Characteristics of road factors in multi and single vehicle motorcycle crashes in Queensland

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Abstract

Motorcyclists were involved in 6.4% of all police-reported crashes and 12.5% of all fatal crashes in Queensland during 2004-2011. Of these crashes, 43% were single-vehicle (SV) and 57% were multi-vehicle (MV). The overall reduction in motorcycle crashes in this period masked different trends: single-vehicle crashes increased while MV motorcycle crashes decreased. However, little research has been undertaken to understand the similarities and differences between SV and MV motorcycle crashes in Queensland and the factors underlying these diverging trends. The descriptive analyses and regression model developed here confirm international research findings regarding the greater role of road infrastructure factors in SV crashes. In particular, road geometric factors such as horizontal and vertical alignment and road surface factors such as sealed/unsealed and wet/dry were more important in SV than MV crashes.

Introduction

Globally there has been a significant increase in the number of motorcycles (Haworth, 2012; Rogers, 2008). In Australia, the number of motorcycles increased 8.2% per year between 2006 and 2010. Despite comprising only 4.3% of registered vehicles, motorcycles were involved in 15.8% of total fatal crashes in 2011 (ABS, 2012). Motorcycles have a higher risk of being involved in serious crashes than other vehicles and motorcyclists are more vulnerable to injury (DFT, 2008; Hurt, Ouellet, & Thom, 1981).

Many authors have commented that road infrastructure factors (geometry and surface condition) play a larger role in the occurrence (ACEM, 2004; Haworth, Smith, Brumen, & Pronk, 1997; Saleh et al., 2010) and severity (Elslande et al., 2013) of motorcycle crashes than in crashes of four-wheeled vehicles. The geometric characteristics of roads that can contribute to crash occurrence include minimum stopping sight distance, minimum horizontal radius, minimum crest vertical curves, and maximum superelevation (Hall et al., 2009; Underwood, 1991). Motorcycle crashes frequently occur on curves and descending gradients (Saleh et al., 2010; Yannis, Vlahogianni, Golias, & Saleh, 2010). Curves are not only associated with the highest crash risk but also the highest severity level for motorcycle crashes (Blackman & Haworth, 2013; Clarke, Ward, Bartle, & Truman, 2005; Mohammad, Tay, & de Barros, 2012).

Road surface characteristics also play an important role in motorcycle safety. Typical road surface characteristics include road-based hazardous objects, deformation, cracking, texture, edge defect, potholes, patches, and skid resistance (Austroads, 2012). Road-based hazards such as gravelled road shoulders, slippery road markings, slippery manhole covers plates and uneven road surfaces increase the crash risks for motorcyclists (Haworth, Symmons, & Kwadlo, 2000; Miller, 1997). Surface irregularities such as unclean road or loose material, poor road condition or road markings also increase motorcycle crash risk (Haworth, 1999;

Haworth et al., 1997). Wet bitumen for road surface repairs can cause steering problems for motorcyclists which can lead to a crash (Elliott et al., 2003; Huang & Preston, 2004).

International studies have shown road factors such as road geometry and road surface defects to be common in single vehicle (SV) motorcycle crashes (Hurt et al., 1981; Saleh et al., 2010). Many fatal motorcycle crashes involve the rider losing control and running off the road, falling from the motorcycle, and hitting road obstacles (Jama, Grzebieta, Friswell, & McIntosh, 2011; Preusser, Williams, & Ulmer, 1995). Previous comparisons of SV and MV motorcycle crashes have demonstrated differences in the locations of these crashes. SV motorcycle crashes more commonly occurred on non-arterial roads, rural roads, two lane roads, mid-block, and roads with high speed zones (Chang & Yeh, 2006; Diamantopoulou, Brumen, Dyte, & Cameron, 1995; Johnston, Brooks, & Savage, 2008; Saleh et al., 2010). In contrast, intersections, merging, turning areas, and mid-block locations were common in MV crashes (ACEM, 2004; Haque, Chin, & Debnath, 2012). Stationary objects were more likely to contribute to the severity of injury and damage in SV crashes (Quddus, Noland, & Chin, 2002). A US analysis of the severity of SV motorcycle crashes showed that wet pavement with no rain falling was common in SV crashes but that the severity of these crashes tended to be limited to property damage (Shankar & Mannering, 1996). Interstate freeways with high-speed traffic with adequate radii on curves and sufficient sight distance on grades were the safest roadways (Shankar & Mannering, 1996).

The aim of this paper is to explore the similarities and differences between MV and SV motorcycle crashes in order to provide a preliminary assessment of the importance of road factors in motorcycle crashes in the Australian riding environment.

Method

Study Approach

To understand the similarities and differences between SV and MV motorcycle crashes, a descriptive analysis was first undertaken to understand the characteristics of these crashes in term of road factors and environment factors. A regression model was then developed which estimated the relative likelihood of SV and MV motorcycle crashes for different characteristics of crashes, road factors, and environment. Crashes such as hit fixed/temporary object or fall from vehicle were coded as SV crashes if no vehicle other than the motorcycle was involved. Those crashes which involved another vehicle were coded as MV crashes. Types of multi vehicle crashes included angle, sideswipe, rear-end, and head-on crashes.

Data

Crash data were acquired from the Department of Transport and Main Roads for the period 1 January 2004 to 31 December 2011. Crash severity was coded by police as fatal, hospitalisation, medical treatment, and minor injury. Data after 2011 were incomplete for crashes of severity levels lower than hospitalisation so it was decided not to analyse the later data. Property damage only crashes were excluded because of high levels of under-reporting of these crashes. The final dataset contained 12,657 crashes of which 57% were MV crashes (n=7,202) and 43% were SV crashes (n=5,455). Lighting conditions were recorded ‘unknown’ in the 0.04% of MV crashes and 0.07% of SV crashes. Road surface conditions were recorded as ‘unknown’ in 0.01% of MV crashes and 0.07% of SV crashes.

Regression Model

A regression model was formulated to examine the similarities and differences between MV and SV motorcycle crashes. By using the two types of crashes (MV = 1, SV =0) as a response variable, a Binary Logistic Model (BLM) can be well formulated. A set of explanatory variables describing the characteristics of crashes, road factors, and environment (Table 1) which were hypothesised to be associated with the likelihood of MV and SV motorcycle crashes was included in the model. To identify the subset of explanatory variables which yield the most-parsimonious model, a backward elimination procedure was employed to remove the non-significant variables one by one so that the Akaike Information Criteria (AIC) was minimized. In order to evaluate if the model has sufficient explanatory power, the likelihood ratio statistics (G^2) was used.

Result

Descriptive statistics

The characteristics of the 12,657 motorcycle crashes are summarized in Table 1. Figure 1 shows that the numbers of both MV and SV crashes increased from 2004 until 2008, then decreased until 2011. The rate of decrease for MV crashes appeared to be higher than that for SV crashes. During 2008-2011, the number of registered motorcycle has increased from 139,355 to 156,825 (Queensland Government, 2015). It suggests that exposure of motorcyclists might have increased, whereas the number of crashes have decreased. SV crashes were more likely to occur during weekends (41% vs. 23%) and night periods (25% vs. 18%) than MV crashes.

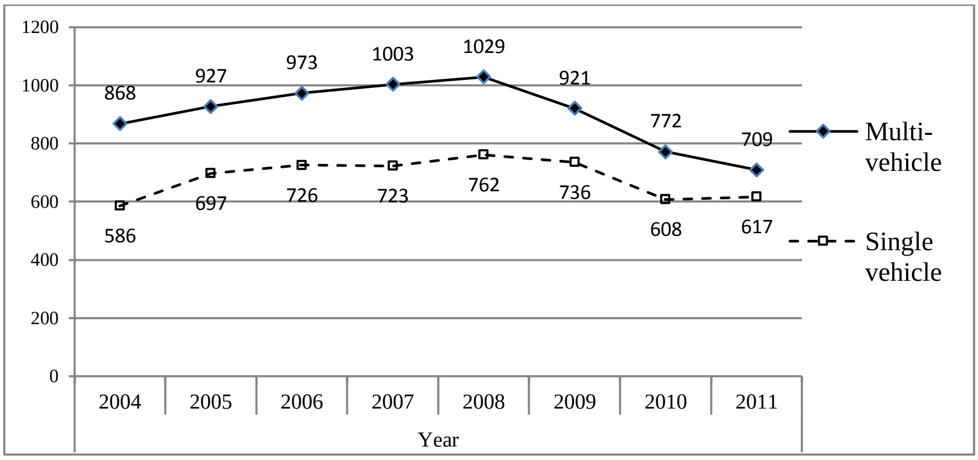

Figure 1 Multi and single motorcycle crashes in Queensland between 2004 and 2011

Most MV (61%) and SV crashes (46%) occurred on roads with a 60 km/h speed limit. On roads with posted speed limits of 80 km/h and above, SV crashes occurred more often than MV crashes (80-90 km/h: 13% vs. 7%; 100-110 km/h: 19% vs. 7%). MV crashes were more likely to occur at straight sections (84% vs. 54%), but less likely to occur at curves with both obstructed view (5% vs. 16%) and open view (11% vs. 29%). There were more MV crashes on level roadways (77% vs. 64%), but less on roadways with grade (15% vs. 24%) than SV crashes. Most crashes occurred on dry sealed pavement roads (MV: 92%, SV: 84%), wet sealed pavement roads had a greater share of SV crashes (12%) than MV crashes (7%). As expected, a larger proportion of MV than SV crashes occurred at intersections with give way, stop, and traffic signal controls. The injury severity patterns of the crashes showed that the majority resulted in hospitalisation (MV: 50%; SV: 57%) or medical treatment (MV: 31%; SV: 27%).

Regression model results

The parameter estimates, odds ratios (O.R.), and their statistical significance were obtained using the maximum likelihood estimation method in STATA 13.1 (Table 1). The backward elimination process removed two non-significant variables (crash month and atmospheric condition) from the most-parsimonious model that yielded an AIC value of 14,702. The likelihood ratio statistics of the resulting model was 2670 (34 df), which was well above the corresponding critical value for significance at 99% confidence level.

In 2011 (relative to 2007), MV crashes were significantly less likely (16.8% lower odds) to occur than SV crashes. MV crashes were less likely than SV crashes to occur on weekends (O.R. = 0.58) and during night hours (O.R. = 0.63). Similarly, the odds of MV crashes occurring in darkness with no street lighting were 41% lower than SV crashes (relative to daylight).

MV crashes were less likely than SV crashes to occur in both low speed zones (15.5% lower odds in 50 km/h or less roads) and high speed zones (80-90 km/h: 35.6% lower odds; 100-110 km/h: 50.7% lower odds) compared to 60 km/h speed zones. MV crashes were also less likely than SV crashes to occur on curves where the view was obstructed (68.6% lower odds) and open (69.7% lower odds) compared to straight road sections. Relative to level road sections, MV crashes were less likely than SV crashes to occur on dips (27.9% lower odds) and grades (16.2% lower odds).

Relative to dry sealed roads, the odds of MV crashes occurring on wet sealed roads were 53% lower than SV crashes. Similarly, the odds of MV crashes occurring on unsealed roads under both wet (O.R. = 0.22) and dry conditions (O.R. = 0.53) were lower compared to dry sealed roads. Relative to locations with no traffic control, MV crashes were more likely than SV crashes at locations with give way sign (142% increase in odds), stop sign (338% increase in odds), and traffic lights (140% increase in odds).

Relative to the crashes resulting in hospitalisation injury, the odds of MV crashes to produce fatal injury and minor injury were 39.7% and 25.7% higher, respectively, than SV crashes.

Table 1. Descriptive statistics and logistic regression model for the multi and single vehicle motorcycle crashes

Explanatory variables	Descriptive statistics		Logistic Regression				
	Multi-vehicle	Single-vehicle	Beta	O.R.	*p*	*95% of CI*	
	% (N=7202)	% (N=5455)				*Lower*	*Upper*
Constant			0.966		<0.001	2.301	2.996
Year							
2004	12.1	10.7	0.06	1.062	0.458	0.906	1.244
2005	12.9	12.8	-0.032	0.968	0.679	0.830	1.129
2006	13.5	13.3	-0.049	0.952	0.525	0.818	1.107
2007*	13.9	13.3					
2008	14.3	14	0.0004	1	0.996	0.860	1.161
2009	12.8	13.5	-0.098	0.907	0.208	0.778	1.056
2010	10.7	11.1	-0.058	0.944	0.478	0.804	1.107
2011	9.8	11.3	-0.184	0.832	0.024	0.708	0.976

Explanatory variables	Descriptive statistics		Logistic Regression				
	Multi-vehicle	Single-vehicle	Beta	O.R.	*p*	*95% of CI*	
	% (N=7202)	% (N=5455)				*Lower*	*Upper*
Day of week							
Weekday*	76.9	59					
Weekend	23.1	41	-0.544	0.581	<0.001	0.532	0.633
Time period							
Day (6 am - 6 pm) *	82	74.9					
Night (6 pm - 6 am)	18	25.1	-0.456	0.634	<0.001	0.522	0.770
Speed limit zone (km/h)							
≤ 50	18.5	17.2	-0.168	0.845	0.002	0.760	0.940
60 *	60.9	46					
70	6	4.7	0.012	1.012	0.892	0.848	1.209
80 - 90	7.2	12.9	-0.439	0.644	<0.001	0.561	0.740
100 - 110	7.4	19.1	-0.708	0.493	<0.001	0.433	0.561
Lighting condition							
Darkness - Lighted	13.6	15.6	-0.062	0.94	0.562	0.761	1.160
Darkness - Not lighted	2	6.5	-0.532	0.587	<0.001	0.445	0.776
Dawn/Dusk	6.6	5.6	0.136	1.146	0.144	0.954	1.375
Daylight *	77.7	72.2					
Unknown	0.04	0.1	-0.469	0.626	0.597	0.110	3.552
Horizontal alignment							
Curved - view obscured	5.1	16.3	-1.159	0.314	<0.001	0.271	0.363
Curved - view open	11	29.4	-1.196	0.303	<0.001	0.273	0.335
Straight *	83.9	54.3					
Vertical alignment							
Crest	5.4	6.9	0.015	1.015	0.864	0.856	1.202
Dip	2.5	4.7	-0.328	0.721	0.004	0.578	0.899
Grade	15	24.1	-0.176	0.838	0.001	0.754	0.932
Level *	77	64.3					
Road surface condition							
Sealed - Dry *	92	83.7					
Sealed - Wet	6.7	12.1	-0.752	0.472	<0.001	0.411	0.541
Unknown	0.02	0.1	-1.819	0.162	0.116	0.017	1.565
Unsealed - Dry	1.2	3.6	-0.639	0.528	<0.001	0.399	0.697
Unsealed - Wet	0.1	0.5	-1.501	0.223	0.001	0.090	0.552
Traffic control Type							
Give way	18.9	8	0.882	2.415	<0.001	2.135	2.733
No control *	61.9	85.4					
Stop sign	5.1	1.2	1.478	4.383	<0.001	3.309	5.805
Operating traffic lights	13.8	5	0.875	2.399	<0.001	2.067	2.785
Others	0.3	0.3	0.04	1.04	0.907	0.538	2.011
Crash severity							
Fatal	3.1	4.2	0.334	1.397	0.002	1.127	1.733
Hospitalisation *	49.8	56.7					
Medical treatment	30.8	27.4	0.025	1.026	0.588	0.936	1.123
Minor injury	16.4	11.8	0.229	1.257	<0.001	1.115	1.417
Summary statistics							
Number of observation	12657						
Log-likelihood (at zero)	-8652.21						
Log-likelihood (at model)	-7317.01						
AIC	14702.03						
G^2	2670.40 (34 *df*)						
	P <0.001						

* Reference category

Discussion

Both MV and SV motorcycle crashes peaked in the year 2008 with increasing trends since 2004, but have decreased since 2008, suggesting that the safety of motorcyclists has improved in the recent years. While such improvements are encouraging, greater reductions were seen in the numbers of MV crashes than the SV crashes. The differences in reduction of crash numbers warrant more research on understanding the safety issues in MV and SV motorcycle crashes.

The finding that SV motorcycle crashes are more likely to occur during weekends than MV crashes was in consistent with other studies (e.g., Haworth et al., 1997). Weekend riding is generally for recreational purposes rather than commuting purposes (Johnston et al., 2008; Moskal, Martin, & Laumon, 2012) which might be a possible explanation for observing the greater likelihood of SV crashes. Roads in rural area are very common for touring activities. The current study shows that single motorcycle crashes were common on rural roads. This is consistent with the findings of Saleh et al. (2010) that outside urban areas the most frequent collision type is a SV crash (run-off the road).

SV crashes were more likely than MV crashes to occur during night hours and on roads without street lighting. Motorcyclists rely on single headlamps and retroreflective materials from road marking or guide post, therefore riders may take longer to detect any hazardous road conditions such as wet surface, debris or potholes. Haworth et al. (1997) found that about one-quarter occurred under difficult lighting conditions including night-time. They indicated that SV crashes were more likely than MV crashes to occur at night.

SV crashes were more likely to occur on curves than MV crashes. This finding was consistent with earlier research by Schneider, Savolainen, and Moore (2010) who found that horizontal curves significantly influenced the frequency of SV motorcycle crashes. More importantly, SV crashes on rural roads segments have been shown to have higher likelihoods to be fatal than on urban roads (Chang & Yeh, 2006; Saleh et al., 2010). Quddus et al. (2002) further demonstrated that crashes at bends may result in motorcyclist leaving the carriageway and overturning onto off-road stationary objects such as a guardrail, rocks or trees and increasing the probability of being fatal. ACEM (2004) noted that a roadway design defect such as curve with decreasing radius was considered to be a condition which presented a danger to riders. Riders could experience difficulties in maintaining the control of their motorcycles while manoeuvring or negotiating a sharp curve.

Descending gradients have been identified as critical factors in both MV and SV crashes (Saleh et al., 2010). The current research found that SV crashes were more likely to occur on descending gradients than MV crashes. On steep downgrades, the acceleration will increase and the front wheel will be carrying most of the weight. Limebeer, Sharp, and Evangelou (2001) found that the wobble mode becomes significantly less stable under braking and the effects become exaggerated as the deceleration rate increases. Hurt et al. (1981) found that wobble, unstable oscillatory motion of the motorcycle front mass is the most common loss of control mode in SV crashes.

Single motorcycle crashes were more likely to occur on roads with 80 km/h or more speed limits. The 80+ km/h roads are generally the highways and motorways where there are fewer intersections than roads with 60 km/h limits (mostly urban and sub-urban roads), which could possibly suggest that there are less numbers of conflicts in these roads than the urban 60 km/h roads. Elliott et al. (2003) found that SV motorcycle crashes involve larger machines which are ridden more often on high-speed rural roads than smaller machines. However, they are not confident with the outcome unless the distance ridden for different engine capacities are included the analysis. Engine size does not emerge as a risk factor in a number of studies (Haworth, Blackman, Rolison, Hewson, & Hellier, 2013; Langley, Mullin, Jackson, & Norton, 2000; Van Honk, Klootwijk, & Ruijs, 1997). The possible explanations are rider speeding behaviour (Elliott et al., 2003) and active safety system technology (Antilock Braking System) reliability for motorcycle (Burton, Delaney, Newstead, Logan, & Fildes, 2004), whilst a further observation is required.

The analysis demonstrated that road surface condition influenced the relative probability of SV motorcycle crashes. Compared to dry sealed roads, SV crashes were more likely to occur on wet roads (both sealed and unsealed) and dry unsealed roads than MV crashes. These findings suggest that riders' inability to control motorcycles on rough and slippery surfaces could often lead to causing out-of-control or leaving-carriageway types of crashes. Furthermore, earlier research showed that riders are likely to reduce speed as they compensate for the increased risk of riding when the road surface is wet (Quddus et al., 2002; Savolainen & Mannering, 2007).

MV crashes are more likely to occur than SV crashes at locations where the give way, stop sign, and traffic lights controls are present. Conflicts involving vehicles from different directions are likely to occur in these locations. Therefore, it was not surprising to see that MV crashes were more common at these locations. Preusser et al. (1995) found that ran traffic control crashes in intersections (72%) occur when one vehicle with an obligation to stop, remain stopped, or yield, fails to do so and thus collides with other vehicles.

The higher likelihood of fatality in MV crashes than in SV crashes may reflect the greater impact force resulting from two or more road users in MV crashes. Drivers find it difficult to estimate the speed of approaching motorcycles because they are less conspicuous (Gould, Poulter, Helman, & Wann, 2012; Thomson, 1980). Motorcycles that are further away have a smaller apparent size in other road user's vision (Clabaux et al., 2012) and therefore if they are travelling at a high speed, the time to react to changes is shorter. Walton and Buchanan (2012) indicated that motorcycles are generally faster than the other traffic in the intersection, thereby increasing their odds of creating the conditions for a crash. To conclude, earlier research showed the likelihood of rider being injured is extremely high: in 98% of multi-vehicle crashes and injury severity increases with speed and motorcycle size (Hurt et al., 1981).

This paper explores the similarities and differences both the effects of road and environment factors on MV and SV motorcycle crashes. However, it is acknowledged that other factors such as rider and vehicle characteristics might have significant effects on the crashes. Examining the effects of these factors was beyond the scope of the current study.

Conclusion

Although the explanatory variables included in the regression were limited to those features of the road elements that are recorded in police crash data, the findings are consistent with earlier research that showed the importance of road factors such as geometry and road surface, and environment factors such as lighting condition in single motorcycle crashes.

The greater importance of road and environment factors in SV crashes underlines the need to improve road infrastructure to reduce the occurrence and severity of motorcycle crashes.

Further research is needed to gain a more comprehensive understanding of the appropriate treatments to reduce the risks associated with the factors identified in this study. More detailed information such as road design (e.g., curve radii, descending grade) and road surface condition (e.g., skid resistance, unevenness) at crash sites will be collected in later studies in order to better estimate the quantitative contributions of these factors.

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