MONASH University
Accident Research Centre

A centre within the Monash University Injury Research Institute

Project report to Accident Compensation Corporation and the Motorcycle Safety Advisory Council

EFFECTIVE TARGETING OF MOTORCYCLE SAFETY COUNTERMEASURES IN NEW ZEALAND

by Michael Keall

Christine Mulvihill

David Logan

& Stuart Newstead

Report No. Final

December 2013

1. EXECUTIVE SUMMARY

1.1 Aims

The specific aims of the research are to:

1. Describe motorcycle, scooter or moped crash and injury distributions and trends in New Zealand and, as far as possible, risk factors associated with these;
2. Summarise current knowledge on the effectiveness of the full range of motorcycle safety countermeasures;
3. Estimate the potential crash reduction and injury benefits that could be expected from applying identified effective motorcycle safety countermeasures to the New Zealand motorcycle crash problem to inform potential investment of the motorcycle safety levy.

1.2 Methods

New Zealand crash data, licensing data and travel survey data were all analysed to describe patterns of exposure and risk of motorcyclists, including the identification of important trends that need to be accounted for. The literature review involved an extensive search of national and international transport, education, engineering and health/medical science databases; search engines and road safety websites to identify interventions with proven potential to increase motorcyclist safety.

1.3 Results

As for other road user groups, young people have the highest crash risk. Only 7% of motorcycles were owned by people aged under 25, but 26% of casualties were from this group. Most of the injuries to riders aged under 25 were minor, however, typical of their exposure to mainly urban speed limit environments. Recent trends in the motorcycle fleet are for there to be growing numbers of small motorcycles/mopeds and large motorcycles (750cc plus). These two classes of motorcycles have quite different crash patterns, are ridden in different environments, and are owned by different sorts of owners. The motorcycles in between gradually take on the crash and ownership characteristics of the larger motorcycles as the engine size increases.

Large motorcycles

Generally as the size of the motorcycle increased, so did the proportion of owners who were male, and the average age of the owners also increased. Larger motorcycles have much higher rates of ownership by older people (aged 40 plus) and are owned almost exclusively by males. When the engine capacity of the motorcycle was considered with respect to the owner's location, motorcycles over 250cc were most likely to be located in smaller towns. Although 40% of licensed motorcycles were large (750cc plus), riders of these motorcycles constituted two thirds of all fatalities. Only 20% of car crashes had fatal/serious injury outcomes compared to 25% for small motorcycles and 48% for large motorcycles. The proportion of crashes of larger motorcycles that were in higher speed limit areas increased from around 35% in 1995 to around 60% in 2012. The increase in loss of control crashes for large motorcycles was an important trend, which taken in the context of the high levels of excess speed and increasing rates of single vehicle crashes, at-fault crashes, crashes in higher speed limit areas and crashes when cornering, indicates that some fundamental changes in riding styles and/or riding environments have been taken place over this period for the riders of larger motorcycles. Even controlling for the speed limit zone and the setting of the crash (at an intersection or otherwise), the larger motorcycles had a considerably higher fatal and serious injury rate in crashes than the other classes of motorcycles, which is likely to arise from higher speeds when crashing. There are also recent trends of an increasing proportion of the larger motorcycles' crashes occurring in higher speed limit areas, accompanied by the higher injury severities arising from the higher speed crashes. Riding at night can present additional risks in terms of the visibility of motorcycles. However, recent trends show gradually lower levels of crash involvement after sunset and before sunrise, which were lowest for large motorcycles.

Smaller motorcycles/mopeds

Smaller motorcycles have much higher rates of ownership by young people and by females. Compared to motorcycle owners in the smaller centres, a considerably larger proportion of owners resident in large cities, including Auckland, owned motorcycles of size 250cc and under. Consistent with their mainly urban exposure, small motorcycles had a large proportion of intersection crashes in which they were rarely judged to be at-fault. The smaller motorcycles at intersections were more likely to be victims of car driver misjudgement/not seeing and failure to stop/give way than were larger motorcycles. Only a relatively small proportion of their crashes were fatal or serious: 25% for small motorcycles (compared to 48% of large motorcycle crashes).

Literature review of potentially effective interventions

The review summarised current knowledge on the effectiveness of the full range of motorcycle safety countermeasures in Australia and internationally. Countermeasures identified as demonstrating the most substantial crash and or injury reduction benefits through evaluation studies were: anti-lock brakes; daytime running lights; accident black-spots and black-length treatments; and protective gear. A number of emerging countermeasures have demonstrated crash and or injury reduction benefits in specific circumstances but the results need to be verified by further research. These countermeasures were: motorcycle airbags, alcohol interlocks, and traction/stability control. Countermeasures associated with the design of other vehicles including truck under-run protection, blind spot mirrors, lane change/warning systems, better A-pillar design and collision avoidance systems are likely to be effective but have not yet been evaluated. Although some road user behaviour measures including licensing and training have shown mixed results or in some cases negative results, there is potential for these to be effective if designed and implemented and/or enforced appropriately. The small number of road side safety barrier evaluations have demonstrated a significant reduction in the relative risk of serious injury to motorcyclists compared to collisions with other roadside hazards (such as trees, poles or the ground). However measures to reduce the severity of injuries to riders impacting the steel posts of some types of barrier (such as the installation of padding on WRSB) are urgently needed to ensure that motorcyclists are not seriously injured following collisions with barriers.

It is widely known that enforcement coupled with a high level of publicity and education is effective in reducing speed and alcohol related crashes involving all road users. As such, enforcement countermeasures targeting unsafe behaviours in motorcyclists, including alcohol interlocks, have potential to achieve crash and injury reductions. As enforcement for car drivers will also benefit other road users with whom they may crash, motorcyclists will derive a modest safety benefit.

1.4 Conclusions

The motorcycle fleet in New Zealand would benefit from various cost-effective technologies and safety features, including anti-lock brakes, traction/stability control, alcohol interlocks and anti-theft devices. The uptake of these features can be increased using various measures, including publicity, education, subsidisation, and regulation. The road network can be better adapted to motorcycle safety by identifying lengths of road, as in the above analysis, with high concentrations of motorcyclist injuries and applying specific treatments over these lengths. Such treatments are also likely to increase safety for other road users. Protective gear is likely to be underutilised by motorcyclists, but particularly scooter users. Further research is required to identify barriers and appropriate marketing segments. Likewise, the vehicle testing regime with respect to motorcycles requires some examination to see whether safety benefits currently exceed costs, and whether fine-tuning of the scheme could lead to further safety gains. Increased levels of penalties and enforcement for motorcyclists and for other road users who impose excessive risk on motorcyclists is likely to be merited on cost-benefit criteria.

2. BACKGROUND AND AIMS

The ACC and the Motorcycle Safety Levy Advisory Council have approached the Monash University Accident Research Centre (MUARC) to undertake research that will assist in targeting investment of the motorcycle safety levy to best meet the objectives of reducing the number and severity of motorcycle, scooter and moped crashes. The specific aims of the research are to:

4. Describe motorcycle, scooter or moped crash and injury distributions and trends in New Zealand and, as far as possible, risk factors associated with these;
5. Summarise current knowledge on the effectiveness of the full range of motorcycle safety countermeasures;
6. Estimate the potential crash reduction and injury benefits that could be expected from applying identified effective motorcycle safety countermeasures to the New Zealand motorcycle crash problem to inform potential investment of the motorcycle safety levy.

3. METHODS

3.1 New Zealand Travel Survey

The New Zealand Travel Survey has been run for single years, from mid-1989 to mid-1990, similarly in 1997/98, and then has been run continuously since 2003. Using in-person interviews, supported by travel diaries, the survey collects detailed travel behaviour data for two specified days of the year from all occupants of randomly sampled households. Annual travel is then derived from the particular travel days by ensuring that the travel days are spread throughout the year and there is minimal geographic clustering of surveying that could lead to biases. Travel activity as drivers, motorcycle riders, passengers, cyclists and pedestrians can be estimated from these data.

3.2 Vehicle licensing data

A national register of licensed drivers is held by the New Zealand Transport Agency (NZTA), allowing analyses of the numbers of licensed vehicles according to age, gender and general address location of the owner together with vehicle details, including vehicle type, make and model, manufacture date, engine capacity.

3.3 Crash data

The Ministry of Transport maintains the Crash Analysis System, which records details of police-reported crashes involving motor vehicles in which a medically treated injury occurred. Such crashes are legally required to be reported to police. These data were analysed to show trends over time and identify key features of crashes and injuries that might be amenable to policies or interventions designed to reduce injury rates.

3.4 Literature review

An extensive search of national and international transport, education, engineering and health/medical science databases; search engines and road safety websites was conducted. The following sources were accessed:

- Australian Transport Index (ATRI)
- Transport
- TRID – The TRIS and ITRD database
- Web of science/knowledge
- Pubmed
- Scopus
- Google scholar
- Scirus for scientific information.
- SAE
- MUARC reports – www.monash.edu/muarc
- Bureau of Infrastructure – www.bitre.gov.au
- Main Roads Western Australia – www.mainroads.wa.gov.au
- Austroads – www.austroads.com.au
- Transport and Main Roads – www.transport.qld.gov.au
- Roads and Traffic Authority NSW – www.rta.nsw.gov.au
- Ministry of Transport NSW – www.transport.nsw.gov.au
- Office of the Auditor General NZ – www.oag.govt.nz/reports/by-sector/transport/
- NZ Transport Agency – www.nzta.govt.nz/index.html
- Insurance Institute for Highway Safety (IIHS) US – www.iihs.org
- Federal Highway Administration (FHWA) US – www.fhwa.dot.gov
- National Highway Traffic Safety Administration (NHTSA) US – www.nhtsa.gov
- Transport Canada – www.tc.gc.ca/en/menu.htm
- Transportation Research Laboratory (TRL Crowthorne) England – www.trl.co.uk

- Royal Society for the Prevention of Accidents (RoSPA) UK – www.rospa.com/index.htm
- Swedish Road Administration (SRA) Sweden – www.vv.se
- Institute for Road Safety Research (SWOV) Netherlands – www.swov.nl/index_uk.htm
- European Road Safety Observatory – www.erso.eu
- The French National Institute for Transport and Safety Research – www.inrets.fr

Key word search terms including 'motorcycle /PTW' and 'safety' and 'effectiveness/evaluation' were used for each of the known or potential countermeasures listed below under the four safe system pillars:

- Safe Vehicles
  - Safety features (including vehicle based Intelligent Transport Systems)
    - Automatic braking systems (ABS)
    - Combined braking systems (CBS)
    - Stability/traction control
    - Alcohol interlocks
    - Collision/crash avoidance systems
    - Intelligent speed adaptation (ISA)
  - Safety ratings
  - Vehicle design (motorcycle)
    - Day time running lights (DRL)
    - Leg protection
    - Airbags
    - Crumple zones
  - Vehicle design (other road users)
    - Truck under-run protection
    - Blind spot mirrors
    - Lane change warning/blind spot warnings
    - A-pillar design

        - Collision/crash avoidance systems

- Safe Speeds
    - Enforcement
    - Speed management technology (see ISA under ‘Safe Vehicles’).
- Safe Roads
    - Engineering treatment including black-spot treatments (route and intersection based)
        - Improved sight distance and visibility
        - Delineation
        - Road surfaces
        - Restricting or relocating roadside furniture
        - Road curvature
        - Intersection design
    - New road construction
    - Road side barriers
    - Bus lanes and motorcycle only lanes (better road space allocation)
    - Rating roads for motorcyclist safety
- Safe Road Users
    - Protective clothing
    - Licensing (including graduated licensing restrictions such as curfews)
    - Training
    - Penalties and enforcement
        - Unlicensed riding
        - Unregistered riding
        - Speeding
        - Drinking
        - Unsafe behaviours such as lane splitting or riding in an unsafe manner

        - Unsafe behaviours by other road users including the above and others such as mobile phone use).
    - Road safety publicity
        - As above for penalties and enforcement

The primary objective of the review was to identify effective countermeasures to improve motorcycle safety. These could then be related to the New Zealand specific motorcycle crash problem in order to develop recommendations for the most effective investment in a package of countermeasures in terms of expected road trauma reductions. Each countermeasure was reviewed in terms of the following criteria, where available:

- The strength of evidence of the effectiveness of the countermeasure;
- Estimated crash or injury severity reduction estimated for the countermeasure and range if appropriate;
- The crash and /or exposure population to which it applies;
- Estimates of economic worth and measures from which it derived (e.g. program implementation cost).

The focus of outcome evaluations in the road safety domain is typically the measurement of changes in observed event (usually injury or crash) frequency or rate due to the countermeasure or program. However, real world crashes are not always the outcome of interest, particularly for new countermeasures being evaluated using simulation; or those for which behavioural outcomes have high potential for influencing crash outcomes such as speed, road user compliance or attitudes towards safety. An objective in this review was to focus on studies reporting actual crash effects while acknowledging other countermeasures with possibly unproven potential to influence crashes, where applicable

4. RESULTS

The analysis sought to describe motorcycle usage and risk factors in New Zealand, including trends over time that require future-focused policies to improve safety levels. The objective was to identify key patterns in motorcycle crashes and ownership that can inform safety programmes. Analyses were also made of likely errors made by car drivers who crashed with motorcyclists as well as the setting of these crashes. Such information can inform programmes aimed at motorcyclists or aimed at driver faults that appear to be characteristic of their crashes with motorcycles. Car crashes with motorcycles were contrasted with car crashes with other cars to highlight motorcycle-specific issues that could be targeted.

The first subsection describes the New Zealand motorcycle fleet and the amount of exposure (distance ridden) that is typical of different sized motorcycles of different ages. The second subsection looks at motorcycle ownership patterns with respect to motorcycle engine size and year of manufacture, and geographical areas. The third subsection analyses crash and injury rates and identifies characteristics of motorcycle crashes that are distinct from car crashes (and hence require different preventive measures or policies).

4.1 The NZ motorcycle fleet and distances ridden

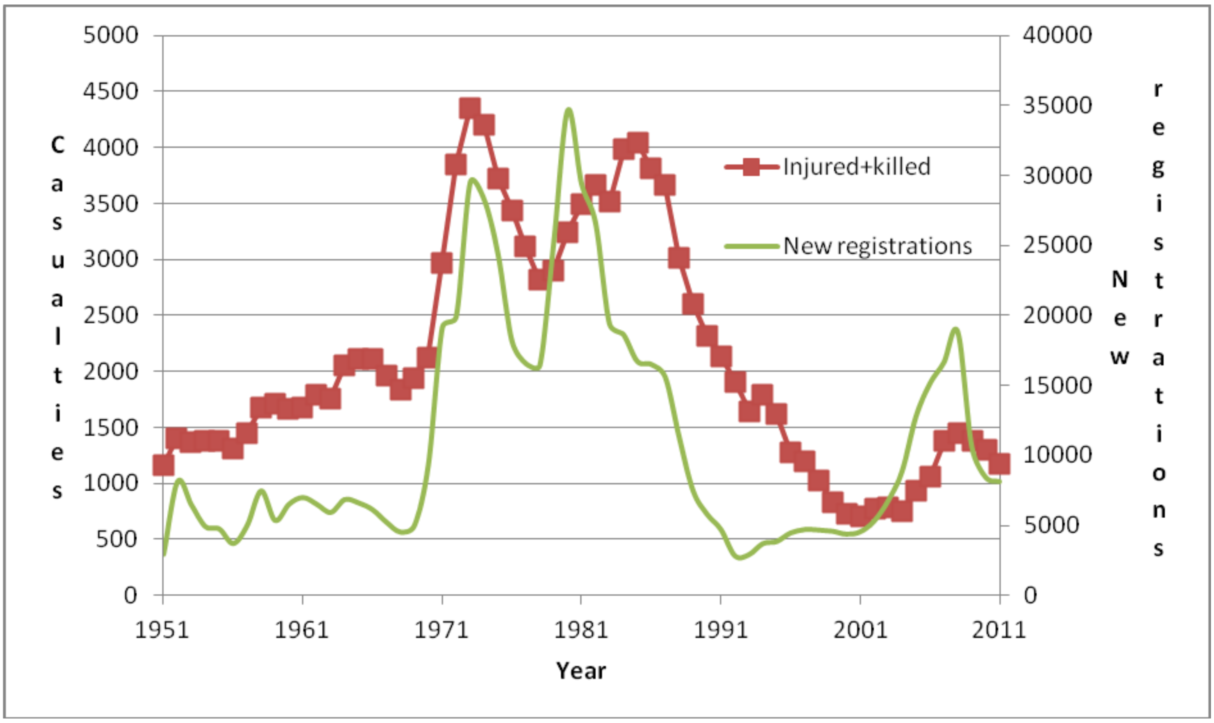

Figure 1: Number of new motorcycle/moped registrations and number of motorcyclist casualties by year in New Zealand (Ministry of Transport, 2009)

Following peaks in the 1970s and early 1980s, motorcycle ownership was gradually declining, accompanied by falling casualty rates (see Figure 1). From about the year 2000 to 2008, there was a sharp increase in new registrations, with a concomitant increase in casualties. However, the subsequent period of three years has seen a decline in both new registrations and casualties from the local peak in 2008 (Figure 1). These new registrations from the year 2000 are disaggregated by the size of the motorcycle in Figure 2, below, which shows the number of new motorcycles entering the New Zealand fleet as either new vehicles or imported used vehicles by the engine capacity of the motorcycle.

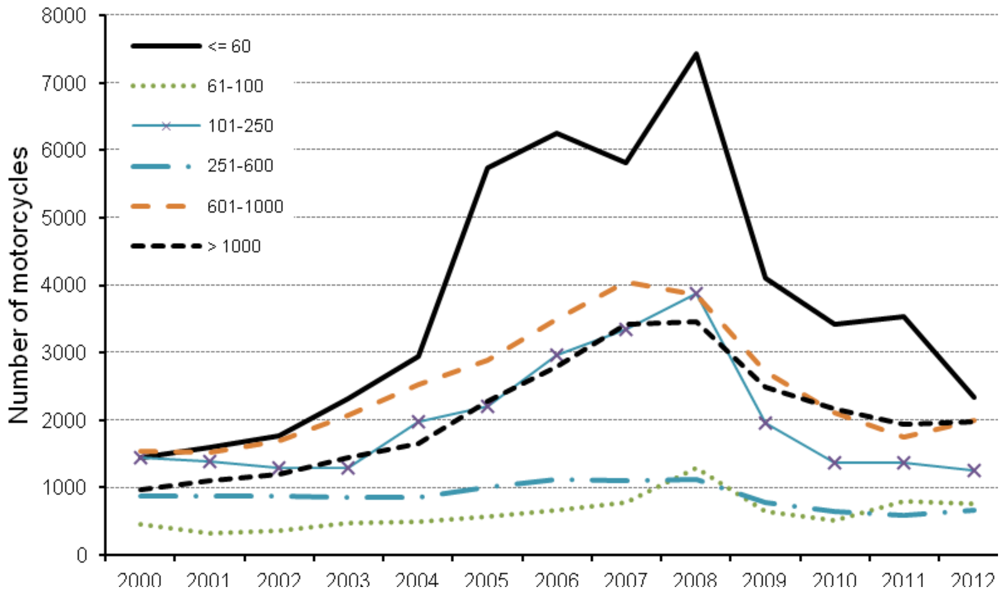

Figure 2: Motorcycles newly licensed (new and imported) by year of first NZ licensing and engine capacity

Figure 2 shows that since the year 2000, the largest number of motorcycles added to the fleet was in 2008, with a general increase up until then, and a decline subsequently. The motorcycles new to the fleet shown in Figure 2 were predominantly very small (60cc and under: 32% over the period shown) or very large (600cc and over: 39% over the period shown). Figure 3 shows that the motorcycle fleet (as currently licensed in 2012) was considerably younger than the car (light passenger vehicle) fleet. In fact, for motorcycles, more than half (55%) were manufactured since 2004; in comparison, only a quarter of licensed cars were manufactured since 2004. But there were also larger proportions of older motorcycles: 9% were over 30 years old compared to only 2% of cars.

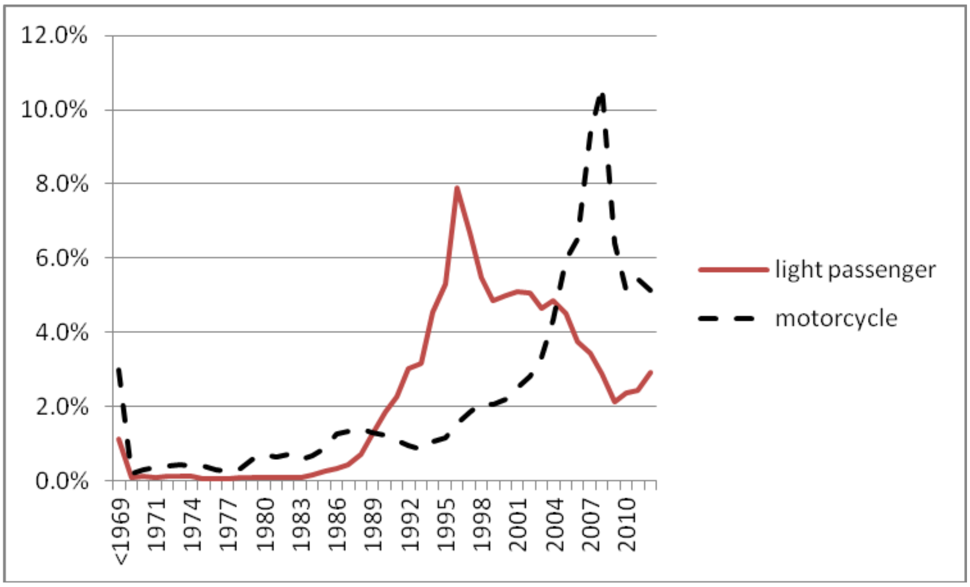

Figure 3: Comparing distributions with the fleets by year of manufacture at the end of 2012 for motorcycles and cars (new and imported combined)

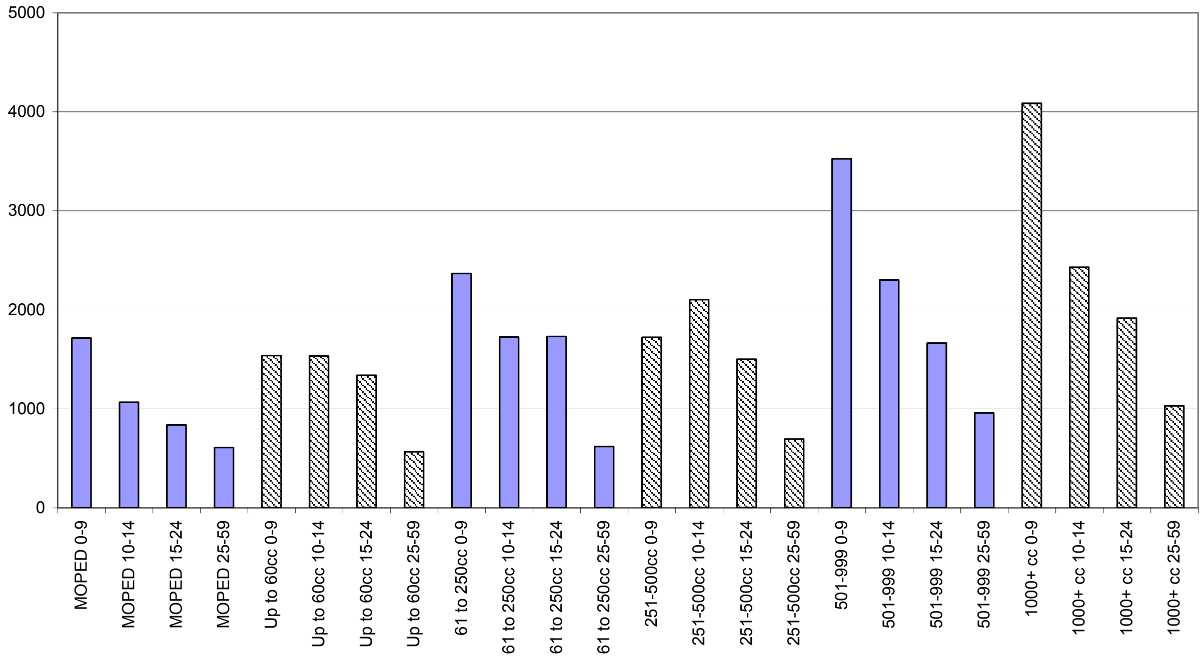

Figure 4: Median distance ridden per year by mopeds (LHS of graph) and motorcycles by capacity of engine and age of vehicle. NZ data for 2005 and 2006.

The degree of exposure to risk is an important factor in the current analysis. Distances travelled per vehicle per year can be derived from odometer readings obtained when the vehicle is mechanically inspected as part of the warrant of fitness scheme. Only about half the sample of motorcycles on the MVR could provide a distance ridden estimate and only a very small proportion of mopeds provided distance ridden: mopeds are not required to undergo periodic vehicle inspection, which means that odometer readings are not regularly recorded. Nevertheless, Figure 4, from Keall and Newstead

(2008), shows that median km driven per year generally fell as the motorcycle or moped became older. This figure also shows that the annual distance ridden also generally increased with the size of the engine. These associations mean that older, smaller capacity bikes are generally ridden less than newer bikes that are more powerful.

4.2 Current ownership

In the following subsection, data on licensed motorcycles and mopeds as at the end of 2012 are analysed, including information on both the bike and the registered owner. Analysis of crash data has shown that generally the person using a vehicle is in the same age group as the person owning the vehicle (Keall and Newstead, 2006), so these data do provide a good guide as to who is riding the motorcycles. At the end of 2012, there were 150,422 motorcycles licensed, including mopeds. Figure 5 shows that larger motorcycles (750cc plus) made up 40% of the fleet and a similar proportion (42%) were 250cc and under. Figure 6 shows that the licensed motorcycle/moped fleet was owned predominantly by older owners. About 87% were owned by people aged 30 plus. Mopeds were much more commonly owned by younger people (see Figure 7, but the 40 plus age group still owned 57% of mopeds). According to the 2012 data on licensed vehicle owners shown in Figure 7, the age distribution of car owners lay between those of the motorcycle owners and the moped owners (younger than the motorcycle owners, but older than the moped owners).

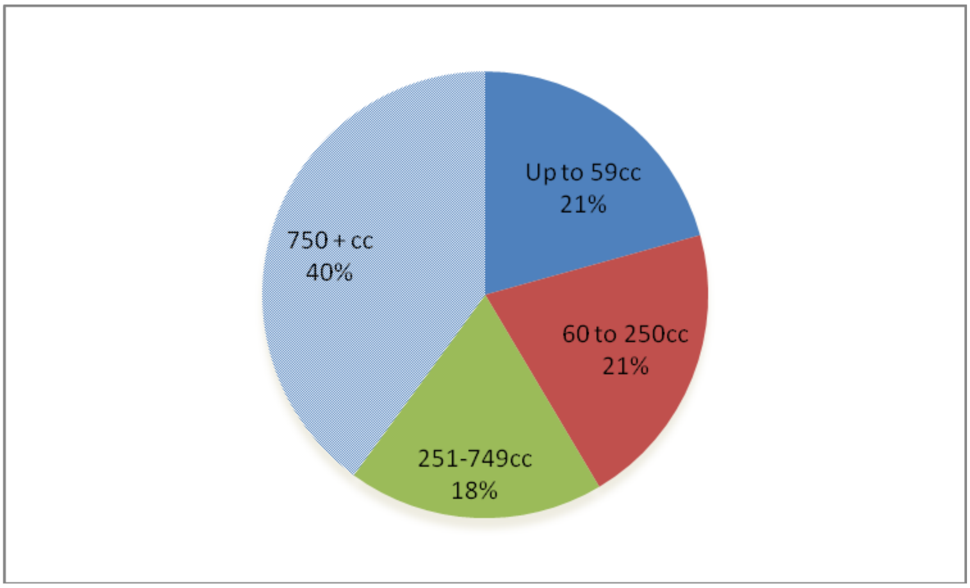

Figure 5: The distribution of licensed motorcycles and mopeds as at the end of 2012, by engine capacity (NZTA licensing data)

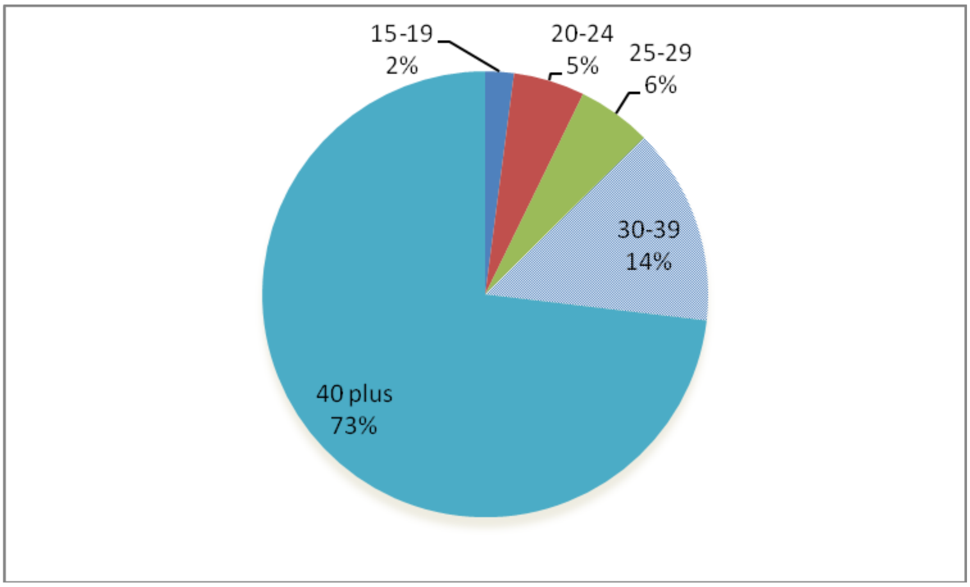

Figure 6: The distribution of licensed motorcycles and mopeds as at the end of 2012, by owner age group (NZTA licensing data)

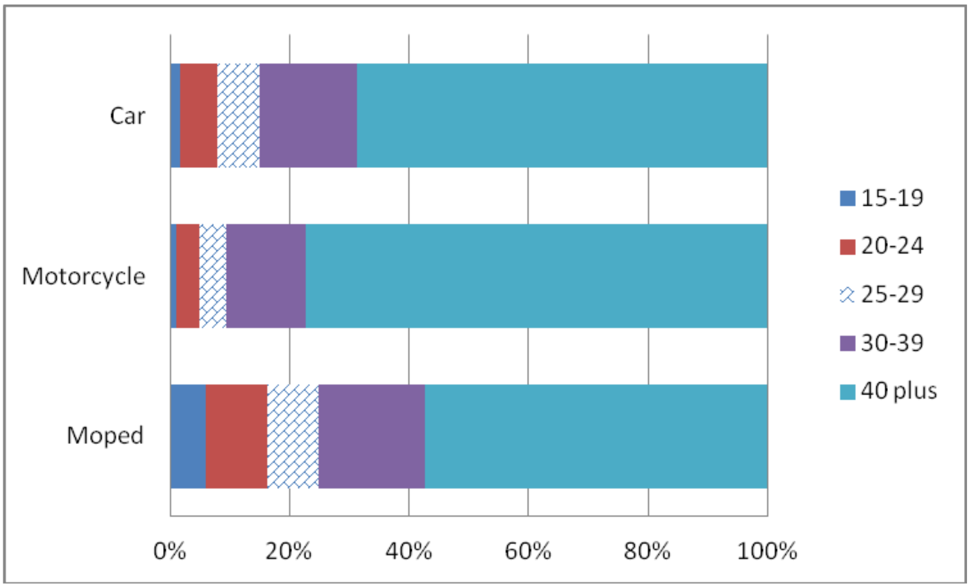

Figure 7: The distribution of licensed cars, motorcycles and mopeds as at the end of 2012, by owner age group (NZTA licensing data)

There were also notable differences in the age of the owners and the engine capacity of the motorcycle. Figure 8 and Figure 9 show that the smaller motorcycles were generally favoured by the younger age groups and the larger capacity engines by the older owners. This is shown very clearly in Figure 10, which shows that a steadily diminishing proportion of the larger engine motorcycles were owned by younger people. It is likely that there are influences both from the Graduated Driver Licensing System, which restricts learner and restricted licence drivers from riding motorcycles with capacity over 250cc, and economic factors, which may dissuade younger people with lower incomes from purchasing higher capacity motorcycles, which are more expensive.

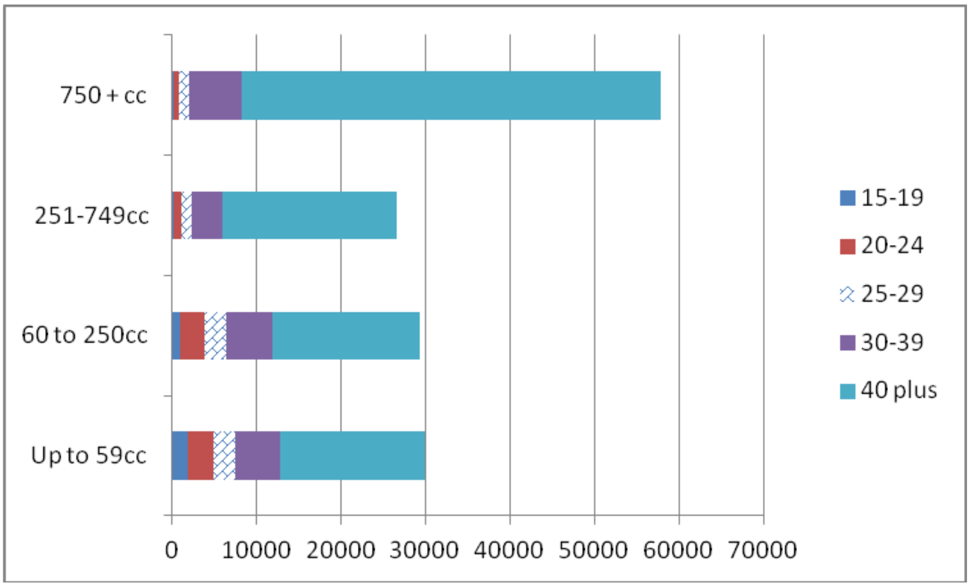

Figure 8: Numbers of licensed motorcycles and mopeds as at the end of 2012, by engine capacity and owner age group (NZTA licensing data)

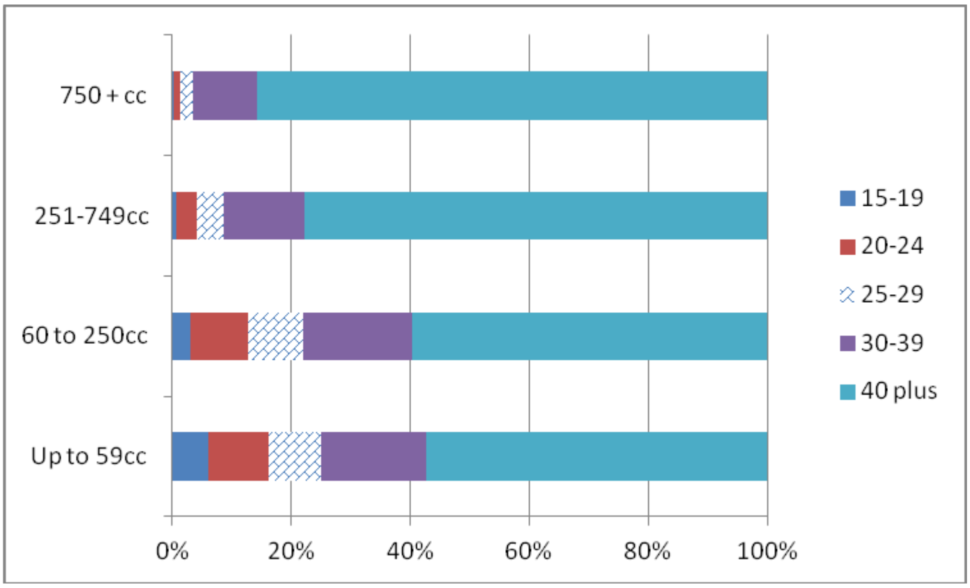

Figure 9: Within engine capacity range, distribution of licensed motorcycles and mopeds as at the end of 2012, by owner age group (NZTA licensing data)

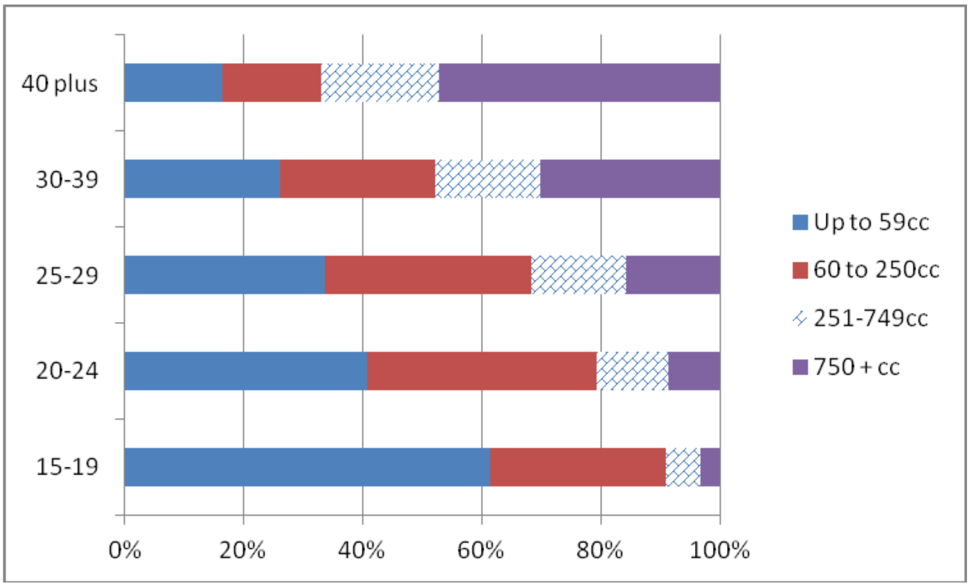

Figure 10: Within owner age group range, distribution of licensed motorcycles and mopeds as at the end of 2012, by engine capacity (NZTA licensing data)

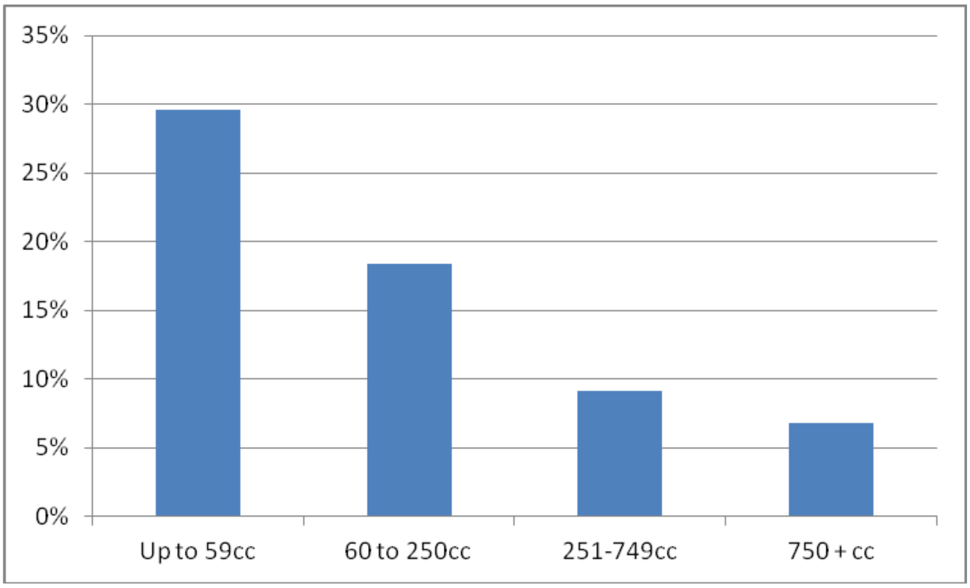

Figure 11: Percentage of licensed motorcycles and mopeds that were *owned by females* within engine capacity range, as at the end of 2012 (NZTA licensing data)

For 97% of the licensed motorcycles and mopeds, an owner gender was recorded. Of these, only 14% of all motorcycles and mopeds were owned by females. Figure 11 shows that the proportion owned by females was much higher for the lower capacity motorcycles and mopeds. Figure 12 shows proportions of female ownership for cars in comparison with vehicles licensed as mopeds and as motorcycles. This shows that the female share of ownership is generally lowest for the younger age groups and is highest for those aged 40 plus for each of the motorcycle engine size classes. The exception was for the largest motorcycles, 750 cc plus, for which females owned only a small proportion overall (as shown in Figure 11), and within the oldest age group represented, only 7% of such motorcycles were owned by women.

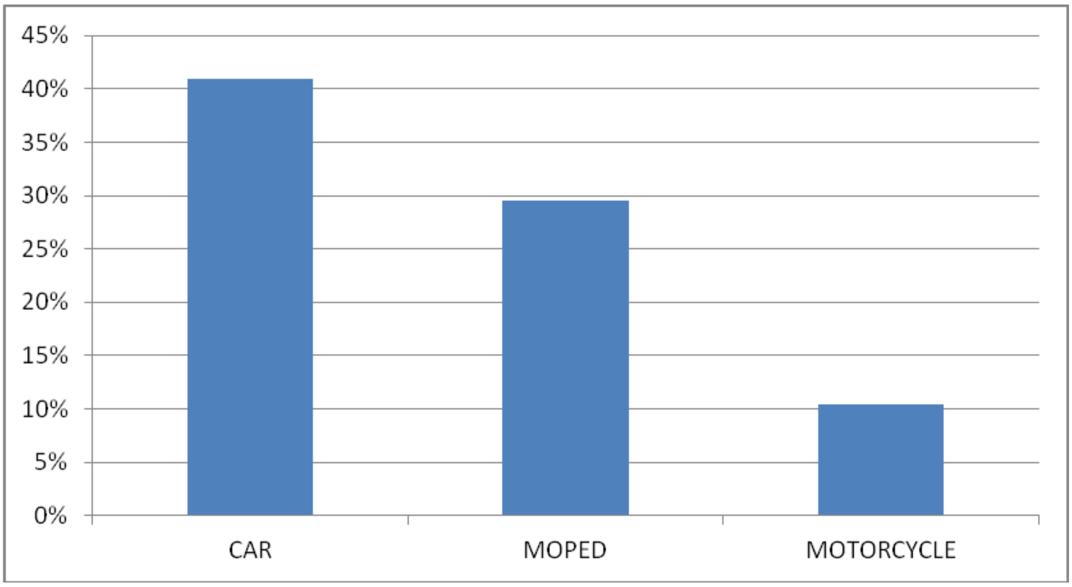

Figure 12: Percentage of licensed cars, motorcycles and mopeds that were *owned by females* as at the end of 2012 (NZTA licensing data)

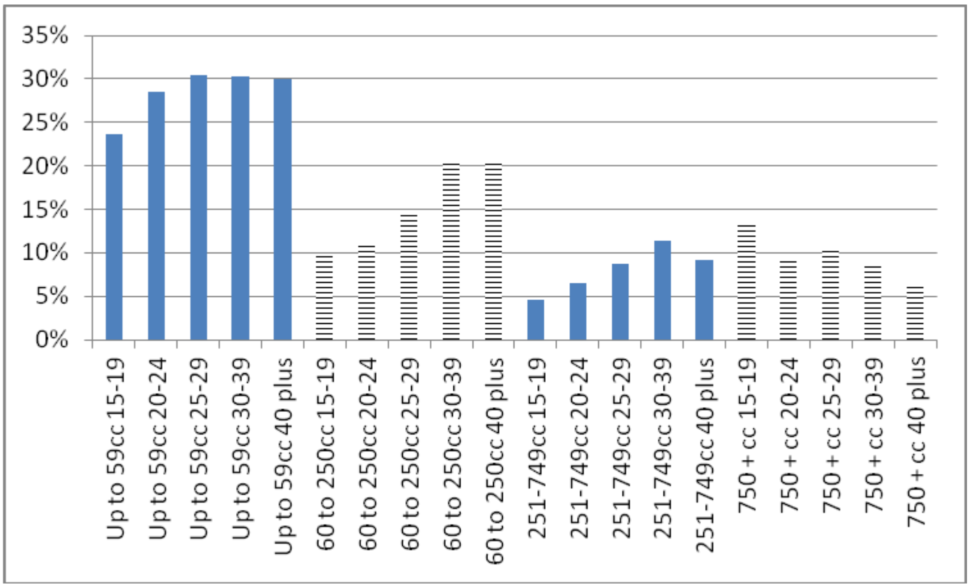

Figure 13: Percentage of licensed motorcycles and mopeds that were *owned by females* within engine capacity range and owner age group, as at the end of 2012 (NZTA licensing data)

Finally, the licensing data were analysed according to the location of the owner's address, coded to Auckland (the four cities that constitute Auckland), other large main urban (greater Wellington, Hamilton, Christchurch, Dunedin, Tauranga), smaller main urban (Palmerston North, Levin, Napier, Hastings, Nelson, Gisborne, etc.), and the rest (mainly smaller towns and rural). Figure 14 shows the distribution of all passenger cars, motorcycles and mopeds by the degree of urbanisation of the owner's home address. When these figures are shown as percentages within vehicle types (Figure 15), it is apparent that Auckland had more than its fair share of cars, but a smaller proportion of motorcycles and mopeds. Motorcycles were most commonly licensed in smaller towns; mopeds were commonly found in the larger urban areas outside Auckland.

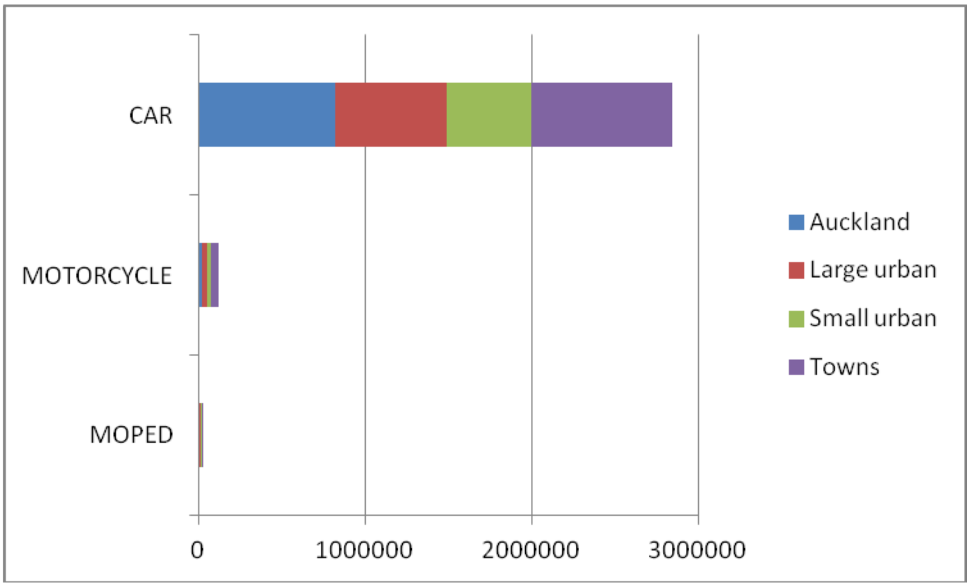

Figure 14: Numbers of licensed cars, motorcycles and mopeds that were *owned by people with addresses in the specified areas*, as at the end of 2012 (NZTA licensing data)

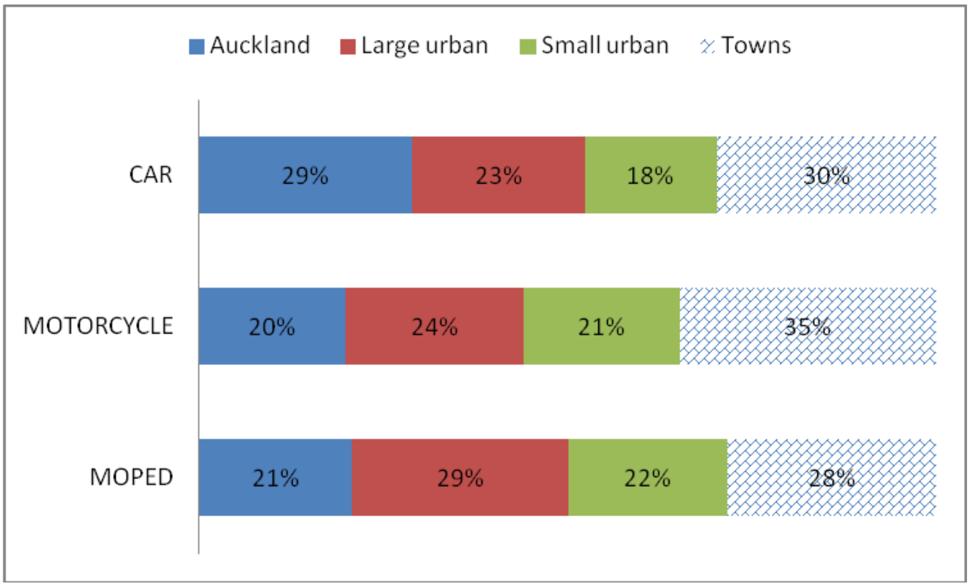

Figure 15: Proportion of licensed cars, motorcycles and mopeds that were *owned by people with addresses in the specified areas*, as at the end of 2012 (NZTA licensing data)

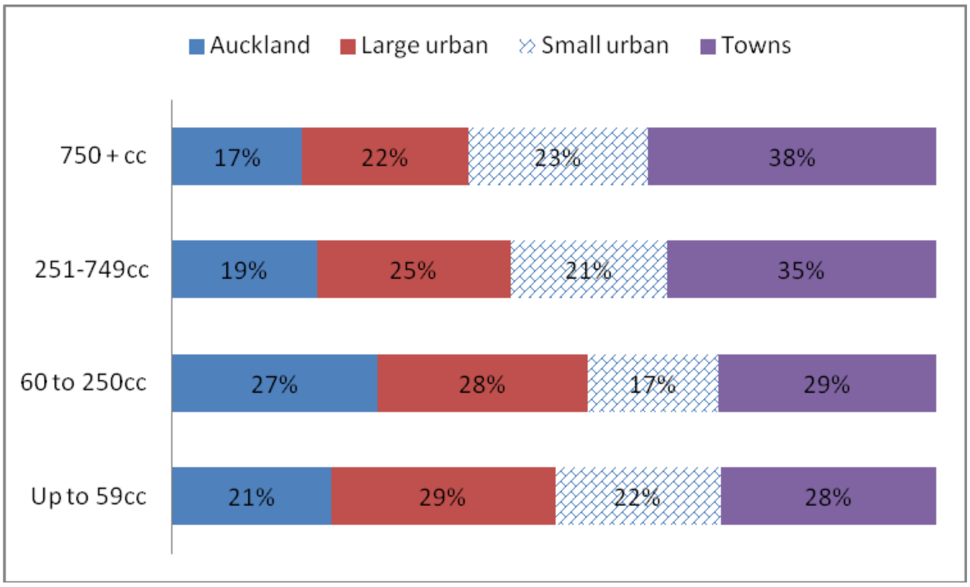

Figure 16: Proportion of licensed motorcycles and mopeds that were *owned by people with addresses in the specified areas*, by engine capacity, as at the end of 2012 (NZTA licensing data)

When the engine capacity of the motorcycle is considered with respect to the owner's location, Figure 16 shows that larger motorcycles (over 250cc) were most likely to be located in smaller towns (in comparison with the other three geographical areas). Aucklanders did not favour motorcycles as much as other areas in general, but 27% of the moderately small motorcycles (60cc to 250cc) were owned by Aucklanders, a larger proportion than for any of the other engine capacity groupings shown. Figure 17 shows the same information, but this time within the geographical areas shown. Of all motorcycle owners in small towns or rural areas, approaching half (45%) owned large motorcycles (750 cc plus), and a similar proportion of owners in small cities. Contrastingly, of all owners resident in large cities, including Auckland, 34%-35% owned these large motorcycles, and compared to motorcycle owners in the smaller centres, a considerably larger proportion owned motorcycles of size 250cc and under.

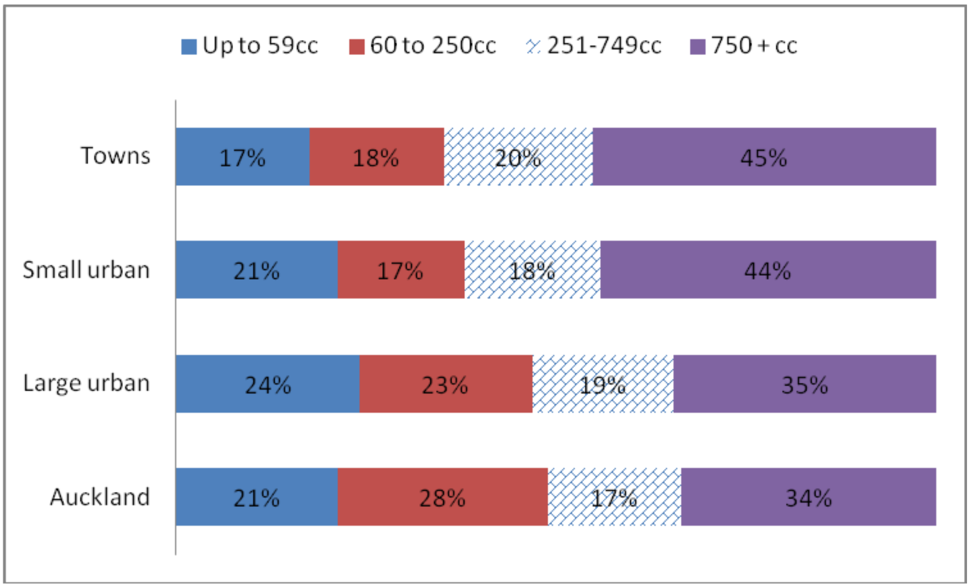

Figure 17: Proportion of licensed motorcycles and mopeds with specified engine capacity that were *owned by people with addresses in the specified areas*, as at the end of 2012 (NZTA licensing data)

4.3 Analysis of crash and injury data

This subsection looks at patterns of crash involvement and injury severity outcomes according to available data recorded in the Crash Analysis System (CAS). It focuses on characteristics of motorcycle crashes that are distinct from car crashes (and hence require different preventive measures or policies), including the likely errors made by car drivers when they crash with motorcycles and the likely errors made by motorcyclists when they crash.

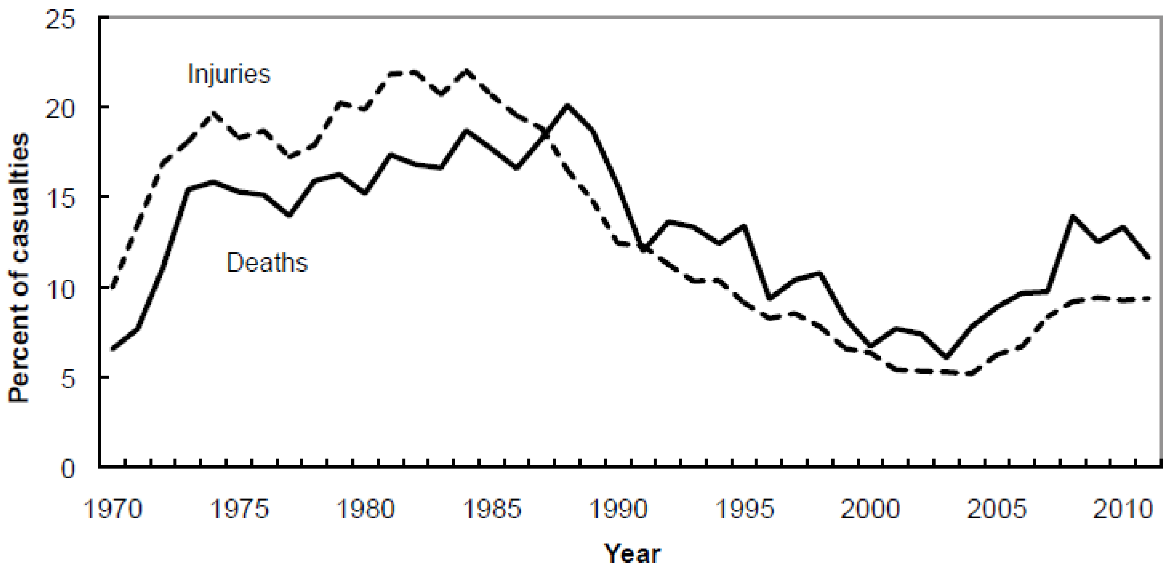

Figure 18: Motorcyclist deaths and injuries from 1970 to 2011 as a proportion of all road injuries (Ministry of Transport, 2012)

Figure 18 provides some context for motorcyclist injury and death with respect to New Zealand road injury more generally. The proportion of road injuries and deaths that were motorcyclists peaked in the mid to late 1980s, dropped to a relatively low level in the early 2000s before increasing again to similar levels as seen in the mid-1990s.

Table 1 shows total numbers of motorcycle casualties for 2011 and 2012 according to the severity of the injury, the age of the casualty and the engine capacity of the motorcycle, where recorded. Two years' data are shown combined here as fatalities (fortunately!) are sparse and do not provide a good basis for calculating year-by-year percentages. Although riders aged 40 and over clearly dominate the casualties (almost half being from this age group), their representation is nevertheless lower in terms of casualties than their motorcycle ownership levels would suggest (see Figure 6: people aged 40 plus own 73% of all licensed motorcycles). Although 40% of licensed motorcycles are large (750cc plus) according to Figure 5, riders of these motorcycles constitute two thirds of all fatalities (Table 1). This can be explained by the much higher distances travelled by these motorcycles (Figure 4) and the much higher proportion of crashes on higher speed limit roads (Figure 27), where higher speeds lead to greater injury severity. Only 7% of motorcycles were owned by people aged under 25 (see Figure 6), but 26% of casualties were from this group (Table 1). The overrepresentation of this age group is common in all crash analyses and is symptomatic of a combination of inexperience and tendency to take risks that is often characteristic of this group. Most of the injuries to riders aged under 25 were minor, however, typical of their exposure to mainly urban speed limit environments (see Figure 30).

Table 1: 2011 and 2012 motorcycle casualties by severity, age of casualty and engine capacity of motorcycle (percentages exclude missing values)

	fatal		serious		minor		all	
age	n	%	n	%	n	%	n	%
missing	0		11		29		40	
15-19	1	1%	59	8%	196	13%	256	11%
20-24	8	10%	93	13%	255	16%	356	15%
25-29	3	4%	72	10%	162	10%	237	10%
30-39	19	23%	113	16%	268	17%	400	17%
40 plus	52	63%	374	53%	676	43%	1102	47%
cc								
missing	16		156		310		482	
<= 59cc	3	4%	90	16%	299	23%	392	21%
60-250cc	6	9%	118	21%	361	28%	485	25%
251-749cc	14	21%	83	15%	178	14%	275	14%
750cc+	44	66%	275	49%	438	34%	757	40%
TOTAL	**83**	**100%**	**722**	**100%**	**1586**	**100%**	**2,391**	**100%**

Figure 19 shows trends in motorcycle casualties by age group. In 1985, motorcyclists aged 15-19 were by far the dominant group, with over 1,800 casualties per year. Since then, likely to be associated with the availability and affordability of imported used cars as an alternative to motorcycles, the casualty numbers for this group have plummeted to about 10% of this level. Although less dramatic, the next age group up, riders and pillions aged 20-24 have also experienced a significant decline. The recent rise in casualties can be seen to be almost solely due to increases for the age group 40 plus, whose casualties have trebled from a relatively static level in the 80s and 90s. Figure 20 shows that pillion passengers have constituted a steadily declining proportion of motorcyclist deaths and injuries over this period, likely to be related to the decline in motorcycle usage by the 15-19-year-old age group, who most commonly are pillion passengers. Even within this age group, however, there was a decline in the proportion of casualties that were pillion passengers over the period shown.

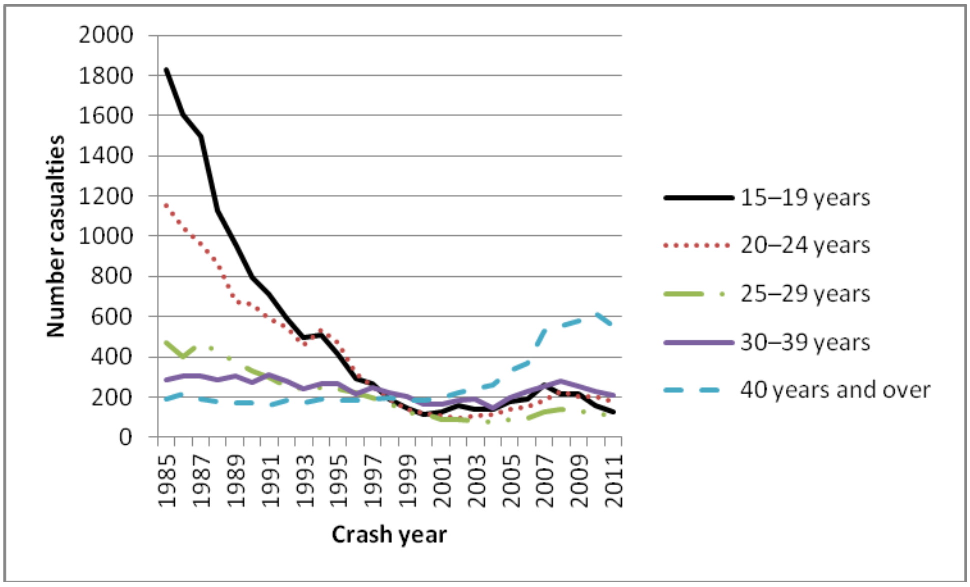

Figure 19: Deaths and injuries of motorcycle riders and pillion passengers, 1980–2011

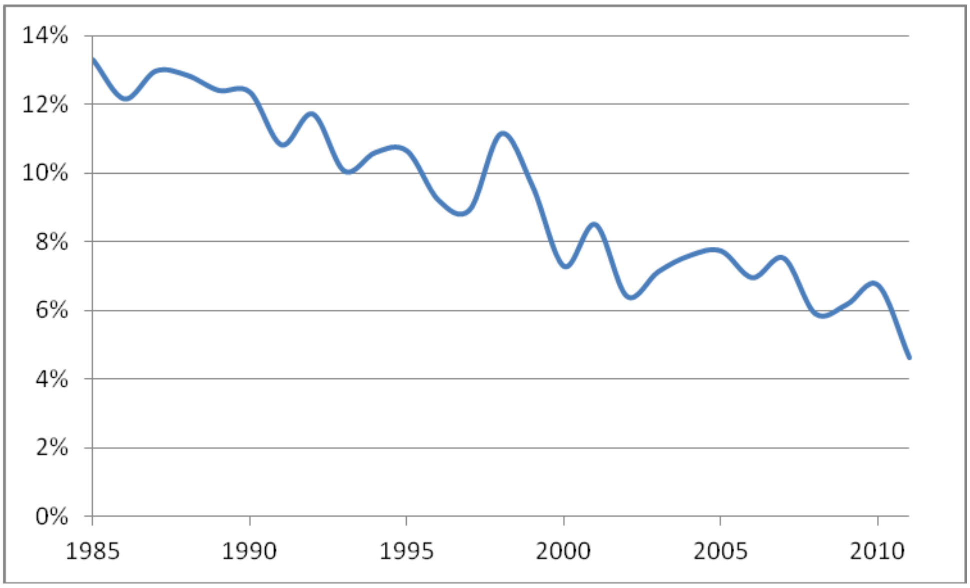

Figure 20: Proportion of motorcyclist deaths and injuries that were pillion passengers, 1980–2011

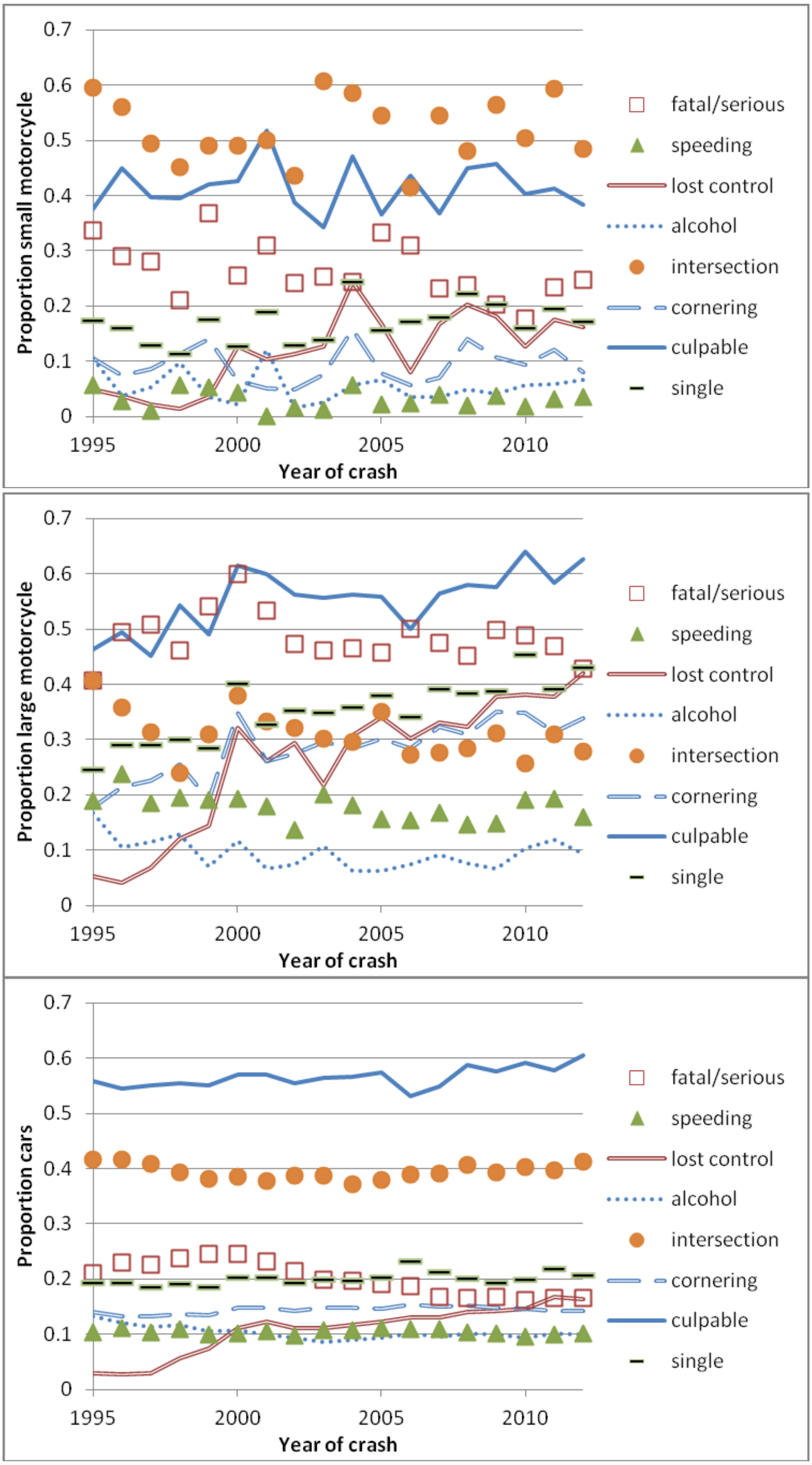

Figure 21: Characteristics of crashes by motorcycles under 60cc, 750cc plus and cars by year of crash

Figure 21 compares the crash characteristics over time for three different classes of vehicles: small and large motorcycles (under 60cc and 750cc plus respectively), and cars. This shows some trends over time and also shows how the nature of driving and riding differs for these different vehicles. The relevant aspect of the graph is bolded in the following commentary.

Over the period 1995 to 2012, small motorcycles had a large proportion of **intersection** crashes (an average of 52% of all small motorcycles compared to 31% of large motorcycles and 39% of cars). This arises from the mainly urban environments in which the smaller motorcycles are ridden. Riders of small motorcycles were **culpable** (adjudged primarily “at fault”) a relatively constant 41% of the time compared to an increasing proportion of crash-involved large motorcyclists (46% and 63% for 1995 and 2012 respectively) and an average of 56% of car drivers over that period. In terms of the injury outcomes, the proportion of crashes that had a serious (hospitalised) or fatal injury (“**fatal/serious**”) generally fell for all three vehicle types considered over this period. As car occupants are the best protected in crashes, an average of 20% of their crashes were fatal/serious compared to 25% for small motorcycles and 48% of large motorcycles. The much higher average severity for the larger motorcycles reflects the high proportion of riding on higher speed limit roads where the higher speeds lead to more severe outcomes on average. Only 6% of the small motorcycle crashes were in speed limit areas greater than 70km/h. In comparison, as shown in Figure 22, the proportion of crashes of larger motorcycles that were in higher speed limit areas has increased from around 35% in 1995 to around 60% currently.

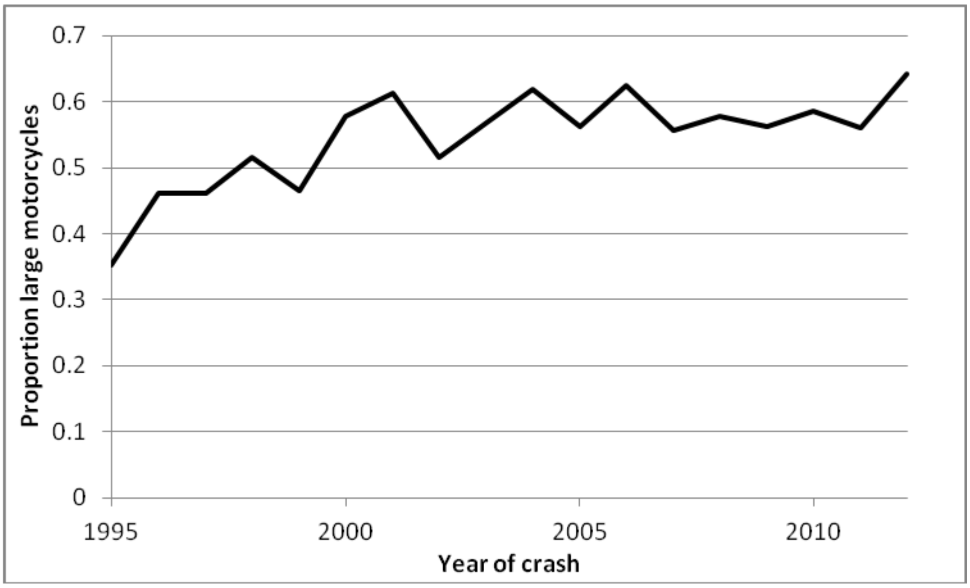

Figure 22: Proportion of crashed motorcycles 750cc plus that were in speed limit areas 75km/h plus

Figure 21 shows that excess **speed** was considered a factor for only 3% of small motorcycles and 10% of cars, but an average of 18% of the crash-involved large motorcycles. The proportion of all crashed vehicles adjudged to have **lost control** increased markedly for all vehicle types shown, which is likely to reflect changes in the recording and coding of crash characteristics rather than degradation in vehicle control generally. Nevertheless, the increase for the large motorcycles was particularly marked, which taken in the context of the high levels of **excess speed** and increasing rates of **single vehicle** crashes, **at-fault** crashes, crashes in higher speed limit areas and crashes when **cornering**, indicates that some fundamental changes in riding styles and/or riding environments have been taken place over this period for the riders of larger motorcycles.

Crashes at night

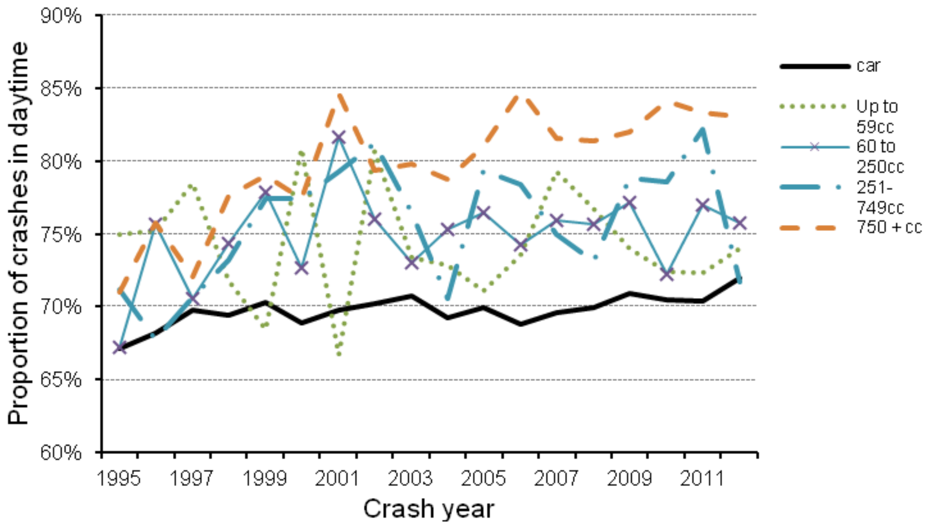

Figure 23: Proportion of crashed cars and motorcycles with specified capacity that crashed during the day (sunrise to sunset) by crash year

Figure 23 shows that there has been a gradual trend towards a higher proportion of crashes during the daytime. Daytime was defined as from sunrise to sunset, using a geographical midpoint as Wellington to define these periods by day of year (Royal Astronomical Society of New Zealand, 2013). Although there is a lot of variation in this graph across time, clearly cars crashed proportionately more during the night and larger motorcycles crashed proportionately least at night; the other classes of motorcycles were between these extremes. The overall averages of the proportion of crashes in daytime were 70% for cars, 80% for the larger motorcycles, and 74% to 75% for the other classes of motorcycles. As noted above, smaller motorcycles are much more likely to be owned by people aged under 30, who are also more likely to be riding at night. Figure 24 shows that the proportions of daylight crashes do vary considerably against driver or rider age, but the ordering by vehicle and engine capacity groups is generally still consistent within age groups. The larger motorcycles were rarely ridden by riders aged under 20, so the leftmost point on this group for larger motorcycles is subject to considerably random variation.

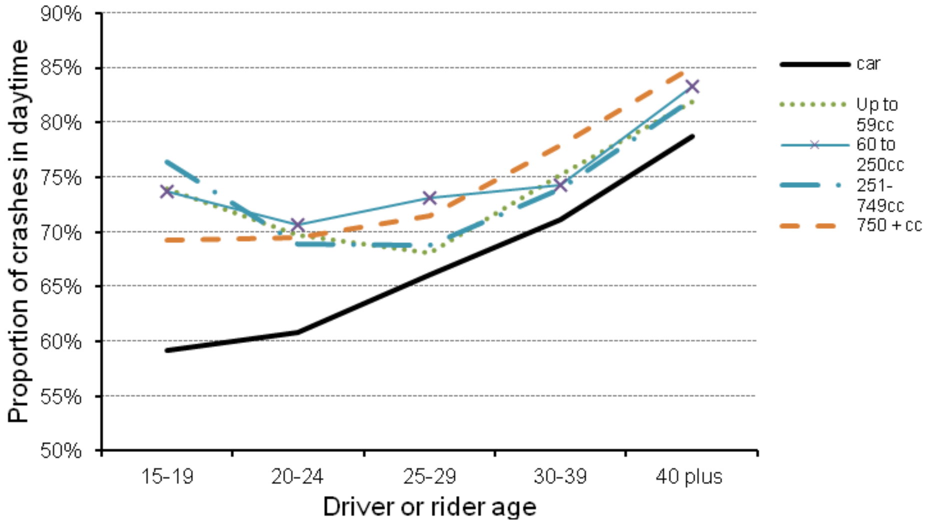

Figure 24: Proportion of crashed cars and motorcycles with specified capacity that crashed during the day (sunrise to sunset) by age group of driver or rider

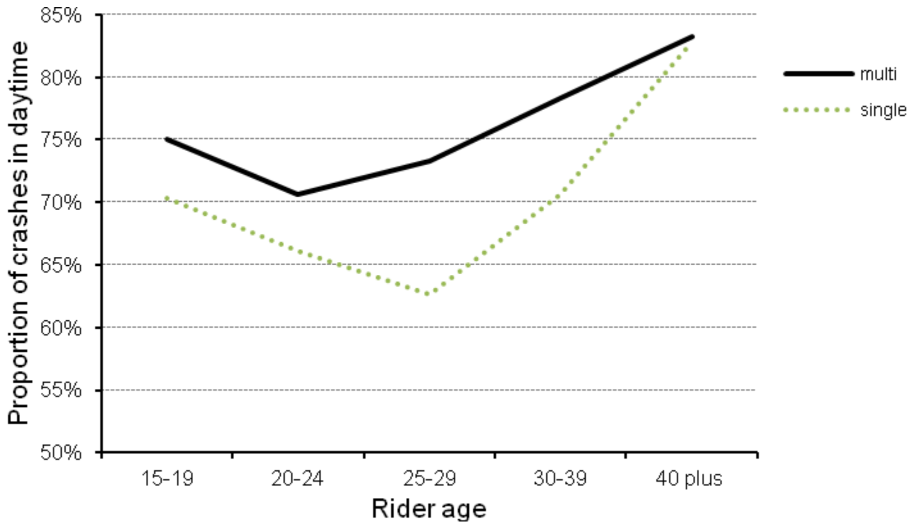

Figure 25: Proportion of crashed motorcycles either single vehicle crashes or crashes with another vehicle that crashed during the day by rider age group

As multi-vehicle crashes happen more readily when there is a lot of traffic with resultant vehicle conflicts, it is not surprising that Figure 25 shows that multi-vehicle motorcycle crashes were generally more common during daytime than single vehicle crashes. Older riders (aged 40 plus) had the highest proportion of daylight crashes, and little difference between their multi-vehicle and single-vehicle crash proportions that were during the day.

Figure 26 shows that as the age group of the rider increased, the proportion of crashes involving another vehicle (normally a car) decreased. This will be influenced by the amount of riding undertaken in urban settings, which is much higher for younger motorcyclists, who ride mainly smaller motorcycles that are used predominantly in urban settings (see Figure 29). The speed limit setting of the crash reflects the likely speeds involved, which in turn have a strong effect on the injury outcomes. Figure 27 shows that the injury outcome in crashes involving cars (these include single vehicle crashes and crashes involving other road users, including motorcycles) had a smaller proportion of serious outcomes within speed limit area classification than the motorcycle classes. This is expected as the car occupants are protected to some extent by the chassis of the car and other safety features such as airbags and seatbelts, where used. Within each vehicle classification, in urban speed limit areas, single vehicle crashes were generally more serious, whereas in rural speed limit areas, multi-vehicle crashes were generally more serious.

Figure 26: Proportion of crashed motorcycles that crashed with another vehicle (normally with a car) by rider age group

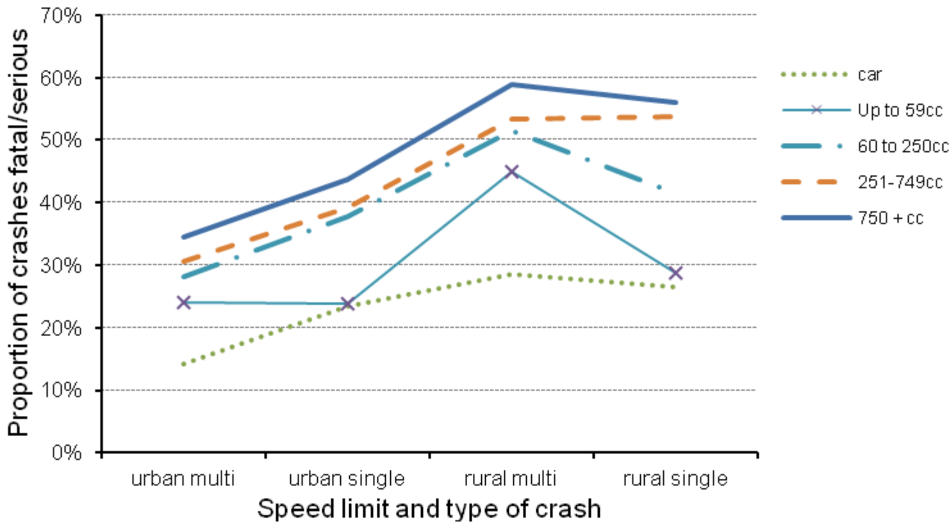

Figure 27: Proportion of crashed motorcycles and cars that were in crashes with a fatal or serious outcome by the speed limit area of the crash location, the vehicle class (motorcycles grouped by cc class), and whether another vehicle was involved or not (multi or single, respectively)

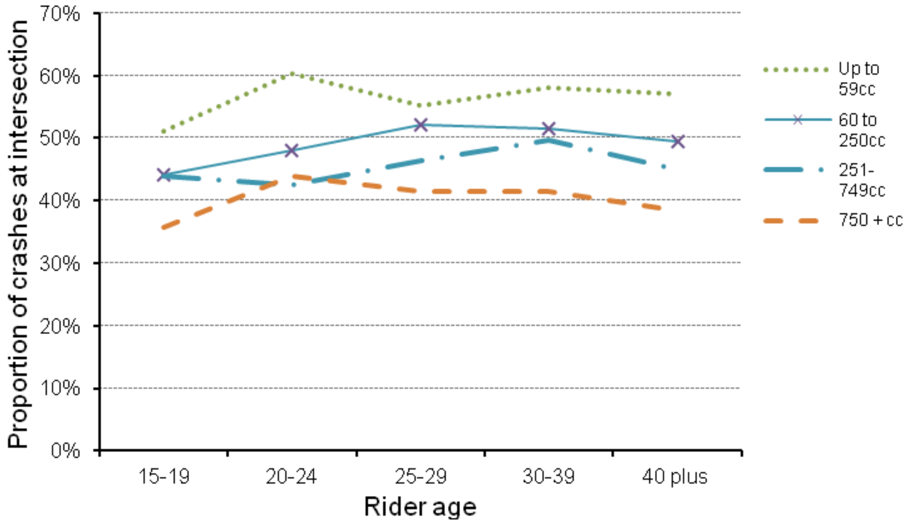

Figure 28: Proportion of motorcycles crashing with other vehicles that crashed at intersections by rider age group

Figure 28 shows that when motorcycles crashed with other vehicles, between 40% and 60% were at intersections. As the smaller motorcycles generally get used in urban speed limit areas (as shown in Figure 29), it is not surprising that their rate of crashing at intersections is higher than for other motorcycles. Note that this figure also shows that there is little influence of driver/rider age on the proportion of crashes in rural speed limit areas, apart from the motorcycles with capacity between 251 and 749 cc and those with capacity of 750 plus, for which rural speed limit area crashes became proportionately more common for older riders. From Figure 22, above, it is also notable that the proportion of the larger motorcycles' crashes occurring in higher speed limit areas was increasing steadily with time. This is an important trend when considering the high injury severities that tend to accompany higher speed limit crashes.

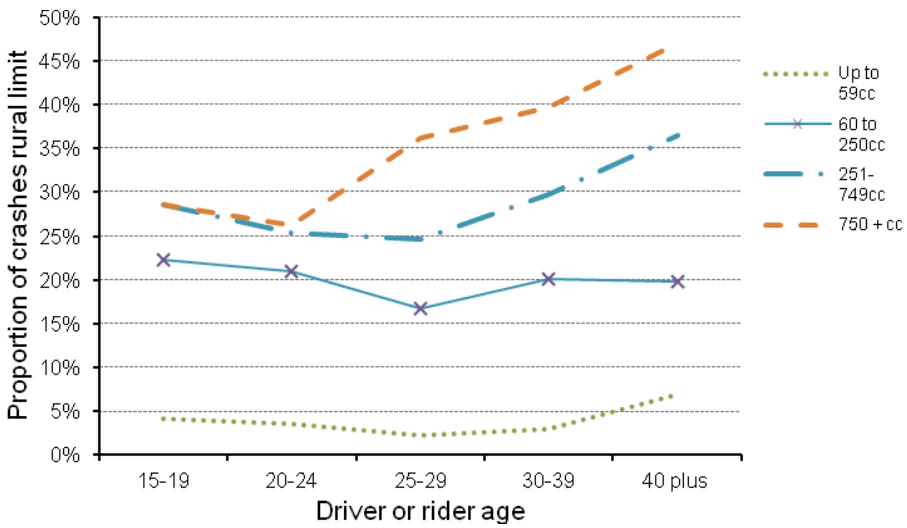

Figure 29: Proportion of motorcycles crashing with other vehicles that crashed in rural speed limit areas by rider age group and vehicle type or engine capacity (just for motorcycles)

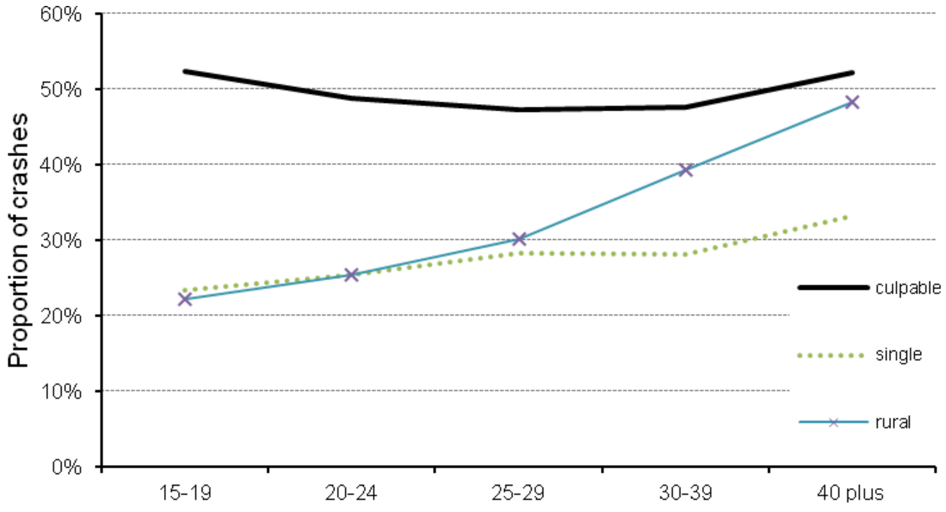

Figure 30: Within rider age group, proportion of motorcycles crashing that crashed in rural speed limit areas, were single vehicle crashes, of where the rider was judged primarily at-fault

Fault in crashes and factors probably contributing

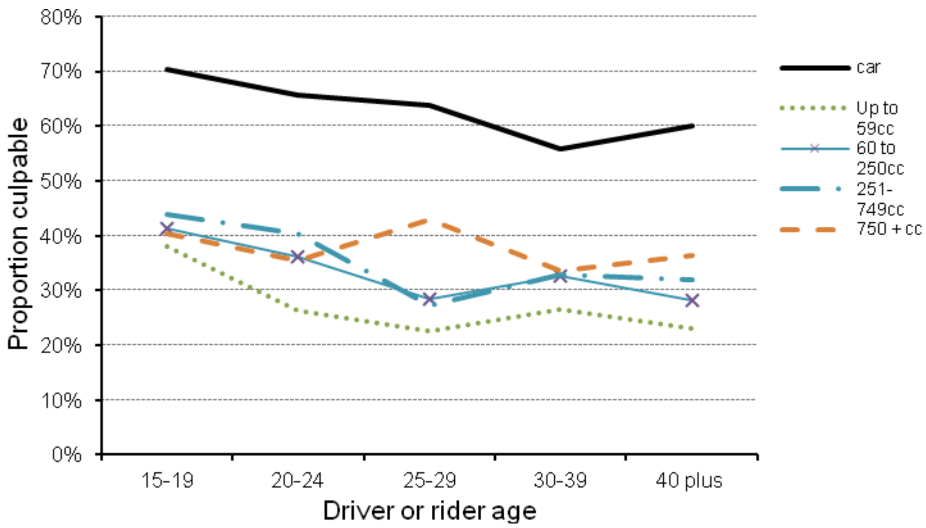

Figure 31: Proportion of cars crashing with motorcycles or motorcycles crashing with other vehicles that were adjudged to be primarily at fault for the crash by rider age group and vehicle type or engine capacity (just for motorcycles)

Figure 31 looks at the coding of responsibility for the crash for those cars crashing with motorcycles and motorcycles crashing with other vehicles. Primary responsibility generally diminished with increasing age of the rider or driver, although car drivers were adjudged primarily at fault in the majority of crashes. Least at-fault were the riders of very small motorcycles. There was little to distinguish the rates of being at-fault for the other motorcycle size groupings.

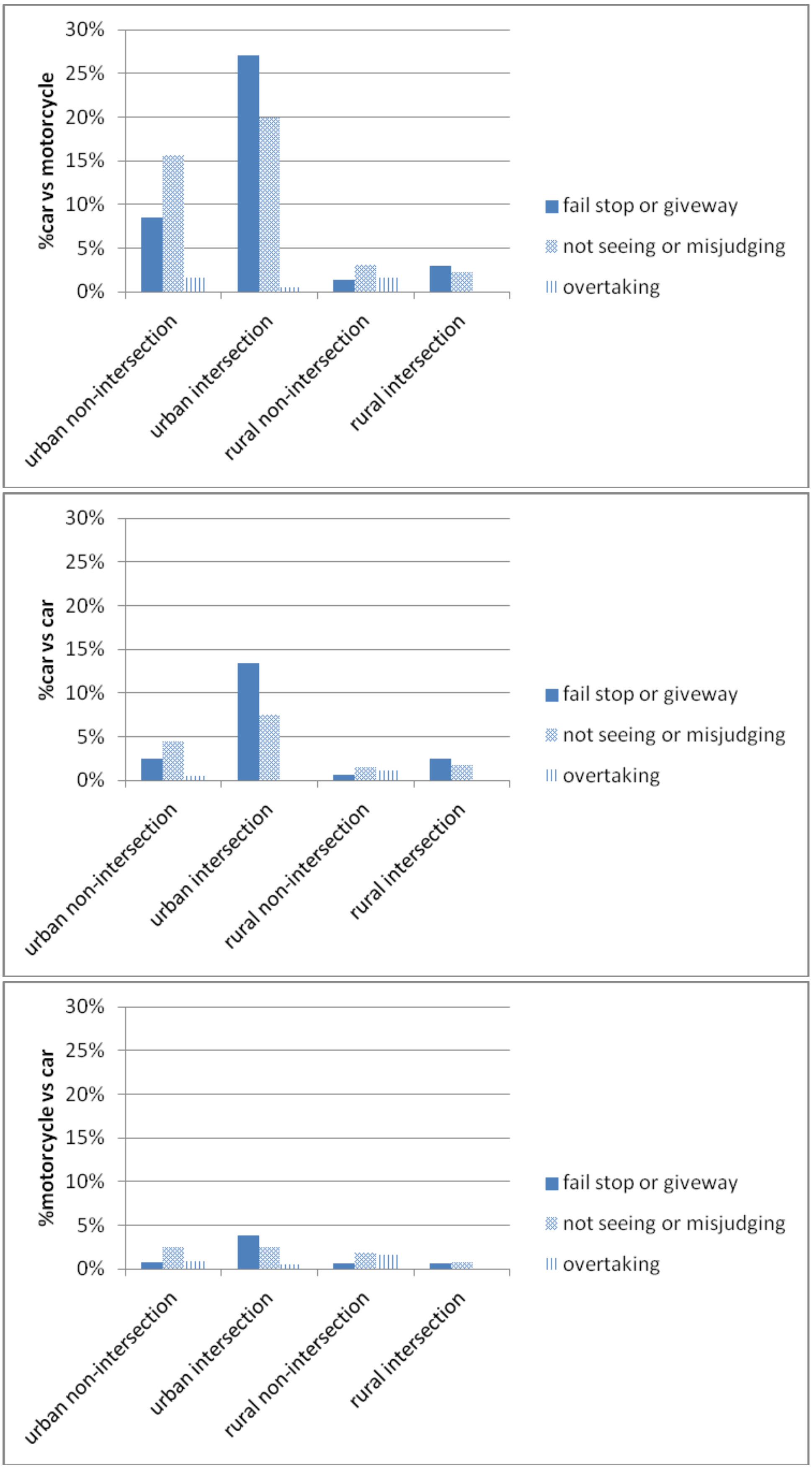

Figure 32: Proportion of cars and motorcycles crashing with other vehicles that were adjudged to have failed to stop/give way, not seen or misjudged, or overtaking, by the speed limit and road configuration

Figure 32 compares the proportion of three sorts of crashes where the driver or rider was considered to have been overtaking, failed to stop or give way, or misjudged/failed to see. The three situations compared are cars involved in collisions with motorcycles (at the top), collisions between cars and cars (middle) and motorcycles involved in collisions with cars. Note that the same driver or rider is commonly coded as failing to see or misjudging when they fail to stop or give way (so a given crash often contributes to both of these bars). Clearly, in urban settings, car drivers were far more likely to have been coded as failing to stop/give way, or not seeing/misjudging when colliding with motorcycles than with other cars. At rural intersections, there was little difference between cars vs motorcycles and cars vs cars. In contrast, motorcyclists were relatively rarely coded as committing these errors when colliding with cars.

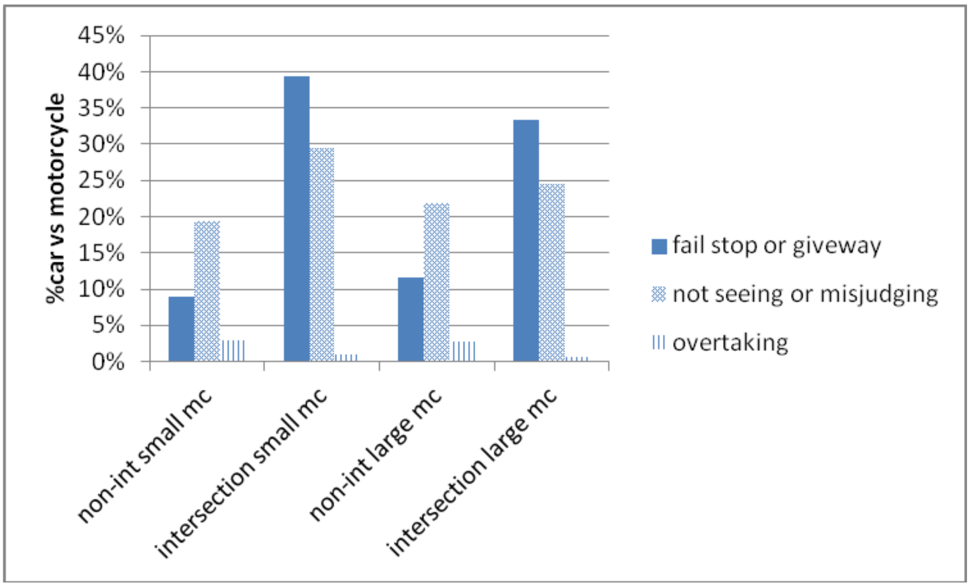

Figure 33: Within urban speed limit areas, proportion of car drivers crashing with either small or large motorcycles that were adjudged to have failed to stop/give way, not seen or misjudged, or overtaking, by the road configuration

Figure 33 identifies differences in the car driver factors within urban speed limit areas for small motorcycles (under 60cc) and large motorcycles (750cc plus). This shows that the smaller motorcycles at intersections were more likely to be victims of car driver misjudgement/not seeing and failure to stop/give way than were larger motorcycles. At non-intersections in urban areas, larger motorcycles were somewhat more likely to be subject to these car driver errors, which could be consistent with higher speeds adopted by larger motorcycles.

4.4 Literature review of potentially effective countermeasures

Table 2, below, provides a summary of all countermeasure evaluations with demonstrated crash effects for each of the four safe system pillars. Empty cells in Table 2 indicate no evidence on this aspect of effectiveness is available which is most common for estimates of economic worth. Sections 3-6 provide: background material for Table 2; a summary of countermeasures for which there is no demonstrated evidence of crash effects; and a summary of countermeasures with outcomes other than, or in addition to, crash effects. Also included in the summary is an indication of the amount and quality of research for each reviewed countermeasure.

Table 2 Motorcycle safety countermeasures with demonstrated crash and or injury reductions

Source	Strength of evidence of effectiveness	Estimated crash/injury severity reduction	Crash/exposure population	Economic worth estimate
SAFE VEHICLES (MOTORCYCLES)				
Anti-lock brakes				
Rizzi et al. (2011)	High	Estimated 21 lives saved annually in Sweden or 40% reduction in all types of fatal injury accidents	In-depth studies of 182 fatal motorcycle crashes in Sweden, 2005-2008 Assessment made of whether countermeasure could have prevented the crash or mitigated the injury outcome based on in-depth analysis of each fatal crash and known potential of countermeasure to affect crash outcome	

Rizzi et al. (2009)	High	38% casualty crash reduction (minimum 11%) and 48% severe and fatal crash reduction (minimum 17%) Intersection crashes most affected: 42% severe and fatal crash reduction	Police reported motorcycle casualty crashes in Sweden between 2005 and 2008 Study 1: all fatal crashes in Sweden 2005-08 (n=164) to determine circumstances under which ABS would have affected crash outcome Study 2: Induced exposure method using Study 1 data to estimate effectiveness of ABS on crash reductions
Rizzi et al. (2013)	High	Motorcycle injury crash reductions of 24%, 29% and 34% in Italy, Spain and Sweden respectively Motorcycle severe injury crash reductions of 34% and 42% in Spain and Sweden respectively Scooter (250 cc and above) severe and fatal crash	Police reported motorcycle crash data from Spain (2006-2009), Italy (2009) and Sweden (2003-2012) Used induced exposure method to estimate effectiveness of ABS on crash outcomes

		reduction of 31% in Spain	
Teoh (2011)	High	37% reduced involvement in fatal crashes per 10,000 registered vehicles.	13 types of motorcycle model with and without ABS in fatal crashes in the US. Compared fatal crash involvements by total registered vehicle years for 13 motorcycle models with and without ABS
Gwehenberger et al. (2006)		17-38% reduction in serious motorcycle crashes	200 serious crashes identified from insurance claims data in Germany, half of which were deemed relevant to ABS
Roll et al. (2009)	Medium	Up to 50% reduction in fatal or serious crashes	350 real-world crashes in Germany between 1996-2007, 51 multi-vehicle serious or fatal crashes deemed relevant to ABS
Highway Loss Data Institute (2009)	High	ABS vehicles had 22% fewer insurance claims for collision damage per insured vehicle year than models without ABS	Regression analyses to quantify effect of ABS on frequency of insurance claims and claims costs by motorcyclists in the US (2003-2008) while controlling for rated

		No significant differences were found regarding claim severity	driver age and gender, vehicle age, and vehicle density of the garaging postal code of the vehicle	
Baum et al. 2007 cited in Seiniger et al. (2012)		Not available, paper in German		BCR of more than four, taking into account system costs, the effect of ABS on current crash statistics and predicted changes in future crash statistics
Sporner & Kramlich (2003)	Medium	10% reduction in crashes involving sport and touring motorcycles (preventing 90 deaths and about 3000 serious injuries)	In-depth information on 610 motorcycle/car collisions and 300 single vehicle crashes involving motorcycles in Germany between 1990-97 of which 239 crashes were relevant to ABS use.	BCR 1.1-1.4 or with tax initiative 9.39-11.24

Air bags			
Dreher (1998) cited in Berg & Rücker (2007)	Low	An airbag would have deployed in 58% of cases, reduced injury severity in 11% of cases; and had no influence in 75% of cases. The outcome in 13% of cases was not known	Retrospective file review of 97 motorcycle crashes in Germany to assess whether an airbag would have changed crash outcome
Motorcycle traction/stability control			
Rizzi et al. (2011)	High	5 lives saved annually in Sweden or 9% reduction in all types of fatal injury crashes	In-depth studies of 182 fatal motorcycle crashes in Sweden, 2005-2008 Assessment made of whether countermeasure could have prevented the crash or mitigated the injury outcome based on in-

			depth analysis of each fatal crash and known potential of countermeasure to affect crash outcome
			Considered to be effective in crashes in which the critical event was rear wheel skid or the rider doing a 'wheelie'
Seiniger et al. (2008)	High	4 to 8 % of fatal motorcycle crashes	In depth analysis of German motorcycle crashes
Alcohol interlocks			
Rizzi et al. (2011)	High	8 lives saved annually in Sweden or 15% reduction in all types of fatal injury crashes	In-depth studies of 182 fatal motorcycle crashes in Sweden, 2005-2008
			Assessment made of whether countermeasure could have

			prevented the crash or mitigated the injury outcome based on in-depth analysis of each fatal crash and known potential of countermeasure to affect crash outcome
Vehicle test approvals			
Rizzi et al. (2011)	High	2 lives saved annually in Sweden or 4% reduction in all types of fatal injury crashes	In-depth studies of 182 fatal motorcycle crashes in Sweden, 2005-2008 Assessment made of whether countermeasure could have prevented the crash or mitigated the injury outcome based on in-depth analysis of each fatal crash and known potential of countermeasure to affect crash outcome

			Considered applicable to crashes in which there were significant technical defects of the motorcycle which could be expected to have been detected in a vehicle test
Anti-theft devices			
Rizzi et al. (2011)	High	3 lives saved annually in Sweden or 6% reduction in all types of fatal injury crashes	In-depth studies of 182 fatal motorcycle crashes in Sweden, 2005-2008 Assessment made of whether countermeasure could have prevented the crash or mitigated the injury outcome based on in-depth analysis of each fatal crash and known potential of countermeasure to affect crash outcome

Day time running lights (DRL)				
Wells et al. (2004)	High	75% riders had their headlight turned on during the day. Headlight use associated with 27% lower risk (multivariate odds ratio 0.73, 0.53 to 1.00)	Population based case-control study New Zealand, 1993-1996. N = 463 hospital treated or fatal cases, 1233 controls	
Henderson et al. (1983)	Low	Motorcycle crashes reduced by about 5% after the introduction of the DRL legislation for motorcycles in North Carolina in 1973. Other crashes were not influenced		
Williams & Lancaster (1996)	Low	Estimated 13% reduction in motorcycle crashes through the use of motorcycle DRLs (mostly headlights) in the USA		
Paine et al. (2008)	Medium	Bright yellow DRLs have the potential to reduce fatal motorcycle crashes by more than 13% in Australia		Break-even point for cost-effectiveness of factory-fitted turn-signal (or dedicated) DRLs

				is a saving of about 2% of all motorcycle crashes in Australia.
Radin, Mackay & Hills (1996)	Low-medium	Reduction in conspicuity-related crashes by 29%	Detailed analysis of 4,958 conspicuity-related motorcycle crashes following a three month national campaign 'daytime running headlight' implemented in July 1992 to increase daytime headlight use in Malaysia. The campaign preceded introduction of compulsory DRL in September 1992	
Yuan (2000)	High	No significant effect for all crashes; significant effect for fatal and serious injury crashes but not for minor crashes	All police-reported multiple-party crashes involving motorcycles, (including motorcycle-pedestrian crashes), for the years 1992 to 1996 pre and post implementation of compulsory DRL for motorcyclists in Singapore in 1995	

Quddus et al. (2002)	High	No significant effect for all crashes but significant reductions in fatal and serious injury crashes	All police-reported crashes for the years 1992-2000 Singapore	
SAFE ROADS				
Black-spots or black-lengths				
Scully et al. (2008)	High	Statistically significant 24% reduction in casualty crashes Non-statistically significant 16% reduction in serious casualty crashes Statistically significant 16% reduction in casualty crashes involving all types of vehicles Route based treatments were more effective in reducing casualty motorcycle crashes (35%) than intersection treatments (27%) but the differences	All crashes involving motorcyclists at 87 black-spot treatment sites before (1997- 2007 = 2,804 crashes)) and after treatment implementation (2007 to 2008 = 819) at treatment and control sites in Victoria.	Estimated $84.5 million saved, preventing 40 casualty crashes per annum involving all types of vehicles BCR: 15.1 Average expenditure less than $19,000 to prevent one

		were not significant		casualty crash involving a motorcycle
Scully et al. (2006)	High	Statistically significant 31% reduction in casualty crashes involving all types of vehicles including motorcycles Statistically significant 36% reduction in serious casualty crashes involving a motorcycle		
Good road surface condition				
Rizzi et al. (2011)	High	2 lives saved annually in Sweden with ‘sound, clean and smooth road surfaces’ or 4% reduction in all types of fatal injury crashes	In-depth studies of 182 fatal motorcycle crashes in Sweden, 2005-2008 Assessment made of whether countermeasure could have prevented the crash or mitigated the injury outcome based on in-depth analysis of each fatal crash and known potential of	

			countermeasure to affect crash outcome
			Considered to be effective in situations in which the condition of the road surface is the primary contributing crash factor
Road side safety barriers			
Wire-rope safety barriers			
Carlsson (2009)	Medium	40-50% reduction in risk of motorcycle fatalities on 2+1 roads with cable barriers	Comparison of fatal and serious injury crash rates before (2002-2008) and after (2008-09) treatment of 1,745km of 2+1 roads with cable barriers on highways and expressways in Sweden
Guard rails			
Bambach et al. (2012)	High	Roadside barriers (guardrail) provide a significant reduction in the relative risk of serious injury to motorcyclists compared with other roadside	1,364 motorcyclists injured in single vehicle collisions with roadside barriers, trees, poles and

		hazards: Significant odds ratios for sustaining one or more serious injuries relative to guard rail: 1.55 times for trees and 2.15 times for poles	other fixed roadside infrastructure in NSW Australia from 2001 to 2009
		The relative risks for motorcyclists were approx. 21-24% smaller than those for passenger vehicle occupants indicating that the protective effect of barriers for motorcyclists is less pronounced than that for passenger vehicle occupants	
Daniello & Gabler (2011)	High	Collisions with guardrails were 7 times more likely to be fatal than collisions with the ground	3,600 fatal motorcycle crashes in the US with roadside objects
		Collisions with trees were 15 times more likely to be fatal than collisions with the ground	
Motorcycle only lanes			
Sohadi, Mackay & Hills (2000)	High	39% reduction in all crashes. The benefits of motorcycle exclusive lanes were evident when traffic flows exceeded 15,000 motorcycles per lane, per day	Police reported crashes before (1991-1993) and after (1993-1994) the opening of a lane designated exclusively for motorcyclists along a federal highway in two districts of Malaysia

Use of bus lanes for motorcycles			
York, Ball & Hopkin (2011)	Medium	No significant change in collision rates in bus lanes affecting motorcyclists or pedestrians when compared to control sites, but an 11.6% reduction in overall cycling collision rates	Police reported collisions resulting in injury after bus lanes were opened for use by motorcyclists in London (18 month period 2009-2010) compared to before (18 month period 2008-2009). Enforcement and publicity were used to improve awareness among road users
Newcombe & Wilson (2010)	Medium	Use of bus lanes had little overall effect on motorcyclist collisions except at one site where there was an 80% increase from 16 to 32 (caution: low numbers at all sites)	Police reported collisions, Auckland, NZ, 5 years pre and post implementation of bus lanes (which could be used by cyclists and motorcyclists) in 1998 (x 2 locations), 1999 and 2000
SAFE ROAD USERS			
Protective gear			

McIntyre, Nieuwesteeg & Cockfield (2011)	Medium	Motorcyclists wearing five items of protective clothing (47%) (helmets, jackets, gloves, boots and pants) spent significantly less time in hospital (average 5.6 days) than those wearing less than five items of protective clothing (average 10.5 days). But some of this difference may reflect differences in rider and accident type that were uncontrolled for in the analysis Significant association between jacket wearing (jackets worn by 79% of riders) and open wounds to the trunk, fewer of those who were wearing a jacket sustained open wounds (15%), compared to those not wearing a jacket (25%), and fewer of those wearing a jacket sustained an upper limb open wound (9%) compared to those not wearing a jacket (22%) Significant association between wearing motorcycling gloves and open wounds to the upper limbs, fewer of those wearing gloves sustained an open wound injury to the upper limbs (45%) compared to those not wearing	500 motorcyclists (mean age 38) injured in crashes between 2006-08 in Victorian who received insurance coverage by the Transport Accident Commission

		protective gloves (9%) Significantly lower incidences of lower limb open wounds, for protective pants (14% v 30%) and boots (16% v 29%) respectively A third of those wearing protective pants sustained a nerve injury, compared to 48% of those not wearing protective pants, 35% of those wearing boots sustained a nerve injury, compared to 78% of those not wearing boots	
De Rome, Ivers, Fitzharris et al. (2011)	High	Proportion of riders wearing: motorcycle jackets (82.5%), motorcycle pants (34.9%); motorcycle gloves (87.3%); motorcycle boots (38.2%) or other heavy (non-motorcycle) boots (25.9%). Body armour was worn over shoulders and elbows (71.7%), hands (50.9%), feet/ankles (29.7%) backs (18.9%), knees 9.9% and hips (7.6%). 45.8% wore foam inserts in their jacket backs. Motorcyclists significantly less likely to be admitted to hospital if they crashed wearing a motorcycle jacket (RR=0.79, CI: 0.69-0.91);	212 motorcyclists who sustained minor injuries in a crash between 2008-09. Recruited through hospitals and motorcycle repair services in the ACT, Australia.

motorcycle pants (RR=0.49, CI: 0.25-0.94); or motorcycle gloves (RR=0.41, CI: 0.26-0.666) compared to those not wearing these items. Motorcycle boots did not significantly affect hospitalisation.

Motorcyclists wearing motorcycle protective clothing *fitted with body armour* were significantly less likely to sustain injuries to the protected areas compared to those wearing non-motorcycle protective clothing. Specifically, when body armour was fitted there was a 23% lower injury risk associated with wearing a motorcycle jacket (RR=0.77, CI: 0.68-0.86); 45% for motorcycle gloves (RR=55, CI: 0.37-0.81); 39% for motorcycle pants for leg injuries only (RR=0.61, CI: 0.41-0.91); and 45% for motorcycle boots (RR=0.55, CI: 0.35-0.85). The risk of foot or ankle injuries reduced by 53% for heavy non-motorcycle boots (RR=0.47, CI: 0.28-0.77) when compared to shoes or joggers.

Where *body armour was not fitted,* motorcycle gloves (RR=0.60, CI: 0.38-0.96); and motorcycle boots (RR=0.35, CI: 0.13-0.91) significantly reduced risk of soft tissue injuries as did non-

		motorcycle boots (RR=0.39, CI: 0.22-0.70) compared to when not wearing motorcycle protective clothing. No significant reduction for motorcycle jackets or pants.	
De Rome, Ivers, Fitzharris et al. (2012)	High	Full protection (motorcycle jacket and pants) significantly associated with less average time in hospital (0.7 days) (n=47 riders) compared to partial protection (motorcycle jacket) (2.6 days) (n=80 riders) and unprotected (neither) (3.5 days) (n=19 riders)	As above but 147 of original sample of riders followed up two and six months post-crash to assess general health status; disability treatment and recovery progress; quality of life and return to work
		At 2 months post crash, riders with partial protection were less likely than unprotected riders to report reduced quality of life (adj. OR=0.25, CI: 0.08-0.80) or to have moderate or severe disabilities (adj. OR=0.12, CI: 0.02-0.80).	
		At 2 months post crash, riders with full protection were less likely than unprotected riders to have	

moderate or severe disabilities (adj. OR=0.12, CI: 0.02-0.95).

At 6 months post crash, riders with partial protection were more likely than unprotected riders to rate themselves as fully recovered (adj. adj. OR=4.69, CI: 1.32-16.63) and to have returned to pre-crash work roles (adj. OR=5.7, CI:1.57-20.68).

At 6 months post crash, fully protected riders were less likely than unprotected riders to have treatment ongoing (adj. OR=0.13, CI: 0.03-0.59) and more likely to rate themselves as fully recovered (adj. OR=6.22, CI: 1.60-24.15) and to have returned to pre-crash work roles (adj. OR=7.98, CI: 1.66-38.42).

No significant differences in any outcomes between the partial and full protection group.

Rizzi et al. (2011)	High	Estimated 3 lives saved annually in Sweden by wearing full body protective clothing or 6% reduction in all types of fatal injury crashes	In-depth studies of 182 fatal motorcycle crashes in Sweden, 2005-2008 Assessment made of whether countermeasure could have prevented the crash or mitigated the injury outcome based on in-depth analysis of each fatal crash and known potential of countermeasure to affect crash outcome
Otte et al. (2002)	Medium	Riders wearing protective clothing had significantly fewer leg injuries in crashes at the same relative speed (between 31-50 km/h) compared to riders not wearing protective clothing (40% versus 29% respectively) Riders without protective clothing sustained injuries at lower speeds (80% at less than 50 km/h compared to 80% at less than 60 km/h for riders with protective clothing)	1,933 crashes involving injured riders in Germany examined to determine injury patterns of persons wearing versus not wearing protective gear

ACEM (2004) ‘MAIDS’	Based on 921 injured riders and 79 injured rider passengers: <u>Upper torso clothing - riders</u> Prevented/reduced AIS 1 injury 64.6% cases Worn but no injury reduction effect 8.3% cases. Injured but no coverage 6.3% of cases <u>Upper torso clothing – passengers</u> Prevented/reduced AIS 1 injury 49.4% cases Worn but no injury reduction effect 6.3% cases Injured but no coverage 5.1% of cases <u>Lower torso clothing - riders</u> Prevented/reduced injury (level unstated) 61.3% cases; Worn but no injury reduction effect 11.8% cases Injured but no coverage 9.9% cases	3,644 injuries sustained by 923 riders based on in-depth study of 921 motorcycle crashes in Europe 1999-2000. Case control method used ; 923 controls

Lower torso clothing - passengers

Prevented/reduced injury (level unstated) 45.6% cases

Worn but no injury reduction effect 15.2% cases

Injured but no coverage 10.1% cases

Footwear - riders

Prevented/reduced AIS 1 injury severity 48.7% cases

Worn but had no injury reduction effect 4.5% cases

Injured but no coverage 3.4% cases

Footwear - passengers

Prevented/reduced AIS 1 injury severity 29.1% cases

Worn but no injury reduction effect 6.3% cases

Injured but no coverage in 5.1% cases

		Gloves - riders Prevented/reduced AIS 1 injury severity 43.5% cases Worn but no injury reduction effect 2.3% cases Injured but no coverage 11.1% cases Gloves – passengers Prevented/reduced AIS 1 injury severity 25.3% cases Worn but no injury reduction effect 2.5% of cases Injured but no coverage 16.5% cases	
Graduated licensing			
Reeder et al. (1999)	Medium	Significant 22% reduction in motorcycle traffic crash hospitalizations for the 15-19 year age group after implementation of GLS in 1987. However, an examination of vehicle registration and driver licensure data suggests that the	Serious injury crash data from the New Zealand Health Information Services national public hospital inpatient data files for the years 1978-1994, inclusive. Cases

		reduction in injury crashes may, largely, be attributable to an overall reduction in exposure to motorcycle riding	disaggregated into three age groups, 15-19 years, 20-24 years, and 25 years or older
McGwin et al. 2004	Low	Lower mortality rates observed in states with: skill test for a learner permit; driver training; longer duration of learner permit and three or more learner permit restrictions	Police reported motorcyclist fatalities between 1997-1999 for all 50 US states
Penalties and enforcement			
Christie et al. (2003)	High	Speed camera networks were associated with a significant reduction in all types of injurious crashes involving two-wheeled motor vehicles (TWMV) compared to control sites Rate ratio TWMV=0.37, CI: 0.13-0.80. 0.1 injurious crashes prevented per site during follow-up, CI: 0.0-0.1)	All persons injured in crashes in South Wales, UK (based on STATS 19 data, 1996-2000) during a controlled 38 month before and 17 month after period of implementation of mobile speed cameras at 101 sites
French (2009)	Low	Lower speed limits on rural interstate highways significantly reduced motorcyclist serious (non-fatal) injuries	All available US state level crash data (fatal and non-fatal injuries) from 1990 to 2005

Villaveces et al (2003)	Low	Incidence of motorcycle rider alcohol-related mortality per 100,000 person years was lower when laws specifying a blood alcohol concentration of 0.08 g/dl were in effect (adjusted rate ratio 0.87 (95% CI: 0.79, 0.95). Overall motorcycle mortality per 100,000 person years was lower when administrative license revocation laws were in effect (adjusted rate ratio = 0.95, 95% CI: 0.92, 0.98)	US motor motorcycle mortality rates during periods when each of several alcohol-related laws were in effect compared with mortality rates during other periods (1980-1997) Examined 63,052 motorcycle deaths 1980-1997 from US Fatality Analysis Reporting System, 49% of which were due to alcohol use
Novoa et al. (2011)	Medium	Significant reduction in number male motorcyclists injured following intervention (relative risk 0.83 CI 0.77-0.90) Significant reduction in number of male motorcyclists fatally or seriously injured following intervention (relative risk 0.82 CI 0.72-0.93) Significant reduction in number female motorcyclists injured following intervention	Time series analyses used to compare number of drivers involved in injury collisions and number of persons injured in traffic collisions before (2000-2007) and after (2007-2009) introduction of a law in 2007 to criminalise traffic offences (speeding – above 60 km/h urban roads and above 80 km/h non-urban roads ; drink driving above 0.08% BAC and reckless driving). Penalties ranged

		(relative risk 0.85 CI 0.76-0.95)	from prison terms, fines, community service and licence suspension)
			Traffic crash data, Spain, 2000-2009: 1,668,889 drivers involved in injury collisions (13.5% were motorcyclists) and an additional 1,454,971 persons were injured in traffic collisions (17.7% were motorcyclists)
Rizzi et al. (2011)	High	Estimated 3 lives saved annually in or 6% reduction in all types of fatal injury crashes if unregistered motorcycles are not permitted on the road	In-depth studies of 182 fatal motorcycle crashes in Sweden, 2005-2008
			Assessment made of whether countermeasure could have prevented the crash or mitigated the injury outcome based on in-depth analysis of each fatal crash and known potential of countermeasure to affect crash

			outcome
Road safety publicity			
Radin, Mackay & Hills (1996)	Low-medium	Reduction in conspicuity-related crashes by 29%	Detailed analysis of 4,958 conspicuity-related motorcycle crashes following a three month national campaign 'daytime running headlight' implemented in July 1992 to increase daytime headlight use in Malaysia. The campaign preceded introduction of compulsory DRL in September 1992

5. SUMMARY OF FINDINGS

The number of crashes and injuries to motorcyclists tend to be closely correlated with the size of the motorcycle fleet (with increases in the fleet accompanied by increases in injuries, as shown in Figure 1). The following summary focuses on aspects that might help focus programmes and policies to reduce injuries given expected changes to the motorcycle fleet and their increasing popularity amongst some groups.

This summary provides a guide as to the makeup of the "audience" of motorcyclists for publicity and programmes aimed at this group. Relevant aspects of crash and injury patterns are then outlined to highlight potential countermeasures that may be effective in addressing aspects of the crash problem. Finally, the literature on potential countermeasures is summarised to guide the next stage of the project, which is to list appropriate countermeasures to reduce New Zealand motorcycle crash rates, along with information to help prioritise a programme of countermeasures. A key criterion will be the demonstrated potential of the countermeasures to reduce crashes, which should be considered alongside barriers to their implementation and associated costs.

4.1 Ownership of motorcycles

Ownership patterns were studied to assist in programmes targeted to particular motorcycle owner groups. At the end of 2012, there were 150,422 motorcycles licensed. Since the year 2000, motorcycles new to the fleet have been predominantly very small (60cc and under: 32%) or very large (600cc and over: 39%). The motorcycle fleet as currently licensed in 2012 was considerably younger than the car fleet (Figure 3). In fact, more than half (55%) of motorcycles were manufactured since 2004; in comparison, only a quarter of licensed cars were manufactured since 2004. But there were also larger proportions of older motorcycles: 9% were over 30 years old compared to only 2% of cars. In general, higher annual distances were ridden by newer motorcycles and by larger engine capacity motorcycles. The dominance of newer motorcycles in the fleet presents an opportunity for newer technologies (e.g., braking technologies to benefit stopping distances and stability) to be introduced.

There are distinct groups of motorcycle owners according to the type of motorcycle owned. Generally, motorcycle owners tend to be male, particularly the owners of the large capacity motorcycles. Of all car owners, a little over 40% were owned by females. In comparison, 30% of moped owners were female and a mere 10% of motorcycle owners were female. Although motorcycles used to be favoured by young people, particularly young males, 73% of current motorcycle (including moped) owners were aged 40 plus. In comparison, 69% of car owners were aged over 40. Moped owners tended to be younger: only 57% were aged over 40. Generally as the size of the motorcycle increased, so did the proportion of owners who were male, and the average age of the owners also increased.

The licensing data were analysed according to the location of the owner's address, coded to Auckland (the four cities that constitute Auckland), other large main urban (greater Wellington, Hamilton, Christchurch, Dunedin, Tauranga), smaller main urban (Palmerston North, Levin, Napier, Hastings, Nelson, Gisborne, etc.), and the rest (mainly smaller towns and rural). When the engine capacity of the motorcycle was considered with respect to the owner's location (Figure 16), the larger motorcycles (over 250cc) were most likely to be located in smaller towns (in comparison with the other three geographical areas). Aucklanders did not favour motorcycles as much as other areas in general, but 27% of the moderately small motorcycles (60cc to 250cc) were owned by Aucklanders, a larger proportion than for any of the other engine capacity groupings shown. Of all motorcycle owners in small cities, towns or rural areas, approaching half (45%) owned large motorcycles (750 cc plus). Contrastingly, of all owners resident in large cities, including Auckland, 34%-35% owned these large motorcycles, and compared to motorcycle owners in the smaller centres, a considerably larger proportion owned motorcycles of size 250cc and under.

4.2 Crash patterns and trends

The proportion of road injuries and deaths that were motorcyclists peaked in the mid to late 1980s, dropped to a relatively low level in the early 2000s before increasing again to similar levels as seen in the mid-1990s (Figure 18). The recent rise in casualties can be seen to be almost solely due to increases for the age group 40 plus, whose casualties have trebled from a relatively static level in the 80s and 90s. Pillion passengers have constituted a steadily declining proportion of motorcyclist deaths and injuries since 1985, likely to be related to the decline in the proportion of all motorcycle casualties who were in the younger age groups.

Although riders aged 40 and over clearly dominate the casualties (almost half being from this age group: Table 1), their representation is nevertheless lower in terms of casualties than their motorcycle ownership levels would suggest. Although 40% of licensed motorcycles were large (750cc plus) (Figure 5), riders of these motorcycles constituted two thirds of all fatalities (Table 1). This can be explained by the much higher distances travelled by these motorcycles (Figure 4) and the much higher proportion of crashes on higher speed limit roads (Figure 27), where higher speeds lead to greater injury severity. Only 7% of motorcycles were owned by people aged under 25 (see Figure 6), but 26% of casualties were from this group (Table 1). The overrepresentation of this age group is common in all crash analyses and arises from a combination of inexperience and tendency to take risks that is often characteristic of this group. Although New Zealand already has graduated driver licensing restrictions on novice riders (who are mostly young), the safety benefits of this scheme may be enhanced by attaining better levels of compliance, achieved via enforcement and information campaigns. Most of the injuries to riders aged under 25 were minor, however, typical of their exposure to mainly urban speed limit environments (see Figure 30). Although protective gear has been shown to be effective in reducing the severity of motorcyclist injuries, increasing the use of this gear may be particularly beneficial for the riders of smaller motorcycles and scooters, who may currently wear little protection.

Over the period 1995 to 2012, small motorcycles had a large proportion of intersection crashes (an average of 52% of all small motorcycles compared to 31% of large motorcycles and 39% of cars). This arises from the mainly urban environments in which the smaller motorcycles are ridden. As car occupants are the best protected in crashes, an average of 20% of their crashes were fatal/serious compared to 25% for small motorcycles and 48% of large motorcycles. The much higher average severity for the larger motorcycles reflects the high proportion of riding on higher speed limit roads where the higher speeds lead to more severe outcomes on average. Only 6% of the small motorcycle crashes were in speed limit areas greater than 70km/h. In comparison, as shown in Figure 22, the proportion of crashes of larger motorcycles that were in higher speed limit areas increased from around 35% in 1995 to around 60% in 2012. Excess speed was considered a factor for only 3% of crashed small motorcycles and 10% of cars, but an average of 18% of the crash-involved large motorcycles. The increase in loss of control crashes for large motorcycles is particularly marked, which taken in the context of the high levels of excess speed and increasing rates of single vehicle crashes, at-fault crashes, crashes in higher speed limit areas and crashes when cornering, indicates that some fundamental changes in riding styles and/or favoured riding environments have been taken place over this period for the riders of larger motorcycles. Even controlling for the speed limit zone and the setting of the crash (at an intersection or otherwise), the larger motorcycles had a considerably higher fatal and serious injury rate in crashes than the other classes of motorcycles, which is likely to arise from higher speeds when crashing. There are recent trends of an increasing proportion of the larger motorcycles' crashes occurring in higher speed limit areas. This is an important trend when considering the high injury severities that tend to accompany higher speed limit crashes. These trends highlight the potential for technologies that assist in maintaining control of the motorcycle, particularly ABS and stability control. Although reductions in speeds will reduce crash severity and intelligent speed adaptation (ISA) could be fitted to motorcycles to enforce speed limit adherence, there is likely to be little support for this technology amongst motorcyclists, particularly if they are singled out relative to cars and trucks. A proven intervention that can reduce loss of control crashes and injuries is the identification of black spots or black lengths, where specific routes with high levels of motorcyclist injuries are then scrutinised by traffic engineers and subject to appropriate treatments to address particular environmental risks posed to motorcyclists. The treatments typically focus on preventing run-off-road and intersection crashes by: improving sight lines and delineation; controlling vehicle speed, improving the road surface; reducing the risk of crashes with fixed roadside objects; providing effective signage or controls; and managing traffic flows

Riding at night can present additional risks in terms of the visibility of motorcycles. However, recent trends show gradually lower levels of crash involvement after sunset and before sunrise, with lowest rates for large motorcycles. For large motorcycles, 80% of recent crashes were in daytime compared to 74% to 75% for the other classes of motorcycles. Relatedly, smaller motorcycles are much more likely to be owned by people aged under 30, who are also more likely to be riding at night. As multi-vehicle crashes happen more readily when there is a lot of traffic with resultant vehicle conflicts, it is not surprising that multi-vehicle motorcycle crashes were considerably more common during daytime than single vehicle crashes even when rider age was controlled for (Figure 25).

Crash-involved drivers and riders are adjudged to be primarily at-fault when their role in the crash clearly shows misjudgement or failure to adhere to the road rules that would have made a significant contribution to the crash occurrence. Considering all vehicles involved in motorcycle crashes (including cars crashing with motorcycles), primary responsibility generally diminished with increasing age of the rider or driver, although car drivers were adjudged primarily at fault in the majority of such crashes. Least at-fault were the riders of very small motorcycles. Car drivers in collisions with motorcycles very commonly failed to give way and did not see (or misjudged the speed of) the motorcycles. In urban areas, these errors were markedly more common than in car crashes with other cars. This indicates that motorcycles commonly present perceptual issues to car drivers, primarily in urban speed limit areas. These appear to be different for car collisions with small (under 60cc) and large motorcycles (750cc plus). The smaller motorcycles at intersections were more likely to be victims of car driver misjudgement/not seeing and failure to stop/give way than were larger motorcycles. At non-intersections in urban areas, larger motorcycles were somewhat more likely to be subject to these car driver errors. Although daytime running lights (DRLs) can help motorcyclists be more visible, the use of DRLs are already a legislated requirement for most motorcycles. Some aspects of car drivers' failure-to-see errors may be addressed by intersection treatments that provide better cues to traffic or regulate speeds. Some errors are likely to be caused by drivers expecting to give way only to cars and larger vehicles, visually scanning the road for these vehicles, while failing to apply these expectations to smaller vehicles such as motorcycles. It is unlikely that billboards exhorting drivers to look for motorcycles can improve such expectations, but if motorcycles become a more normal and expected part of traffic, the risk of failure-to-see errors may become correspondingly lower.

4.3 Literature review of interventions

4.3.1 SAFE VEHICLES - MOTORCYCLE

Countermeasures with demonstrated crash and or injury reductions

The literature review identified five vehicle based countermeasures with demonstrated safety benefits measured in terms of crash or injury severity reductions: day time running lights; anti-lock braking systems; stability/traction control; airbags; and alcohol interlocks. Daytime running lights and anti-lock brakes have been the focus of a much larger volume of research than the other systems and so estimates of their safety benefits are relatively more reliable at this stage.

<u>Daytime running lights</u>

Day time running lights are bright white or yellow forward-facing lights that improve the forward conspicuity of vehicles in the daytime. They are intended to increase the chance of other road users seeing the approach of the vehicle. DRL are a standard feature on many motorcycles, and have been made mandatory in a number of jurisdictions, including New Zealand. A substantial body of evidence has shown that DRL are effective in reducing daytime crashes for motorcyclists. However, their use has had mixed success in different countries (Muller et al. 1992; Wells et al., 2004; Attewell, 1996; Rossman & Ryan, 1996; Yuan, 2000; Zador, 1985), and studies with positive outcomes disagree over the size of crash and injury severity reductions (e.g., Paine, 2005; Wells et al., 2004; Radin-Umar et al., 1996).

Many of the inconsistencies reflect factors that have not been adequately controlled for in the study designs or analyses, including regional variations in motorcycle crashes, or factors such as changes in speed limits, police enforcement, and the possibility that motorcyclists who use their headlights may be more likely to engage in other safety-related behaviours as well. None of the studies on DRL have employed high quality designs (such as randomised control trials) which would eliminate most of these confounders. However, as pointed out by Helman et al (2012) a 'weight of evidence' approach can be taken in situations whereby generally consistent findings combined with plausible underlying mechanisms of effect are taken as an indication of the efficacy of a given intervention. For example, extensive laboratory studies and field trials have demonstrated that motorcycles equipped with DRL are more easily seen than motorcycles without such equipment (e.g., Dahlstedt, 1986; and see Helman et al. 2012 for a recent review). This finding is consistent with crash reductions likely to occur through increasing the visibility, search and attention conspicuity of motorcycles during the daytime.

As daytime headlamp use for motorcycles is already a legislated requirement in New Zealand, the effectiveness of DRL will be less important compared to other vehicle countermeasures. However, it is important to take account of methodological issues that will impact on any estimates of crash effects that occurred after the implementation of DRL legislation in New Zealand.

More recently, laboratory based and on-road field studies have been conducted to identify the most appropriate lighting configurations for increasing motorcycle conspicuity (e.g., Roger et al, 2012; Gould et al. 2012). On-road crash evaluations will be critical if and when these configurations are implemented and taken up in sufficiently large numbers by the motorcycling population. An important consideration in the use and design of DRLs is the possibility that any requirement for DRLs for *all* vehicles might diminish the safety benefits of lights for motorcycles (Paine, 2009; Wang, 2008).

Anti-lock brakes

Anti-lock brakes are designed to prevent motorcycle wheel lock-up and facilitate maximum deceleration during braking conditions. The systems have been subject to numerous evaluations, all of which have demonstrated generally consistent and substantial crash and injury reductions (Sporner & Kramlich, 2003; Gwehenberger et al., 2006; Baum et al., 2007 cited in Seiniger et al., 2012; Moore & Yan; 2009; Highway Loss Data Institute, 2009; Roll et al., 2009; Teoh, 2009; Rizzi et al., 2009; Swedish Transport Administration, 2010). In addition to crash evaluations, a growing number of studies conducted on closed test tracks have demonstrated that ABS can reduce motorcycle stopping distances by 5-10% and deceleration by 18-35% (Varyn & Winkelbauer, 2004). Green (2006) found that average stopping distances with ABS were 5-7% better than non-ABS equipped motorcycles, on both dry and wet roads. Similarly, Gail et al (2009) found that stopping distances were shorter with ABS than without, including when braking in a corner.

Stability/traction control, alcohol interlocks and air-bags

Stability/traction control is designed to assist a rider in maintaining control of the motorcycle through computer controlled modulation of the engine and accelerator inputs in an attempt to prevent traction levels from being exceeded. Alcohol interlocks work to prevent the operation of a motor vehicle by a person under the influence of drugs or alcohol. Air-bags are designed to reduce the deceleration experienced by a motorcycle rider during a crash and hence decrease the resultant chance of serious injury (Anderson et al., 2011).

These systems have received scant attention in the research literature, largely because their availability and or use on motorcycles are currently very low. The available evidence estimates relatively minimal crash savings (Anderson et al. 2011; Dreher, 1998 cited in Berg & Rücker, 2007; Swedish Transport Administration, 2010) however more research is needed to substantiate the findings.

A small number of simulation studies have demonstrated injury reductions associated with airbags on motorcycles, as well as airbags fitted to the inside of a jacket worn by the rider (e.g., Bellati, 2006; Thollon et al., 2009).

Countermeasures with potential for crash and or injury reductions

Some technologies and programs are still in development and as a result they have not been subjected to a level of evaluation that would allow a definitive statement about their effect on motorcycle trauma. Technologies and programs that fall into this category include: safety ratings for motorcycles; combined (linked) braking systems; collision/crash avoidance systems; and intelligent speed adaptation (ISA).

Other technologies such as leg protection devices and crumple zones have demonstrated mixed and/or negligible results, including in some studies an increased risk of injury when evaluated under crash test conditions (Sakamoto, 1990).

ISA is a system designed to electronically control a vehicle so that it complies with the prevailing speed limit. ISA systems are not common on motorcycles. They have theoretically been considered to have potential in preventing accidents in which speed has been the decisive reason for the accident. However, this assessment is highly uncertain, since no evaluations have been conducted following actual accidents (Trafikverket Swedish Transport Administration, 2012).

ISA has only been trialled on motorcycles using a test-track in Leeds in the UK (Carsten et al. 2008). The trial demonstrated both the technical feasibility of ISA on motorcycles and the potential for controlling excessive speed. However the ‘speed limiting’ function appears to provoke resistance amongst riders, making it a relatively unpopular countermeasure. In addition, it is not clear that ISA will not create safety dis-benefits for riders - there is potential that the system may disrupt the process of smooth, progressive power reduction that is fundamentally important for safe riding.

4.3.2 SAFE VEHICLES – OTHER ROAD USERS

Countermeasures with potential for crash and or injury reductions

Modifications to other vehicles may have the potential to reduce the number and extent of the types of injuries resulting from motorcycle-to-vehicle collisions or being run over after having been thrown from the motorcycle (Haworth & Mulvihill, 2007; Haworth et al., 2010). However, none of the vehicle based modifications identified in this review have been assessed for their impact on reducing motorcyclist crashes or injuries including: truck under-run protection; blind spot mirrors; lane change warning/blind spot warnings; and A-pillar design. There has been some research into the benefit of avoidance systems in other vehicles to prevent motorcycle crashes in Taiwan. Chen and colleagues (2005) investigated Side-Collision Avoidance Systems (SCAS) to test their effect on perception-reaction times in a simulator. They found that the audible beep given off by the system resulted in significantly faster perception-reaction times reducing the likelihood of an accident with another vehicle. Whilst this simulation study provides some evidence for a collision avoidance system such measures need considerably more evaluation (Haworth & Mulvihill, 2007; Haworth et al., 2010).

4.3.3 SAFE SPEEDS

Measures designed to reduce crash and injury reductions associated with speeding include enforcement, publicity, motorcycle rider licensing and training, and speed management technology including ISA. With the exception of speed management technology which is discussed under ‘Safe Vehicles’ these countermeasures are addressed under ‘Safe Road Users’ (See Section 6).

4.3.4 SAFE ROADS AND ROADSIDES

Countermeasures with demonstrated crash and or injury reductions

The literature review identified three road or roadside based countermeasures with demonstrated safety benefits measured in terms of crash or injury severity reductions: black-spot treatments; road side barriers; and use of 'motorcycle only' lanes. While all three countermeasures have been the focus of limited research, black-spot treatments have demonstrated the strongest and most consistent evidence in terms of crash and injury reductions.

Black-spot or black-length treatments

Victoria has implemented the most extensive program of treating locations where multiple motorcycle crashes have occurred. These hazardous locations are commonly termed black-spots (individual sites) or black-lengths (lengths of road) (Scully et al., 2008). The treatments typically focus on preventing run-off-road and intersection crashes by: improving sight lines and delineation; controlling vehicle speed, improving the road surface; reducing the risk of crashes with fixed roadside objects; providing effective signage or controls, and managing traffic flows (Brennan & Beer, 2007). Evaluations of motorcycle black-spots over the past 10 years in Victoria have consistently shown crash and injury reductions for motorcyclists and other road users (Scully et al., 2006; Scully et al., 2008).

Roadside barriers

Roadside safety barriers are used to prevent vehicles from veering off the road into oncoming traffic, from crashing into roadside obstacles (such as trees, light posts, culverts etc) or from driving into ravines or gullies. The mechanism by which a barrier slows a vehicle down or prevents it from colliding with another object depends on its construction (Road Safety Committee, 2012). In Australia, for example, there are three types of barriers: steel beam barriers, concrete barriers, and wire rope safety barriers (WRSB).

While safety barriers have significantly reduced fatalities and serious casualties for car occupants, the limited research into their effects on motorcyclists has generally shown inconsistent results. The low number of motorcycle crashes involving barriers does not allow a conclusive analysis of their safety benefits or dis-benefits. Analysis of data from the National Coroners Information System and New Zealand Crash Analysis System by Grzebieta et al. (2011) shows that rider crashes into barriers represent about 6% of all motorcycle fatalities in Australia and only 2% in New Zealand.

Wire rope safety barriers (WRSB)

WRSB have the potential to present different and more serious risks to motorcyclists compared to occupants of other vehicles, and most motorcyclists are highly opposed to their use. While evidence suggests that WRSB are involved in more fatal motorcycle collisions than other types of barrier (Bambach, Grzebieta & McIntosh, 2010), they are involved in fewer motorcycle crashes, fatalities and serious injuries than other fixed objects (Bambach, Mitchell & Grzebieta, 2012). Collisions with fixed objects such as trees are more harmful to motorcyclists than collisions with barriers (Daniello & Gabler, 2011).

Jama, Grzebieta, Friswell & McIntosh (2011) found that 6% of the 1,462 motorcycle fatalities in Australia and New Zealand between 2001 and 2006 involved a collision with a barrier. Of the 6% of fatalities, WRSB accounted for 7.8% of all deaths, or three cases. Comparisons of the safety performance of WRSB with other types of barrier systems for motorcyclists are limited (EuroRAP, 2008).

Research (e.g. EuroRAP, 2008; AustRoads, 2012) has started to focus on the protective effect of re-designing or retro-fitting safety barriers to make them more forgiving to motorcyclists in the event of a collision (e.g. such as placing padding over the posts of wire rope safety barriers). These types of countermeasures show high potential. For example, the implementation of barrier protectors in South Australia by Anderson, Dua & Sapkota (2012) has shown positive crash outcomes to date, although it is too early to draw firm conclusions about the results.

Use of motorcycle only lanes

Motorcycle only lanes exist only in Malaysia where they have been used since the 1970s. While the crash reductions have been impressive, the results may not generalise to developed countries where motorcycle use and crash types are vastly different. Consequently, investment in separate lanes for motorcycles is likely to be much less cost effective in developed countries where motorcycle transport represents a much lower proportion of travel than in Asian countries.

Countermeasures with potential for crash and or injury reductions

A number of road based countermeasures have potential for crash and injury reductions but have not yet been evaluated (or have been the focus of very few evaluations). These include: use of bus lanes to accommodate motorcyclists; rating roads for motorcyclist safety; and engineering treatments associated with designing, building and maintaining roads with motorcyclists in mind including delineation, road surface; restricting or relocating roadside furniture, road curvature and intersection design.

Only two evaluations have examined the crash effects of permitting motorcyclists to use bus lanes. This is not surprising because the practice is relatively new in some jurisdictions or does not exist at all. To date, there is no evidence that crashes or injuries have changed following implementation or trial of this countermeasure (York et al., 2011; Newcombe & Wilson, 2010), although if implemented with appropriate enforcement and education, there is potential for safety benefits. Further research is required before conclusive outcomes can be established.

Ratings roads to improve motorcyclist safety is modelled on the approach taken to improve the safety of roads for all users (Daniello, Swanseen, Mehta & Gabler, 2010). However, since the approach taken for all road users is generally dictated by the requirements of four wheeled vehicles, a motorcycle road rating system has greater potential to account for the unique needs of riders and their greater crash and injury risk. Development of a motorcycle road assessment program has potential to improve motorcycle safety by warning riders to take extra caution in hazardous areas or to avoid the areas altogether (Daniello et al., 2010). However the concept is still under development and so no evaluations have been conducted.

In Victoria, engineering based treatments are generally addressed under the motorcycle black-spot and black-length programs. However, individual treatments (such as improving delineation, road surface etc) have not been examined for their contribution to the overall crash and injury reductions achieved by the program. As such it is not possible to ascertain the effects of these treatments in isolation.

4.3.5 SAFE ROAD USERS

Countermeasures with demonstrated crash and or injury reductions

The literature review identified three road user countermeasures with demonstrated safety benefits measured in terms of crash or injury severity reductions: motorcycle protective clothing; graduated licensing; and penalties and enforcement.

Protective gear

Protective gear is a blanket phrase that consists of protective clothing, protective boots, gloves and body armour. Protective gear has an important role in motorcycle safety both before and after a crash. Its primary function is to lessen the severity of injury in the event of a crash and, in some minor crashes, to prevent injury altogether (Road Safety Committee, 2012). Boots, gloves and protective clothing provide an important barrier between a rider's skin and the road surface which can work to reduce abrasion wounds and the risk of contamination where the barrier is broken. Body armour acts to reduce injuries by absorbing the energy of an impact and spreading it across a wider surface area and at a rate that is less damaging to the rider (Road Safety Committee, 2012). Although protective clothing cannot prevent injuries such as fractures in a high-impact crash, most motorcycle crashes occur at low speed. For example, the Motorcycle Accident In-Depth Study - MAIDS found that 75% of all motorcycle crashes occurred at speeds lower than 56 km/h (ACEM, 2004).

Protective gear also offers protection from the weather and, in some cases, provides increased conspicuity. Protection from the elements can contribute to rider safety by reducing the effects of dehydration and physiological stress which can increase crash risk. The symptoms of physiological stress include distraction, loss of sensation and thereby operational control, dulled responses and reaction times, impaired motor responses and fatigue (Woods, 1986, EEVC, 1993). Protective clothing has the potential to increase riders' visibility to other motorists. Failure to see the motorcyclist was the primary contributing factor in 37% of all motorcycle crashes investigated in the MAIDS (ACEM, 2004). Although the researchers found no apparent contribution of garments to the conspicuity of the rider in 65% of crashes, they did report that dull or dark clothing may have decreased conspicuity in 13% of cases.

The benefits of protective clothing for motorcyclists have been documented in research since at least the 1970s (Feldkamp & Junghanns, 1976; Zettas & Zettas, 1979; Hurt, Oullet & Wagner, 1981; Pegg & Mayze, 1983; Schuller, Beier & Spann, 1982; 1986; Hell & Lob, 1993; Otte, Schroeder & Richter, 2002; ACEM, 2004). Although protective gear was less specialised at the time that many of these early studies were conducted, recent research has confirmed its benefits in crashes over the past decade, with evidence indicating that it can reduce soft tissue injuries (Aldman et al., deRome et al., 2011), open wounds (McIntyre et al., 2011); cuts and abrasions, friction burns, the stripping away of muscle, and contamination of wounds (deRome et al., 2006). Motorcycle riders wearing protective gear are less likely to be admitted to hospital (de Rome et al., 2011) and spend less time in hospital (Schuller, Beir & Spann, 1986; McIntyre et al., 2011; de Rome et al., 2012) compared to riders wearing no or very little protective gear. More recently, deRome et al. (2012) found that motorcyclists wearing partial or full protective gear were more likely to be fully recovered six months after their crash and returned to pre-crash work than riders who were not wearing protective gear.

Graduated licensing

Graduated licensing targets factors associated with age and inexperience that are known to contribute to young novice rider crash risk (Haworth et al., 2007). The system allows novices to gain their initial riding experience under conditions of lower risk before being introduced to more complex riding situations at full licensure. The licensing structure and restrictions vary across jurisdictions but most typically include a restricted period with limits on: consumption of alcohol; type and size of the motorcycle; and minimum age and time periods for holding a learner or restricted licence.

Graduated licensing for motorcyclists exists in all states of Australia, in New Zealand and some states in the US. Although studies exploring the effectiveness of GLS for motorcyclists are scarce and tend to suffer from methodological limitations, the few that have been conducted have generally shown positive safety benefits, particularly for motorcyclists in the youngest age groups (McGwin et al., 2004; Reeder et al., 1999). A recent study examined the impact of relaxed licensing requirements for driving light motorcycles in Spain (Perez et al., 2009). Allowing car drivers to ride motorcycles without passing a licence test was associated with an increase in the number of motorcycle rider injuries. Unfortunately, the relative contribution of individual components of successful GLS systems on crash outcomes has not yet been investigated.

Although few evaluations of GLS exist for motorcyclists, GLS has potential to be a highly effective countermeasure. This is particularly likely when coupled with high levels of enforcement, and in those jurisdictions willing to implement and enforce more stringent conditions or restrictions (such as a higher minimum age to obtain a learner permit and restrictions on night riding and carriage of pillion passengers).

Penalties and enforcement

There was very little research on the impact of penalties and enforcement in reducing crashes due to unsafe behaviours in motorcyclists specifically, such as speeding, drink-riding, unlicensed and unregistered riding or other unsafe behaviours such as lane splitting. While much of the available research has focussed on all road users combined, Christie et al. (2003) and French et al. (2009) found that speed camera networks were effective in reducing non-fatal injuries in motorcyclists, whilst Villaveces et al (2003) found reductions in motorcycle death rates following implementation of laws criminalising blood alcohol concentrations of 0.08% and above. Rizzi et al. (2011) recently estimated that three lives per year could be saved in Sweden if unregistered motorcycles were banned from travelling on the roads. In Spain, Novoa et al. (2011) found a significant reduction in the number of male motorcyclists fatally and seriously injured and in the number of female motorcyclists injured following implementation of new laws to criminalise offences including speeding, drink-driving and risky riding behaviours. Unfortunately the authors did not determine the impact on crashes of each of the different types of offences; and the exact circumstances under which an offender could be imprisoned were not clear. These limitations make it difficult to apply the results to the system of traffic enforcement and penalties in New Zealand.

Despite the limited research in this area, it is widely known that enforcement coupled with a high level of publicity and education is effective in reducing speed and alcohol related crashes involving all road users. As such, enforcement countermeasures targeting unsafe behaviours in motorcyclists have potential to achieve crash and injury reductions.

Countermeasures with potential for crash and or injury reductions

Training

As less riding experience is monotonically associated with a higher risk of motorcycle crashes and injuries (e.g Groeger, 2001; Ballesteros & Dischinger, 2002) training is a popular countermeasure aiming to reduce motorcycle rider trauma and to help bridge the gap between the skills of a novice and experienced rider. Although training is encouraged and is compulsory in most jurisdictions, its efficacy in achieving crash reductions has not been well established for motorcycle riders (see Karamanidis; Martinuik, Ivers et al., 2010) (or for car drivers). However it is likely that some form of training is necessary to teach motorcyclists basic vehicle handling skills and to ride a motorcycle safely.

Evidence suggests that voluntary motorcycle training does not reduce crashes and in many cases seems to increase crash risk. Compulsory training, on the other hand, has weak evidence to support a reduction in crashes (e.g., TOI, 2003; French, 2009). It is suggested that increased confidence of riders who voluntarily complete training may explain the potential increase in crash risk.

Two possible explanations for the lack of a demonstrated effect of training on crashes and safety are that the content, amount and or delivery style of current training programs is ineffective, and/or that there are limitations in the research used to evaluate training programs. Less is known about the first explanation. Improvements to rider training programs have recently become the focus of further investigation however at the time of writing; evaluations of these programs will not be available for at least another year (Ivers et al, personal communication, 2013). A recent Cochrane review of motorcycle training confirmed the lack of quality evaluation studies in the area (Kardamanidis, Martiniuk, Ivers, Stevenson, Thistlethwaite, 2010), making it difficult to provide recommendations about a best practice system for motorcycle rider training. The poor quality of training evaluations to date likely reflects the relatively high level of resources required to conduct research of this type.

Simpson and Mayhew (1990) also point out that most evaluations of training programs analyse only the number of crashes and that if severity and type of crash were examined as well, positive effects might be found. For example, a rider may avoid an obstacle and slide or fall off as opposed to crashing into the obstacle. This would indicate heightened hazard perception ability, but lack of practice in avoidance actions. While number of crashes is the ultimate assessment of improved rider ability, some weighting of the crash based on severity as measured by injury (e.g. number of days of hospitalisation) may be more appropriate.

At this stage, it is not recommended that training (particularly pre-licence training) be omitted from licensing systems or that riders be discouraged from taking part in training. However there is an urgent need for research to establish the most effective type of training to reduce motorcycle rider trauma.

Road safety publicity

The review identified very little research on the effectiveness of motorcycle safety publicity on crash and injury outcomes despite widespread use of the countermeasure. For example, Haworth & Greig (2007) identified 125 motorcycle safety programs operating in Australia and New Zealand, of which just under 30% used advertising or educational materials. They found that only 4% and 1.6% of all programs had been subjected to an outcome evaluation or a process evaluation respectively. However, the authors did not describe the results of the outcome evaluations, making it difficult to identify which programs have been beneficial. This is an unfortunate characteristic shared by larger-scale motorcycle safety programs both in Australia and internationally.

4.4 Formulation of Packages of Countermeasures

4.4.1 Introduction

Stage 4 builds on Stage 3 (Assessment of Available Countermeasures against the PTW Crash Population) by adding cost data to the analysis to estimate the likely economic worth of each countermeasure considered. Economic worth is derived by considering the value of the crash savings derived from the countermeasure over its useful life against the cost of implementing the countermeasure.

Once economic worth of each relevant countermeasure has been estimated, the next phase of the proposed project is to examine the cost effectiveness of various packages of countermeasures in which the motorcycle safety levy might be invested. This component would be carried out in close consultation with the ACC and the Motorcycle Safety Levy Advisory Council. Consultation would involve the level of investment proposed and the specific mix of countermeasures of interest which could be informed by the Stage 1-3 analysis results. Using the economic analysis and the level of safety levy expenditure proposed, the analysis would examine the likely crash cost and ACC claims reductions of various suites of countermeasures. The general aim of the analysis would be to identify packages of countermeasures that resulted in the highest trauma reductions for the funding available and constrained by the types of countermeasures supported or deemed feasible in the New Zealand environment.

4.4.2 Victorian study of motorcycle black spot, black length and long route treatments

In 2003 the Victorian Government announced that funds collected from the Motorcycle Safety Levy would be used for the implementation of a Motorcycle Blackspot Programme. This program involved the treatment of sites or sections of the road network with high rates of crashes involving motorcyclists. The programme differed from previous blackspot programmes as it was designed with motorcycle safety specifically in mind. The programme consisted of three components: treatments aimed at addressing run-off-road type crashes; intersection treatments; and long route treatments. The first two components were employed either at a discrete location (i.e. a blackspot) or along a length of road (i.e. a black length). Long route treatments were intended to provide consistency along the whole length of high-risk motorcycle routes (Scully et al, 2008).

The predicted benefits of proposed treatments with respect to motorcycle crashes only were also used to prioritise which sites were treated. For run-off-road and intersection treatments, sites that posed a high-risk for motorcyclists were identified through detailed crash analysis and detailed reviews of crashes and sites by experienced motorcyclists. The types of work completed as part of the long route treatments used a mass action approach to reduce crashes and injuries along a high-risk road by implementing engineering treatments along the whole length. In the Motorcycle Blackspot Program, these treatments aimed to make the conditions, delineation and warnings along the route more consistent to make riding along the route more predictable for motorcyclists and reducing points where they encounter unexpected hazards or features in the road environment.

4.4.3 The current analysis

ACC cost data

ACC provided total, mean and median costs and total claims made to date for motorcyclist injuries linked to CAS data for the years 2008 and 2009. These were provided in three tables: CAS injury severity by cc rating of motorcycle; CAS injury severity by age group of claimant; CAS injury severity by road category of injury site. Although it had been anticipated that on-going costs might have been able to have been estimated (all other things being equal) from the mean claim costs per injury comparing 2008 and 2009 (with an expectation that 2008 mean costs would be higher than 2009 costs because of the extra year available for on-going costs to accumulate), in fact 2009 costs were higher on average than 2008 costs ($27,400 compared to $26,000). Various factors could have led to such a difference, including increased costs for compensation and medical care, or differences in injury severities between years. To keep the analysis simple, the mean costs for the pooled 2009 and 2008 claims data were used to provide an approximate value per claim, adjusted for inflation to 2013 dollars using the Consumer Price Index change from the year when the crash occurred to 2013.

Table 3, Table 4 and Table 5 show average costs per motorcyclist ACC injury claimed to date for 2008 and 2009, by CAS injury severity level and claimant age, engine size and road classification of the crash site respectively. Clearly, the CAS injury severity provides the strongest predictor of ACC claims costs, with the overall average costs for Fatal, Serious and Minor injuries being around $87K, $56K and $6K respectively (Table 3). There is also an association between claimant age and claims costs. Even within CAS severity levels, costs generally are higher for middle-aged claimants than for claimants aged under 25 (Table 3). Claims costs by motorcycle engine size (Table 4) will be influenced by rider age to some extent, and also by the speed limit of the crash site, as the larger motorcycles are favoured by riders aged 40 plus, and these motorcycles are ridden (and crashed) with greater frequency on roads with rural speed limit. Generally costs were higher for the larger motorcycles. It is likely that some unusually expensive claims may have boosted the average for the motorcycles of capacity below 60cc, but for privacy reasons individual-level data (or data for cells with fewer than three claims) were not available for analysis. Apart from fatal injuries, claim costs were higher for the higher speed limit roads (the “open” roads in Table 5). This is likely to arise from the generally higher speeds on such roads, which result in more severe injuries, even within the CAS injury severity classes.

Table 3: Average cost per motorcyclist ACC claim to date for 2008 and 2009, by claimant age and CAS injury severity level

Claimant age:	19 years or under	20-24 years	25-29 years	30-39 years	40 years or more	Overall average cost	Total claims
Fatal	$5,400	$29,890	$86,757	$135,614	$86,798	$87,334	95
Serious	$36,150	$17,094	$58,315	$41,708	$74,140	$56,138	802
Minor	$2,108	$4,325	$3,624	$9,224	$7,849	$6,344	1164
Overall average cost	$11,938	$9,737	$28,418	$29,785	$39,548	$29,240	
Total claims	264	266	187	421	939		2,077

Table 4: Average cost per motorcyclist ACC claim to date for 2008 and 2009, by engine size and CAS injury severity level

Engine size:	Up to 59cc	60 to 250cc	251-749cc	750 cc or more
Fatal	-	$52,408	$77,458	$111,772
Serious	$91,047	$29,976	$47,772	$68,868
Minor	$4,843	$3,394	$8,433	$8,464
Overall average cost	$30,764	$13,756	$27,415	$39,816
Total claims	63	561	275	949

Table 5: Average cost per motorcyclist ACC claim to date for 2008 and 2009, by crash site and CAS injury severity level

Crash site:	Major urban road	Minor urban road	Open Road, State highway	Other open road	Motorway	Car parks / off road	Unknown
Fatal	$26,232	$152,999	$79,408	$101,280	-	-	-
Serious	$46,805	$33,769	$65,461	$82,986	$36,445	$19,002	$15,667
Minor	$6,076	$4,674	$8,249	$9,695	$2,632	$4,146	$2,845
Overall average cost	$19,050	$17,550	$41,298	$51,485	$9,157	-	$9,666
Total claims	455	486	406	474	57	135	47

Table 6: Percentage of annual cost from motorcyclist ACC claims to date for 2008 and 2009, claimant age and CAS injury severity level

Claimant age:	19 years or under	20-24 years	25-29 years	30-39 years	40 years or more	TOTAL
Fatal	0.2%	0.5%	1.6%	5.8%	5.6%	13.7%
Serious	4.4%	2.5%	6.5%	11.5%	49.2%	74.1%
Minor	0.6%	1.2%	0.6%	3.4%	6.3%	12.2%
TOTAL	5.2%	4.3%	8.8%	20.6%	61.1%	100.0%

Table 6 shows the proportion of annual ACC claim costs from the 2008 and 2009 motorcyclist data linked to CAS crash data by the age of the claimant and the CAS injury severity level. Clearly, serious injuries (as defined in the CAS data) account for by far the greatest proportion of ACC claims cost. More than 80% of claims costs arise from injuries to motorcyclists aged 30 plus.

Table 7 shows a number of routes identified with high concentrations of motorcycle crashes. The routes with the highest levels of social cost per kilometre of road are at the top. In general, those routes with the highest concentration of social cost also have high concentration of claims costs. These estimated claims costs were not based on the actual claims but on the data shown in Table 3, which provide a basis for estimating the costs of claims (in 2013 dollars) from the CAS injury severity level of the injured motorcyclist and the motorcyclist’s age.

Table 7: Road sections with high levels of social cost ($millions) per km, with estimated claims costs ($thousands) and claims costs per km

Number	Route	Start	End	Length	Fatal	Serious	%Mid-block	Social cost ($M)	Social cost($M) / km	Claims costs ($K)	Claims costs($K) / km
1	SH 2	Lower Hutt (≥174.892°)	Featherston (≤175.3230°)	48.5	10	69	85%	$68	$1.40	$4,827	$100
2	SH 1N	Auckland, Beaumont St (≥-36.8443°)	Unsworth Heights (≤-36.7508°)	12	2	16	94%	$16	$1.32	$1,765	$147
3	SH 17	Albany (≥-36.727°)	SH 1N (≤-36.6246°)	16	3	12	73%	$17	$1.04	$1,074	$67
4	SH 22, SH 1N	Start of SH 22, SH 1N (≥-37.1387°)	Alfriston Rd (≤-37.0145°)	18	3	16	63%	$19	$1.03	$540	$30
5	SH 2	Tauranga (≥-37.7037°)	Waihi (≤-37.3963°)	53	6	25	52%	$34	$0.64	$2,696	$51
6	SH 2	SH 1N (≥-37.289°, ≥175.016°)	SH 25 (≤-37.211°, ≤175.342°)	33	4	8	83%	$19	$0.57	$1,127	$34
7	SH 16	Kahikatea Flat Rd (≥-36.625°)	SH 1N (≤-36.296°)	47	4	19	87%	$23	$0.49	$1,724	$37
8	SH 3/SH 2	Palmerston North (≤-40.341°, 175.647°)	SH 50 (≤-40.021°, 176.324°)	82	7	15	95%	$33	$0.40	$1,177	$14
9	SH 1N	Silverdale @ SH 17 (≥-36.6245°)	SH 14 (≤-35.732°)	127	9	37	80%	$50	$0.40	$4,643	$37
10	SH 25A	full length		27	2	7	100%	$11	$0.40	$768	$28
11	SH 16	Te Atatu Road (≥-36.8581°)	Kahikatea Flat Rd (≤-36.625°)	46	2	20	68%	$17	$0.36	$2,082	$45
12	SH 1N	Wellington, Kaiwharawhara (≥-41.260°)	Bulls (≤-40.175°)	145	6	60	82%	$49	$0.34	$6,598	$46
13	SH 23	Raglan (≥174.891°)	Whatawhata (≤175.1535°)	29.5	1	12	85%	$9	$0.30	$793	$27
14	SH 3	New Plymouth (≥-39.0440°)	Te Kuiti (≤-38.3388°)	157	9	28	78%	$46	$0.29	$3,531	$22
15	SH 3	Palmerston North (≤-40.333°)	New Plymouth (≤-39.0738°)	227	11	44	65%	$61	$0.27	$4,677	$21
16	SH 25	full length		230	9	54	90%	$57	$0.25	$4,781	$21
17	SH 50	full length		88	3	23	92%	$21	$0.24	$2,295	$26

Number	Route	Start	End	Length	Fatal	Serious	%Mid-block	Social cost ($M)	Social cost($M) / km	Claims costs ($K)	Claims costs($K) / km
18	SH 1S	SH 7 (≥-43.064°)	Kaikoura (≤-42.412°)	122	5	20	84%	$28	$0.23	$2,133	$17
19	SH 6	Greymouth (≥-42.4455°)	Richmond (≤-41.345°)	292	12	46	79%	$65	$0.22	$5,426	$19
20	SH 29	SH 27 (≥175.776°)	SH 2 (≤176.225°)	54	1	20	71%	$12	$0.23	$2,076	$38
21	SH 5	Taupo (≥176.113°)	SH 2 (≤176.871°)	121	5	18	83%	$27	$0.22	$2,153	$18
22	SH 41	full length (≥175.335°)	≤175.802°	58	2	10	100%	$12	$0.20	$1,167	$20
23	SH 45	full length		99	3	20	78%	$20	$0.20	$2,355	$24

Table 8: Interventions with measured efficacy in the literature, with range of benefits in terms of monetised injuries prevented (social cost and estimated claims cost) with estimated break-even costs that could be borne by the intervention to meet the benefits.

		Total benefits $million per year				Break-even costs			
		Social cost		Estimated claims		Social cost		Estimated claims	
Intervention	**Estimated reduction**	**lower**	**upper**	**lower**	**upper**	**lower**	**upper**	**lower**	**upper**
Anti-lock brakes	24-38% all injury	$86.52	$137.00	$7.83	$12.40	$5,663	$8,967	$512	$811
Motorcycle traction/stability control	15% fatal injury	$26.32	$54.08	$2.32	$18.58	$1,723	$3,540	$152	$1,216
Alcohol interlocks	15% fatal	$26.32	$54.08	$2.32	$18.58	$1,723	$3,540	$152	$1,216
Vehicle test approvals	4% fatal	$7.02	$14.42	$0.62	$4.96	$43	$89	$4	$31
Anti-theft devices	6% fatal	$10.53	$21.63	$0.93	$7.43	$689	$1,416	$61	$487
Black-spots or black-lengths 23 sites	16% all	$14.23		$1.21		$140M**		$12M**	
Black-spots or black-lengths top 10 sites	16% all	$5.78		$0.41		$57M***		$4M***	
Guard rails	65% serious trees; 47% serious poles	$4.74		$0.63		$47M		$6M	
Protective gear*	23% minor jacket	$0.74		$0.21		$188		$55	
	45% minor gloves	$1.05		$0.30		$368		$107	
	39% minor pants	$4.64		$1.35		$319		$93	
	45% minor boots	$6.10		$1.77		$368		$107	
	6% fatal full protection	$7.80	$16.03	$0.18	$1.45	$471	$968	$11	$88
Penalties and enforcement	6% fatal	$10.53	$21.63	$0.24	$1.96	$103M	$212M	$2M	$19M

*adjusted for estimated prevalence of wearing: jackets (82.5%), pants (34.9%) or gloves (87.3%) boots (worn by 25.9%) according to a study in the ACT (De Rome, Ivers, Fitzharris et al., 2011). The non-wearing rate for "full protection" was arbitrarily taken to be 74.1%, as for boots.

** break-even costs per km treated are $65,500 and $5,600 in terms of social costs and estimated claims costs respectively

***break-even costs per km treated are $122,500 and $8,600 in terms of social costs and estimated claims costs respectively

4.4.4 Economic evaluation of potential interventions

Table 8 shows summarised information on interventions with measured efficacy in the literature, including the range of benefits in terms of monetised injuries prevented (social cost and estimated claims cost) with estimated break-even costs that could be borne by the intervention without exceeding the benefits. Lower and upper estimates of benefits and break-even costs are provided where the literature provides a range or where the estimated benefit was only stated in terms of fatalities prevented. As these interventions would certainly prevent at least some injuries of lower severity, the upper limit used here includes reductions to the other severity levels to the same extent as estimated for the fatalities.

The motorcyclist injury data on which the estimated benefits were based are CAS data on all motorcyclist injuries over the period 2008-2012. Annual savings per year were estimated by applying the effectiveness estimates from the literature (in column 2 of Table 8) to the average annual rate of injuries over this period. The break-even costs are firstly presented in terms of social costs and then in terms of estimated claims costs. This provides a societal perspective on the benefits (the social costs) as well as an ACC-centric perspective (purely costs to the organisation in terms of claims costs). The break-even costs were derived from the estimated benefits at the average rate for 2008-2012 using the present value at an 8% discount rate. For those interventions that incur a one-off cost and which have an effective life of approximately 20 years, discounted benefits were aggregated over a 20-year period. Such interventions include technologies such as: anti-lock brakes; motorcycle traction/stability control; alcohol interlocks; anti-theft devices; black-spots or black-lengths; guard rails.

4.4.5 Discussion

The following section discusses each of the potential interventions in terms of benefits and costs. As the costs of these measures are likely to be borne mainly by central government and/or by individuals, the discussion of benefits mainly centres on the social costs rather than the costs of ACC claims. A measure is cost-beneficial if the costs are less than the break-even level stated in Table 8. Note that some technologies or interventions may overlap in terms of their safety effects, meaning that the benefits of two safety measures applied together may not equal the sum of the benefits of the two measures individually.

Anti-lock brakes (ABS)

The costs of ABS as an additional feature on a BMW motorcycle have been estimated at around $AU 1,000 (Anderson et al, 2010), orders of magnitude less than even the lower estimated break-even social cost of $5,663. This technology is therefore clearly cost-beneficial using this criterion. ABS is likely to be most beneficial for motorcycles with high fatality rates, such as larger motorcycles.

Motorcycle traction/stability control

The costs of stability control as an additional feature on a BMW motorcycle have been estimated at around $AU 1,200 (Anderson et al, 2010), less than the lower estimated break-even social cost of $1,723. As larger motorcycles have high rates of loss-of-control crashes, this technology is particularly suited to these motorcycles.

Alcohol interlocks

As noted by Anderson (2010), alcohol interlocks are not available in cars either optionally or as standard fitment, and certainly not in motorcycles. Costs of retrofitting a hand-held breath-alcohol analyser attached to a vehicle's ignition system are likely to be around $AU 1,500, which lies below the lower estimate of the social cost benefits and can therefore be considered cost-beneficial. The most likely barrier to their widespread adoption is consumer resistance: motorcyclists will not generally wish to pay for a device that yields little apparent benefit to them personally.

Vehicle test approvals

Using the estimates from Rizzi et al. (2011), the warrant of fitness regime currently used in New Zealand would be estimated to justify per motorcycle only $43-$89 in terms of social cost annually. This clearly is less than the current costs of the scheme as borne by the motorcyclist in terms of the costs of the inspections and the time and travel involved in attending the inspections. It would be worthwhile to investigate the likely safety benefits of this scheme using local data, as was done recently in the case of the warrant of fitness scheme for cars (Keall and Newstead, 2013). It is possible that New Zealand road conditions demand a higher degree of roadworthiness for motorcycles than Swedish conditions, which was the setting of the one study that estimated the social cost benefits for this measure (Rizzi et al., 2011).

Anti-theft devices

Anti-theft devices can be purchased as accessories relatively cheaply, costing around $200 for an alarm disc lock, for example. Such devices will therefore be highly cost-effective.

Black-spots or black-lengths

Break-even costs per km treated were $65,500 in terms of social costs for the 23 routes identified, and $122,500 for the 10 routes with the highest injury rates. The costs of treating these lengths of road need to be determined by detailed examination by traffic engineers of the features imposing greater risk for motorcyclists, which is outside the scope of the current project. It should be noted that treating the lengths of road in Victoria with a view to increasing motorcycle safety also yielded significant safety benefits to other road users (Scully et al, 2008), so it would make sense to pool resources from different funders (NZTA, ACC, motorcycle levy funds) to reflect the range of expected benefits to motorists generally, to ACC claims, and to motorcyclists.

Guard rails

Some form of black-spot analysis is required to identify sites with concentrations of motorcycle injuries from collisions with posts, poles and trees. Although expenditure of $47 million would be justified, guard rails are expensive to install, so these treatments need to be carefully targeted, and may form part of the treatment of black spots and lengths in the previous paragraph.

Protective gear

The break-even costs for protective gear are based on a cost per licensed motorcycle for motorcyclists not estimated to be wearing the gear, assuming a 10-year lifetime for the gear. So social cost considerations would suggest that $188 was justified to be spent on a jacket in terms of predicted benefits of injuries prevented. Interventions to encourage the wearing of protective gear would logically involve information campaigns to change motorcyclists' attitudes. The entire motorcycling population would be a target audience for such a campaign, although the campaign should be informed by further research, including on-road surveys of the use of such gear, and interviews with motorcyclists to identify barriers.

Penalties and enforcement

The costs associated with increased penalties for infringements and/or higher levels of enforcement tend to be associated with increased Police resources. In general, enforcement will bring benefits to multiple road users, not just to motorcyclists, so a pooling of funds from different sources would be justified to meet increased costs. The graduated licensing conditions for motorcyclists may currently have a relatively low level of compliance if the results of a recent study on (mainly) car drivers can be extrapolated to motorcyclists (Brookland et al, 2013). Increased enforcement can therefore yield safety benefits via increased compliance for novice motorcyclists.

6. CONCLUSIONS

5.1 General conclusions

As for other road user groups, young people have the highest crash risk. Only 7% of motorcycles were owned by people aged under 25, but 26% of casualties were from this group. Most of the injuries to riders aged under 25 were minor, however, typical of their exposure to mainly urban speed limit environments. Recent trends in the motorcycle fleet are for there to be growing numbers of small motorcycles/mopeds and large motorcycles (750cc plus). These two classes of motorcycles have quite different crash patterns, are ridden in different environments, and are owned by different sorts of owners. The motorcycles in between gradually take on the crash and ownership characteristics of the larger motorcycles as the engine size increases.

5.2 Large motorcycles

Generally as the size of the motorcycle increased, so did the proportion of owners who were male, and the average age of the owners also increased. Larger motorcycles have much higher rates of ownership by older people (aged 40 plus) and are owned almost exclusively by males. When the engine capacity of the motorcycle was considered with respect to the owner's location, motorcycles over 250cc were most likely to be located in smaller towns. Although 40% of licensed motorcycles were large (750cc plus), riders of these motorcycles constituted two thirds of all fatalities. Only 20% of car crashes had fatal/serious injury outcomes compared to 25% for small motorcycles and 48% for large motorcycles. The proportion of crashes of larger motorcycles that were in higher speed limit areas increased from around 35% in 1995 to around 60% in 2012. The increase in loss of control crashes for large motorcycles was an important trend, which taken in the context of the high levels of excess speed and increasing rates of single vehicle crashes, at-fault crashes, crashes in higher speed limit areas and crashes when cornering, indicates that some fundamental changes in riding styles and/or riding environments have been taken place over this period for the riders of larger motorcycles. Even controlling for the speed limit zone and the setting of the crash (at an intersection or otherwise), the larger motorcycles had a considerably higher fatal and serious injury rate in crashes than the other classes of motorcycles, which is likely to arise from higher speeds when crashing. There are also recent trends of an increasing proportion of the larger motorcycles' crashes occurring in higher speed limit areas, accompanied by the higher injury severities arising from the higher speed crashes. Riding at night can present additional risks in terms of the visibility of motorcycles. However, recent trends show gradually lower levels of crash involvement after sunset and before sunrise, which were lowest for large motorcycles.

5.3 Smaller motorcycles/mopeds

Smaller motorcycles have much higher rates of ownership by young people and by females. Compared to motorcycle owners in the smaller centres, a considerably larger proportion of owners resident in large cities, including Auckland, owned motorcycles of size 250cc and under. Consistent with their mainly urban exposure, small motorcycles had a large proportion of intersection crashes in which they were rarely judged to be at-fault. The smaller motorcycles at intersections were more likely to be victims of car driver misjudgement/not seeing and failure to stop/give way than were larger motorcycles. Only a relatively small proportion of their crashes were fatal or serious: 25% for small motorcycles (compared to 48% of large motorcycle crashes).

5.4 Literature review of potentially effective interventions

The review summarised current knowledge on the effectiveness of the full range of motorcycle safety countermeasures in Australia and internationally. Countermeasures identified as demonstrating the most substantial crash and or injury reduction benefits through evaluation studies were: anti-lock brakes; daytime running lights; accident black-spots and black-length treatments; and protective gear. A number of emerging countermeasures have demonstrated crash and or injury reduction benefits in specific circumstances but the results need to be verified by further research. These countermeasures were: motorcycle airbags, alcohol interlocks, and traction/stability control. Countermeasures associated with the design of other vehicles including truck under-run protection, blind spot mirrors, lane change/warning systems, better A-pillar design and collision avoidance systems are likely to be effective but have not yet been evaluated. Although some road user behaviour measures including licensing and training have shown mixed results or in some cases negative results, there is potential for these to be effective if designed and implemented and/or enforced appropriately. The small number of road side safety barrier evaluations have demonstrated a significant reduction in the relative risk of serious injury to motorcyclists compared to collisions with other roadside hazards (such as trees, poles or the ground). However measures to reduce the severity of injuries to riders impacting the steel posts of some types of barrier (such as the installation of padding on WRSB) are urgently needed to ensure that motorcyclists are not seriously injured following collisions with barriers.

It is widely known that enforcement coupled with a high level of publicity and education is effective in reducing speed and alcohol related crashes involving all road users. As such, enforcement countermeasures targeting unsafe behaviours in motorcyclists, including alcohol interlocks, have potential to achieve crash and injury reductions. As enforcement for car drivers will also benefit other road users with whom they may crash, motorcyclists will derive a modest safety benefit.

5.5 Recommended interventions

The motorcycle fleet in New Zealand would benefit from various cost-effective technologies and safety features, including anti-lock brakes, traction/stability control, alcohol interlocks and anti-theft devices. The uptake of these features can be increased using various measures, including publicity, education, subsidisation, and regulation. The road network can be better adapted to motorcycle safety by identifying lengths of road, as in the above analysis, with high concentrations of motorcyclist injuries and applying specific treatments over these lengths. Such treatments are also likely to increase safety for other road users. Protective gear is likely to be underutilised by motorcyclists, but particularly scooter users. Further research is required to identify barriers and appropriate marketing segments. Likewise, the vehicle testing regime with respect to motorcycles requires some examination to see whether safety benefits currently exceed costs, and whether fine-tuning of the scheme could lead to further safety gains. Increased levels of penalties and enforcement for motorcyclists and for other road users who impose excessive risk on motorcyclists is likely to be merited on cost-benefit criteria.

7. Further research

To maximise the potential safety gains of some interventions, some further research is merited:

- Protective gear is likely to be underutilised by motorcyclists, but it is necessary to identify particular groups who may use this gear least and what barriers there may be to their uptake. This would require on-road observation and interviews or focus groups with motorcyclists, particularly those groups with low current usage of protective gear.
- The current warrant of fitness with respect to motorcycles requires some examination to see whether safety benefits currently exceed costs, and whether fine-tuning of the scheme could lead to further safety gains. Analysis of the scheme such as that undertaken recently by Keall and Newstead (2013) could be applied specifically to motorcycles.

8. REFERENCES

ACEM, (2004). MAIDS: *In-depth investigations of accidents involving powered two-wheelers.* Brussels: Association des Constructeurs Européens de Motocycles.

Anderson, C., Dua, A. & Sapkota, J. (2012). Motorcycle safety barrier trials in South Australia: Case study – Adelaide Hills. *Australasian College of Road Safety Conference,* Sydney, November, 2012.

Anderson RGW, Hutchinson TP, Linke B, Ponte G (2010) Analysis of crash data to estimate the benefits of emerging vehicle technology. University of Adelaide. Centre for Automotive Safety Research, Adelaide.

Anderson, R., Hutchinson, T., Linke, B. & Ponte, G. (2011). *Analysis of crash data to estimate the benefits of emerging vehicle technology*. CASR Report Series CASR094. The University of Adelaide, Adelaide.

Attewell, R. (1996). *Road safety evaluation of daytime running lights for motor cycles. INSTAT Australia*. Report to Federal Office of Road Safety.

AustRoads. (2012). *Improving roadside safety stage 3 - Research report*. Austroads.

Ballesteros, M.F. & Dischinger, P.C. (2002). Characteristics of traffic crashes in Maryland (1996-1998): differences among the youngest drivers. *Accident Analysis & Prevention 34,* 279-284.

Bambach, M.R., Grzebieta, R.H. & McIntosh, A.S (2010). Crash characteristics of motorcycles impacting road side barriers. *Proceedings of the Australasian Road Safety Research, Policing and Education Conference,* Canberra, 31 August – 3 September, 2010.

Bambach, M.R., Mitchell, R.J. & Grzebieta, R.H. (2012). The protective effect of roadside barriers for motorcyclists. *Traffic Injury Prevention,* DOI:10.1080/15389588.2012.752077

Bellati, R. (2006). *Influence of an airbag jacket system of rider safety.* IFZ: Cologne.

Berg A, Rücker P. (2007). *Motorcycle airbags – an option to improve the secondary safety for powered two-wheeler riders*, in Science and Motor Vehicles 2007, JUMV International Automotive Conference and Exhibition, 23-25 April, Beograd, Serbia, viewed 22 May 2013, http://www.riedal-dz.com/resources/08_berg.pdf

Brennan, C. & Beer, K. (2007). Motorcycle safety in Victoria: Black”spot” the difference. *Proceedings Road Safety Research, Policing and Education Conference,* Melbourne, October 2007.

Brookland R, Begg D, Langley J, Ameratunga S (2013) Parental influence on adolescent compliance with graduated driver licensing conditions and crashes as a restricted licensed driver: New Zealand Drivers Study, Accident Analysis & Prevention

Cairney, P. & Sytles, T. (2003). *Review of literature on daytime running lights.* Report to Australian Transport Safety Bureau by ARRB Transport Research; Melbourne.

Capitani, R., Pellari, S, Lavezzi, R. (2010). *Design and numerical evaluation of an airbag-jacket for motorcyclists,* 77, Wirtschaftsverlag NW, Germany. Paper presented to the 4th International Conference on ESAR 16-18 September, 2010, Hannover.

Carsten, O., Fowkes, M., Lai, F., Chorlton, K., Jamson, S., Tate, F & Simpkin, B. (2008). *ISA-UK. Intelligent speed adaptation. Final Report.* TRL Report. UK: TRL.

Christie, S. M., Lyons, R.A. & Dunstan, F.D & Jones, S. J. (2003). Are mobile speed cameras effective? A controlled before and after study. *Injury Prevention, 9*, 302–306.

Dahlstedt, S. (1986). *A comparison of some daylight motorcycle visibility treatments*. National Swedish Road and Traffic Research, Report No. 302A.

Daniello, A. & Gabler, C. (2011). Fatality risk in motorcycle collisions with roadside objects in the Untied States. *Accident Analysis & Prevention 43,* 1167-1170.

Daniello, A. Swanseen, K., Mehta, Y & Gabler, H.C. (2010). Rating roads for motorcyclist safety. Development of a motorcycle road assessment program. *Journal of the Transportation Research Board,* 67-74, doi:10.3141/2194-08.

deRome, L. (2006). *The injury reduction benefits of motorcycle protective clothing.* Paper presented at the National Transportation Safety Board Motorcycle Forum, Washington DC, 12-13 September, 2006.

deRome, L., Ivers, R., Fitzharris, M. et al. (2011). Motorcycle protective clothing: Protection from injury or just the weather? *Accident Analysis & Prevention 43,* 1893-1900.

deRome, L., Ivers, R., Fitzharris, M. (2012). Effectiveness of motorcycle protective clothing: Riders' health outcomes in the six months following a crash. *Injury, Int. J. Care Injured 43,* 2035–2045.

EuroRAP, (2008). *Barriers to change: designing safe roads for motorcyclists.* Position paper on motorcycles and crash barriers. EuroRAP.

Feldkamp, G. & Junghanns, K. (1976). The typical traffic accident in adolescents: The motorcycle accident – some epidemiologic features and the effectiveness of safety helmets and clothing. Proceedings of the IRCOBI Amsterdam, 1976, p 75-80.

French, M.T., Gumus, G. & Homer, J.F. (2009). Public policies and motorcycle safety. *Journal of Health Economics,* 28, 831-838.

Gail, J., Funke, J., Seiniger, P. & Westerkamp, U. (2009*). Anti-lock braking and vehicle stability control for motorcycles – why or why not?*

Gould, M., Poulter, D.R., Helman, S. & Wann, J.P. (2012). Judgements of approach speed for motorcycles across different lighting levels and the effect of an improved tri-headlight configuration. *Accident Analysis and Prevention 48* (2012) 341– 345.

Green, D. (2006). *A comparison of stopping distance performance for motorcycles equipped with ABS, CBS and conventional hydraulic brake systems*. Paper presented at 2006 International Motorcycle Safety Conference; March 28-30, 2006; Long Beach, California.

Groeger, J.A. (2001). *Understanding driving. Applying cognitive psychology to a complex everyday task.* New York: Psychology Press.

Haworth, N., Buckley, L., Watson, B. & King, M. (2010). *A review of potential countermeasures for motorcycle and scooter safety across APEC for project: Compendium of best practices on motorcycle and scooter safety.* APEC: Singapore.

Haworth, N., Mulvihill, C. & Clark, B. (2007). *Motorcycle safety in Queensland.* Technical Paper prepared for Queensland Transport by Monash University Accident Research Centre, Melbourne.

Haworth, N., Greig, K. & Wishart, D. (2009). A survey of motorcycle safety programs across Australasia. *Journal of the Australasian College of Road Safety,* November 2009.

Hell, W. & Lob, G. (1993). Typical injury patterns of motorcyclists in different crash types-Effectiveness & improvement of countermeasures. In proceedings 37th Annual Proceedings Association for the Advancement of Automotive Medicine, Nov 4-6, San Antonio, Texas.

Helman, S., Weare, A., Palmer, M. & Fernandez-Medina, K. (2012). *Literature review of interventions to improve the conspicuity of motorcyclists and help avoid 'looked but failed to see' accidents.* TRL, Crowthorne: UK.

Henderson, R.L., Ziedman, K., Burger, W.J., and Cavey, K.E. (1983). *Motor vehicle conspicuity* (SAE Technical Paper Series 830566). Warrendale, PA: Society of Automobile Engineers.

Hurt, H.H. Jr., Oullet, J.V. & Wagner, I.J. (1981). Effectiveness of motorcycle safety helmets and protective clothing. Proceedings of the Annual Conference of the American Association for Automotive Medicine, San Fransisco, pp 223-235.

Jama, H. H., Grzebieta, R., Friswell, R. & McIntosh, A. (2011). Characteristics of fatal motorcycle crashes into roadside safety barriers in Australia and New Zealand. *Accident Analysis & Prevention (43),* 652-660.

Kardamanidis, K, Martiniuk A., Ivers R.Q., Stevenson, M.R. & Thistlethwaite, K. (2010). Motorcycle rider training for the prevention of road traffic crashes. *Cochrane Database of Systematic Reviews, Issue 10.*

Keall MD, Newstead S (2006) Development of a benchmark tool for the secondary safety of the New Zealand light vehicle fleet, Report to the Ministry of Transport. Monash University Accident Research Centre, Melbourne.

Keall MD, Newstead S (2008) Motorcycle ownership and risk in New Zealand. Monash University Accident Research Centre, Melbourne.

Keall MD, Newstead S (2013) An evaluation of costs and benefits of a vehicle periodic inspection scheme with six-monthly inspections compared to annual inspections, Accident Analysis & Prevention 58:pp. 81-87.

Moore, M.J. & Yongping, Y. (2009). *Antilock braking systems for motorcycles and insurance collision losses.* Transportation Research Board, 88th Annual Meeting, 11-15 January, 2009.

McGwin, G. Whatley, J., Metzger, J., Valent, F., Barbone, R., Rue, L. (2004). The effect of state motorcycle licensing laws on motorcycle driver mortality rates. *Journal of Trauma, 56,* 415-419.

McIntyre, A., Nieuwesteeg, M. & Cockfield, S. (2011). Motorcyclist injuries and protective clothing. Research with TAC clients. *Proceedings Australasian Road Safety Research Policing and Education Conference;* Perth, Australia; 6-9 November, 2011.

Ministry of Transport (2009) Motor vehicle crashes in New Zealand 2008. Ministry of Transport, Wellington.

Ministry of Transport (2012) Motor vehicle crashes in New Zealand 2011. Ministry of Transport, Wellington.

Muller, A. (1982). An evaluation of the effectiveness of motorcycle daytime headlight laws. *American Journal of Public Health, 72* (10), 1136–1141.

Newcombe, D. & Wilson, D. (2010). Cycle and motorcycle crash trends on Auckland city bus lane routes. *IPENZ Transportation Group Conference,* Auckland March, 2011.

Novoa, A., Perez, K., Santamarina-Rubio, E. & Borrell, C. (2011). Effect on road traffic injuries of criminalizing road traffic offences: a time-series study. *Bulletin World Health Organisation,* 89, 422-431.

Otte, D., Schroeder, G. & Richter, M. (2002). Possibilities for load reductions using garmet leg protectors for motorcyclists – a technical, medical and biomechanical approach. 46th Proceedings Association for the Advancement of Automotive Medicine, 367-385.

Paine, M. (2009). Day time running lights for motorcycles – an idea and research proposal. *Journal of the Australian College of Road Safety,* 40-41.

Pegg, S.P. & Maze, T.D. (1983). Burn injuries associated with motorcycles. *Burns, 9* (40), pp288-91.

Perez, Mari-Dell'Olmo, M., Borrell, C., Nebot, M., Villalbi, J.R., Santamarina, E. & Tobias, A. (2009). Road injuries and relaxed licensing requirements for driving light motorcycles in Spain: a time-series analysis. Bulletin World Health Organisation, 87, 497-504. DOI: 10.2471/BLT.08.051847

Quddus, M.A., Noland, R.B., Chin, H.C. (2002). An analysis of motorcycle injury and vehicle damage severity using ordered probit models. *Journal of Safety Research, 33* (4), 445-462.

Radin-Umar, R.S., Mackay, M.G., Hills, B.L. (1996). Modelling of conspicuity-related motorcycle accidents in Seremban and Shah Alam, Malyasia. *Accident Analysis & Prevention, 28,* 325-33.

Reeder A.I., Alsop, J.C., Langley, J.D., & Wagenaar, A.C. (1999). An evaluation of the general effect of the New Zealand graduated licensing system on motorcycle traffic crash hospitalisations. *Accident Analysis and Prevention, 31*, 651-661.

Rizzi M., Strandroth J., Kullgren, A., Tingvall, C. & Fildes, B. (2013). Effectiveness of anti-lock brakes (ABS) on motorcycles in reducing crashes, a multi-national study. Proceedings of the 23rd International Technical Conference on the Enhanced Safety of Vehicles, May 27-30, 2013, Seoul, Republic of Korea.

Rizzi M., Strandroth J., Johansson, R., Lie, A. (2011). The potential of different countermeasures in reducing motorcycle fatal crashes: What in-depth studies tell us. Proceedings of the 22nd International Technical Conference on the Enhanced Safety of Vehicles, June 13-16, 2011, Washington DC.

Rizzi M., Strandroth J. and Tingvall C. (2009). The effectiveness of antilock brake systems on motorcycles in reducing real-life crashes and injuries. *Traffic Injury Prevention, 10:*5, 479 - 487.

Road Safety Committee, (2012). *Inquiry into Motorcycle Safety.* Parliament of Victoria, Melbourne.

Roger, L., Hagen, K., Kryzywinski, J., Schlag, B. (2012). Recognisability of different configurations on front lights of motorcycles. *Accident Analysis and Prevention 44,* 82– 87.

Rosman, D. & Ryan, G. (1996). *The effect of ADR 19/01 on day-time motorcycle-car crashes.* Road Accident Prevention Unit – University of Western Australia. Report to Federal Office of Road Safety, RR46.

Royal Astronomical Society of New Zealand (2013) Sun rise and set times for New Zealand.

Sakamoto, S. (1990). Research history of motorcycle leg protection. *SAE Technical Paper 900755*, doi:10.4271/900755.

Schuller, E., Beier, G. & Spann, W. (1982). Effectiveness of protective clothing in Munich area motorcycle accidents. Proceedings 26th Stapp Car Crash Conference, Ann Arbor, SAE Technical Paper 821162, pp. 259-267.

Schuller, E., Beier, G. & Spann, W. (1986). Disability and impairment of protected and unprotected motorcycle riders, Proceedings fo the SAE International Congress and Exposition – Crash Injury Impairment and Disability: Long Term Effects, Detroit, MI, Warrendale, PA, pp. 51-56.

Scully, J., Newstead, S. & Corben, B. (2008). *Evaluation of the motorcycle blackspot program.* Consultancy Report to VicRoads by Monash University Accident Research Centre, Melbourne.

Scully, J., Newstead, S. & Corben, B. & Candappa, N. (2006). *Evaluation of the effectiveness of the $240M Statewide Blackspot Program – Accident blackspot component.* Consultancy Report to VicRoads by Monash University Accident Research Centre, Melbourne.

Seiniger, P., Winner, H. & Gail, J. (2008). Future vehicle stability control systems for motorcycles with focus on accident prevention. Proceedings ASME 2008 9th Biennial Conference on Engineering Systems Design and Analysis July 7–9, 2008, Haifa, Israel.

Seiniger, P., Schroter, K. & Gail, J. (2012). Perspectives for motorcycle stability control systems. *Accident Analysis and Prevention* 44, 74-81.

Sohadi, R., Mackay, M. & Hills, B. (2000). Multivariate analysis of motorcycle accidents and the effects of exclusive motorcycle lanes in Malaysia. Journal of Crash Prevention and Injury Control, 2 (1), 11-15.

Swedish Transport Administration, (2010). *Improved safety for motorcycle and moped riders*. Joint strategy for the period 2010-2020. Version 1.0. Swedish Transport Administration: Borlange, Sweden.

Teoh ER (2011). Effectiveness of antilock braking systems in reducing motorcycle fatal crash rates, *Traffic Injury Prevention, 12*: 169-173, Insurance Institute for Highway Safety, Arlington VA, viewed 25 May 2013 <http://www.iihs.org/research/topics/pdf/r1110.pdf>

Thollona, L., Godioa, Y., Bidalb, S. & Brunet, C. (2010). Evaluation of a new security system to reduce thoracic injuries in case of motorcycle accidents. *International Journal of Crashworthiness*
Vol. 15, (2), 191–199

TOI. (2003). *Motorcycle safety – a literature review and meta-analysis of countermeasures to prevent accidents and reduce injury*. (English summary).

Varyn, K, Winkelbauer, M. *Braking performance of experienced and novice motorcycle riders – results of a field study.* Paper presented at 2004 International Conference on Transport and Traffic Psychology; 2004; Nottingham, UK.

Wang, J.S. (2008). *The effectiveness of daytime running lights for passenger vehicles.* NHTSA, Washington DC.

Wells, S., Mullin, B., Norton, R., et al. (2004). Motorcycle rider conspicuity and crash related injury: case control study. *British Medical Journal,* 328, 857-860.

York, I., Ball, S & Hopkin, J. (2011). Motorcycles on bus lanes – monitoring of the second Tfl trial, Version 1 – Client Project Report CPR 1224, UK: Transport Research Laboratory.

Yuan, W. (2000). The effectiveness of the 'ride bright' legislation for motorcycles in Singapore. *Accident Analysis and Prevention, 32,* 559-563.

Williams A. and Lancaster K. (1996). The prospects of daytime running lights for reducing vehicle crashes in the United States, *Public Health Vol.110 (3)*, 233-239.

Zettas, J.P., Zettas, P. & Thanasophon, B. (1979). Injury patterns in motorcycle accidents. *Journal of Trauma Injury infection & Critical Care, 19* (11), 833-6.