entirely absent in some cases, especially when the street was narrow, suggesting an association between zigzagging and street width. The behavior variables are expressed as occurrences per hour.

Considering 85th percentile speed, we analyzed the difference between cars and motorcycles and between peak period traffic and off-peak period traffic using Student's *t* test at the 5% level of statistical significance. In the first test, no significant difference in speed was observed between peak period traffic and off-peak period traffic (cars p=0.54; motorcycles p=0.86), making it possible to pool the two samples for further analysis. In the second test, we found a highly significant difference in speed between cars and motorcycles (p=0.002).

A preliminary exploratory analysis of the variables using a Pearson's correlation matrix and a bivariate scatter plot revealed a non-normal distribution. We therefore chose to employ Kendall's correlation matrix (Table 3).

Table 2 – Descriptive statistics of study variables

		Mean	Minimum	Maximum	SD	CV
Environment	Lane width	3.2	2.3	4.0	0.31	0.10
	Number of lanes	2.4	2.0	5.0	0.67	0.28
Behavior	Zigzagging	53.9	0.0	164.0	35.17	0.65
	Zigzagging rate	192.4	0.0	639.0	124.1	0.64
	Red light running	0.7	0.0	12.0	1.50	2.03
	Red light running rate	3.7	0.0	111.0	11.53	3.10
	Wrong-way riding	3.6	0.0	113.0	16.13	4.44
	Sidewalk riding	2.7	0.0	55.0	8.56	3.18
	Sidewalk riding rate	11.3	0.0	207.0	37.63	3.31
	ΔSpd85	4.4	-0.2	18.7	3.16	0.72
Traffic	Number of cars per lane/hour	368	138	588	96.93	0.26
	Number of motorcycles per lane/hour	131	18	360	70.55	0.54
	Number of heavy vehicles per lane/hour	28	0	70	15.35	0.55
	Total mean number of vehicles/hour	1.244	588	2.256	384.29	0.31
Crashes (30 locations)		6.4	0.0	13.0	3.35	0.53

SD=standard deviation; CV=coefficient of variance; ΔSpd85=difference in 85th percentile speed between cars and motorcycles.

Table 3 – Kendall correlation coefficients between the study variables

	TW	NL	Curb	TEC	PhySep	Markers	Car volume	Motorcycle volume	Heavy v. volume
Zigzagging	0.18	0.2	0.12	0.13	0.03	0.17	0.34	0.41	0.27
Zigzagging rate	-0.08	-0.07	0.13	0.01	0.12	-0.09	-0.04	-	-0.15
Red light running	-0.05	-0.14	0.24	-0.17	-0.12	0.06	-0.14	-0.02	-0.09
Red light running rate	-0.04	-0.14	0.23	-0.18	-0.12	0.04	-0.16	-	-0.11
Wrong-way riding	-0.33	-0.19	-0.15	-0.27	-0.99	-0.30	-0.16	0.04	-0.06
Sidewalk riding rate	-0.18	-0.10	-0.47	-0.13	-0.18	-0.07	-0.16	-	0.10
Sidewalk riding	-0.17	-0.10	-0.46	-0.13	-0.19	-0.07	-0.14	0.04	0.12
ΔSpd85	0.003	0.03	-0.35	0.03	0.16	0.17	-0.10	0.02	0.02

TW=total street width; NL=number of lanes; TEC=traffic enforcement cameras; volume=number of vehicles per hour; PhySep=physical separation; ΔSpd85=difference in 85th percentile speed between cars and motorcycles.

The frequency of zigzagging was moderately and positively correlated with all environmental variables. However, the latter were strongly inter-correlated (0.35-0.50), making it difficult to distinguish the effect of motorcycle traffic volume (the more motorcycles, the more opportunities of lane splitting) from the difficulty of changing lanes during intense traffic flow. This is evidenced by the change in the coefficient when the zigzagging rate was used instead of motorcycle traffic volume. As shown in Table 3, the correlation becomes slightly negative for cars (-0.04) and strongly negative for heavy vehicles (-0.15), suggesting an increased difficulty of lane splitting due to lack of space or blocked view. In addition, zigzagging displayed a slightly positive correlation with lowered curbs and the presence of physical separations (circumstances favoring movement along the edges), but the association was not strong enough to draw conclusions.

The association between zigzagging, environmental variables and heavy vehicle traffic was tested using generalized linear models with Poisson distribution. The best-adjusted model is shown in Equation (1):

$$zigzagging = exp(2.864 + 0.001869 * VolMtc + 0.0006871 * VolCar - 0.001887 * VolHvcl) \quad (1)$$

where *VolMtc* is the volume of motorcycle traffic, *VolCar* is the volume of car traffic, and *VolHvcl* is the volume of heavy vehicle traffic (vehicles per hour).

All variables had very low p-values ($<1 \times 10^{-6}$). The CURE plot below shows that the model is within two standard deviations of the mean in almost the entire range of motorcycle traffic volume (Figure 3).

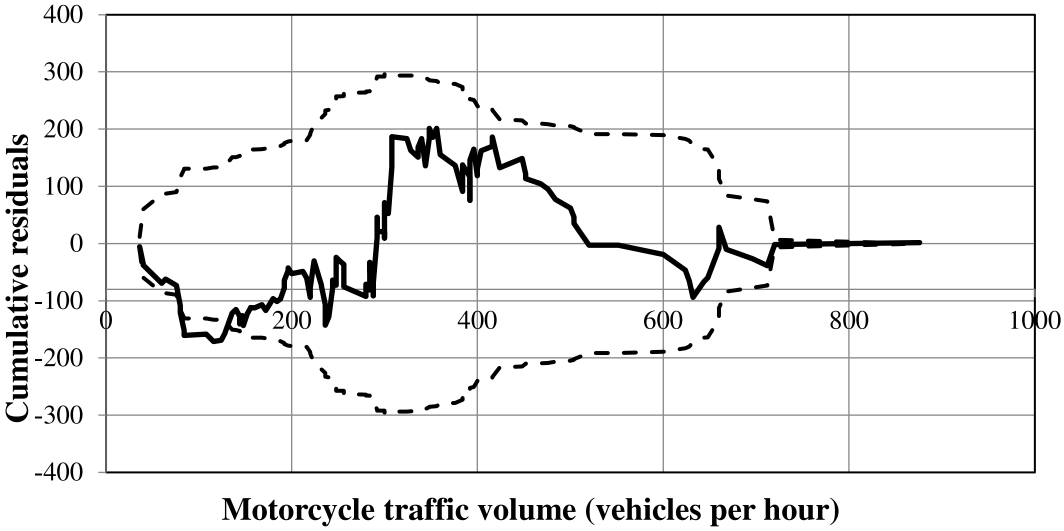

Figure 3. CURE plot of the zigzagging rate model

Figure 4 is a graphic representation of the influence of the presence of heavy vehicles on the frequency of zigzagging, taking motorcycle traffic volume into consideration. The association was negative, possibly because motorcyclists feel uncomfortable splitting lanes in and out between large vehicles.

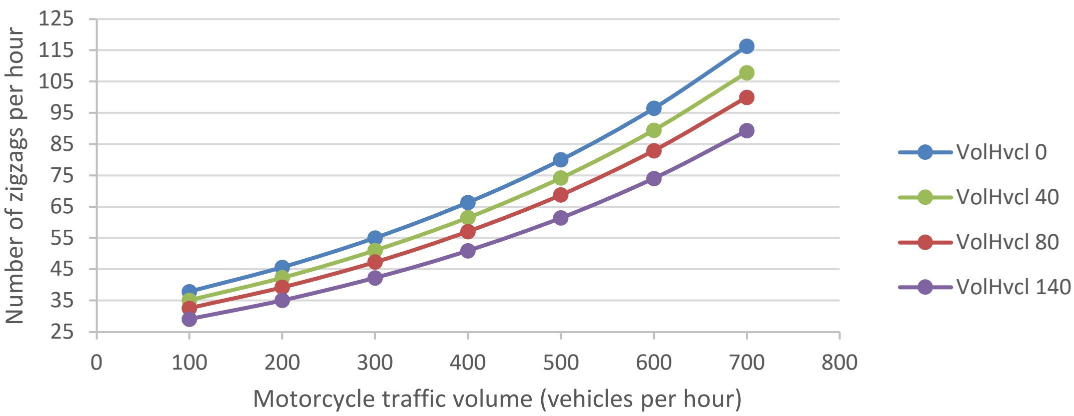

Figure 3. Zigzagging according to motorcycle and heavy vehicle traffic volume

Red light running was also weakly correlated with the study variables. The behavior was positively affected by the absence of raised curbs and negatively affected by the presence of traffic cameras. The absence of raised curbs makes it easier for motorcyclists to reach the stop line and, when circumstances allow, go through the red light.

Unsurprisingly, sidewalk riding was negatively correlated with the presence of raised curbs. As for wrong-way riding, the presence of physical separations displayed the strongest negative association, as observed in the initial analysis.

The 85th percentile speed of cars and motorcycles yielded weak to moderate correlations. The multiple linear regressions with stepwise forward selection of all the study variables resulted in Equation (2):

$$\Delta Spd85 = -10.32 + 3.30 * \log(VolMtc) - 0.004 * VolTotal - 2.95 * factor(Curb) + 4{,}09 * factor(PhySep) \quad (2)$$

The volume of motorcycle traffic and the presence of physical separations yielded positive coefficients, meaning these variables may have contributed to increasing the difference in speed between motorcycles and cars. The opposite was true for total traffic volume and the presence of raised curbs. In the analysis of residuals, the root-mean-square deviation was 2.57 while R^2 was 0.33. The relatively low explanatory power of the model suggests that this risk behavior would be more appropriately modeled with the addition of variables representing types of motorcycle use, cultural aspects, and individual propensity to risk taking.

Figure 5 shows the association between ΔSpd85 and total traffic volume in an environment with physical separations and curbs: the heavier the traffic, the smaller the difference in speed between cars and motorcycles, most likely due to lack of "virtual space" for motorcyclists.

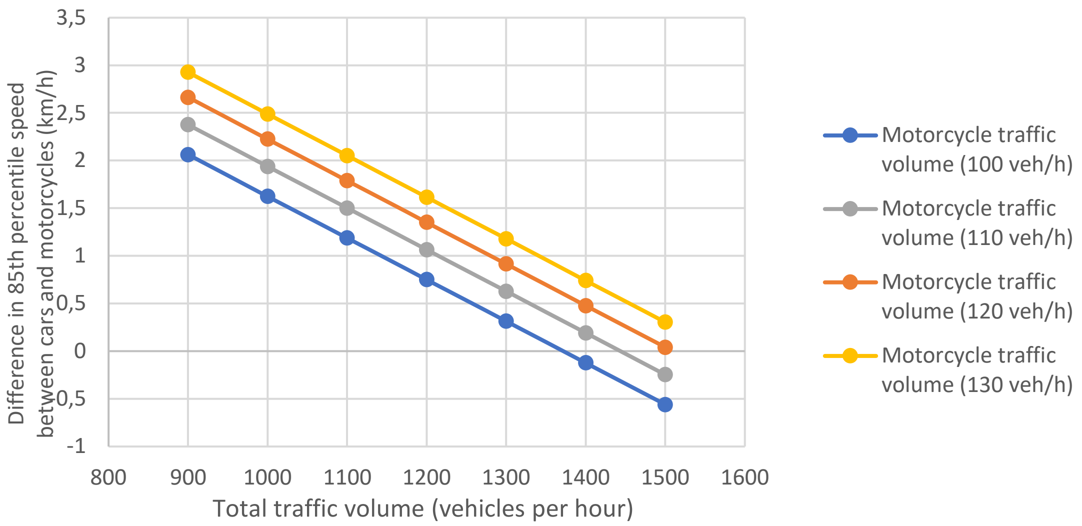

Figure 4. Difference in 85th percentile speed between cars and motorcycles according to total traffic volume

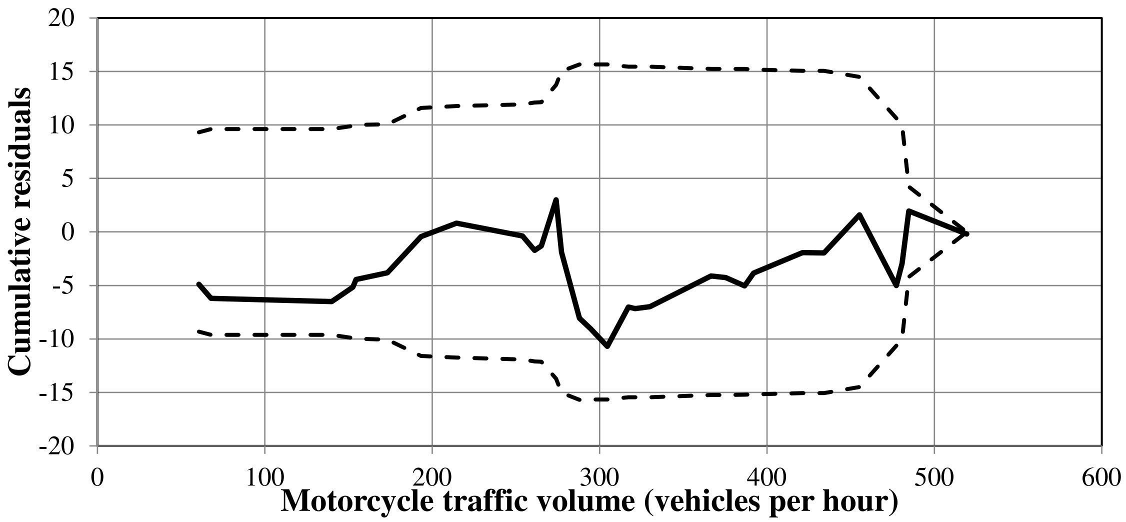

Figure 5. CURE plot of the crash model

The association between non-conforming behaviors and crashes was evaluated with generalized linear models, using crashes as outcome variable and assuming the negative binomial distribution was representative of the observed crashes. The model used all variables of non-conforming behavior and all traffic variables not directly associated with non-conforming behaviors. The only significant variables were ΔSpd85 and NL, leading to Equation (3):

$$Crashes = exp(0.82377 + 0.07551 * \Delta Spd85 + 0.28179 * NL) \quad (3)$$

The residuals of the proposed model displayed good distribution along the tested range of motorcycle traffic volume (Figure 6). Based on Equation (3), we estimate that the number of crashes involving motorcycles on 2-lane streets rises by about 16% for each 2-km/h increase in ΔSpd85. A similar pattern was observed for 3-lane streets.

5. CONCLUSIONS

In this quantitative analysis, the association between motorcyclists' non-conforming behaviors, traffic and environmental variables, and crashes involving motorcyclists in the period 2015-2017 at 24 signalized intersections in Fortaleza was evaluated. Five types of non-conforming behavior (zigzagging, red light running, sidewalk riding, speeding, wrong-way riding) were identified and quantified in 124 hours of traffic camera footage covering 31 approaches.

Zigzagging was most strongly influenced by traffic volume (positively by motorcycle traffic volume and negatively by heavy vehicle traffic volume). According to the model, traffic with a high proportion of heavy vehicles (15% of the total volume) would, due to the greater difficulty of splitting lanes, reduce zigzagging by up to 22% in relation to a scenario with 0% heavy vehicles.

The frequency of red-light running was affected positively by the absence of raised curbs and negatively by the presence of traffic enforcement cameras. Lowered curbs make it easier for motorcyclists to reach the stop line, especially during peak periods. The absence of traffic cameras was associated with a higher frequency of red light running, supporting the notion that many motorcyclists run lights at non-monitored intersections in order to compensate for wasted traffic time.

Wrong-way riding was most strongly inhibited by the presence of physical separations. The absence of raised curbs increased the frequency of sidewalk riding, most likely with the purpose of reducing traffic time. The maneuverability and generally small size of the motorcycles used in our area make this means of transportation particularly permeating, favoring non-conforming behaviors.

The difference in speed between cars and motorcycles (ΔSpd85) increased in the presence of physical separations and greater motorcycle traffic volume, and decreased in the presence of raised curbs and greater total traffic volume.

Motorcycles traveled on the average 11% faster than cars and trucks, regardless of the time of day (peak vs. off-peak). The first finding matches the literature in general; the second shows that the behavior of drivers and motorcyclists with regard to speed remained unaffected by flow dynamics.

The safety performance function identified two significant contributing factors: ΔSpd85 and NL. This is supported by studies on road safety which associate higher speeds with greater incidence and severity of crashes and point to the number of lanes as a contributing factor due to the greater severity of the conflicts between different types of vehicles at intersections.

The present study focused on signalized intersections with relatively dense traffic monitored by traffic cameras, observing both peak and off-peak traffic. However, further studies are necessary to confirm these results, for example by evaluating intersections with smaller traffic volume, non-signalized intersections, uninterrupted segments, and different time frames. Moreover, the use of more advanced video data extraction technologies can help increase sample size and include behavioral aspects not covered by the present study.

Driving behavior is strongly influenced by cultural elements and their interaction with environmental factors. Thus, caution is needed when extrapolating our results to traffic scenarios in culturally different regions. Cross-sectional studies would allow to evaluate the consistency of the identified risk factors for road safety in a wider geographical context.

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