



**MONASH** University  
Accident Research Centre

**FEASIBILITY OF ASSESSING THE  
INFLUENCE OF SHIFTS IN TRAFFIC  
SPEED ON MOTORCYCLE TRAUMA**

**VICROADS PROJECT RDS-0516**

by Mark Symmons  
& Stuart Newstead

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**Title and sub-title:**

Feasibility of Assessing the Influence of Shifts in Traffic Speed on Motorcycle Trauma

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**Abstract:**

The two principle aims of this project were to:

1. Identify literature examining the likelihood and severity of outcome of motorcycle-involved crashes as a function of travel speed; and
2. Consider the traffic counts data currently collected by VicRoads as a tool for assessing inappropriate versus excessive speed of motorcyclists and crash likelihood and outcome.

Only two studies were found that modelled crash outcome as a function of motorcycle travel speed, and none that considered crash likelihood. Both studies were based primarily on urban crashes and mostly European roads and European traffic mixes, and therefore may not be immediately applicable for Victorian (or Australian) conditions and situations.

VicRoads currently collects traffic counts data that includes vehicle speeds. Over a five year period Victoria's "whole" road network is sampled. Accordingly, the proportion of motorcycles versus cars that are exceeding the speed limit as a function of time of day (and day of week, season, etc), class of road, and so on could be easily determined. Assessing inappropriate speed (ie a travel speed too fast for the prevailing conditions) is more problematic. By comparing motorcycle speeds with those of other vehicles (and other motorcycles) in the same traffic stream and at similar times and potentially at similar sites, some inferences could be drawn about *potential* inappropriate speed.

The traffic counts data could also be analysed together with Victoria's crash database, with site selection driven by site crash history or site speed profile (or both) to undertake a limited but useful case-control type of study. The traffic counts data would have to be recovered and reprocessed by VicRoads' Information Services division before determining its completeness and the potential extensiveness of such a study, but if additional fieldwork is not required it could be quite cost-effective.

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**Key Words:**

motorcycle, speed, crash risk

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# Preface

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## 1.0 BACKGROUND

Due to the greater forces involved, increasing travel speed directly increases the severity of a crash. The relationship between travel speed and the risk of a crash occurring is more complex. For example, travelling at 100 km/h on an urban freeway may not be any more or less risky than travelling at 50 km/h in a residential area. Two elements of travel speed are important in this regard – exceeding the speed limit and travelling at a speed too high for the prevailing conditions. Given their manoeuvrability and high acceleration performance, and the challenge and thrill inherent in such behaviour, motorcycle riders may be more likely to travel at speeds inappropriate for the conditions. However, there is a paucity of data to make such conclusions. The focus of this assignment is a feasibility study to determine what can be concluded from the speed data currently collected by VicRoads, and what additional speed data needs to be collected, in order to examine the separate effects of inappropriate and excessive motorcycle speed and changes in traffic speed on the frequency and severity of motorcycle crashes.

This brief report consists of several elements, the first of which is a literature review exploring the effects of changes in travel speeds on the number and severity of motorcycle crashes, with particular attention to excessive and inappropriate speed. The second main component of the report is a treatment of the speed data currently collected at rural and metropolitan sites across Victoria by VicRoads, including a discussion of its potential application as a tool for estimating and measuring the effects of changes in travel speeds on motorcycle crash patterns.

## 2.0 THE RELATIONSHIP BETWEEN TRAVEL SPEED AND CRASH OUTCOME FOR MOTORCYCLISTS

Travel speed is acknowledged as a road safety risk factor – an increase in speed generally increases the likelihood of a crash due to a reduction in the time available to spot, interpret and react to a hazard. A crash at a higher speed is also likely to result in more injury as well as an increased severity of any injury that does occur. In that sense, speed can be considered a crash contributory factor and the absolute travel speed at the time of the crash is then the primary variable of interest. Whether a particular travel speed can *cause* a crash is a more complicated question.

While they are often used interchangeably in the literature, the term “excess speed” is generally used to denote travelling at a speed in excess of the prevailing speed limit (although there are notable exceptions identified later, highlighting the need for caution when using the terms), and the term “inappropriate speed” indicates travelling at a speed unsuitable (or unsafe) for the prevailing conditions and road environment, or exceeding the capabilities of the driver/rider, or exceeding the tolerances of the vehicle and its equipment. Most sections of road have a set speed limit where the maximum speed allowable is sign-posted. However, this maximum would not be suitable for all conditions. This consideration is recognised in the application of variable speed limits, such as the reduction of the speed limit in school zones during times children are most likely to be crossing the road. On other sections of road the driver/rider must make a decision as to whether the speed limit is an appropriate travel speed for the conditions at the time. For instance, travelling at the speed limit of 100 km/h on a particular section of rural highway may be significantly less safe at dusk due to the increased possibility of animal incursion, or after light rather than drenching rain, or at night compared with daylight conditions, etc.

Coupled with the transitory nature of the appropriate speed is the complication that a speed in excess of the prevailing speed limit may in fact *seem* quite safe for a particular section of road – a subjective rather than objective conclusion. Further, this conclusion is likely to be reinforced for the driver/rider when they do indeed successfully negotiate that section of road while exceeding the speed limit. However, such a conclusion can only be drawn post-hoc – we can only be certain that it *was* safe, not that it *will be* safe, owing to the unexpected nature of the road environment and other factors. Travelling at or below the speed limit should always reduce the likelihood of being involved in a crash as well as the severity of any crash that does occur.

One important reason excess and inappropriate speed are used interchangeably is the difficulty in separating them as crash factors (whether causal or contributory) during a crash investigation. Inappropriate speed in particular is very transitory; for example, weather conditions can change quickly and a driver’s level of alertness or vigilance can vary moment to moment due to a number of factors, and need not always reliably decrease with time spent driving. Lack of knowledge about the driver’s familiarity with the particular section of roadway and the vehicle in question may also complicate assigning inappropriate speed as a crash factor – both high and low familiarity can be problematic if the driver was complacent or not expecting a particular hazard, respectively. Patterns of skid marks as part of a crash reconstruction and eyewitness statements can lead to a conclusion that the vehicle was travelling in excess of the prevailing speed limit, but a myriad of variables can determine whether the speed was inappropriate, particularly if the speed was not in excess of the speed limit. Eyewitness judgements of motorcycle travelling speed are particularly problematic as they “almost always overestimated motorcycle



speeds, usually by 30% to 50%, and other vehicles drivers often...said it came out of 'nowhere'" (Hurt, Oullet & Thorn, 1981, p.25).

Speed as a crash factor is particularly pertinent for motorcycles and motorcycle riders. In many instances the quick acceleration and manoeuvrability, if not high speed, are features that attract many to motorcycling, especially leisure riders. But those very same factors result in a smaller margin for error than might apply to most other vehicles in terms of crash possibilities, and the relative lack of protection offered when a crash does occur means that a crash is likely to be more severe for a motorcyclist.

## 2.1 CRASH INVESTIGATIONS

Clarke, Ward, Bartle and Truman (2004) built a database of 1,790 motorcycle crashes that occurred in the UK in the period 1997-2002. A retrospective study, all information relating to each crash was used to build a "crash narrative" for each incident. The cases were then analysed by the research team to determine factors involved in the crash. They determined that travelling in excess of the speed limit was deemed to be a contributory factor in 3.5% of crashes, and "misjudging the appropriate speed for the conditions" (p. 35) was a contributory factor in another 5.6% of crashes where the speed limit was not actually broken. Accordingly speed, travelling too fast for conditions or exceeding the speed limit, was a factor in 9.2% of their motorcycle crashes. A common speed-related crash, and the most common cause of single-vehicle motorcycle crashes in Clarke et al's database, resulted from riders misjudging the appropriate speed to negotiate a bend in the road.

Clarke et al (2004) also conducted a survey of motorcyclists about crash factors and safe riding behaviours. One clear finding was the recognition by riders that there is a difference between exceeding the speed limit and riding too fast for the conditions. Of their 147 respondents, 80% considered observing the speed limit as one of the least important safety measures a motorcyclist can take, and 58% always or frequently broke the speed limit, and the rest admitted to occasionally breaking the limit when they thought it was safe to do so – all of their rider respondents were prepared to speed. Despite this self-reported propensity to speed, a quarter of all respondents said that riding "too fast for conditions" was a major cause of crashes (this question asked for the respondent's free-text opinion as to the three main causes of motorcycle crashes). Assuming that they could be assured of confidentiality (ie that their utterances would not be passed on to the police or their own insurance company), it would be useful to ask crashed riders to what degree they thought their *own* crash had been caused by speed (excessive or inappropriate).

In a prospective study of crash data, Mosedale and Purdy (2004) defined excessive speed as "either excessive for the conditions / location or exceeding the speed limit. It is not possible to differentiate between these two aspects" (p.1). As part of crash investigations, Police forces across Britain noted what they considered was the principal "precipitating factor" of the crash and any attendant "contributory factors". A precipitating factor was a key action or failure without which the crash was not likely to have occurred, while contributory factors were those that caused the precipitating factor. Precipitating factors for which excessive speed was noted as a contributory factor included following too close, aggressive driving, reckless behaviour, etc. Across all vehicle types, excessive speed was recorded as a contributory factor in 12% of all crashes and 28% of fatal crashes.

Motorcyclists often self-report exceeding the speed limit, and willingly admit that travelling at speed is part of the thrill and challenge of riding a motorcycle, and indeed may

not perceive such behaviour as particularly risky (Natalier, 2001). Consistent with the search for a thrill, Alway and Poznanski (nd) found that riders were less likely to exceed the speed limit on straight sections of road than on corners<sup>1</sup>. Sexton, Baughan, Elliot and Maycock (2004) found that getting pleasure from motorcycling and a rider's liking for speed were both predictors of crash involvement.

As speed and acceleration are attractions for motorcycle riding, it is worthwhile attempting to ascertain who is primarily at fault for crashes involving motorcycles and for which crashes excessive speed has been identified as a crash factor. From an in-depth motorcycle crash investigation study of 47 crashes in Victoria, Alway and Poznanski (nd) determined that in 77% of cases the rider was at fault or the "primary agent of the collision"; it is not known whether this figure includes single-vehicle crashes where the rider *must* be the "primary agent". Accordingly fault, meaning liability, may be less for multi-vehicle crashes. "Speeding" (it is not clear whether Alway and Poznanski are referring to excessive or inappropriate speed) increased the chance of being at fault 12-fold. The average pre-impact speed of those riders deemed to be at fault was 83 km/h, compared with 69 km/h for riders not at fault. Interestingly, all non-fault crashes occurred in metropolitan areas.

Mosedale and Purdy (2004) analysed factors that precipitated or contributed to crashes involving motorcycles. A precipitating factor is the "key action or failure that led to the impact, while contributory factors are factors contributing to the accident taking place" (p1). Each crash may have only one precipitating and four contributing factors assigned to it. Excessive speed is one of 54 potential contributory factors, and was considered to be involved in 12% of all crashes and 28% of fatal crashes. While it is not clear, since these factors are assigned to the crash in this instance rather than the separate crash parties, they do not imply fault for any particular party. Excessive speed as a crash factor was more likely to apply to younger drivers and riders, and to larger capacity motorcycles.

Lynam, Broughton, Minton and Tunbridge (2001) also considered speed as a crash factor in a database of 717 fatal crashes. As an indication of fault, they assigned the precipitating factor noted for the crash to one of the crash parties. In cases for which the precipitating factor was assigned to the motorcyclist the rider's speed was "known" (though that information may have come from a range of sources, including witness statements) at the time of the crash in 65% of cases; when the precipitating factor was assigned to another party (including pedestrians), the speed of the motorcyclist was known for 74% of cases. Figure 1 contains a speed distribution for the motorcyclist travelling speed at the time of the crash, differentiating between whether the precipitating factor had been assigned to the motorcyclist or the other party. Note that "speed" can not be a precipitating factor (rather it can be assigned as a contributory factor).

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<sup>1</sup> Alternatively, given that Alway and Poznanski's (nd) statistics are for crashed riders, the high speeds of crashed riders on corners compared with straight sections of road may reflect a lack of skill or attention and be an inadvertent excess of speed rather than an intentional act to increase the thrill of the ride.

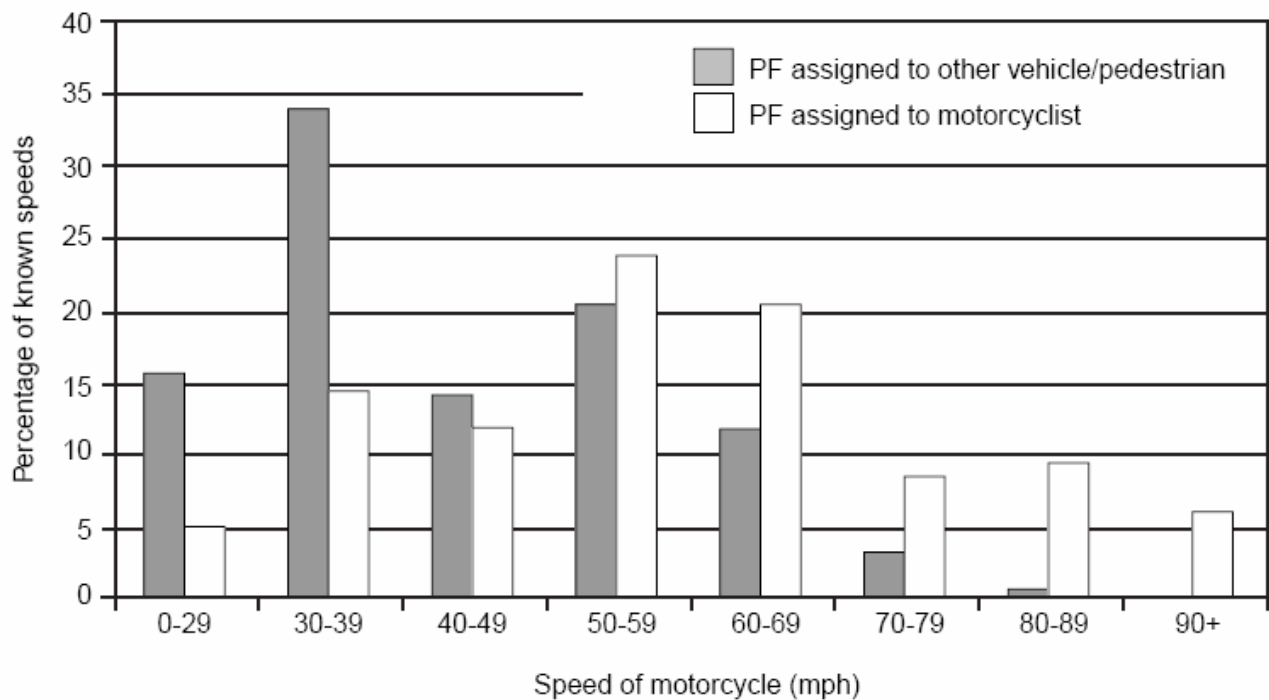


Figure 1. Comparison of fault (precipitating factor – PF) between rider and other party as a function of motorcycle travelling speed (mph) at the time of the crash (from Lynam et al, 2001).

Figure 1 demonstrates that at speeds lower than 80 km/h (50 mph) the motorcyclist was less likely than the other party to be at fault (ie be assigned the crash precipitating factor), whereas when the rider’s speed at the time of the crash was greater than 80 km/h the motorcyclist’s actions were more critical. In the cases where motorcyclist was assigned responsibility for the crash their mean speed was 91 km/h (57 mph), and the average speed of the motorcycle when the other party was primarily responsible was 69 km/h (43 mph). The counterpart average crash speeds for cars and larger vehicles were 54 km/h (34 mph) for other vehicles when the motorcyclist was deemed responsible, and 45 km/h (28 mph) for motorcycles when the other vehicle was responsible for the crash.

According to Hurt et al’s (1981) motorcycle crash investigation study, the most common offence being committed by riders at the time of their crash was exceeding the speed limit, which occurred in 16% of the cases (144 crashes). In 1.4% of cases the other vehicle was exceeding the speed limit. Clarke et al (2004) determined that motorcyclists were primarily blameworthy for around half of the crashes they had been involved in. In comparison, the MAIDS study reported that in 50% of motorcycle-involved crashes the driver of another vehicle was assigned the primary contributing factor, with the rider responsible for 37% of crashes, and the remainder made up of the environment, vehicle and other failure (ACEM, 2004). According to Haworth, Smith, Brumen and Pronk (1997), the motorcycle rider contributed to around two-thirds of crashes involving another vehicle. Always and Poznanski (nd) found that crashed Victorian motorcyclists who were deemed to be at fault in their crash tended to have more traffic infringements than those not at fault.

The MAIDS project (ACEM, 2004) involved a case-control in-depth investigation of 921 powered two-wheeler (PTW) crashes and 923 controls across five European countries. Their definition of a powered two-wheeler included mopeds and the like. (Given the focus of the current project, where ACEM supplied statistics for motorcycles separately from mopeds etc they will be noted.) The majority of crashes took place in urban environments

(72% overall, and 62% for motorcycles only), and so travelling and impact speeds were not likely to be in “free speed” conditions. Additionally, the speed limits at crash locations were predominantly 30-60 km/h, probably reducing the applicability of their results somewhat to the current project, “There were relatively few cases in which excess speed was an issue related to accident causation” (p. 9). Additionally, travel speed was not included as a control comparison variable and the speed limits at the crash location were also not provided, and therefore the results from this report should be viewed with caution.

In 72% of the MAIDS cases the motorcycle was considered to be travelling at a “normal” speed relative to the surrounding traffic or travelling without any other traffic (ACEM, 2004). In 21% of cases the speed difference was deemed to have contributed to the crash, and in the remaining 7% of crashes the speed was considered “unusual” but not a contributing factor. This speed could be higher or lower than the speed of the surrounding traffic. In 13% of crashes in which another vehicle was involved, that other vehicle was travelling at a speed higher or lower than the surrounding traffic, and in 5% of cases the speed difference was a contributing factor (note that these figures include moped crashes). Three-quarters of the PTW crashes occurred at speeds below 50 km/h, and only 5% of impacts were at speeds of 100 km/h or more. While these findings relate to speed differential rather than excessive or inappropriate speed per se, a vehicle travelling faster than the surrounding traffic is likely to be travelling at an inappropriate speed relative to the speed the surrounding drivers have decided *is* appropriate.

Lardelli-Claret, Jiménez-Moleón, de Dios Luna-del-Castillo, García-Martín, Bueno-Cavanillas, and Gálvez-Vargas (2005) analysed crashes involving two vehicles where one was a motorcycle, and in which one of the drivers/riders could be ascribed primary responsibility for the crash. In a logistic regression analysis covering a range of variables, they found that inappropriate speed for the road or traffic conditions was the best predictor of the risk of causing a collision, for both mopeds and motorcycles. Travelling at excess speed (ie breaking the speed limit) was also associated with an increased risk of a crash, but not to the same extent. They also found that these speed factors explained all of the increase in risk for males – that being female was no longer protective when the speed variables were removed from the analysis.

In Haworth, Smith, Brumen and Pronk’s (1997) case-control study of 222 motorcycle crashes, 23% were judged to have involved inappropriate speed (although they referred to it as “excessive speed” for the conditions). Inappropriate speed contributed to 35% of single-vehicle crashes and 17% of multi-vehicle crashes, to 48% of crashes in which the rider had a BAC reading greater than zero and 25% of crashes with a zero BAC level, and to 25% of crashes in which the rider was aged less than 25 years and 15% of riders 35 years and over.

Shankar (2001) reported ten years (1990-1999) of single vehicle crashes involving motorcycle fatalities that included whether the motorcycle was speeding at the time of the crash (it is assumed that in this instance that “speeding” refers to exceeding the speed limit rather than inappropriate speed, though insufficient detail is provided to be certain). On average, in 58% of fatal crashes the rider was speeding, compared with 41% of cases in which speeding was not noted (the remainder were unknowns).

## 2.2 SPEED-CRASH RELATIONSHIPS

Only two publications were found in which the relationship between speed and crash or injury risk was modelled or able to be derived specifically for motorcycles. Tominaga and Sakurai (2002) used logistic regression to determine the influence of a number of factors on motorcycle crash severity outcome. Figure 2 demonstrates the probability of a minor injury (MAIS2+, where MAIS is maximum abbreviated injury scale), serious injury (MAIS3+), and fatality or critical injury (MAIS 5+) occurring to the rider as a function of motorcycle travel speed and the speed of the opposing car. It can be seen that for both minor and serious injuries sustained by the rider, the speed of the motorcycle has a greater effect, but for fatal or critical injuries the speed of the opposing car is more important. A 25% chance of injury will be used to illustrate: there is a 25% chance of a minor injury if either the motorcycle or the car it impacts is travelling at around 30 km/h (note that the figure is in miles per hour and these speeds are estimated from the graphs), a 25% chance of a serious injury if the motorcycle is travelling at 45 km/h or the car involved in that crash is travelling at 56 km/h, and a 25% chance of the rider being killed or critically injured if the motorcycle is travelling at 100 km/h or the opposing vehicle is travelling at 85 km/h. These relationships were based on 509 crashes occurring between motorcycles and passenger cars in Hanover and Los Angeles.

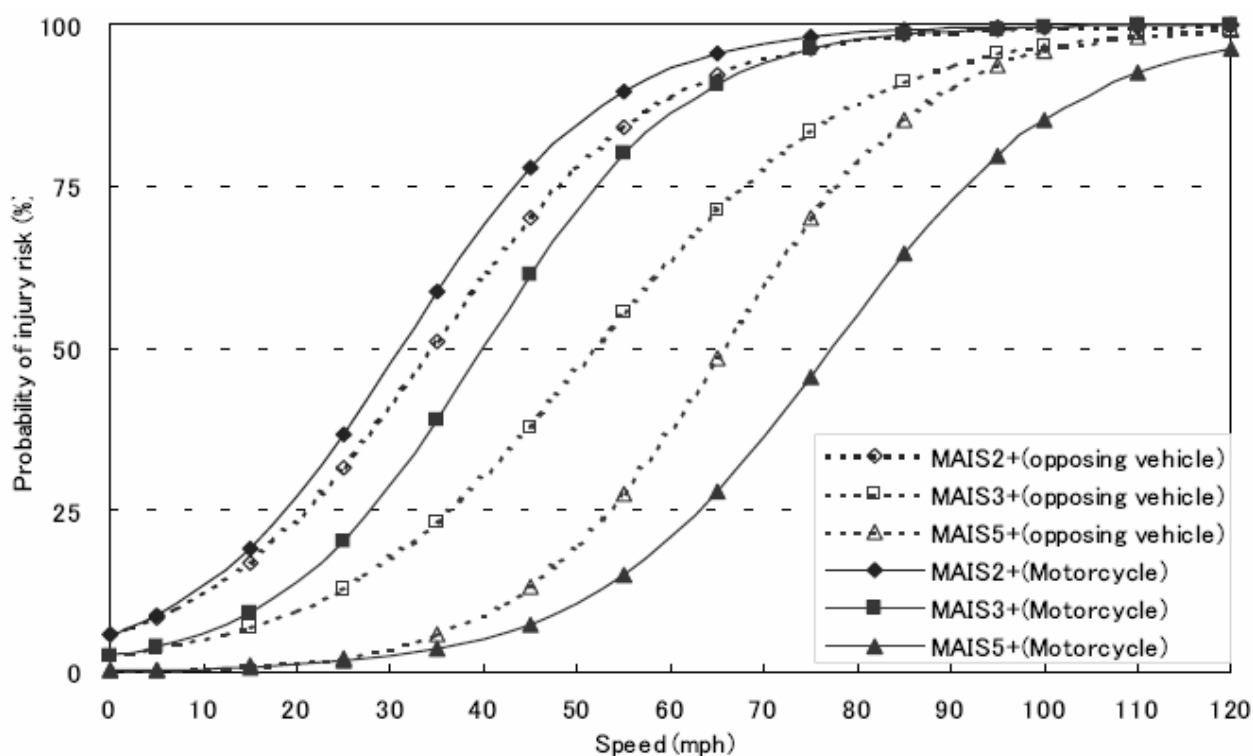


Figure 2. Relationship between injury risk (maximum abbreviated injury scale) for a motorcycle rider involved in a crash with a car, and the travel speed for the motorcycle and the opposing car (from Tominaga & Sakurai, 2002).

Given that a (unknown) proportion of Tominaga and Sakurai's (2002) crashes were taken from the Los Angeles crash database, it may be important to also report here the effect of helmet use, which they assessed for fatal and critical injury crashes. There is a 25% chance of an MAIS5+ injury (a fatality or critical injury) when a helmeted motorcycle rider is travelling at 110 km/h. The speed required to achieve the same probability for a non-

helmeted rider is 99 km/h (see Fig 3). It is interesting to note that an even chance (i.e. 50% probability) of a motorcyclist being killed in a collision with a passenger car occurs at a speed of around 75-80 mph (120-128 km/h), a speed in excess of the speed limit, regardless of whether the rider is wearing a helmet or not.

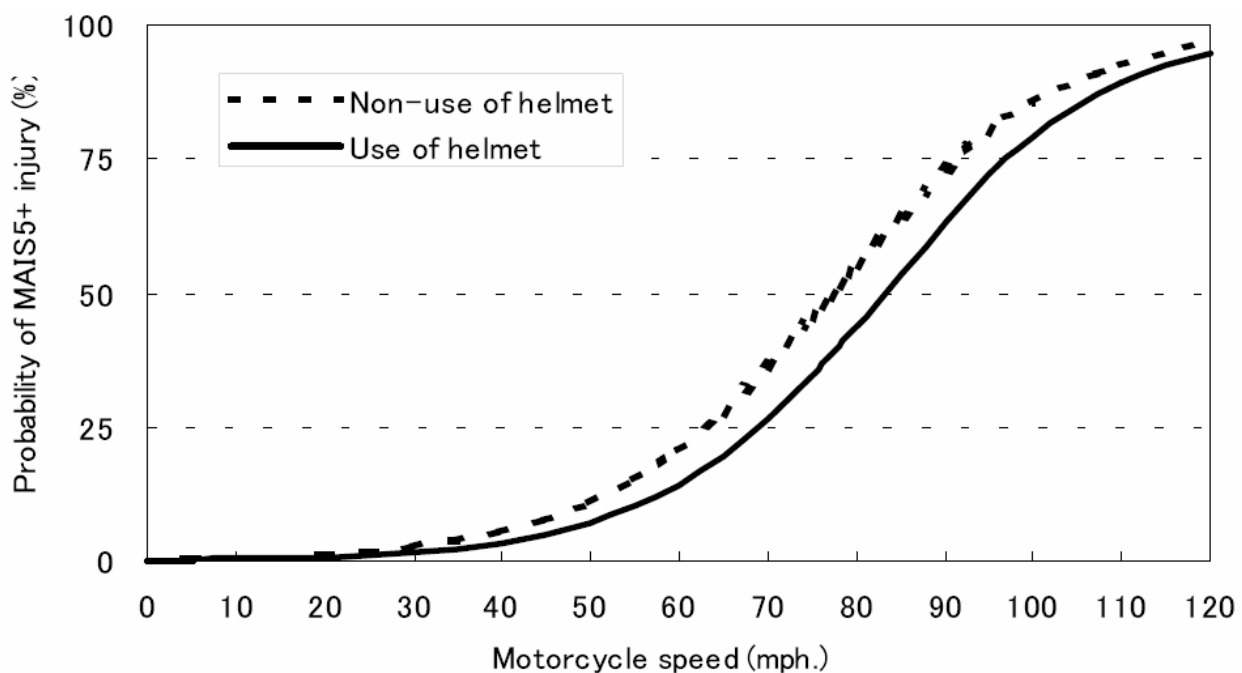


Figure 3. Relationship between injury risk (maximum abbreviated injury scale) for a helmeted or non-helmeted motorcycle rider involved in a crash with a car (from Tominaga & Sakurai, 2002).

The MAIDS report (ACEM, 2004) provides a table of the percentage of motorcycle crashes that were fatal at various speeds – they are plotted in Figure 4. Approximately consistent with Tominaga and Sakurai’s (2002) modelling that showed that there was a 25% chance of the rider being killed or critically injured if the motorcycle was travelling at 110 km/h at the time of the crash, the MAIDS data also shows around a 25% chance of a fatality between 80-110 km/h. The plot derived from the MAIDS data is not smooth at higher speeds due to the small number of crash cases collected at high speeds, and so should be treated with some caution.

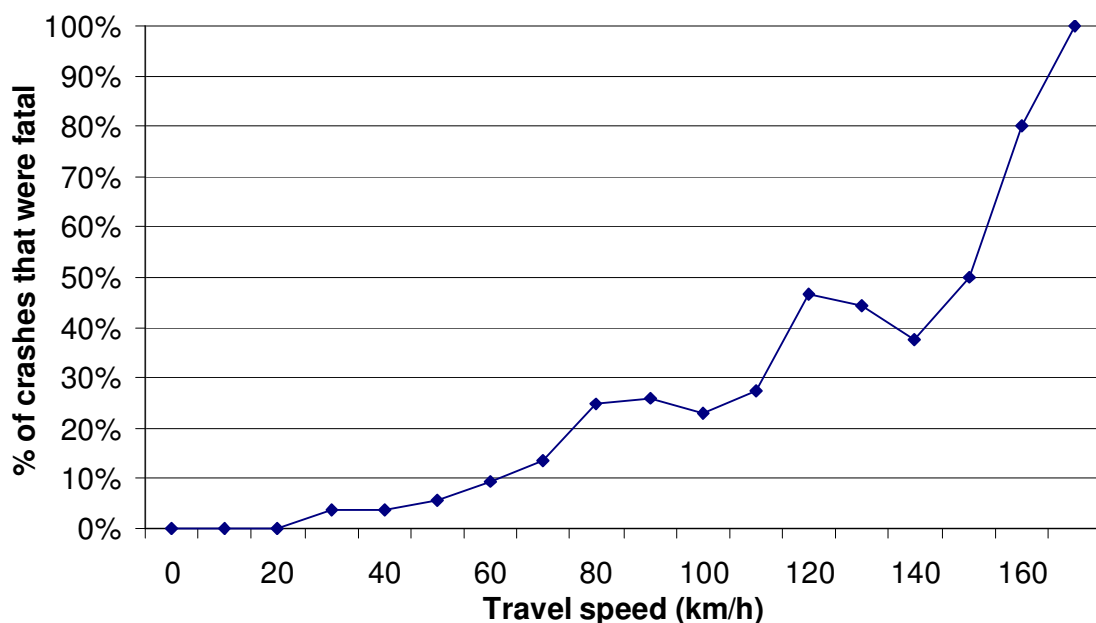


Figure 4. Percent of crashes that resulted in fatality as a function of travel speed (based on data from ACEM, 2004).

The likelihood of a crash also depends on speed relative to the surrounding traffic rather than just absolute travel speed. This may be particularly relevant to motorcycles given their potentially high acceleration rates and the practice of lane splitting and filtering, which involve a motorcycle sharing a lane with other vehicles travelling at a lower speed, or indeed stationary, in order to overtake them. In a summary report, DETR (2000) reproduced a figure from Taylor, Lynam and Baruya (2000) that shows the relative crash involvement of a driver travelling faster or slower compared to that of a driver travelling at the average speed (i.e. one with a relative speed of 1.0). Travelling at a speed 10% greater than the average would seem to increase risk (ie the number of crashes), ranging from a doubling to approximately 3.5 times (see Fig 5).

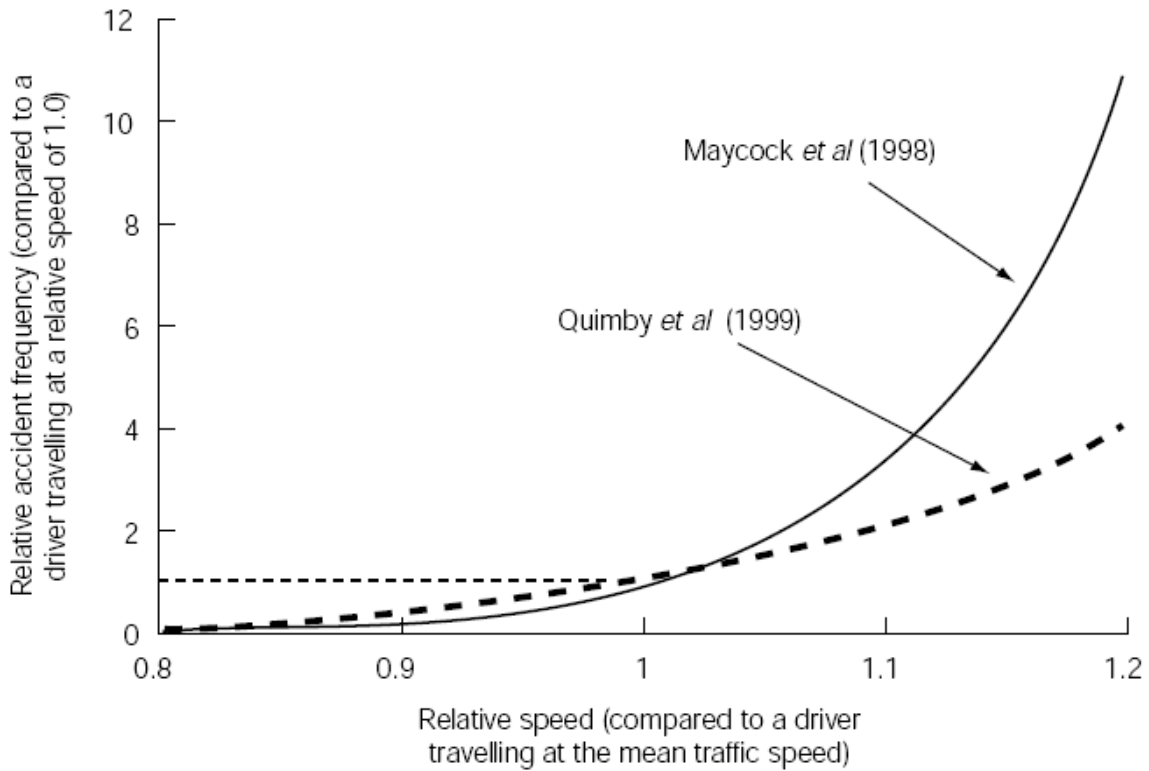


Figure 5. Relative crash frequency as a function of deviation from average traffic speed (from Taylor et al 2000, cited in DETR, 2000).

Figure 6 illustrates the relative risk of crash involvement (for all drivers) as a function of speed deviation on an Australian rural road. An increase in a vehicle’s speed by 10 km/h doubles the risk, and at 20 km/h more the risk increases by a factor of six. The authors of the report also note that, based on coroner’s records, inappropriate speed (they called it excessive speed) is a causal factor in around 26% of fatal crashes (ATSB, 2004).



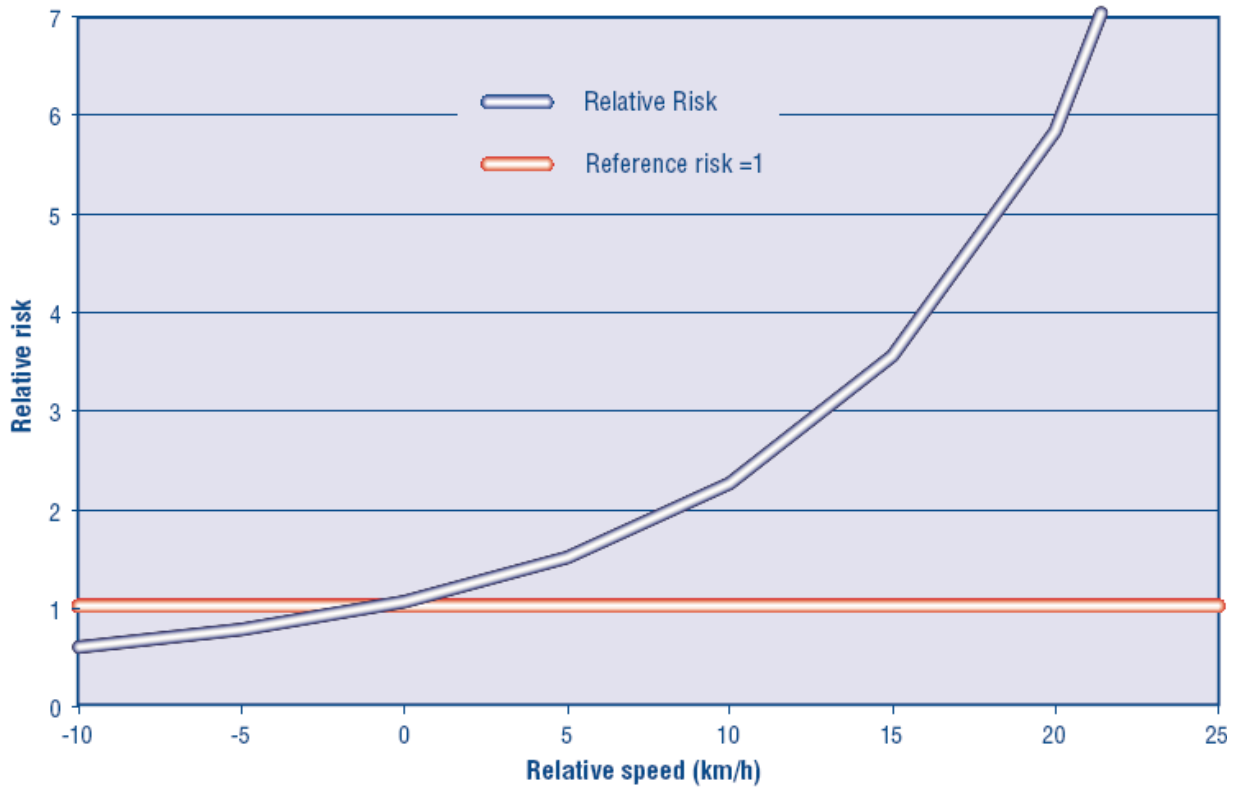


Figure 6. Relative risk based on change in speed for rural roads (from ATSB, 2004).

ERSO (2006) note that the complexity of the road environment also plays a part, such that risk curves start to climb earlier and more steeply as the number of intersections increases, traffic becomes heavier, pedestrians are more likely, etc. This can be seen in Figure 7, based on Australia data (Kloeden & colleagues, cited in ERSO 2006), which shows that the relative crash rate increases at a higher rate for urban roads than rural roads, even though speeds on the latter are likely to be higher.

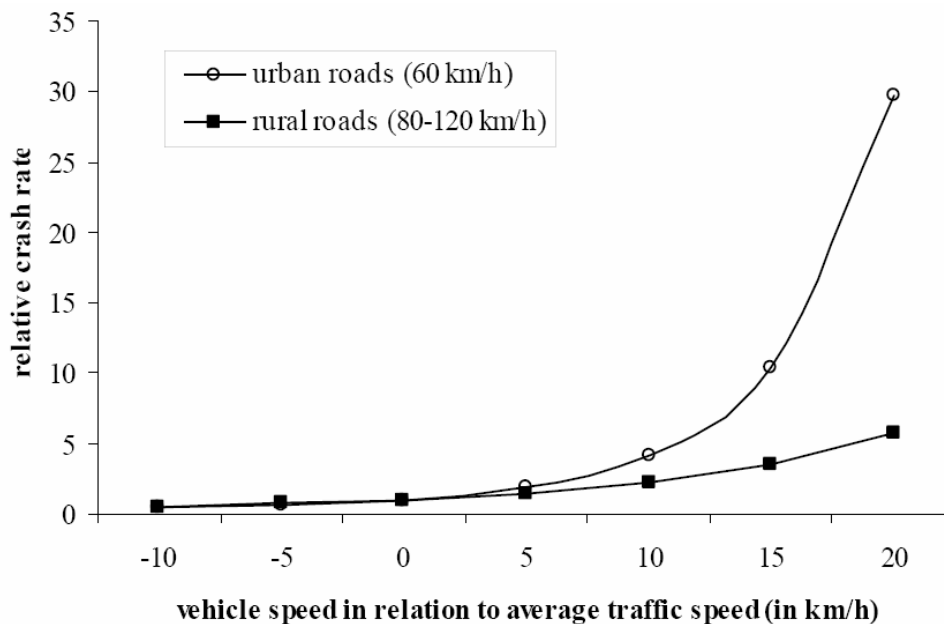


Figure 7. Relative crash rate as a function of relative traffic speed for urban and rural roads (from ERSO 2006, based on Kloeden & colleagues).

Andersson and Nilsson's (1997) model (reproduced in Fig 8) is also based on change in speed and separately plots fatal and injury crashes. It demonstrates that the probability of a fatal crash is related to the fourth power of the speed. Accordingly, a 10% reduction of mean speed results in a reduction of the number of fatalities of approximately 40%. ERSO (2006) note that according to this model a 1% change in speed would result in a 2% change in injury crashes, a 3% change in severe injury crashes, and a 4% change in fatal crashes.

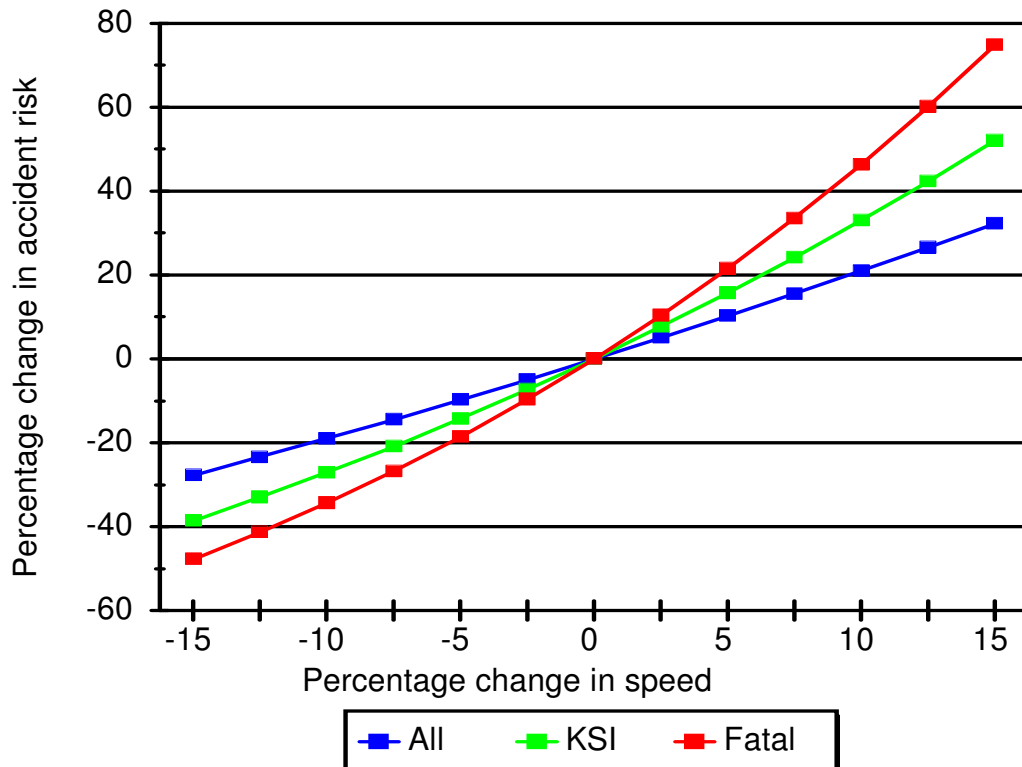


Figure 8. Percentage change in crash risk as a function of percentage change in mean speed (based on Andersson & Nilsson, 1997).  
 Note: KSI denotes Killed or Seriously Injured.

Neither Taylor et al's (2000) nor Andersson and Nilsson's (1997) models suggest the crash risk also increases when a vehicle's travel speed is *less* than that of the surrounding traffic. Wilmot and Khanal (1999) note that a speed variation, or speed dispersion, whether higher or lower than the rest of the traffic increases crash risk (see Figure 9).

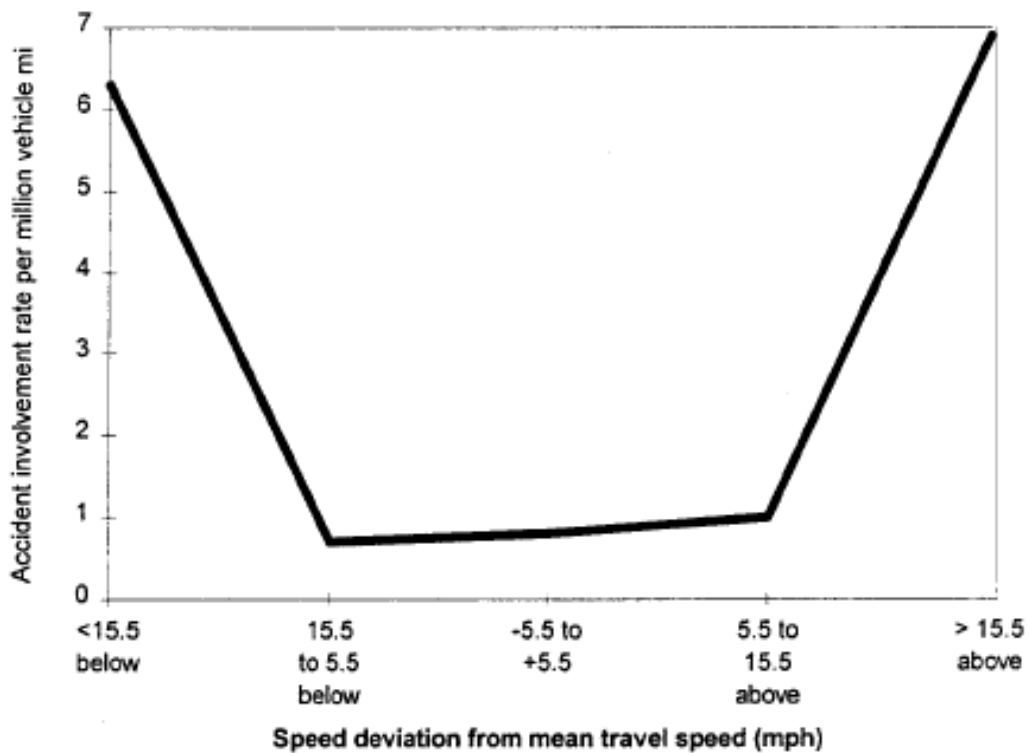


Figure 9. Crash involvement as a function of speed variation or dispersion in the traffic stream (from Wilmot & Khanal, 1999).

Due to their relative lack of protection it can be cogently argued that the injury risk for a motorcyclist is likely to be significantly higher than for a car occupant involved in a crash. It might be possible to take as a lower bound for such a relationship as the risk to a pedestrian struck by a vehicle. Though somewhat dated, DETR (2000) reproduced a figure from Ashton and Mackay (1979) that relates impact speed to pedestrian injury severity (see Fig 10). According to this model, there is a 25% chance of the pedestrian being killed at 42 km/h. However, according to more recent data (and therefore possibly involving cars that are more pedestrian-friendly), at 42 km/h (25 mph) the percentage of pedestrians killed range from around 3% to 17%, depending on the age of the pedestrian (see Fig 11, taken from Leaf & Preusser, 1999), where older pedestrians are more likely to die from injuries sustained in a crash at a lower speed than younger pedestrians. According to Tominaga and Sakurai (2002), a travel speed of 100 km/h is required for a 25% risk of a motorcyclist fatality in a collision between a motorcycle and a passenger car.

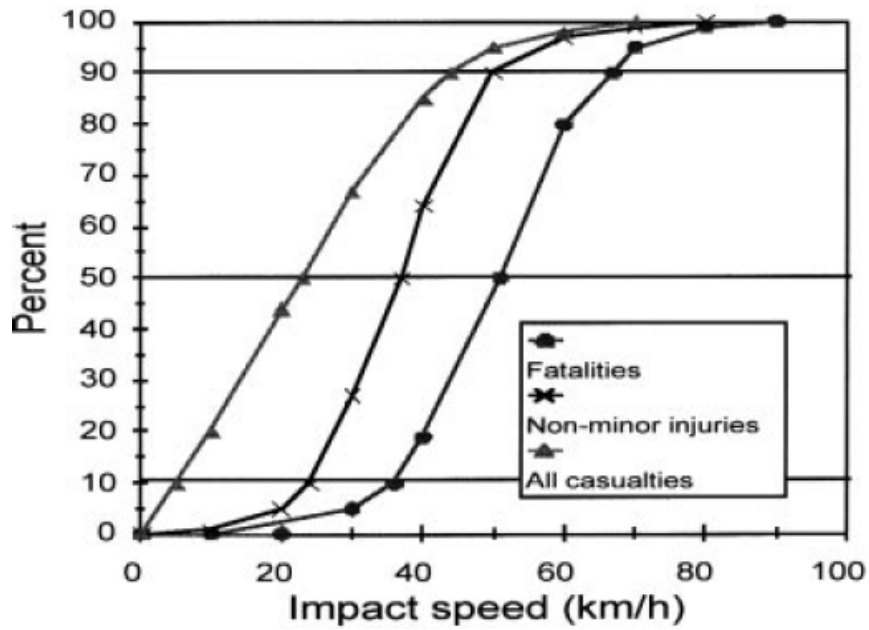


Figure 10. Probability of various pedestrian injury severities as a function of crash impact speed (Ashton & Mackay, 1979, cited in DETR, 2000).

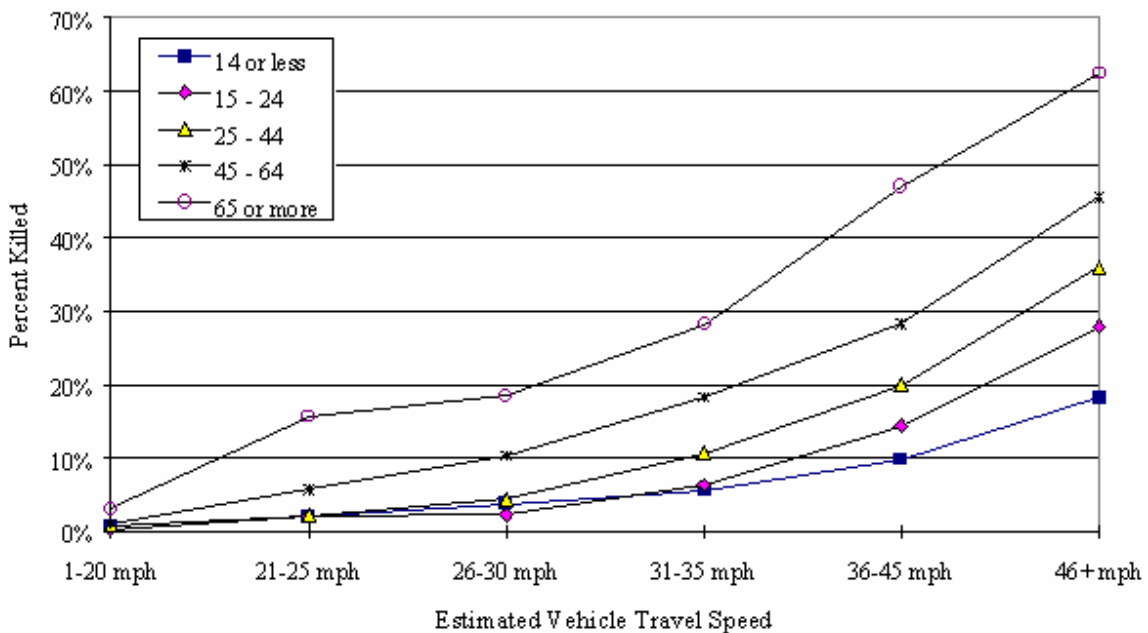


Figure 11. Percent of various age groups of pedestrians killed as a function of vehicle travel speed (from Leaf & Preusser, 1999).

## 2.3 CONCLUSIONS

Exceeding the speed limit and travelling at a speed inappropriate for the prevailing conditions can coincide or be mutually exclusive. Both increase the likelihood of being involved in a crash and increase the severity of a crash that does occur, for motorcycle riders and drivers. However, it is difficult to reliably separate these factors in crash investigations with certainty.

The high acceleration, speed and manoeuvrability of a motorcycle riding attracts many to ride, and possibly encourages a significant proportion of riders to take advantage of these features. Riders travelling at speed, whether exceeding the limit or their limitations for the conditions, would seem to be more likely to be at fault in a crash.

Based on US and German data, at a speed of approximately 100 km/h there is a 25% chance of a rider dying as the result of a collision between the motorcycle and a passenger car, and a 25% chance of a serious injury at 45 km/h (Tominaga & Sakurai's, 2002). These speeds would seem somewhat high, but the only other study found to specifically examine the relationship between motorcycle speed and crash risk is the MAIDS study which, while thorough, included very few high speed crashes. The alternative is to base the risk of a motorcyclist being involved in a crash on models developed for car travel – a problematic and unknown proxy.

### 3.0 SPEED DATA COLLECTED BY VICROADS

VicRoads currently collects traffic volume data through two principle types of device: electromagnetic loop detectors and pneumatic tubes. Most traffic counting in urban areas is carried out using loop detectors cut into the road surface. Some of these detectors have other primary functions, for example SCATS is integral to the traffic signal network, but can be used for traffic counting as well. As loop detectors are located in the centre of traffic lanes they are not reliable for counting motorcycles in urban conditions, particularly in heavy traffic when many motorcyclists thread gaps in congested traffic (lane splitting) or manoeuvre between lines of traffic at signals (lane filtering) in order to be at the head of a line of traffic when a traffic signal changes from red to green.

Pneumatic tubes ('tubes') are deployed for a set counting period on urban roads not served by loop detectors and in rural areas. Unlike loop detectors, tubes are laid across the road and must be anchored and secured to fixed infrastructure such as traffic signs. Accordingly, tubes will reliably detect and count motorcycles travelling in the middle of the road or towards the edge of a lane, both circumstances not consistently counted by loop detectors. A single tube will count all vehicles that cross it. In order to isolate one direction of travel from another, tubes must be deployed in pairs – an A tube and a B tube. Vehicles driving over the A tube before the B tube are known to be travelling in one direction, while those crossing the B tube first are known to be travelling in the opposite direction.

Pneumatic tubes are rotated across Victoria's major rural and regional roads in an ongoing, systematic manner, with the aim of covering "all" of Victoria's rural and regional network within any five year period. Tubes can also be deployed as requested for making counts on urban roads not served by loop detection systems. VicRoads' Corporate Traffic Database – TraffStats – is a repository of traffic count data containing up to 20 years of traffic counts for some sites. When processed, the count data is summarised for vehicle type and sometimes overall volume speed. It is possible to re-process stored data to "recover" individual vehicle speeds.

Earlier in 2007 VicRoads Information Services reprocessed traffic volume data collected in 2005 to isolate motorcycles from other vehicles counted. The data was provided as a set of Excel spreadsheets. Motorcycle counts were presented separately as a function of speed zone. Each line of motorcycle data within each speed zone represented an individual motorcycle and included the count location and date and time of the specific record. Importantly, the speed of each motorcycle was also provided. Thus, in each instance it was possible to determine whether the motorcycle was exceeding the speed limit at that time on that section of road. Counts were also provided for all vehicles as a function of date, time and location in order to calculate the proportion of vehicles using that section of road at that time that were motorcycles. Thus popular motorcycling routes could be identified (at least amongst the sites at which data was collected in that year) and patterns of usage estimated as a function of time of day and day of the week. This allowed some inferences to be drawn as to the likely purpose of many motorcycle trips – commuting versus work-related travel versus leisure riding.

The motorcycle count data as provided indicated whether each motorcycle was exceeding the speed limit. However, this information is insufficient to make any estimate as to whether the motorcyclist was travelling at an inappropriate speed – a speed too fast for the prevailing conditions. With additional data already recorded and additional information

about the site it might be possible, however, to begin to infer whether a travelling speed may have been inappropriate, regardless of whether it was in excess of the speed limit.

When vehicles are counted by pneumatic tubes the record is defined by a time stamp, the direction and lane of travel is known, and the vehicle's speed is recorded. The data provided previously included other traffic volumes by the hour rather than as individual records. With individual records it would be possible to determine whether cars passing the detector site at approximately the same time, or at the same time on a different day, were travelling at a speed similar to that of the motorcycle. If the speeds of the motorcycle and surrounding traffic (or similar traffic on another day) are similar it is probably less likely that the speed was inappropriate (although it may still be in excess of the limit).

Tubes are deployed by both VicRoads field staff and subcontractors. The guiding policy is that they must be located at a sign or other infrastructure so that the device can be secured against theft. Additionally, to guard against spurious counts tubes are placed away from intersections and significant curves. A particular speed is more likely to be inappropriate in the vicinity of an intersection or a curve, when a slower speed is more likely to be appropriate given the additional cognitive and physical demands on the motorcyclist to negotiate such sections of road, than it is mid-block on a straight section of road. As they are temporary, tubes are not fixed to the ground/road. Accordingly, locating them at the approach to or exit from, or within a curve would potentially create a serious hazard for motorcyclists in particular.

It would be possible, but laborious, to inspect a series of specific sites included in the data to estimate at what speed it would be inappropriate to travel. The site selection could be informed by the data, such as a site at which a large proportion of motorcycles travel at excessive speed in relation to car speeds. The site selection could also be based on crash records in an approach similar to, but significantly less extensive than, a case-control method. Alternatively, popular motorcycling routes could be determined from five years of motorcycle count data – to take in the whole network – and sites selected that are likely to allow for free-speed travel.

As noted earlier, many of the factors that make a particular speed inappropriate for the conditions are transient. For example, weather conditions can change abruptly and road surface quality (including presence of debris) can change weekly, and as neither factor is detailed in the traffic counts data it is difficult to determine the appropriateness of a particular speed for a particular time.

The current project also aimed to consider the potential of using the traffic counts data to assess changes in speed, possibly as a result of a particular intervention. Again, individual speed data would be required to determine statistics such as average speed, 85<sup>th</sup> percentile of speed and speed well in excess of the posted limit (for example >30km/h over the posted limit). However, relying on data already collected to determine the effect of a specific intervention would be difficult, given that a particular section of road may only be counted at five-year intervals as part of the set VicRoads counting program. Many other potential confounds could not be controlled for over such a long period.

It would of course be possible to request a before and after count to obtain vehicle (motorcycle, car and truck) speeds pre- and post-intervention (and potentially during, depending upon the nature of the intervention). Tubes could also be deployed in the wider area to assess possible network changes as a result of the intervention. The seasonal popularity of the site and the mixture of uses by motorcycle riders (eg commuting versus

leisure riding) would influence the duration of the counting interval required to judge the effectiveness of the intervention. The location of the tubes relative to roadway infrastructure such as barriers, road geometry, shoulder width etc would of course be influenced by the type of intervention being assessed, and with regard for the potential of the tubes to be a hazard themselves to motorcycle riders (as would be the case if locating them within a curve).



## 4.0 CONCLUSIONS AND RECOMMENDATIONS

### 4.1 THE SPEED-CRASH LITERATURE

A literature review revealed a body of research that sought to model the differing effect of speed on crash likelihood and crash severity, particularly for car occupants, and to a lesser extent pedestrians and motorcyclists. The relationships between speed and crash likelihood and crash outcome for cars can not be reliably generalised to motorcycles and motorcycle riders due to significant differences in vehicle handling and “occupant” (or user) protection. Nor can any reliable conclusions be based on modelling conducted for pedestrian-related crashes.

A number of studies investigating speed as a motorcycle crash factor were found. In some instances excessive or inappropriate speed were deemed contributory and in others causal. It is important to note that when it was a factor, however, speed was not always assigned to the motorcyclist. In some cases the speed of another vehicle involved in the crash was primarily to blame. There may be a pattern when apportioning blame for speed, with crashes in metropolitan areas associated in particular with a car travelling too fast, and for those crashes in rural, or perhaps free-speed areas, speed more likely to be assigned to the motorcyclist. In addition, speed *difference* between the vehicles in addition to absolute speeds should also be taken into account. Neither issue has been examined in any detail for motorcycles, a glaring omission given the common practice of motorcyclists for lane splitting.

No studies were found that modelled the likelihood of a motorcycle crash as a function of travelling speed, and only two studies (one of which was the MAIDS project) were identified in which the crash severity was or could be plotted against speed. Together they indicated that there was a 25% chance that the rider would be killed or critically injured if the motorcycle was travelling at around 80-100 km/h at the time of the crash. In considering their applicability to Victoria, it should be noted that these studies were based on crashes that occurred primarily in European cities and Los Angeles. The MAIDS study was overwhelmingly based on relatively low speed crashes and a relatively large proportion of scooter-type powered two-wheelers.

### 4.2 VICROADS TRAFFIC COUNT DATA

VicRoads possesses a repository of traffic counts data that covers the “whole” road network in Victoria (if a five-year period is taken). The method of collection, primarily pneumatic tubes, allows for vehicle type to be ascertained and the travelling speed of the vehicle to be recorded. While the speed data is rarely used it is present in the data held in archive form, though it must be re-processed by VicRoads staff to recover it. VicRoads provided a twelve month sample of traffic counts data with motorcycle speed present for another project, and it was analysed and interpreted by one of the current authors. This represents a limited number of sites (perhaps 20% of all sites given a five year rotation). From this data it is possible to ascertain travel speed characteristics of motorcycles but not whether travel speed was inappropriate for the prevailing conditions. In addition, measurements are usually taken on straight sections of road away from intersections.

It appears feasible to link the currently collected speed measurement data to crash data in order to measure crash risk as a function of absolute travel speeds for motorcyclists. Risks associated with inappropriate travel speeds could generally not be derived from the data.

Despite the coverage of the speed survey data currently collected, the generally low frequency of motorcycle crashes at any given site means it is questionable as to whether there would be sufficient crash data at the speed monitoring sites to give accurate risk estimates. Due to the transient nature of speed selection it is also unclear whether the speed measurements taken could be considered to represent the speed profile in the broader local area in order to broaden the area over which crash data could be collected beyond the speed measurement site. Furthermore, use of the currently collected speed data to assess risk on curves or at intersections does not seem possible due to the nature of the collection protocols.

### **4.3 OPTIONS FOR ADDITIONAL RESEARCH**

The “gold star” standard for a rigorous, in-depth study examining the relationship between speed and both crash occurrence and crash outcome for motorcycle-involved crashes would be a case-control study. A number of significant case-control studies (reviewed earlier) have been conducted, including one in Victoria a little over a decade ago. However, none of these studies have enabled solid conclusions to be drawn on speed-related questions applicable to the Victorian (or Australian) environment – both in terms of regulation and training, as well as the road environment. Given a potential rise in the popularity of riding both for recreation and as a response to congestion, parking restrictions and rising fuel costs, and an increasing take-up of scooter-type powered two-wheelers, the time is ripe for a new case-control study. Such a study would build upon but extend previous studies, with a particular focus on (but not be limited to) speed and its consequences.

The opportunity also exists for a case-control “lite version” that could stand on its own or serve as a precursor to a full case-control study. Such a study would involve identifying high motorcycle crash locations using the crash database and measuring traffic speeds of motorcycles and other vehicles at times (and potentially in conditions) matching the crash, and at other times, to begin to gain an understanding of the mix of inappropriate and excessive speed as crash factors, for both motorcycles and other vehicles.

The VicRoads traffic count data in conjunction with the police reported crash data could be used to refine the site selection for either a full or lite case-control study by providing the opportunity to choose sites that have a high relative motorcycle crash history (ie as a function of the number of motorcycles that use that particular route rather than sites with a high absolute number of crashes). Alternatively, sites could be chosen based on the prevalence of excessive speed by motorcyclists and a knowledge of the speed limit at the count location as informed by the traffic counts; or sites could be chosen with a focus on the disparity between the average speed (or 85<sup>th</sup> percentile or some other statistic) of the motorcycle traffic and other traffic – again from the count data. Both versions of case-control could be prospective, by requesting the strategic deployment of pneumatic tubes at selected sites to collect counts (and speed) data. Review of the deployment strategy for the tubes or the potential use of other speed measurement technology may also allow both curves and other hazardous road geometries to be covered by the study. This is further considered below.

Alternatively, adopting a smaller retrospective analysis over a five-year timeframe may mean that VicRoads already holds most or perhaps all of the data required. VicRoads’ Information Services office would need to recover and reprocess data in their storage systems to access the speed information for all vehicles, which could then be analysed

alongside the crash database for the same period. Depending upon the integrity and completeness of the traffic counts data (and previous experience with this data is promising), and the success of efficiently matching the sites between the databases, this approach is likely to be a cost-effective and fruitful endeavour on its own. This approach would however be subject to the limitations discussed in the previous section.

A difficulty of the current method of collecting counts data is the need to deploy the pneumatic tubes away from corners so that they do not present a hazard to riders. A travel speed in advance of a bend may not reliably represent the speed a motorcyclist is likely to adopt while negotiating the bend. If a relatively small number of sites (informed by the crash history and counts/speed data) are targeted, speeds within the bend could be monitored and logged surreptitiously and automatically with the careful placement of laser speed detection equipment in the corner in combination, if necessary, with pneumatic tubes in advance of the corner to log the approach speed and vehicle type – time stamps would be used to later match the tube data with the laser data. Such a “naturalistic” study would also be useful to examine before and after speed profiles for new countermeasures that address the site (or a site elsewhere in the nearby network).

Regardless of the study method, inappropriate speed may be problematic. It could be argued that the successful negotiation of a bend (or some other situation or environment) by definition infers that the speed chosen was not inappropriate (though it may have been excessive). Following this logic, crashes will always infer an inappropriate speed. Even a crash in which another road user is completely at fault may have been avoided by the rider had their travel speed been slower. A case-control study in which crashed riders are interviewed along with an in-depth examination of the crash circumstances would allow for a better understanding of inappropriate speed and its contribution to the crash outcome. In addition the precipitating factors behind inappropriate speed could be ascertained. For example, a crash may have occurred because of a rider’s inappropriate speed, but that inappropriate speed in those circumstances may have been due to fatigue, distraction, lack of familiarity, weather conditions, road hazard, insufficient training in picking and responding to hazards, or any number of a myriad of factors. Inappropriate speed (rather than excessive speed) is a convenient catch-all to note on a crash report form, but has little value in designing effective countermeasures. A better understanding of why and how the speed was inappropriate clearly would be of more use, and may be determined from a case-control study.

#### **4.4 SUMMARY OF RECOMMENDATIONS**

- A rigorous modelling of the relationship between both excessive speed and inappropriate speed and both crash risk and crash outcome, along with the identification of factors that precipitated either type of speed, would require a carefully designed case-control study. Such a study would be internationally significant and complementary to the MAIDS and other studies, but it would also be the most expensive option. The traffic counts/speed data would be a valuable tool in such a study but significant enhancement of the collection would be required to deliver a comprehensive study.
- Various options are available for a case-control “lite” (in terms of both cost and usefulness) study, such as pairing the traffic counts/speed data with the crash database. A set number of crashes for which crash speed information could be gleaned from the crash record (including photos, sketches, free text fields in the crash form, etc) would

be chosen. The control counterparts could be matched on the basis of site, timing (time of day, day of week, season, etc) and potentially traffic density. A prospective matching would require pneumatic tubes or other speed measuring technology to be deployed for data collection, while a retrospective matching would mean additional restrictions on case choice in order to match for season (given that counting is done on a rotational basis).

- While such a study would provide little insight into the relationships between speed and crash (risk &/or outcome), the counts/speed data could be analysed to identify potentially problematic sites in terms of motorcycle travelling speed. Excessive speeds are easily identified and inappropriate speed could be inferred from the comparison of motorcycle versus car speeds. The data required is already held by VicRoads.
- By request within VicRoads, pneumatic counting tubes can be strategically deployed at specific sites or within an area for a network analysis to carry out before and after studies of new countermeasures. The current procedure of recording continuously for a week at a site seems sufficient, though of course this will be dictated in particular by motorcycle traffic volumes. Tubes can not be deployed within corners due to the potential hazard they would present to riders. A combination of tubes in advance of a bend and laser speed detection (and logging) hidden within the bend may prove particularly beneficial without a significant addition to costs above tube deployment (so long as the laser equipment can be secured against theft and therefore not attended during data collection).
- The archived counts/speed data could be usefully analysed to paint a picture of changes across the network over time in terms of the number of motorcycles being ridden and their travel speeds. With up to 20 years of archived data, most sites across the network should have been counted three or four times, or perhaps more often if specific counting requests had been made. This data would need to be retrieved and re-processed by VicRoads before being passed to the research team. Based on previous experience with a subset of this data, the further analysis should be relatively straightforward and not a highly expensive exercise. However, relying on the existing data would limit the scope of analysis outcomes that could be achieved.
- Regardless of whether it is prospective or retrospective, the counts/speed data on its own provides no information regarding crashes or trauma. Linking with the crash data is imperative to be able to assess risk.
- There is much flexibility in the use of pneumatic tubes in terms of site selection and duration of counting. The few limitations include the need to avoid presenting a hazard (such as deployment within or too close to a bend), and the need to secure the device against theft. One pair of tubes can count two lanes of opposing traffic (ie two-way). Road characteristics such as shoulder width, presence of barriers and speed limit are not in any way limiting. The type of sites chosen are only important considerations if specific questions are asked, such as the speed profile of urban vs rural roads, wide vs narrow roads, etc. The number of sites required and the count duration is entirely dependent upon traffic (particularly motorcycle) density – the current standard is continuous monitoring for seven full days. Deployment costs are likely to be completely in-house such that VicRoads staff (or their contractors) would be provided with locations, durations and any other specific requirements. The data would then be collated by VicRoads staff and could then be passed to the research team. The costs of

analysis and interpretation are completely dependent on the number of sites chosen and any additional complexities, such as matching to the crash database.

- As a measure of exposure, the counts/speed data would seem to be valid in that it provides information on the number of motorcyclists passing a particular point in the network and their speeds (and the number and speed of other vehicle types). It does not provide the number of unique motorcyclists or any information about the rider or the motorcycle. However, counting in this mode is automatic after deployment and so relatively inexpensive. A more detailed picture of the riders could be gained with the significantly more expensive option of stopping motorcyclists for interview (and that would need to be the case for a full case-control study).



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