Motorcycle Speeds at Urban Intersections

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Abstract

Five urban, uncontrolled T-intersections known to be motorcycle crash 'black spots' were monitored using instrumentation and a roadside observer. Two sets of twelve-hour observations were collected for each site (N ≈ 100,000). Instrumentation recorded the 'events' of vehicles passing to measure, speed, direction, lane position, vehicle type (broadly characterised) and headway. Observers further recorded times of bicycle events, type of motorcycle (scooters or motorcycles), the behaviour of motorcycles and the use of 'high visibility' gear. Results establish that motorcycles travel around 10% faster than the other traffic (car mean speed = 34.97 kph), with motorcycles travelling on average 3.3 kph faster than cars. Most motorcycles are travelling within the speed limit, but are 3.4 times more likely to be exceeding the speed limit than cars. Similar results are described for scooters. The mean speeds of all vehicles is less in the evening commuter time, and more so for motorcycles than any other type of vehicle. The presence of a car at the intersection did not affect mean speed. Motorcycles and scooters have a shorter headway to the vehicle in front, than any other vehicle type. The results are compared for robustness across locations and days. It is concluded that in urban areas motorcycles are travelling significantly faster than other traffic. These findings are discussed against a concern to reduce motorcycle crashes at intersections where the car driver is deemed 'at fault'.

Introduction

Internationally, motorcyclists are usually found to be over represented in road accident statistics. In New Zealand motorcyclists account for 9% of road crashes (MOT 2010a) while only contributing around 0.5% of travel time or trip legs (MOT, 2010b). Using these types of statistics to determine relative risk of injury or death it is found that motorcyclists are around 16-20 times more likely to be involved in a fatal or injury crash than car/van drivers.

This work is part of a set that includes two previous investigations relating to motorcycle safety (Walton, 2010; Walton & Murray 2010). The overall aim of the set of research is to create a better understanding of the factors influencing the high rate of car vs motorcycle crashes at intersections, in which the car driver is at fault. The question of interest in this work is whether motorcyclists are no different from other traffic in respect to driver behaviour.

It is estimated that more than 25% of all motorcycle accidents could be eliminated if an effective solution can be discovered that removes the driver-at-fault right of way violations (Clarke et al., 2007). The work also develops from Olson's (1989) acknowledgement that a concern to understand motorcycle conspicuity is based on the assumption that motorcycles are no different from other traffic in respect to driver behaviour but over-represented in accident statistics through being unable to be seen (the so called 'looked but failed to see' type accident, Brown, 2002).

Method

Observation Sites

Five motorcycle ‘black spots’ in Wellington, New Zealand were selected from a ranked list of locations within the official accident record (The Crash Analsyis System (CAS) Database, NZTA) across 10 years of data records, 2000 to 2009.

The criteria used to determine the sites were narrowed to match the analysis undertaken by Clarke et al (2007). Specifically, sites were considered viable if they met four conditions :(1) urban, (2) within 100 m of a T-intersection or cross road, (3), had crash histories with at least one motorcycle or moped (4) both non-injury and injury crashes were included.

Equipment

The equipment used was the TIRTL (The Infra-Red Traffic Logger), a traffic logging system developed and manufactured by CEOS Ltd in Australia.

A TIRTL sending and receiving pair can monitor speed, direction, lane position, headway and vehicle type across eight lanes of traffic simultaneously. Vehicle identification is achieved as the system observes configurations of beam breaks due to vehicle wheel passing through the beams. Motorcycles are identified because they tend to have a shorter wheel base to all other traffic (excluding bicycles).

Procedure

Two sets of twelve-hour observations were collected for each site, (N ≈ 100,000).

When a motorcycle was observed crossing through the site, observers recorded:

(1) If the rider had high visibility gear.
(2) The classification as either a motorcycle or a scooter.
(3) If a car was present at the intersection.
(4) If the rider was under-passing or over-passing other traffic; and
(5) Any other observation of the motorcyclist.

Observers classified the motorcycle types into two categories (motorcycle and scooter) based on if it looked and behaved like a scooter, then it was.

Observers recorded the event time of non-powered cyclists creating beam events, to later exclude them from the data.

Data cleaning

Of around 100,000 vehicle observations 1582 (less than 2%) were removed from further consideration. These were events recorded as being in the wrong lane, going improbably fast, or both being in the wrong lane going too fast and having negative or no headway. These data errors arise, typically, through the configuration of wheel patterns with vehicles overlapping each other from the perspective of the TIRTL.

Results

The data establishes that of all the vehicle types motorcycles travel the fastest, on average. Motorcycle mean speeds are about 10% higher than those of other traffic.

Table 1 provides the mean score and standard deviations for each vehicle type across all five sites, with the data from each of the two days of observation combined.

The observed speed differences, though comparatively small are large effects for vehicle type, establish that these mean scores are all significantly different from each other $F(3,98371)= 202.97$, $p <.001$.

The observed mean speeds are different across sites $F(4,98372)=2745.95$ $p. <.001$. Each site was observed across two days (the same day a week apart) to gain some measure of the reliability of observations. The data are reliable for motorcycles and scooters $F(1,1882)= .128$ $p.<.721$ but not for cars $F(1,90419)= 9.54$ $p.<.001$). This is largely due to site 3 showing a faster travel profile for car traffic on the second day.

When site 3 is excluded from the sample, the observed difference between days disappears. While the overall average speed changes across the different sites, the relative ranking of speeds remains unchanged.

Motorcycles are always found to be faster than scooters, and both scooters and motorcycles are fasters than cars and other traffic.

TABLE 1. AVERAGE SPEEDS OF DIFFERENT VEHICLE TYPES APPROACHING UNCONTROLLED INTERSECTIONS ACROSS FIVE SITES IN WELLINGTON

	n	Average speed (kph)	SD
Cars	90,429	34.97	8.92
Trucks	6,062	32.47	9.65
Motorcycles	752	38.28	10.94
Scooters	1140	37.22	9.37

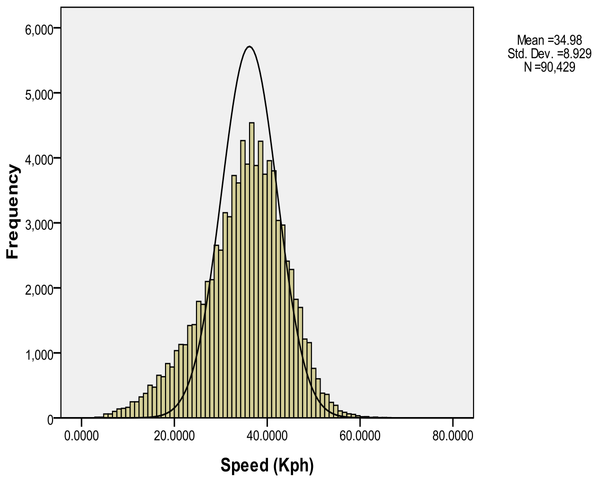
Table 2 provides an indication of the meaningfulness of the variation in the speeds observed. By convention traffic speeds are represented by the 85^{th} percentile but the more useful measure may be the percentage of vehicles travelling above 50 kph, the speed limit. Here it is observed that motorcycles are around 3.4 times more likely to be speeding than car traffic, following from their tendency to travel around 10% faster than the other traffic.

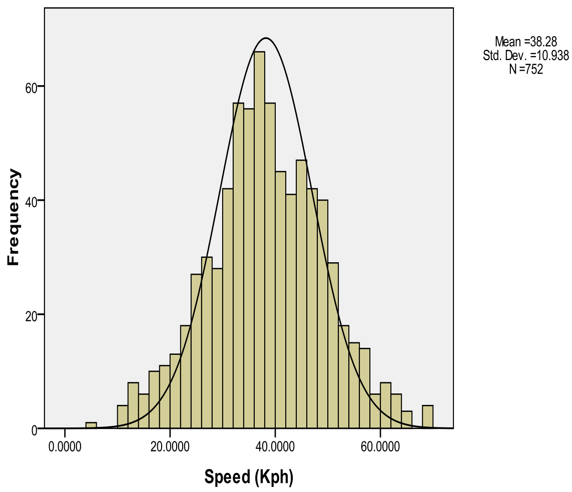
TABLE 2. THE PERCENTAGE OF VEHICLES TRAVELLING IN EXCESS OF THE SPEED LIMIT, THE 85^{TH} PERCENTILE SPEED AND THE CO-EFFICIENT OF VARIATION FOR VEHICLE SPEEDS BY VEHICLE TYPE.

	n	% Travelling above 50 kph	85^{th} Percentile Speed kph	COV
Cars	90,429	4.65%	43.8	25.55
Trucks	6,062	3.51%	42.2	27.71
Motorcycles	752	14.23%	49.5	28.61
Scooters	1140	8.69%	46.8	25.16

Figures 1 and 2 (below) represent the speed distributions for each of cars and motorcycles. The two distributions are similar in shape but the motorcycle distribution is offset on the x-axis reflecting the circumstances in which motorcycles are seen to travel faster than the other traffic.

FIGURE 1 (LEFT) CAR AND VAN SPEEDS MEASURED ACROSS 5 SITES OVER 10 DAYS (N = 90 429)
FIGURE 2. (RIGHT) MOTORCYCLE SPEEDS MEASURED ACROSS 5 SITES OVER 10 DAYS (N= 752)





Examination of the distributions establishes that around a quarter of the combined group of scooter and motorcycles (502 of 1892 observations) were travelling at a speed equal or greater than the 85% percentile speed of car traffic.

Influences on speeds

Car at T-intersection: The speeds of the motorcycles and scooters were not influenced by the occurrence of a vehicle appearing at the T-intersection, $F(1,1888) = .094$, $p < .76$, *n.s*. This finding holds, even accounting for the direction from which the motorcycles and scooters were approaching the intersection.

Time of day: Time of day was separated into three periods of observation 7am-9am, 9am-4pm, and 4pm-7pm. These periods reflect the uneven distribution of peak traffic and the variability of trip purposes that are likely in any urban area across the time of day the travel is observed.

Time of day does have an influence on overall traffic speeds, with the morning peak hours of traffic being faster than the evening and the highest mean speed observed during the off-peak hours. The finding reflects the level of congestion associated with a highly dense city centre and the convention that allows more flexibility in the arrival time of daily commute than the departure time. The highest mean speed is observed during the off-peak hours 36.45 kph (95% CI 36.11 - 36.80).

The general trends across the day for each of the vehicle types are not different by vehicle type, except for motorcycles (but not scooters) being significantly slower in the evenings.

While the other types of traffic slow around 2 kph from their morning peak hours, motorcycles slow around 4 kph from morning peaks of 39.45 kph (SD = 10.021) to 35.18 kph (SD = 11.27). The effect is not likely due to thin sample sizes (motorcycle evening peak hours *n* = 244) although it does disappear when motorcycles and scooters are combined $F(4,98374) = 1.935$, $p < .102$. The effect might arise through an uneven distribution of motorcycle and scooter observations across sites $\chi^2(12, 98383) = 225.5$, $p < .001$. For example, motorcycles and scooters were less common at site 5 compared to site 1. When considered on a site-by-site analysis the main effect of speeds varying across the day does not interact with vehicle-type except at site 3 where the speed of motorcycles in the evening peak hours of traffic reduces to 35.17 kph (SD= 12.68) (n =54). When site three is excluded and considering only motorcycles, the effect disappears $F(6, 575) = .835$, $p < .543$ *n.s.*. It is reasonable to infer that while vehicle speeds are found to vary with the congestion experienced at different sites, at different times of the day, these circumstances are not differentially exploited by motorcycles or scooters.

Lane Positions: The sites observed have different carriageway widths and vehicles travelling in different directions. To make it possible to compare where on the road the different vehicle types were most likely to travel the scores were standardised against the dominant vehicle type (Cars and Light Vans).

It is observed that there are no overall correlations between lane position and observed speed for motorcycles ($r(752) = .042$ $p. < .251$) or scooters($r(1140) = -.027$ $p. < .356$).

When grouped into the categories of left, middle and to the right of car traffic mean motorcycle speeds remain independent of lane positioning, $F(2,751) = 1.382$ $p. < .252$. A similar finding is observed for scooters, $F(2, 1137) = 1.719$ $p. < .18$.

Free Speeds: Free speeds occur when headways are ‘relatively clear’, here defined as a vehicle having a headway greater than 4 Seconds (refer Baldock et al, 2010).

Table 3 presents the speeds of motorcycles and other traffic in free speed conditions. It is observed that having a clear headway has the effect of increasing vehicles speeds generally (cf Table 2 above) $F(1, 98339) = 86.613$ $p. < .001$. This interacts with vehicle type to produce the relatively larger increases in average speeds for motorcycles and scooters than for cars and trucks.

TABLE 3. FREE SPEEDS OF VEHICLES AND THE PERCENTAGE OF VEHICLES TRAVELLING IN EXCESS OF THE SPEED LIMIT BY VEHICLE TYPE

	n	Average Free speed (kph)	SD	%travelling in excess of 50 Kph
Cars	48761	35.68	9.24	6.18
Trucks	4207	32.48	9.74	3.67
Motorcycles	375	40.31	11.78	20.61
Scooters	551	37.22	9.80	9.68

Observations of motorcycle behaviours

Headway: The headway data indicate the seconds between observations of different vehicles and establish the following distance between vehicles In addition to the data cleaning that removed negative headways, data were refined to examine only those with headway of 4 seconds or less.

Table 4 presents the average headways for the four different types of vehicles across the five locations.

TABLE 4. AVERAGE TRUNCATED HEADWAY OF DIFFERENT VEHICLE TYPES APPROACHING UNCONTROLLED INTERSECTIONS ACROSS FIVE SITES IN WELLINGTON

	n	Average headway (s)	SD
Cars	41637	2.78	.954
Trucks	1851	2.55	.916
Motorcycles	376	2.05	.944
Scooters	589	2.10	.990

The differences between the observed headways across vehicle type are significant, F(3,44441) = 117.262 p. .001. Motorcycles and scooters are found to travel closer to the car in front of them than did other vehicle types. These differences are not significantly different across the three times of day F(2,44441) = .208 p. <.974 NS .

High visibility gear: Of the 1892 motorcyclists observed, 119 (around 6%) displayed a piece of hi-visibility gear. There was no significant difference between scooters and motorcyclists in the likelihood of these observations being made.

Passing: Motorcycles and scooters over and under passing other traffic occurred in small numbers of the observations (around 3%).

Over passing is over represented in motorcycles compared to scooters, χ^2(1, 1892)= 12.425 p. <.001. Motorcycles are around 2.5 times (OR = . 415 95% CI .251 - .687) more likely than scooters to overpass traffic.

Scooters are no more or less likely than motorcycles to underpass traffic, χ^2(1, 1892)= 2.347. *p* <.125, *n.s*.

Those travelling faster than traffic by over-passing were travelling significantly slower than other motorcyclists observed in traffic, *t*(750) = 2.512, *p* <. 012. This implies that the opportunity for motorcycles to over pass is when the other traffic is moving relatively slower than usual.

Discussion

Motorcycles and scooters travel faster than other traffic, although usually under the speed limits set for urban areas. However, motorcycles at least travel with a much higher probability of exceeding the speed limit than cars or trucks. These findings are robust when subjected to critical assessment across the five sites and two days of observation.

The findings that motorcycles travel faster and with greater likelihood of speeding are exaggerated when considering vehicles in free speed but are otherwise not influenced by other critical elements such as the presence of a vehicle at the intersection, or the time of day of the observation.

Baldock et al (2010) investigated motorcycle speeds around Melbourne, Australia for highway conditions without heavy traffic. They collected a sample from a week's automated observations that is a similar size to that of this work. They find that motorcycles travel significantly faster than cars and the likelihood of exceeding the speed limit is around 3.3 times more than cars. This is similar to the findings of this work

The findings here indicate that motorcycles are *generally* travelling faster than the other traffic; the result does not arise through circumstances such as travel faster under congestion or 'scooting' in and out of traffic.

This might show up as having fewer motorcycles than expected travelling at the speeds of congested traffic, but this does not appear in the observed distributions. Those found over-passing were established to be travelling slower than the average speed observed for motorcycles in free flowing traffic. The finding is further reinforced by the absence of an effect between speed and the lane position of the motorcycles or scooters.

Motorcycles and scooters have smaller headways and have faster relative speeds. The interpretation of the close proximity headway data (i.e less than 4 secs) needs to take into account that lane position may affect the genuine available headway for a scooter or motorcycle, that scooters and motorcycles have shorter stopping distances (see table 5 below) and the more flexible ability to manoeuvre to avoid a collision.

TABLE 5. STOPPING DISTANCES FOR MOTORCYCLES AND CARS AT SPECIFIED SPEEDS.

	Stopping Distance (m)	
Speed (km/h)	Motorcycle[1]	Car (estimate)[2]
67	21.96[3]	27.61
59	19.37[3]	21.41
37	6.6[4]	8.4
35	6.2[4]	7.5
25	2.9[4]	3.8

Figures taken from Stables and Ruller (2007)

Stopping distances estimated using a tool provided by CSG Network (2011) using a coefficient of friction of 0.64 (taken from Stables and Ruller, 2007).

Context for this work:

- Since the early 1980s there has been a concern that motorcycles and scooters are more likely than larger motor vehicles to have intersection crashes due to the relatively lower frontal conspicuity of motorcycles compared to other vehicles (e.g. Lin & Kraus, 2009; Thompson, 1980; Pai & Saleh, 2008a, b; Wells et al, 2004; Williams and Hoffman, 1979).
- The most common reason given by car drivers that collide with motorcycles is that they 'didn't see them' and this is termed the 'looked but failed to see' effect by Brown (2002).

- Around eighty percent of car drivers are described in crash reports to be at fault in the car-vs-motorcycle crashes at intersections (see Clarke et al., 2007, Walton, 2010). This is cited as reinforcing the idea that something about the drivers' abilities or circumstances is the reason for the apparent over-representation of motorcycle crashes at intersections.

It need not be true that the failure is primarily with the car driver not seeing the motorcycle (the conspicuity theory) rather than, for example, the car driver not accurately recognising the speed of a motorcycle or scooter. (Given this work establishes that motorcyclists and scooter riders travel faster than other vehicle types, and are also observed to more often exceed the speed limit.

When speed is considered as a contributing factor to crashes at intersections then the interesting question is not, for example, whether car vs motorcycle crashes are a special case due to the nature of vehicles involved but rather what contribution variability in approach speeds actually have in the contribution to the likelihood of a crash at an urban intersection.

Limitations

This research does not examine speeds of motorcycles in all urban settings or even a sample of sites that randomly represents all urban settings.

A possible explanation for the observed speeds of motorcycles and scooters is that there is the opportunity to travel faster than other vehicles, related to the design of the roads where the sites of observation were undertaken. This can be observed in the between-site difference in speeds across all vehicle types: some sites are just faster than others.

The road sections observed were typically wide carriageways with high traffic volumes, and relatively slow speeds as a result of urban congestion. Notwithstanding the results of Baldock et al. (2010) who reported observing similar findings on the open road, it is possible that a more random selection of sites would reveal different results – perhaps removing the observed difference between motorcycles and other vehicle types.

The sites were selected to produce a conservative test of the hypothesis that motorcycles travel faster than others at black spots. Motorcyclists have every reason to be more cautious at these sites on the assumption they know or can perceive that they are more dangerous than other locations. It is unlikely that a different set of sites would produce a significantly different set of findings. It could be sensible to assess this hypothesis by considering what features of sites allow motorcycles to travel faster than others, than to establish that other sites can be found without the observed effects reported here.

Conclusions

In urban areas motorcycles and scooters travel significantly faster than cars and other vehicle types. About a quarter of motorcycle and scooter riders travel are likely to be exceeding the speed limit, around 3.4 times more likely than other traffic. From the perspective of trying to understand the aetiology of motorcycle crashes it is important to include consideration of car drivers' recognition of the motorcyclists' behaviours (without prejudice to the consideration of fault or the other factors that contribute to the crash).

Motorcycles' relative speeds in the urban environment should be accounted for when trying to identify ways to reduce the risk of motorcycle crashes at intersections.

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