Asia-Pacific
Economic Cooperation

# A REVIEW OF POTENTIAL COUNTERMEASURES FOR MOTORCYCLE AND SCOOTER SAFETY ACROSS APEC FOR PROJECT: COMPENDIUM OF BEST PRACTICES ON MOTORCYCLE AND SCOOTER SAFETY

APEC Transportation Working Group

July 2010

APEC Project TPT 06/2009A

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APEC# 211-TR-01.5

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# EXECUTIVE SUMMARY

Motorcyclists and scooter riders are among the most vulnerable road users, across APEC. This report assesses the potential road safety measures that can be used to address these issues and selects measures that could feasibly and effectively be implemented across the Asia Pacific Economic Communities (APEC).

The scope of the report is confined to on-road motorcycle riding. While the numbers of injuries resulting from off-road riding (including as part of farm work) are likely to be substantial based on data from other states, many of the issues and measures to reduce trauma in off-road riding would be quite different.

A previous report described important motorcycle and scooter safety issues across APEC economies and any current barriers that might exist in implementing potentially effective countermeasures.

In this report, motorcycle safety measures are classified according to their role: (1) preventing crashes, (2) reducing the severity of injury in the event of a crash or (3) improving treatment of injured persons. The safety measures reviewed were those that specifically aim to improve the safety of riders. There are also measures that improve the safety of all road users (e.g. measures to prevent drink driving) and others where relatively more of the benefit is expected to accrue to riders and other vulnerable road users (e.g. reductions in travel speeds in urban areas). Specific attention is paid to socio-cultural and geographical features of different economies and how this relates to the potential differences in use of motorcycles and potential differences in effectiveness of countermeasures.

The review of the literature found very few measures that have been scientifically proven to improve rider safety. Of the proven measures, in many economies they have already been implemented (e.g. compulsory helmet wearing). Many measures have the potential to improve rider safety but their benefits have not been scientifically tested. There is a need to extend current motorcycle safety programs, evaluate the effects of general road safety programs on rider safety and to explore new ways of improving rider safety across economies.

In addition to measures that directly influence rider safety, other measures are needed to facilitate widespread and effective implementation of the direct measures. These include:

- Better collection of data regarding motorcycle riding activity and crashes to identify issues and monitor trends in motorcycle safety

- Evaluations of the effectiveness of motorcycle safety measures.

The selected measures are presented below according to the Haddon matrix structure used in the report.

**RIDER AND DRIVER MEASURES TO PREVENT CRASHES**

Changes to rider training, licensing and testing:

- Introduce a graduated licensing system

- Zero BAC to apply for all novice riders

Other rider and driver measures to prevent crashes:

- Encourage riders to wear lighter coloured clothing and helmets (which may also be cooler)
- Incorporate sharing the road into driver education and publicity materials. This should not be a major focus given the lack of a proven benefit.
- Educate drivers to be aware of blind spots
- Police targeting of locations and times where unlicensed riding is most common.
- Police enforcement of speed and other illegal behaviours by drivers to reduce risks to riders.

**RIDER MEASURES TO REDUCE INJURY SEVERITY**

- Enforce and encourage helmet wearing
- Monitor research into improved helmet design and promote safer helmets when they are identified
- Create or lobby for improvements to official standards for motorcycle helmet crash performance
- Implement an education program concerning correct fit and fastening, targeted at both riders and helmet retailers
- Monitor wearing rates and implement enforcement and education measures to increase these if they are of concern
- Support attempts standards for motorcycle protective clothing, including provision for hot climates
- Promote to riders the effectiveness of good protective clothing in preventing injury

**VEHICLE MEASURES TO PREVENT CRASHES**

- Motorcycles with antilock and linked braking systems
- Light-coloured motorcycles
- Riding with lights on

While mandating vehicle safety measures may offer the most widespread coverage, this is not always possible. In these cases it may be more prudent to encourage riders to consider safety features when buying a motorcycle and barriers to purchasing safer motorcycles can be removed.

**VEHICLE MEASURES TO REDUCE INJURY SEVERITY**

- Rating the relative safety of different models of motorcycles in terms of their ability to reduce injury severity (crashworthiness) and using this information to influence motorcycle selection by riders (and guide legislation).
- Monitor research to assess if particular motorcycle models or styles provide better leg protection and publicise the results
- Monitor research into motorcycle airbags and their availability and publicise the results

- Encourage vehicle purchasers to consider pedestrian protection ratings when purchasing new vehicles (since vehicles with good pedestrian protection are likely to be friendlier to riders)
- Require vehicles purchased by Government to have good pedestrian protection ratings
- Consider Design Rules for truck under-run protection

**ROAD IMPROVEMENTS TO PREVENT CRASHES**

- Examine the role of road surface in crashes
- Develop guidelines for improving and maintaining road surfaces
- Consider implementing fully-controlled right turn phases at signalised intersections
- Assess whether detectors at traffic signals are adequately working for motorcycles and implement improvements if necessary
- Examine motorcycle crashes at different road designs e.g. roundabouts and identify any improvements to roundabout design that could reduce the occurrence or severity of these crashes
- Clear vegetation near and within intersections (e.g. in the centre of roundabouts) where it may contribute to motorcycles (and other road users) being obscured
- Review whether current road space allocation for motorcycles is optimal in safety terms
- Consider improving delineation on curves
- Consider potential disbenefits to riders when specifying characteristics of devices to improve delineation (e.g. skid resistance of pavement marking materials)
- Consider using less hazardous materials for delineation on high-volume motorcycle routes (e.g. flexible plastic reflective delineators instead of steel)
- Analyse motorcycle crash data to identify blackspots and black lengths

**ROAD IMPROVEMENTS TO REDUCE INJURY SEVERITY**

- Investigate the adequacy of current clear zone guidelines and practice for motorcycle safety
- Educate road managers about the need to provide sufficient clearances between the edge of the carriageway and roadside objects for motorcycles travelling along the carriageway
- Collect information about the nature and prevalence of collisions between motorcycle and barriers

**MEASURES TO IMPROVE TREATMENT OF INJURIES**

- Automatic collision notification for motorcycles
- Discuss issues of emergency response for motorcycle crashes with emergency services personnel to identify any issues that need to be resolved (e.g. safe removal of helmets)

# 1 INTRODUCTION

## 1.1 BACKGROUND

Motorcyclists and scooter riders are among the most vulnerable road users, across APEC. Such riding is more likely to result in injury than many other motor vehicle travel and any injuries that result from motorcycle crashes are likely to be more severe than for vehicle occupants. Studies in developed countries have found fatality and serious injury rates to be 30 to 35 times greater for motorcyclists than car drivers, with brain and orthopaedic injuries prevalent (Johnston, Brooks & Savage, 2008; National Center for Statistics and Analysis Research and Development, 2008).

There is no clear estimate available of the total numbers of motorcyclists and scooter riders killed and injured throughout the world or in the APEC economies as a whole. However, motorcyclists generally comprise a higher proportion of fatalities in developing countries than in developed countries. Among the APEC economies, the proportion of road fatalities comprised by motorized two-wheelers is between 70–90% in Thailand, and about 60% in Malaysia (WHO, 2006) compared with 7% in Canada, 10% in New Zealand, 11% in the United States and 15% in Australia, (IRTAD, 2009). The figures are intermediate in Korea (13%) and Japan (18%). The representation of motorised two-wheelers in fatalities reflects the combined effect of the higher proportion of vehicles in low-income countries that are motorised two-wheelers and the relatively high risk of these motorcycles being involved in crashes involving fatalities (WHO, 2006).

It is estimated that there are 313 million motorcycles in the world of which 77% are in Asia, 5% in Latin America, 2% in North America (Rogers, 2008). While much of the motorcycle safety research emanates from Europe and North America, these two continents comprise only 16% of the world motorcycle fleet. Within Asia, China has the most motorcycles (about 100 million), followed by India (about 40 million), Indonesia (about 30 million) and Thailand, Vietnam and Japan (about 15 million) (Rogers, 2008). Asian countries are also the largest producers of motorcycles. In 2006, the top five motorcycle producing countries were China, India, Indonesia, Japan and Taiwan. Thailand, Vietnam and Malaysia were also among the top 10 motorcycle producing countries (Rogers, 2008).

Internationally, the number of motorcycles is increasing, with the largest increases in Asia. Rogers (2008) also presented growth figures for motorcycles in Asia, based on the Honda World Motorcycle Facts & Figures 2007 and SIAM estimates. From 1995 to 2006, the motorcycle fleet increased from 20 million to about 100 million in China. The motorcycle fleet approximately doubled in India and tripled in Indonesia. In contrast, motorcycle production has decreased in Japan and Taiwan since 1996.

Increases in the numbers of motorcycles have also been occurring in Australia and the United States. The number of motorcycles registered increased by 20% from 2001 to 2005 (Australian Bureau of Statistics, 2006), the strongest growth of any vehicle type in Australia. The number of motorcyclist fatalities in the US has increased from a low of 2,116 in 1997 to 4,810 in 2006 (National Center for Statistics and Analysis Research and Development, 2008). Across Australia, the number of motorcyclist (rider and pillion) fatalities has risen from 175 in 1997 to 238 in 2006 (Johnston et al, 2008).

The differences between economies in the representation of motorcycles and scooters form only part of the picture. There are variations in uses of motorcycles, the personal and social significance of motorcycling as an activity, which segments of the population are more likely to use motorcycles and scooters, and the consequent patterns of injuries and fatalities. The factors that have been identified as contributing to the over-representation of motorcycles in serious crashes include (Haworth, Mulvihill & Clark, 2007):

- Vulnerability to injury
- Inexperience or lack of recent experience
- Driver failures to see motorcycles
- Instability and braking difficulties
- Road surface and environmental hazards
- Risk taking

Strifelt (2008) stresses the differences among riders, in terms of why they ride, whether or not they belong to organised rider groups and their level of safety awareness. Strifelt (2008) also points out that motorcycling provides an affordable means of transporting goods in Asia. In large cities of some developed economies, motorcycles are commonly used for commuting, while in the US and Canada, use for touring is more common than commuting.

Rogers (2008) noted that enjoyment was an important factor in many high-income countries (such as the APEC economies of United States, Canada, Australia and New Zealand) but that employment/entrepreneurship was important in many low- and middle-income countries (such as the APEC economies of Indonesia, Mexico, the Philippines and Thailand). Ease of use is an important factor in locations where significant traffic congestion exists. Economy of purchase and use is also an important factor in many low and middle-income countries.

The types of motorcycles and their main purposes of use also differ markedly between high income economies and emerging and developing economies. In low and middle income economies, many motorcycles are leisure vehicles which have larger engine capacities. In emerging and developing countries, motorcycles are largely used as a means of mobility and most motorcycles are low and medium engine capacity motorcycles and scooters (Rogers, 2008). Perversely, larger motorcycles in developed countries tend to be used by single riders, while the smaller motorcycles and scooters in developing economies frequently carry passengers and are used with a variety of attachments for carriage, delivery, vending and passenger transport.

Motorcycling has traditionally been more popular among males than females and the role of gender differences in motorcycle safety remains an important, if under-researched, topic. In many countries, females have been more common as motorcycle pillion passengers than riders. Australian data shows that while females make up only about 3% of motorcycle riders killed, about half of the pillion passengers killed are female (ATSB, 2004).

There is also some evidence that motorcycle and scooter use by women is increasing in APEC economies. Rogers (2008) reports that the percentage of riders in the US who were females increased from 2% in 1990 to 10% in 2005. There have been claims of increased numbers of female riders in Australia (MSCC, 2009) but little objective data is available.

There was a 6.9% increase in female motorcyclists hospitalised from 1999-2000 to 2003-04, compared with a 4.2% increase in male motorcyclists hospitalised (Johnston et al., 2008).

In developed economies, women make up a larger proportion of scooter riders than riders of traditional motorcycles. In Queensland, Australia, females comprised 38% of moped riders in crashes, compared with 7% of motorcycle riders in crashes (Haworth & Nielson, 2008). Combined with an increase in the popularity of scooters and mopeds in developed countries, this suggests that the number of female riders will continue to increase in importance.

Given the over-involvement of motorcycle riders in crashes and high levels of fatalities and hospitalisations, this report outlines the range of road safety measures that have been used to prevent crashes or reduce injuries to motorcycle riders. It then lists a selection of measures that could potentially be adopted across APEC.

## 1.2 AIM AND SCOPE

### 1.2.1 Project aims

To address the issues of death and injuries associated with the use of motorcycles, the Road Safety Sub-group of the APEC Transportation Working Group (TPT-WG) put forward a project to develop a compendium of best practice measures to improve motorcycle and scooter safety that can be used to reduce crashes, post-crash trauma and associated socio-economic costs.

### 1.2.2 Overview of previous project components

In order to develop the compendium a survey was initially undertaken to assess the most important motorcycle safety issues in APEC economies and any current (including gender) barriers to addressing these issues (the findings of this needs assessment have been reported elsewhere). Together with this needs assessment, the literature review in this report will be used to develop a compendium of best practice measures to improve motorcycle and scooter safety.

### 1.2.3 Report Aims

This report aims to identify the issues that are contributing to the over-representation of motorcycle riders in crashes and recent increases in riders killed and hospitalised, to assess the potential road safety measures that can be used to address these issues and to select measures that could feasibly and effectively be implemented across APEC.

### 1.2.4 Glossary

The report is confined to on-road motorcycle and scooter riding. While the numbers of injuries resulting from off-road riding are likely to be substantial, many of the issues and measures to reduce trauma in off-road riding would be quite different. Further the report refers to countermeasures that are likely to reduce motorcycle and scooter injuries however primarily the term, motorcycle is used when it could also include scooter riding. A full glossary of key terms is provided in Appendix A.

## 1.3 STRUCTURE OF THIS PAPER

The report provides an assessment of potential initiatives to improve the safety of motorcycle and scooter users across APEC. Firstly presented is a framework to describe the way in which safety measures can be conceptualised. The framework includes the way in which safety measures may work and the system in which they may operate. The Haddon matrix has been used in this report to classify the countermeasures for motorcycle and scooter safety that are outlined (as developed by Haworth, Mulvihill & Clark, 2006).

Safety measures can work by preventing crashes, reducing the severity of an injury in the event of a crash and by improving the treatment of injured persons. There are three main systems in which to address factors that may improve motorcycle safety; road user, vehicle and environment.

The following sections of the report provide the detail of particular countermeasure including any evidence of effectiveness and how they might operate to improve motorcycle safety. These include measures that target the rider and other road users, those that target the vehicle (motorcycle and others) and those that target the road environment and all which may operate to prevent crashes, reduce injury or improve treatment. Where appropriate, reference is made to whether the countermeasure is more relevant to particular economies.

Finally, there is a section on selected measures which includes information about the level of available evidence and 'proof' of effectiveness of the countermeasure as well as an indication as to whether the countermeasure has the potential to improve motorcycle safety in high income economies (HIE) and in low/ middle income economies (LMIE) where motorcycle riding is prevalent and where motorcycle riding in the LMIE is uncommon.

# 2 A FRAMEWORK FOR SAFETY INITIATIVES

Crash prevention and reducing injury severity is particularly important for vulnerable road users such as motorcycle and scooter riders who are not encased in a vehicle and do not experience vehicle-related safety features.

This section of the report presents a framework for conceptualising the ways in which overall motorcycle safety can be improved.

Safety initiatives can have their effect by:

- Preventing crashes;
- Reducing the severity of injury in the event of a crash; and
- Improving treatment of injured persons.

Safety measures can reduce the number and severity of motorcycle crashes by reducing the amount of riding (often termed exposure reduction) or by riding more safely (often termed risk reduction). By reducing exposure, crash prevention initiatives are in operation whereas with risk reduction initiatives operate to reduce the severity of harm associated with a crash.

The Haddon matrix (Haddon, 1972) is an internationally recognised method for classifying safety initiatives. An overview relevant to motorcycle safety initiatives is presented in Table 1. These initiatives to improve motorcycle safety will be further described in this report. Typically the Haddon matrix represents:

- safety initiatives in the columns
  (preventing crashes, reducing injury severity, improving treatment)
- system factors in the rows
  (road user, vehicle, environment)
- specific initiatives in each cell
  (these represent examples of preventing crashes, reducing injury severity or improving treatment for the corresponding system)

In general, factors contributing to motorcycle crashes can be reduced by a combination of road user, vehicle, and environment-based measures. In some circumstances, one measure may be more effective than another, but using all three measures aims to maximize the potential safety benefits. As one example, the role of road surface and environmental hazards in motorcycle crashes can be reduced in the first instance by environment (road based) safety initiatives such as improving road surfaces, but it can also be reduced through training (a rider based initiative) and improved maintenance of the motorcycle (a vehicle based initiative). A best practice system is both cost-effective and utilises those measures shown to be most effective in reducing harm without unduly compromising the mobility, independence and related economic security of the community.

**Table 1 Overview of countermeasures to improve motorcycle safety as classified using the Haddon matrix**

| | PREVENT CRASH | REDUCE INJURY SEVERITY | IMPROVE TREATMENT |
|---|---|---|---|
| **ROAD USER** | | | |
| **Rider** | Licensing<br>Training<br>Enforcement | Helmets<br>Protective clothing | Safer removal of helmets |
| **Other road user** | Increased awareness of motorcycles<br>Enforcement | | |
| **VEHICLE** | | | |
| **Motorcycle** | Improvements to braking<br>Improved maintenance<br>Conspicuity<br>Choosing safer motorcycles<br>Improved field of view | Knee protection<br>Fairings<br>Airbags | Automatic collision notification |
| **Other vehicle** | Improved field of view | More motorcycle-friendly design | |
| **ENVIRONMENT** | Better road surfaces<br>Intersection improvements<br>Road space allocation<br>Better delineation<br>Blackspot treatments | Improved roadside safety (incl barriers) | Improved emergency response (access and trauma management) |

# 3 ROAD USER MEASURES TO PREVENT CRASHES

This section describes the effectiveness of measures designed to prevent motorcycle crashes. It examines rider based measures as well as other measures directed at other road users such as car drivers.

The main rider-based measures to prevent motorcycle crashes relate to:

- Rider licensing requirements and training
- Enforcement of rider adherence to road rules (for example, speed restrictions, blood alcohol content (BAC) levels).

The main measures directed at other road users with the aim of preventing motorcycle crashes are:

- Increased awareness of motorcycles
- Enforcement of adherence to road rules.

Table 1 of the Haddon matrix indicates how these measures to improve motorcycle safety have been classified in relation to other measures within the system.

Some of the initiatives will be more relevant to some jurisdictions than others, with particular consideration for the type of riding in the economy (e.g. engine size restrictions in the novice period). Other countermeasures may have a greater likelihood of implementation depending cultural considerations (e.g. enforcement of BAC).

## 3.1 RIDER LICENSING AND TRAINING

In accordance with the Haddon matrix related to motorcycle safety, countermeasures associated with licensing and training may reduce crash involvement however they may also reduce the severity of crashes by addressing the problem of lack of experience (including lack of recent experience). Meeting this later aim is likely achieved through the implementation and enforcement of road safety measures. Particular countermeasures may apply to certain subgroups of an economy who are at a greater risk for crash involvement. For example, this might include age restrictions to increase exposure in safer conditions.

### 3.1.1 Graduated Licensing Systems (GLS)

GLS aims to implement a phased introduction of riding whereby beginning riders' early experiences are in low risk situations with restrictions removed with greater experience. The bulk of the research into graduated licensing systems focuses on young and novice drivers with much less research examining graduated licensing for motorcycle and scooter riders and little graduated licensing research in economies in which a sizeable proportion of road users are motorcyclists. However research in Taiwan for example, shows that young riders, particularly males, experience more crashes and engage in more risky riding behaviours (Chang & Yeh, 2007).

New Zealand is one of the few economies to have implemented and evaluated a GLS for motorcyclists (Mayhew & Simpson, 2001). Reeder, Alsop, Langley and Wagenaar (1999) reported a reduction in hospitalisation among 15-19 year olds. Despite this, there is much to be learnt from our understanding of GLS for car drivers. It is recognised that there are differences between novice motorcycle and car drivers and a complete undertaking of GLS for car drivers may not work for motorcyclists.

The effectiveness of GLS is dependent on the context in which it is implemented (Senserrick & Whelan, 2003). That is, any individual component is dependent on the other components in which it is implemented and by that nature varies across jurisdictions. Further, the effectiveness of introducing new components or altering existing components is dependent upon the combination of components that are already in existence. However, the implementation of restrictions for beginning drivers, in addition to other general road safety measures that apply to all age groups, has proven successful in reducing crashes in many jurisdictions, for example in Australia, New Zealand, USA, (e.g., Langley, Wagenaar & Begg, 1996; Begg, Stephenson, Alsop & Langley, 2001; Begg & Stephenson, 2003). Given the success of these restrictions, it is important to determine which components are most likely to maximise safety benefits and understand that which may apply to motorcycle safety.

Particular components have been examined with greater attention than others as they may be relevant to GLS for motorcyclists. Mayhew and Simpson (2001) note that primarily the effectiveness on applying limits to engine size or power of the motorcycles that are ridden by novice riders has been considered. Such an examination however is only relevant where there are patterns of riding of larger engine size motorcycles. Other restrictions examined, although to a lesser extent, include zero blood alcohol content (BAC), night curfews and supervision. Primarily however the majority of evidence related to the effectiveness of these factors relates to the examination of effectiveness in reducing novice driver crashes. To the extent possible, each component of a GLS has been examined for its impact on crash risk and the amount of riding in the sections that follow and are described below.

#### *3.1.1.1 Age restrictions*

Research has shown that increasing the minimum age for full licensing among car drivers reduces crash risk and conversely reducing the minimum age has been associated with increased crash risk. Evidence from driving research in an Australian jurisdiction showed crash reductions occurred after the minimum full licensing age was raised from 17 years to 19 years and the intermediate licensing age was raised from 16 years to 16.5 years (Senserrick & Whelan, 2003).

Age has been demonstrated as a factor in casualty crashes which has important implications for jurisdictions in which there is a policy to waive licensing restrictions above a certain age. There are fewer crashes among those aged 25 years or over compared to those between the ages of 15 and 19 years. A large case-control study of motorcyclists in New Zealand (Mullin, Jackson, Langley & Norton, 2000) found that age, but not experience, was associated with lower risk of involvement in a casualty crash. The research found that after taking age into account, there was no evidence to support the benefits of experience as a rider or as a car driver and thus it was concluded that licensing policies should emphasise the age of the rider. Further, the research suggested little support for exemptions based on holding a car licence and some support for waiving licensing restrictions for older novice riders. However, given the difficulties associated with separating the combined effects of age and experience on crash risk, licensing systems should apply age-based exemptions with caution. Both age and experience are significant contributors to motorcycle crashes, however, in the absence of further empirical evidence regarding the relative contributions of each of these factors, it is wise to build policies around the assumption that both are important.

As outlined by Senserrick and Whelan (2003), a number of factors among car drivers have been associated with increased crash risks due to a low licensing age, including: immaturity (less well developed perceptual systems and behaviour), an increase in the total number of novices on the road, and reduction in the amount of time available to gain experience in the learner licence phase. The effectiveness of reducing crash risk by increasing the age at which a motorcycle licence can be obtained however has not been directly examined. It is likely that reductions in crash risk would occur through the following:

- Preventing riding among younger than the minimum age, and

- Encouraging potential novice riders to become novice car drivers (if the minimum licensing age for motorcycling is higher than that for car driving and car driving is prevalent).

Reductions in crash risk among motorcyclists associated with implementing GLS are thus likely to result from:

- Having novice riders with a greater level of maturity (associated with less risk taking); and

- Having novice riders with skills learnt from car driving (if the minimum licensing age for motorcycling is higher than that for car driving). For example skills such as greater hazard perception.

In some jurisdictions the timing of the learner period of motorcycle licensing relative to car licensing has implications for safety. For example, the minimum age to obtain a motorcycle learner permit is often higher than for a car learner permit. This encourages novices in economies in which car driving is more common and more readily available to start driving before they start riding. This may accelerate the development of driving skills that could benefit their riding ability and thereby contribute to a reduction in motorcycle road trauma. Incidentally, it may act to divert potential novice riders into becoming car drivers instead.

In high income economies, there is a general pattern of riding for reasons of recreation than for commuting. Thus unlike car drivers, where this may be a primary source of transport, there is potential for less inclination to ride during the learner period if there are sufficient restrictions imposed during the period. Mandating minimum periods for holding a motorcycle learners permit may thus do little to control experience.

While research with car drivers indicates that increasing the length of the learner period and somewhat the amount of supervised experience (see Senserrick & Whelan, 2003) can reduce crash risk, this has not been examined with regard to motorcycle learner licensing. Any effect however is not likely to reflect the magnitude of the effect for car drivers. A learner rider, for example is (or effectively is) unsupervised. Further, motorcycling requires more complex skills than car driving and the lack of protection afforded by the motorcycle compared to that afforded by a car. Supervision is problematic for motorcyclists given, among other factors, the increased crash risk associated with carriage of a pillion passenger. However, at a minimum, increasing the time required for holding learner and restricted licences would allow practice and experience to be gained under conditions that are less risky than those during the full licence stage.

#### *3.1.1.2 Restrictions on carriage of pillion passengers for novice riders*

There is evidence that the carriage of pillion passengers not only increases the total number of persons at risk but that the severity of injury to the rider is greater when a pillion passenger is carried (Social Development Committee, 1992). Balancing the motorcycle is also more difficult with a passenger and with greater loads. Therefore, many jurisdictions impose passenger restrictions on novice riders whose riding skills are likely to be less well developed than those of more experienced riders.

#### *3.1.1.3 Supervised riding for novices*

The very low crash risk among supervised learner drivers is due, in a large part, to the presence and influence of a supervisor who is a fully licensed driver. This is presumably the logic behind licensing systems that permit learner riders to carry a pillion passenger if the role of the pillion is a supervisory one (and the pillion is more experienced and is not subject to riding restrictions). However, supervision for motorcyclists is problematic given the increased crash risk associated with carrying a pillion passenger.

Since balance and coordination is more difficult with a passenger on a motorcycle, some of the benefits of supervision for novice riders could be achieved by having the supervisor follow the learner on another motorcycle, or closely behind in a car (Mayhew & Simpson, 2001). While it is not expected that the benefits of supervised riding will reduce crash risk per distance travelled as much as it does for learner car drivers, a requirement for supervision could reduce the amount of riding by learner riders because of difficulties in obtaining supervision. Thus, it would be expected to have some road safety benefits.

#### *3.1.1.4 Minimum and recorded hours of learner riding*

To increase experience, jurisdictions have set minimum hours of practice in the learner period for car drivers. The aim of this approach is ensure sufficient practice in the learner period. The benefit for car drivers is in the lower crash rate evidenced for learners compared with the newly licensed drivers. For motorcyclists there is not the reduced crash risk during the learner period as is typically seen for the car drivers and as such a similar benefit for motorcyclist of set minimum hours (‘logged’ hours) is unlikely to be evidenced. A requirement for logged hours of learner riding might have the effect of discouraging some potential motorcycle learner permit applicants.

There are also potential concerns for many jurisdictions to eliminate the ‘permanent learner’. That is, those who fail, or never take, the licence test. Some jurisdictions have thus introduced a maximum learner period for those that do not take their test within a required framework needing to wait an additional period before regaining licensing entitlement. This requirement acts as an incentive for learners to obtain practice in order to pass the on-road test and therefore intends to make them safer riders.

#### *3.1.1.5 Engine capacity restrictions and power-to-weight restrictions for novice riders*

There are some APEC economies in which there is a variety of engine sizes in the motorcycles ridden including motorcycles with larger capacities of greater than 250cc (e.g. Australia, U.SA.). Elliot et al. (2003) note that

> motorcycle size can be quantified in several ways, but the concept relates essentially to a motorcycle’s performance. Thus, the key measures include engine

> capacity, power, power-to-weight ratio and laden power-to-weight ratio. Of these four, engine capacity is the most generally available for accident-involved motorcycles: however laden power-to-weight ratio (based on an average loading) is directly related to maximum acceleration and so is probably the most relevant. (p.12).

Langley and colleagues (2000) examined whether the risk of an injury increases with increasing engine capacity of the motorcycle. A strength of this New Zealand study was to control for the amount of riding and other potentially confounding factors such as age, socio-economic status, absence of a licence and car driving experience. Langley et al did not find a strong relationship between increased engine capacity and increased risk of crashing.

One reason for the lack of success of engine capacity restrictions is that some small capacity motorcycles, which satisfy engine capacity restrictions, are very powerful. This has led to pressure for restrictions to be couched in terms of power, or a power to weight ratio, instead of (or in addition to) capacity (Haworth, Ozanne-Smith, Fox & Brumen, 1994).

It is difficult to assess the safety effects of engine size or engine power or power-to-weight ratio restrictions because riders with bigger or more powerful motorcycles generally ride further.

#### *3.1.1.6 Speed limit restrictions for novice riders*

There is little evidence of road safety benefits of speed limit restrictions for novice riders. That is, imposing a lower speed limit for novice riders to the posted limit for other road users. There have been no evaluations of speed limit restrictions for novice motorcyclists, further any benefits to motorcyclists may not be recognised (since serious injuries and fatalities can occur in low speed motorcycle crashes).

#### *3.1.1.7 Requirement to display learner status (L/ P plates)*

No evaluations of the requirement to display plates (L or P plates) that indicate novice status were found. However, some method of identifying those riders to whom particular restrictions apply would appear to be necessary for effective enforcement of those restrictions. Thus, the requirement to display learner status would appear to be a useful component of a motorcycle training and licensing system and its enforcement.

#### *3.1.1.8 Lower BAC limits for novice riders*

Many jurisdictions across APEC have introduced zero BAC for novice riders, in conjunction with zero BAC for novice car drivers. Alcohol impairment can significantly reduce a rider’s ability to control the motorcycle. Impairment from alcohol use is likely to be greater for the novice than for the experienced road users. Mayhew, Beirness, Donelson, and Simpson (1987) found that for a substantial proportion of young inexperienced drivers, accident risk increases at lower concentrations of alcohol than is the case with older, more experienced drivers. While the research for the benefits of zero BAC for novice riders has not been undertaken, it is likely that the same effect would be evident, particularly given the different and additional skills required for motorcycle riding compared to car driving (especially the importance of balance), and the much greater likelihood of injury in the event of a crash for motorcycle riders.

#### *3.1.1.9 Time of day restrictions for novices*

There is little data available regarding the risk of motorcycle crashes as a function of time of day particularly as relevant for novice riders. Haworth, Smith, Brumen and Pronk (1997) collected information about both crashes and the amount of riding in a case-control study. From those data, it was calculated that 34 percent of crashes occurred at night (6pm to 6am), while only 21 percent of motorcycle travel occurred at night. Thus, crash risk does appear to be elevated at night for motorcycles (the calculation was not possible for novice riders only).

There is also some evidence to suggest a greater likelihood of engagement in risk-taking behaviours at night that might subsequently increase crash risk. For example in Thailand, alcohol crashes were more frequent at night and on weekends (Kasantikul et al., 2005). Helmet use is also less common at night than during the day in Thailand (Kasantikul et al., 2005). The peak time for fatality crashes in Malaysia is between 4 and 8 in the evening (Rosmanati, 2004). Further in Taiwan, it was found that the odds of increased injury severity was greater for riding at night compared with riding during the day (1.65 times the risk)(Lin, Chang, Huang, Hwang, Pai, 2003). Although this research also wasn't specific to novice riders.

### 3.1.2 Rider training

While there is little empirical evidence to demonstrate improvements in motorcycle safety as a result of training, training is typically encouraged. However evidence suggests that voluntary motorcycle training does not reduce crashes and seems to increase crash risk. Compulsory training, on the other hand, has weak evidence to support a reduction in crashes (TOI, 2003). It is suggested that increased confidence of riders who voluntarily complete training may explain the potential increase in crash risk. There are two possible explanations for the lack of a demonstrated effect of training on crashes and safety; 1) current training is ineffective, and/or 2) there are limitations in the research. A recent Cochrane review of motorcycle training concluded that there are a lack of quality evaluation studies in the area (Kardamanidis, Martiniuk, Ivers, Stevenson, Thistlethwaite, 2010).

Simpson and Mayhew (1990) also point out that many of the 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 often 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.

#### *3.1.2.1 Content of training*

One suggested reason for the lack of demonstrated effectiveness of rider training in terms of reducing crash risk is suggested to stem from the content of training programs (Chesham, Rutter & Quine, 1993; Crick & McKenna, 1991; Haworth, Smith & Kowadlo; 1999; Reeder, Chalmers & Langley, 1996; Simpson & Mayhew, 1990). Primarily training focus on skill development as a reflection of the end goal; a licence test that is skills based. Typically programs do not address, or adequately address motivation factors (e.g. to engage in risk-taking behaviour) or higher order cognitive skills (Chesham, Rutter & Quine, 1993; Crick & McKenna, 1991; Haworth, Smith & Kowadlo; 1999; Reeder, Chalmers & Langley, 1996; Simpson & Mayhew, 1990; Rothe & Cooper, 1998). While teaching of rider skills is essential, it recognised as not sufficient, with many crashes not necessarily the result of poor riding skills but the more deliberate risk taking behaviour of the rider (Rothe & Cooper, 1998). Chesham et al. (1993) concluded that "training courses concentrate on riding technique and pay little attention to why safe riding is important. That is, they offer little by way of cognitive underpinning for the behaviours they promote." (p.428). In addition, Hunter-Zaworski, Cornell, Jannat (2010) noted that education may be useful for riders of low speed vehicles who may be particularly unaware of the vulnerability as users (particularly in comparison with being a user of a passenger vehicles) and have a need to understand their personal safety risks. The authors note that some low speed vehicles may look like cars but not have comparable safety features.

#### *3.1.2.2 Hazard perception training for motorcyclists*

Primarily the research evidence for hazard perception training originates from understanding the hazard perception skills of novice drivers compared with experienced drivers. Hazard perception skills can incorporate the identification and processing of hazards as well as appropriate responses to hazards. It is noted that this is not just emergency response or collision avoidance but skill in prevention. As Ouelett et al. note at the point of identifying an imminent collision there is very little time to implement even a very well considered response. Novice drivers typically have poorer hazard perception skills in terms of identifying and responding to hazards. Further such deficits are associated with a larger proportion of the crashes in which novice drivers are involved (Catchpole, Cairney & Macdonald, 1994).

There has been very little research examining the role of hazard perception and responding deficiencies in motorcycle crashes (Haworth, Mulvihill & Symmons, 2005). The Case-Control Study of Motorcycle Crashes (Haworth et al.1997) identified a substantial number of crashes in which the rider either failed to perceive a hazard or made an incorrect or poorly timed response to the hazard. The hazards were often other vehicles but sometimes included motorcyclist-specific hazards such as aspects of the road surface. Many of the riders who had crashes involving deficiencies in hazard perception or responding were inexperienced. The requirement for improvements in hazard perception and responding for motorcycling is highly warranted in light of these results. However, most rider training courses do not focus on hazard perception and other higher order cognitive skills.

For motorcyclists, hazard perception requires knowledge of both the physical hazards associated with the road layout and the hazards associated with the behaviour of other road users. Research among car drivers has shown that hazard perception training by novices leads to improved performance on hazard perception tests (Crick & McKenna, 1991; 1992; Mills, Hall, McDonald & Rolls 1998), although it is not yet known whether these drivers go on to be safer drivers and have fewer crashes (McMahon & O'Reilly, 2000). No research has examined whether hazard perception training by motorcyclists leads to improved performance on hazard perception tests or, indeed, whether it leads to increased safety on the road.

There has been little evaluation of the effectiveness of products designed to improve hazard perception and responding by motorcycle riders. The lack of a good test of hazard perception and responding by motorcycle riders has prevented research to evaluate the effectiveness of motorcycle training programs and products in enhancing these skills.

#### *3.1.2.3 Duration of training programs*

Primarily motorcycle training programs for learners or licensing are of limited duration, typically less than one or two days. Such a short time frame is unlikely to produce limited change in rider behaviour (Christie, 2001) however an optimum duration is not known (Senserrick & Whelan, 2003). Haworth and Smith (1999a) concluded that four days were needed to deliver a training program that would allow novice riders to reach a level where they would be considered to be competent to ride unsupervised under Australian road conditions.

#### *3.1.2.4 When training should occur*

In the case of motorcycling, the learner rider is largely unaccompanied in most licensing systems during any learner period, however it would be reasonable to assume that the most basic skills should be well learnt during the time when restrictions are in place.

Training is typically integrated into the licensing system. One approach evaluated in Thailand included components linked to licensing. The program included information on the epidemiology of motorcycle crashes within the area the program was implemented, the risks associated with riding a motorcycle, effective ways of protection (i.e., helmet use), and rider education on traffic laws, vehicle regulations, traffic signs, as well as, written and skills tests for licensure (Swaddiwudhipong, Boonmak, Nguntra, Mahasakpan, 1998). The authors found that after the intervention, injury rates (from police and hospital records) were significantly lower in the districts that received the intervention compared with those that did not after a one-year follow-up period (10.5 compared with 16.9 per 1,000/ population). However, during this time another mass media campaign on injury prevention was also being run.

For higher-order cognitive skills such as hazard perception, however, it has been recommended in the driving context, that training be implemented at a time when the novice has had some on-road solo driving experience (Catchpole, Cairney & Macdonald, 1994; Gregersen & Bjurulf, 1996; West & Hall, 1998). Including hazard perception skills in a graduated licensing system provides encouragement and incentive for novices to develop these skills (Christie, 2001; Lynam, 1996).

Developing safe attitudes and motivations through insight training is likely to benefit riders prior to the learner period, or even earlier during the primary and secondary school years (Henderson, 1991; Fresta, Lee, Leven, Mark, McAlpine, Watson & Watson, 1995, cited in Senserrick & Whelan, 2003). Such a timeline highlights the importance of general road safety messages delivered across the lifespan.

### 3.1.3 Rider testing

The safety objective of rider testing rests on a process of selection; those who lack the required competencies are not permitted to enter the system. In practice, testing tends to operate to encourage training and practice as most who fail on initial attempts simply take the test again (Waller, Li, Hall & Stutts, 1978, cited in Goldenbeld, Baughan & Hatakka, 1999; Macdonald, 1988; McKnight, 1992; Mynttinen, 1996, cited in Goldenbeld et al. 1999, & Baughan, 2000).

Goldenbeld et al. (1999) outline the ways in which a driving test may influence training:

- The content of the test and the test standards directly influence the type, standards and amount of training and practice

- The test itself may serve as training by indicating to "failed" learners the areas that need further work.

Research suggests that there is little evidence for a relationship between test scores and subsequent accident liability, in the case of car drivers (e.g. Macdonald, 1988) and there has been little research on the effectiveness of motorcycle tests, despite their widespread use. Mayhew and Simpson (1989) concluded that improved testing and licensing systems were associated with reductions in casualties among novice motorcyclists in those jurisdictions where evaluations had been conducted. However, they argued that these reductions were likely to result from a reduction in the amount of riding as potential riders were not inclined to participate in more complex schemes and, therefore, were less likely to become riders. Thus it is unknown how such factors might operate in jurisdictions in which riding is primarily for commuting rather than leisure and there is a greater need for motorcycles as a form of transport.

Rockwell, Kiger and Carnot (1990) reported an evaluation of the Ohio Motorcyclist Enrichment Program (OMEP) Basic Riding and Street Skills Course. A higher percentage of the trainees who had scored in the highest skill category had been involved in a motorcycle crash than those in all other skill test categories. However, those trainees who obtained scores above 85 percent on the knowledge test appeared to have a lower motorcycle crash involvement rate.

Buchanan (1988) compared the Motorcycle Operator Skill Test (MOST) II with the current system in New York. MOST II is an eight-segment off-road motorcycle riding skills test, which measures a rider's ability to handle a motorcycle. The exercises comprise a sharp right turn, accelerating and slowing through an arc to the right, then one to the left, controlled stop with the front tyre inside a marked area, turning speed judgement, making a quick stop on the straight, obstacle avoidance, and making a quick stop on a curved path. Riders need to complete all eight sections to achieve a pass. Points are accrued for errors such as touching painted lines, putting your foot down on the ground during a test, or hitting cones. Riders must not accrue more than eight points; otherwise a fail mark is given. Those riders who were assessed by the MOST II as showing higher skill levels were not significantly less likely to be involved in subsequent motorcycle crashes.

Jonah, Dawson and Bragg (1981) attributed the failure of the Motorcycle Operator Skill Test (MOST) to predict accident involvement to the absence of testing for danger perception and risk-taking. "The focus of the MOST test and indeed most licensing tests is still primarily geared towards the acquisition of basic vehicle control, a fact which inevitably influences the content of elementary training courses aimed essentially, whether consciously or unconsciously, at equipping novices to pass the test" (Crick and McKenna, 1991, p.104).

Given the guiding role that testing has in establishing the method and subject matter of training, it is important that researchers and practitioners have a clear theoretical outline of the task and of the goals of training (Goldenbeld et al. 1999). Any limitation in our understanding of the task necessarily places constraints on our knowledge of what should be trained and therefore what should be tested.

#### *3.1.3.1 Knowledge tests*

In the initial stage of many licensing systems, prospective drivers/riders must pass a theory test before being issued with a learner's permit. The theory test is generally written and may cover a wide range of topics including traffic regulations, behavioural rules, automotive engineering, behaviour in risky situations, attitudes towards driving/riding, behaviour of other road users, vehicle safety, vehicle maintenance, and recognition and avoidance of risky situations (Goldenbeld et al., 1999).

In some jurisdictions there is a separate or additional knowledge test for motorcyclists. In other jurisdictions, motorcycle licence applicants are exempted from the knowledge test if they already hold a car licence. There is no evidence available regarding the effects of these different requirements on motorcycle safety.

#### *3.1.3.2 Practical tests*

Current on-road practical tests require candidates to demonstrate satisfactory performance on road and traffic regulations and vehicle control skills but there is very little coverage of characteristics such as propensity to take risks and attitudes and motivation. Additionally, due to the restricted conditions in which they operate, on-road tests do not provide a good measure of higher order cognitive skills such as hazard perception and responding. Yet research to date has demonstrated that these factors may be implicated in the high accident liability of young/inexperienced drivers (e.g. Catchpole, Cairney & Macdonald, 1994; Hall & West, 1994, cited in Goldenbeld, 1999; Parker, Reason, Manstead & Stradling, 1995). However, the difficulty of including these variables in practical tests is associated with a limited understanding about how these skills can be identified, how they should be measured and at what standard of performance they should be assessed. Most motorcycle practical tests are administered off-road, often in a very small area. Thus, while they share the drawbacks of on-road practical tests outlined above, their ability to measure even vehicle control skills at realistic speeds is limited. This may be exacerbated in regions where there is high traffic density.

#### *3.1.3.3 Hazard perception tests*

One of the arguments for hazard perception testing is that it encourages licence applicants to attempt to improve their hazard perception skills, either informally or by undertaking formal hazard perception training. Many current motorcycle learner and licence tests arguably do not measure hazard perception, although they measure some components of the ability to respond (e.g. application of counter-steering techniques to swerving around obstacles, quick stops on straight and curved paths). Performance on these tests has not been found to predict a rider's total number of crashes, their number of reportable crashes (those that resulted in a certain amount of property damage), or the number of crashes recorded in the rider's police file (Chesham et al., 1993). The relationship between performance on car driver tests and later crash involvement is also weak or non-existent.

The importance of hazard perception skills for safe riding has been clearly established. Deficient hazard perception and responding skills have been found to contribute to crashes involving inexperienced motorcyclists (e.g. The Case-Control Study of Motorcycle Crashes (Haworth et al., 1997) as has been documented widely in the literature for inexperienced car drivers. Hazard perception training programs have contributed to improved performance in hazard perception skills for inexperienced car drivers (although no studies have examined the impact on subsequent crash involvement). Horswill and McKenna (1998) found that hazard perception training for car drivers reduced their risk-taking propensity. Given that motorcyclists have been found to engage more often in behaviours known to increase crash risk (e.g. Horswill & Helman, 2001), it might be expected that the potential benefits of a hazard perception training program designed specifically for motorcyclists would be even more critical for this group. Developments to improve hazard perception and responding skills are perhaps more critical for riders than for drivers given the different vehicle control skills involved in riding a motorcycle and the different and additional hazards (including road based hazards) for motorcyclists and their much greater likelihood of injury in the event of a crash compared to car drivers.

More comprehensive empirical research needs to be done in terms of what affects motorcycle rider hazard perception, how this varies among the different classes of hazards, and the extent to which hazard perception in motorcyclists can be trained. It is also questionable whether the hazard perception tests developed for car drivers give sufficient emphasis to hazards specific to motorcyclists such as road surface hazards. This would limit their ability to be able to predict later crash involvement.

### 3.1.4 Licensing, training & testing conclusions

Rider licensing systems are one of several measures designed to prevent motorcycle crashes. Licensing systems vary between jurisdictions, although can include some restrictions and special requirements for beginning riders. The licensing system can bring about reductions in the number and severity of crashes by reducing the amount of the activity being undertaken (often termed exposure reduction) or by ensuring that the activity is undertaken more safely (often termed risk reduction). There has been very little evaluation of the effectiveness of licensing systems for motorcyclists.

Testing is a near universal requirement but there are substantial differences between jurisdictions in the required minimum age of candidate, conditions for issuing a licence, subject matter of testing, practical execution of testing and in the conditions for re-testing. Most motorcycle practical tests are administered off-road, often in a very small area. Thus, their ability to measure vehicle control skills at realistic speeds is limited, particularly for those in which most riding is done at greater speeds. For others, a potential limitation is in negotiating traffic.

Elliot et al (2003, p.60) summarise the reasons for the lack of effectiveness of current motorcycle training programs as follows:

- ‘A relative lack of attention to higher order cognitive skills including those associated with hazard anticipation, recognition and assessment.
- A tendency to improve confidence rather than improve self-assessment of limitations
- Difficulties in dealing with attitudes and motivations, especially in light of research findings that motives associated with sensation seeking are for some riders, an intrinsic part of motorcycling.’

In terms of best practice in training:

- Compulsory training appears better than voluntary training. This may be due to reductions in exposure rather than risk reduction. Compulsory training may act to deter would be riders from applying for a licence (because of the effort involved in completing the training), thereby discouraging riding and, hence, exposure to risk.

- There is no real evidence of particular programs or components leading to reductions in crash risk. The lack of scientific evidence from training evaluations makes it difficult to identify best practice in terms of frequency and duration of training, learning aids, training venues and assessment techniques.

- Longer or more costly compulsory programs might also be expected to lead to larger reductions in riding especially where riding is not for leisure. Such courses may act to deter would be riders from applying for a licence (because of the effort involved in completing the training), thereby discouraging riding and hence, exposure to risk.

Hazard perception training holds promise for developing such skills and reducing crashes.

Rider testing influences training in two main ways; (1) the content of the test and the test standards directly influence the type, standards and amount of training and practice, and (2) the test itself may serve as training by indicating to "failed" learners the areas that need further work.

In general, both knowledge and practical motorcycle tests include very little coverage of characteristics such as propensity to take risks, and attitudes and motivation. The importance of hazard perception skills for safe riding has been clearly established. More comprehensive empirical research needs to be done in terms of what affects motorcycle rider hazard perception, how this varies among the different classes of hazards, and the extent to which hazard perception in motorcyclists can be trained.

There has been little research on the effectiveness of motorcycle tests, despite their widespread use. Improved testing has been associated with reductions in casualties among novice motorcyclists in those jurisdictions where evaluations had been conducted. However, these reductions may result from a reduction in the amount of riding, as potential riders in the studies conducted were not inclined to participate in more complex training schemes and, therefore, it is likely they were less likely to become riders. Nevertheless, for motorcycle licence applicants who are serious about taking up riding, testing is an important component of the licensing system given the guiding role that it has in establishing the method and subject matter of training.

## 3.2 MAKING RIDERS EASIER TO SEE

There are many APEC economies in which larger vehicles, such as passenger cars represent a reasonable proportion of vehicles on the road. In such economies, failure to give way to the motorcycle by the larger vehicle has been found to be a common occurrence in multiple vehicle crashes in a range of studies (e.g. Hancock, Wulf, Thom & Fassnacht, 1990; Olson, Halstead-Nussloch & Sivak, 1980; Brooks, Chiang, Smith, Zellner, Peters & Compagne, 2005; ACEM, 2004).

The possible reasons for these crashes include:

- the driver of the other vehicle failing to see the motorcycle and rider
- improper judgement of the speed and distance of the approaching motorcycle
- disregard for motorcyclists

With regard to the colour of helmets and clothing to improve conspicuity relatively little recent work has been conducted. Haworth et al. (1997) found that in Victoria, Australia more commonly helmets were black or dark-coloured (over 50%) with fewer white or light in colour (over 20%).

The Social Development Committee Inquiry into Motorcycle Safety in Victoria, Australia (1992) considered that in the 3 percent to 8 percent of daytime motorcycle casualty collisions in Victoria, where the vehicles concerned approached each other from the side, motorcycle colour and fluorescence may have improved visibility. The Committee therefore recommended that riders be encouraged to use yellow, white, red and fluorescent colours, a strategy designed to increase the contrast between motorcyclists and their backgrounds. Dahlstead (1990, cited by White, 1994) found that the best conspicuity treatment was to have the largest possible area of a single light fluorescent colour. Patchwork outfits of bright contrasting colours may not be as effective because they may have a camouflaging effect (White, 1994).

## 3.3 EDUCATING OTHER ROAD USERS ABOUT THE PRESENCE OF MOTORCYCLISTS

Another approach to reducing crashes in which other road users fail to notice or give way to motorcycles is to educate the other road users. This may especially be so in economies where other road users represent a reasonable proportion of the vehicle types on the road.

Some evidence suggests that car drivers who have motorcycling experience have a lower chance of being involved in a crash with a motorcyclist than drivers without such experience. Hurt et al. (1981, cited by Hancock et al., 1990) recorded that automobile drivers involved in collisions with motorcycles were usually "unfamiliar" with motorcycles. Since most multi-vehicle motorcycle crashes in similar economies result from an automobile driver violating the motorcyclist's right of way (Potter, 1973; Hancock et al, 1990), efforts to increase the awareness of the car drivers may result in a reduction in these crashes.

Attempts to decrease crash rates by more general educational measures might also be valuable. For example, a wide range of public education and awareness campaigns have grown up around broader motorcycle safety programs in various states of the US and Canadian Provinces. These programs have been aimed at a variety of audiences, from novice motorcyclists to the general driving public. Many of the more successful materials produced from one jurisdiction have been adopted by other jurisdictions. One particular campaign in California involves a series of billboard and bumper stickers promulgating the theme, "My brother (sister, father, etc.) rides, please drive carefully" (Nairn, 1993; p.32). These are designed to both increase driver awareness and to change the image of the motorcyclist from an anonymous black-helmeted threat to somebody's loved one.

The effectiveness of such countermeasures has not been evaluated.

## 3.4 ENFORCEMENT TO REDUCE RISKY BEHAVIOURS

Enforcement can reduce risky behaviours by both riders and other road users. Police enforcement campaigns traditionally target key crash risk factors or common illegal behaviours, for example, unlicensed riding, and speeding by riders and drivers.

### 3.4.1 Enforcement targeting unlicensed riders

Many riders involved in on-road crashes are unlicensed or riding an unregistered motorcycle. In many cases, unlicensed riding is associated with an illegal blood alcohol concentration and not wearing a helmet. Calculations by FORS for the years 1992 and 1994 showed that the fatality rate for “responsible motorcyclists” (sober and licensed riders) was less than half of that for all motorcyclists (5.25 versus 11.24 fatalities per 100 million km ridden). In more recent US research, in 25% of all fatal motorcycle crashes, the rider was unlicensed. A study examining motorcycle crashes in Thailand sampling primarily from the roadside after a police call out included 17% of riders in Bangkok who were unlicensed and 50% in the Upcountry (see Joint OECD/ITF Transport Research Committee – Workshop on Motorcycle Safety, 2008).

Further, official crash databases are likely to underestimate the number of unlicensed riders in non-fatal crashes because of the unwillingness of these riders to report crashes to Police where it is possible to avoid doing so. An Australian study has shown that 45% of riders under the age of 21 hospitalised following crashes coded on the hospital file as “on-road” were unlicensed or unregistered (Haworth et al., 1994). There were three times as many riders under the licensing age of 18 years on the Victorian Inpatient Minimum Dataset (VIMD) and coded as “on-road” than on the Police reported accident database.

The minimum consequence of such a percentage of riders being unlicensed means that many riders have circumvented the skill and knowledge tests that are a major component of those countries’ motorcycle safety programs. Therefore, more effective enforcement of licensing and registration for motorcycles could serve as a deterrent to unsafe practices and thus have potential as a measure to reduce crashes.

### 3.4.2 Speed enforcement

Speed enforcement of both riders and car drivers has the potential to reduce both the incidence and severity of crashes involving motorcycles.

In 2006, a contributing factor to 37% of fatal motorcycle crashes was speed. Speed enforcement helps to make lower speed limits effective. Evaluations of 50 km/h urban speed limits have shown larger reductions for unprotected road users than for car occupants in Australia (RTA, 2000; Hoareau, Newstead & Cameron, 2005). While most of the analyses have focused on the improvements in pedestrian safety, these benefits are likely to extend to motorcycle riders.

There is however difficulty related to enforcement of speed limit restrictions on motorcyclists with regard to enforcement using speed cameras. The front vehicle registration plate is used in many jurisdictions as a means of identifying road users who speed and enforcing fines. However, these are not always required to be fitted on a motorcycle. Motorcyclists have argued that a metal plate on the front of their motorcycle poses a safety risk to themselves and others should they be involved in a crash. Proponents of requiring front number plates to be fitted argue motorcyclists can (and often do) ride at unsafe and illegal speeds past cameras with impunity. Therefore, the argument follows, requiring a front number plate should *improve* motorcycle safety.

Alternatives to front metal plates are under investigation. For example, a speeding vehicle can be is photographed from the front, which activates a second lens to photograph the rear of the vehicle. Replacing current front photographing speed cameras with dual-lens models is perhaps cheaper and politically and practically easier than fitting front number plates.

### 3.4.3 Lane splitting

Another practice considered unsafe by most road users except motorcyclists is "lane splitting", where a motorcyclist will share a lane with another vehicle travelling in the same direction in order to pass it. The term "lane filtering" refers to the act of using the space in a lane to pass a line of vehicles halted at a set of traffic lights (or equivalent) in order to be at the front of the queue when the traffic can move off. Crashes involving a motorcycle lane filtering (or lane splitting) are not counted separately from other crashes. Rather they are generally included in a "manoeuvring" category of crashes, which also includes u-turn crashes and parking-related crashes. No published research was found specifically considering the degree of safety or danger associated with lane splitting or lane filtering.

### 3.4.4 BAC enforcement

There are a considerable number of alcohol-related motorcycle fatalities and as such many jurisdictions legislate a maximum blood alcohol content (BAC). To enforce such a maximum BAC, random breath testing (RBT) is among the most effective countermeasures. While a number of factors have contributed to the reduction in alcohol-related crashes in Australia, RBT is generally acknowledged to be the most successful countermeasure in the area (Henstridge, Homel, Mackay, 1997). A review of RBT in Queensland, Australia found that the introduction of RBTs was associated with an 18% reduction in alcohol-related driver and rider fatalities (Watson, Fraine & Mitchell, 1994).

### 3.4.5 Enforcement of other illegal behaviours by other drivers

Enforcement of illegal behaviours by all road users, including car drivers contributes to improving the safety of motorcycle riders. For example, a clear benefit to random breath testing is to reduce the number of drinking drivers who collide with riders. Additional bans and enforcement of other illegal behaviours such as the use of hand-held mobile phones and cameras to detect violations of a red light are likely to have safety benefits for motorcyclists by reducing driver distraction and preventing crashes in which drivers continue through signalised intersections and collide with motorcycles on intersecting roads.

# 4 RIDER MEASURES TO REDUCE INJURY SEVERITY

The most critical injuries to motorcyclists in crashes are head injuries, followed by upper torso and leg injuries. Arm injuries, while common, are rarely life threatening when appropriate first aid strategies can be administered (RoSPA, 2001; see also Haworth, Smith, Brumen & Pronk’s 1997 Case Control Study of Motorcycle Crashes). Countermeasures have been developed which focus on reducing injuries to the head (helmets and air bags) (Liu, Ivers, Norton, Blows & Lo, 2003), the upper torso (air bags) and the legs (fairings and crash bars) (Pegg & Mayze, 1980; Motorcycle Safety Foundation, 1993; Haworth & Schulz, 1996; ACEM, 2004; de Rome, 2005).

In general, two approaches have been proposed to reduce injuries to motorcyclists in crashes: putting protection on the rider's body (mainly helmets and protective clothing) and mounting protection systems on the motorcycle (mainly lower limb protectors and air bags). Evidence for the effectiveness of the first approach is much more unanimous than for the second. Ouellet (1990) concluded that "the pre-crash and collision motions of the motorcycle, and the freedom of the unrestrained rider to move about during impact, combine to severely limit the effectiveness of motorcycle mounted protection systems" (p.45).

This section describes the effectiveness of countermeasures designed to reduce injury severity in motorcycle crashes through the use of (1) helmets and (2) protective clothing.

According to the Haddon matrix of motorcycle safety, the use of helmets and protective clothing should impact on improving motorcycle safety as injury reduction measures.

## 4.1 HELMETS

The most effective intervention currently available to reduce motorcyclist injuries is the motorcycle helmet. A systematic review of the effectiveness of wearing motorcycle helmets in reducing deaths and head and neck injury concluded that motorcycle helmets appear to reduce the risk of fatal injury (Liu et al., 2003). The authors note that there was also some evidence that the effect of helmets on mortality was modified by speed. From five well-conducted studies they found that motorcycle helmets reduced the risk of head injury by around 72% however that some poorer quality studies suggested that helmets have no effect on the risk of neck injuries or facial injury. Liu and colleagues also concluded that there was insufficient evidence to demonstrate whether different types of helmets (i.e. open-faced versus full-face) are more or less effective in reducing injuries.

There is evidence for the effectiveness of helmets on reducing fatalities as well as serious injuries. Lee, Chen, Chiu, Hwang, and Wang (2010) found Quality-Adjusted Life Years (QALYs) for those who wear helmets can save an average of five quality-adjusted life-years among those sustaining head injuries. A reduction in injuries has also been found using police-report crash data. Keng (2005) found a reduction in head and neck injuries by 53% and fatality from these injuries by 72% and in an adolescent sample, a higher prevalence of severe injuries and other face and head injuries were found among unhelmeted, compared with helmeted, adolescent riders (Lin, Hwang, Kuo, 2001).

There is also evidence of the effectiveness of helmets in a number of jurisdictions. Nakahara, Chadbunchachai, Ichikawa, Tipsuntornsak, and Wakai (2005) and Kanitpong Boontob, and Tanaboriboon (2008) both investigated motorcycle crash victims by using hospital records from the Trauma Centre of Khon Kaen Regional Hospital and another 16 hospitals across Thailand. The researchers found that unhelmeted riders had a higher risk of fatality than helmeted riders. In particular, Kanitpong and colleagues (2008) found that non-helmeted riders were 2.48 times more likely to receive a head injury and 1.7 times more likely to suffer a more severe head injury then helmeted riders. These results show the benefit of helmet use, however, they are based on hospital samples only, thus, excluding those who died at the scene and those with less severe injuries. Oullet and Kasantikul (2006) and Kasantikul, Ouellet, and Smith (2003) however investigated crash scenes monitored through hospital and ambulance dispatch centres. These investigations found that unhelmeted riders were about three times as likely to be killed as helmeted riders (both) and that 8.7% of unhelmeted riders suffered brain injury compared to 2.4% of helmeted (Ouellet, & Kasantikul, 2006). Furthermore, helmeted riders tended to have a higher somatic injury severity than unhelmeted, who were more likely to die with little or no somatic injury, suggesting helmeted riders were less likely than unhelmeted riders to die in minor crashes (Kasantikul et al., 2003). Similar helmet effectiveness studies have also been conducted in Indonesia showing 32% and 15% of helmeted motorcyclists who visited four emergency departments in Yogyakarta received head injuries or serious head injuries compared with 52% and 29% of unhelmeted patients (Conrad, Bradshaw, Lamsudin, Kasniyah, & Costello, 1996).

Head injury can be reduced by:

- increasing wearing rates
- improving motorcycle helmet crash performance
- improving restraining systems for helmets, and
- optimising rider vision.

### 4.1.1 Increasing wearing rates

One of the effective ways to encourage helmet wearing is to mandate wearing. In Thailand the effect of motorcycle legislation was investigated by Ichikawa, Chadbunchachai, and Marui (2003). They examined motorcycle patients admitted to the Kohn Kaen Regional hospital pre and post legislation enforcement (i.e., excluded time period when program was being implemented but not enforced). They found a 33.5% reduction in injuries from pre- to one year post-enforcement. Hyder, Waters, Phillips and Rehwinkel (2007) cite a 1999 study by Umar and Law that found the introduction of the Malaysian Motorcycle Safety Program in 1997, which included the use of motorcycle helmets, resulted in a 32% reduction in motorcycle causalities.

Community programs have also been trialled in an attempt to increase helmet wearing, for example, the Community Youth Helmet Use Project, an 18-month program based on the Helmets manual. It began in 2008 aims to work with 120 villages in Thailand to develop innovative and sustainable ways to encourage helmet use among young people. Throughout 2008 village and district workshops have been organised in which community leaders develop proposals and are trained in good practice for helmet use.

### 4.1.2 Improving the crash performance of helmets

There is also continued importance in improving the performance of helmets. For example, it has been estimated that a 30% increase in helmet absorbing characteristics would convert 50% of the severe injuries to less severe injuries (Mellor & St Clair, 2005). Further work is being undertaken to minimise the cost of advanced motorcycle helmets and to develop a possible consumer information scheme for motorcycle helmets.

Increasing the helmet test area has potential to improve the performance of helmets and remove some helmets that do not appear to provide sufficient coverage (bucket styles). Minor oblique impacts were capable of producing a variety of head injuries, ranging from minor unconsciousness to severe brain damage (Nairn, 1993).

Pegg and Mayze (1980) reported that a full-face visor is helpful in preventing respiratory burns that may result from a crash fire, but the authors argued that standards should ensure helmet visors do not melt when a fire does occur.

### 4.1.3 Improving the retention performance of helmets

Most in-depth studies have found a small number of cases in which the helmet was dislodged, despite evidence that the chin strap had been secured. For example, Huybers (1988, cited in Nairn, 1993) reported that the "coming off" rates of helmets varied from 7 percent to 36 percent.

While improvements to straps etc may need to be investigated, much of the problem may be due to a combination of incorrect fastening and poor fit. Of significance here is an earlier study by Mills and Ward (1985, cited in Nairn, 1993) which found that the position of the chin strap pivots and the correct fit of the helmet at the rear are important factors in the prevention of helmet rotation and loss.

Further, Cooter et al (1988, cited in Nairn, 1993) suggested that the rotation of a full face helmet following impact on the rider's chin guard may cause fatal damage to the brain stem. Krantz (1985) reported a similar injury mechanism in 5 out of 132 helmeted motorcyclist fatalities. The preparation and implementation of an education program concerning correct fit and fastening, targeted at both riders and helmet retailers is recommended (Nairn, 1993).

Tsai, Wang, and Huang (1995) investigated the effectiveness of different helmet types in motorcycle crash victims admitted to emergency care hospitals in Taipei. They found that helmet use reduced the relative risk of head injury when comparing those with head injuries to equivalent on-road controls (photographed later) and when compared to non-head injury emergency room controls (to relative risks of .64 and .54 respectively). Also it was found that full face helmets had a better protective effect than partial or full helmets (those that cover the top of the head only).

Also in Japan research shows that the benefit of helmets is particularly noticeable for full-face compared to open-faced helmets (Hitosugi, Shigeta, Takatsu, Yokoyama, & Tokudome, 2004). However, this latter study also reports that while helmet use can reduce brain contusions they are less effective for neck injuries, injuries remote from the point of impact and injuries resulting from angular acceleration, which again supports the need to consider other safety elements in a crash as well as crash prevention.

## 4.2 PROTECTIVE CLOTHING

While the main aim of helmets is to prevent serious head injuries, protective clothing attempts primarily to reduce the severity of more minor injuries. Minor injuries are more common and thus there are significant benefits to be achieved in reducing their incidence and severity. Given the effectiveness of protective clothing, there is a need for riders to be able to choose clothing that will truly provide good protection. Such choice is balanced with costs of protective clothing and individual practical concerns such as suitability for different weather conditions and cost.

Studies have shown that protective clothing such as leather gloves, jackets and trousers can significantly reduce soft tissue injury, such as lacerations, contusions and abrasions (Motorcycle Safety Foundation, 1993). In addition, protective clothing designed specifically for motorcycling can move the thresholds for more serious injury.

While much of the research in lower limb protection has focussed on systems fitted to the motorcycle, there is considerable evidence that many of the less severe injuries can be prevented or reduced by protective clothing. The extent of burns to the lower extremities can be reduced by covering the legs and wearing adequate footwear (Pegg & Mayze, 1980). Heel flap injury can easily be prevented by the wearing of protective footwear while riding, and by the installation of wheel guards (Das De & Pho, 1982). Benefit-cost calculations for compulsory wearing of protective clothing by motorcyclists and pillion passengers (Torpey, Ogden, Cameron & Vulcan, 1991) demonstrated that this countermeasure would need to be only 2.5 percent effective to reach break-even point. These calculations were based on police-reported crashes. If these figures were adjusted to account for the under-reporting of crashes, the effectiveness needed for the measure to reach break-even point would be further reduced.

# 5 VEHICLE MEASURES TO PREVENT CRASHES

This section describes the effectiveness of vehicle-based measures designed to prevent motorcycle crashes and include:

- Improvements to motorcycle braking
- Improved maintenance
- Making motorcycles easier to see
- Improved field of view for car drivers
- Choosing safer motorcycles.

According to the Haddon matrix of motorcycle safety (Table 1), these measures should have their biggest impact on improving motorcycle safety as crash prevention measures. These measures address the problem of instability and braking difficulties common among riding, as well as driver failures to see motorcycles, as some of the factors contributing to the over-representation of motorcycle riders in crashes.

## 5.1 IMPROVED BRAKING SYSTEMS

One area of concern involving motorcycle braking in wet weather conditions has been the collection of water on brake discs, pads and linings. This phenomenon may adversely affect braking performance and, consequently, increase stopping distances. In 1986, members of the Transportation Research Board's Committee on Motorcycles and Mopeds reviewed a number of alternative brake designs which utilised special friction materials. The Committee concluded that "these materials may improve wet weather brake performance, under some conditions, without compromising performance in dry weather" (Nairn, 1993; p.24). The impact of wet weather on braking performance also highlight the importance of encouraging and promoting well-maintained motorcycles (see section 5.2).

Further research has centred upon anti-lock braking systems suitable for motorcycles. Antilock braking systems monitor the wheel speed of the motorcycle and decrease brake pressure on detection of impending wheel lock (Teoh, 2010). Analysis of crash data in the United States has shown that the rate of fatal crashes was lower for ABS motorcycles compared with motorcycles not equipped with ABS (4.1 per 100,000 versus 6.4 per 100,000 registered vehicles) (Teoh, 2010). The author notes that this equates to a 37% reduction in the rate of fatal crashes per 10,000 registered vehicle years. However, riders without ABS were slightly more likely to have been cited for speeding and impaired by alcohol at the time of the crash yet more likely to have been helmeted compared with riders with ABS. The study has important limitations to recognise in ABS being an optional extra for riders and as such may be a cohort different from riders who choose to purchase motorcycles without ABS.

Hurt (1981) demonstrated that many motorcyclists involved in crashes failed to use full braking capacity because they feared such a strategy might lock the brakes and capsize the motorcycle. Moreover, imbalances between the effects of the front and rear brakes can contribute to crash involvement. To encourage effective brake application and remedy these problems anti-lock brakes are being developed. The chief obstacle to their widespread use appears to be cost. Although some European and Japanese manufacturers offer anti-lock braking systems on selected models there is extra cost (Nairn, 1993).

Systems that equalise braking between the front and rear brakes may be more cost-effective than the more sophisticated concept of anti-lock braking. They have also been shown to reduce the stopping distance among experience riders on closed-circuit tracks (Green cite in NHTSA, 2010).

## 5.2 IMPROVED MAINTENANCE

Because the consequences of a minor technical failure of motorcycles can be more severe for a motorcyclist than for other vehicles, proper care and maintenance of the motorcycle warrants more frequent attention (Motorcycle Safety Foundation, 2005). Learning how to prevent crashes arising from mechanical failure of the motorcycle is an important safety component of motorcycle training. In general, pre-ride inspections by the motorcycle owner and regular servicing by a certified mechanic can help to prevent crashes arising from mechanical failure of the motorcycle. The implications of countermeasures to improve maintenance should be considered alongside minimum standards for quality of motorcycles entering the market at the time of purchase.

The Case-Control Study of Motorcycle Crashes conducted in Victoria, Australia (Haworth et al., 1997) examined the most common mechanical defects identified in the crashed motorcycles were:

- Under-inflated front or rear tyres
- Rust
- Worn or loose chain
- Insufficient brake pad thickness (front or rear)
- Tread badly worn (particularly rust)

Regular maintenance of the motorcycle is likely to decrease the contribution of mechanical deficits to crashes, although little is known about the effect of regular maintenance on crash rates and injury severity. In general, the prevalence of defects in the vehicle fleet has been found to be lower in jurisdictions that require periodic motor-vehicle inspections (up to 16%) (Rechnitzer, Haworth & Kawodlo, 2000). Studies that have compared crash rates before and after the introduction of such requirements (See Rechnitzer, Haworth & Kawodlo, 2000 for a review of these studies) have generally shown decreases in injury crash rates.

## 5.3 MAKING MOTORCYCLES EASIER TO SEE

Failure to give way to a motorcycle has been found to be a common occurrence in multiple vehicle crashes. Improving the conspicuity of motorcycles is one approach to preventing these crashes. As noted, on method to improve conspicuity includes the use of bright coloured clothing however the colour of the motorcycle and daytime use of headlights and running lights may also improve conspicuity.

Olson et al (1980) tested a number of possible methods of improving motorcycle conspicuity by examining their effect on gap acceptance by unalerted car drivers. The results indicated that daytime conspicuity is most improved by fluorescent garments or steady or modulating headlights. Similarly, night-time conspicuity is aided by retro reflective garments and running lights. However, the authors noted that, at night, retro reflective garments cannot be of assistance unless an approaching vehicle's headlights are pointed toward the motorcycle. Night-time right angle collisions would therefore be unaffected by such a measure.

Radin Umar, Mackay and Hills (1995) considered the effect of a campaign in Malaysia in 1992 to encourage motorcyclists to run their headlights during the day to increase conspicuity. The researchers examined change in the number of crashes involving motorcycles moving straight or turning when other vehicles cross their paths (crashes which the authors reported were those most likely relate to conspicuity) from before and after the campaign. They found a decrease in these crashes of 22%. Further, in another Malaysian study, the risk of night time crashes was reduced with the use of rear-end reflectors when the overall use in the community reached 35% (Tran, Hyder, Mani & Umar, 2007).

## 5.4 IMPROVED FIELD OF VIEW

Another approach to reducing motorcycle-car crashes is improving the fields of view of both the other vehicle drivers and riders. Research has examined modifications to car mirrors to improve field of view and also helmet design.

### 5.4.1 Modifications to car rear vision and side mirrors

Haworth and Smith (1999b) examined the involvement of a blind spot on the forward vehicle as a contributing factor to motorcycle crashes and examined possible changes to rear vision mirrors which could improve the performance of mirrors. From an analysis of Victorian and Australian crash data, they found that, as an upper bound estimate, the blind spot of another motor vehicle may have contributed to about 20.3% of motorcycle crashes. The estimated contribution to fatal crashes was lower than for other crashes (9.2% of Victorian crashes, 5.5% of Australian crashes).

Regulations in Australia, Japan and the United States require that the internal rear vision mirror be flat. Both Australia and the United States require that the driver side mirror be flat. The common rationale is that the most important mirrors should be flat to minimise distortions in distance and speed judgements. All of the four jurisdictions examined allowed passenger side mirrors to be flat or curved. Variations existed in terms of minimum radii of curvature, diameter and field of view.

Haworth and Smith (1999b) recommended that convex mirrors be allowed with a minimum radius of curvature of 1200mm and not as the main internal mirror (because of the danger of misperception of distance). The problems of misperception of distance can be reduced by using a compound mirror system, which consists of a flat (or relatively flat) section and a curved section. The flat part would be used for correct distance perception and the convex section used as a "presence" detector. The compound mirror system could be achieved by an aspheric mirror or by placing a small mirror with a small radius of curvature on the flat mirror. If an aspheric mirror is used, the proportion of the aspheric mirror over which the radius is changing should not exceed 40%. If a small mirror is attached to the flat mirror, the diameter of the small mirror should not exceed 40% of the height of the flat mirror.

## 5.5 CHOOSING SAFER MOTORCYCLES

In general, choosing a safe motorcycle means purchasing a motorcycle that is in good mechanical condition and is equipped with adequate safety features. Most vehicle safety features on motorcycles are designed to reduce injury in the event of a crash. These include leg protection devices and airbags. There are fewer vehicle safety features for motorcycles that work to prevent crashes. However these include improved braking, choosing light coloured motorcycles which can improve conspicuity and prevent crashes arising from driver failures to see motorcycles.

For beginning and/ or younger riders, a safe motorcycle may also be one that has a relatively small engine capacity and power to weight ratio.

### 5.5.1 Vehicle safety

Improvements in vehicle safety have contributed significantly to reducing crashes especially for car drivers and will continue to do so. Vehicles that are designed well are easier to control, reliable and predictable in emergency situations are likely to have few crashes in general, including with motorcycles. To improve the uptake of vehicles with increased safety features requires buyers to be able to make informed decisions, which in turn is likely to encourage manufacturers to improve and promote product safety. Safety should be promoted as a key consideration when purchasing a motorcycle and associated equipment.

## 5.6 CONCLUSIONS TO VEHICLE BASED MEASRUES TO PREVENT CRASHES

Vehicle-based measures to prevent crashes include:

- Improvements to motorcycle braking
- Improved maintenance
- Making motorcycles easier to see
- Improved field of view for car drivers
- Choosing safer motorcycles.

Measures to improve braking systems for motorcycles include the improvement of braking performance in wet weather and the use of anti-lock braking systems. The chief obstacle to the widespread use of anti-lock braking systems appears to be cost. As such, systems which equalise braking between the front and rear brakes may be more cost-effective than the more sophisticated concept of anti-lock braking.

Proper care and maintenance of the motorcycle warrants frequent attention given that the consequences of crashing can be severe for motorcyclists. Regular maintenance of the motorcycle is likely to decrease the contribution of mechanical deficits to crashes, although little is known about the effect of regular maintenance on crash rates and injury severity for motorcycle riders. In general, the prevalence of defects in the vehicle fleet has been found to be lower in jurisdictions requiring periodic motor-vehicle inspections, a finding which may contribute to improved safety and potentially fewer crashes.

Failure to give way to a motorcycle has been found to be a common occurrence in multiple vehicle crashes especially where motorcycles are in the minority of vehicle types. Improving the conspicuity of motorcycles is one approach to preventing these crashes. Methods for improving conspicuity include use of bright coloured clothing and motorcycles and daytime use of headlights and running lights. Motorcycle conspicuity during daylight hours can be improved with the use of fluorescent garments or steady or modulating headlights, while retro reflective garments and running lights aid night-time conspicuity.

Choosing a safe motorcycle means purchasing a motorcycle that is in good mechanical condition and is equipped with adequate safety features. There is little information available on the types of safety features being developed to improve motorcycle safety including published evaluations of their effect on safety. Many of the safety features being developed in cars to reduce injury severity have limited application to the design of motorcycles. Apart from the helmet, the motorcyclist is not protected by a vehicle and vehicle related safety features, and often becomes separated from the motorcycle following a crash. Safety should be promoted as a key consideration when purchasing a motorcycle and associated equipment.

# 6 VEHICLE MEASURES TO REDUCE INJURY SEVERITY

This section describes the effectiveness of measures designed to reduce injury severity in motorcycle crashes related to vehicles. The measures are categorised as vehicle based measures and include:

- Leg protection
- Airbags
- More motorcycle-friendly design of other vehicles

According to the Haddon matrix of motorcycle safety, these should have their biggest impact on improving motorcycle safety as injury reduction measures. These measures address the problem of riders' increased vulnerability to injury in crashes.

## 6.1 LEG PROTECTION

Injuries, particularly fractures, to the lower limbs of motorcyclists are common and a considerable amount of research has been conducted in this area. Generally, lower limb protectors incorporate a bar (crash bar) and/or other structure (e.g. fairing) designed to prevent intrusion into the spaces normally occupied by the rider's legs.

The need for a standard to ensure the strength of crash bars was noted by Pegg and Mayze (1980). They argued that many of the fitted crash bars were too flimsy or poorly designed to be effective.

Ouellet (1987) investigated 131 crashes involving crashbar-equipped motorcycles. He concluded that:

> *... leg space preservation is not strongly related to the occurrence of serious leg injuries in motorcycle accidents, primarily because the leg often does not remain in the leg space during the collision events.... (Thus), conventional expectations of crashbar performance and leg injury mechanisms simply are not supported by the in-depth analysis of actual accident events (cited in Nairn, 1993; 26).*

Ouellet also stated that leg protection devices may have the ability to affect favourably those serious leg injuries which result from direct crushing of the rider's leg against the side of the motorcycle during impact. Despite Ouellet's relative scepticism, Nairn (1993; 26) argues that such results nevertheless suggest that the severity of leg injuries would be reduced in approximately 50 percent of crashes which involved serious leg injury.

Fuel tanks can also sometimes cause damage to a rider's knees or legs (Pegg & Mayze, 1980) or pelvis (de Peretti, Cambas, Veneau, & Argenson, 1993). Bothwell (1971; 1975; cited in Nairn, 1993) recommended that to improve motorcycle collision performance the rider's ejection path should be smoothed and cleared of obstacles or, obstacles should be designed to make them less injurious. For example, care should be taken to ensure that petrol filler caps are recessed, not raised as a potential laceration and collision hazard.

## 6.2 AIRBAGS

Air bags and other restraint systems seek to reduce head and chest injury after ejection of the rider in head-on impacts. In head-on impacts,

> the rider continues to move forward in a seated position and hits the opposing object at close to his pre-impact velocity. These accidents often result in fatal or serious injury to the head and upper body of the motorcyclist. The lower body and legs often become entangled with the motorcycle which can impart an additional rotational component of velocity to the upper body, so increasing the potential for injury.
>
> Injury could be reduced if some method of restraint could be provided to protect a rider in frontal collisions by controlling his trajectory and reducing his velocity before he hits the opposing vehicle. (Finnis, 1990, p.1)

The restraint methods which have been proposed include: belts, saddle restraints, chest pads and air bags located either on the motorcycle or in the rider's suit. Finnis (1990) notes that most of these devices have proved unsuitable. Earlier studies with prototype motorcycle seat belts showed that restraint but not complete retention is desirable to reduce injury severity.

## 6.3 MORE MOTORCYCLE-FRIENDLY DESIGN OF OTHER VEHICLES

Modifications to other vehicles may have the potential to reduce the number and extent of the types of injuries resulting from motorcycle-to-vehicle collision or being run over after having been thrown from the motorcycle.

### 6.3.1 Improving truck under-run protection

While many fatal and serious injuries to riders in collisions with trucks are almost inevitable if such a collision occurs, improved under-run protection has some potential for reducing injury (while not preventing it completely) in some crash scenarios. Improved rear under-run protection for trucks may also prevent fatalities when riders (sometimes with high alcohol concentrations) ride into the back of stationary trucks and can be decapitated.

### 6.3.2 Collision avoidance system

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.

# 7 ROAD IMPROVEMENTS TO PREVENT CRASHES

This section describes the effectiveness of measures designed to prevent motorcycle crashes. The measures are categorized as road based (environmental) measures and include:

- Better road surfaces
- Intersection improvements
- Better road space allocation
- Better delineation
- Motorcycle crash blackspot treatments

According to the Haddon matrix of motorcycle safety, the road improvement measures discussed in this section should work to improve motorcycle safety as crash prevention measures.

## 7.1 BETTER ROAD SURFACES

Motorcycles by the very nature that they have only two wheels are more susceptible to difficulties and hazards created by the design, construction, maintenance and surface condition of roads. Road based hazards can be categorised as:

- Permanent characteristics of the road surface – roughness, being an unsealed or gravel road, low skid resistance, tramlines, railway lines, painted lines on roads
- Temporary characteristics of the road surface – potholes, surface irregularities, pit lid covers, oil or gravel on road, debris, gravel, melted tar in hot weather, roads that become greasy and slippery in summer during rainstorms (Allardice, 2002)
- Visual obstructions – stationary vehicles, vegetation, fog and heavy rain
- Characteristics of the road alignment – horizontal curves, vertical curves.

While road based hazards can, in some cases, cause loss of control of the motorcycle, their role is more often contributory when the motorcycle is performing a complex manoeuvre such as turning or braking. For example, a motorcycle braking heavily to avoid colliding with a car turning left across its path may be unsuccessful if the motorcycle had not crossed a manhole cover with an inch high asphalt beam around it which caused the front wheel to lock up and slide out, throwing the rider and passenger to the ground.

Haworth (1999) reported the results of the site inspections and ride-throughs conducted for the Case-Control Study of Motorcycle Crashes (Haworth et al., 1997). This provided an opportunity to assess whether the road conditions or the surrounding environment contributed to the occurrence or severity of the crash. In 31 cases (15% of inspected sites) it was found that the road surface actively contributed to the occurrence of the crash. In many other cases the variables were present at the crash site but did not actively contribute to the occurrence of the crash. In 47% of cases, no site factors were judged to have contributed to the occurrence or severity of the crash. The most common site factors were: lack of visibility or obstructions (20%), unclean road or loose material (14%), poor road condition or road markings (12%), and horizontal curvature (12%).

Better road surfaces provide an opportunity to prevent motorcycle crashes. The extent of the likely benefits depends on how much resources are devoted to such improvements and how much riders behaviour adapts to the better surfaces. If better surfaces lead to higher speeds, then some of the benefits may be dissipated.

## 7.2 INTERSECTION IMPROVEMENTS

As mentioned in earlier sections, many motorcycle crashes occur at intersections. Improvements to intersections, particularly signalised intersections, can reduce the likelihood of motor vehicle drivers failing to give way to riders. Fully-controlled turns at signalised intersections have been shown to have safety benefits for all road users (Newstead & Corben, 2001) and these benefits may be even greater for riders because of the large problem of crashes in which riders are injured at turns across the opposite flow of traffic.

Clearing vegetation near and within intersections (e.g. in the centre of roundabouts) may also prevent motorcycles from being obscured and thus reduce the problem of failure to give way by drivers. Li and colleagues (2009) found that, among other factors, crashes that occurred at intersections and areas with poor sight line conditions in Taiwan had an increased likelihood of death for motorcyclists. Based on these results the authors suggested it was suggested that increasing rider visibility by removing parking, trees and billboards near intersections could reduce the risk of motorcycle crash around the intersection site. Furthermore, Chang and Yeh (2007) mention the need for low risk environments in general for learner riders who are inexperienced in dealing with risky situations.

## 7.3 BETTER ROAD SPACE ALLOCATION

Separation is a fundamental safety principle for vulnerable road users (e.g. footpaths for pedestrians and bicycle lanes for cyclists). With regard to low speed vehicles that are part of the same road network higher speed vehicles this may also be important (Hunter-Zaworski et al., 2010). It has been suggested that regulatory authorities and planners must consider the connectivity of such road designs such that low speed roadways do not intersect with higher speed roadways. Hunter-Zaworski et al. (2010) suggests that this can "entail the identification and signage of existing roadways that provide complementary connections between residential neighborhoods and activity centers" (p.35).

In Malaysia, the first motorcycle lane was constructed along one of the busiest urban expressways in the early 1970s (Umar, Mackay & Hills, 1995). The lane was built as a separate track outside of the guardrail of the expressway. Umar et al. (1995) presented a preliminary analysis of the impact on motorcycle crashes of a 14km extension of this lane. The number of motorcycle crashes fell by approximately 25% immediately following the opening of the motorcycle lane, while the number in the control area remained steady.

While the crash reductions were impressive, the results may not generalise to the many contexts. Umar et al. (1995) note that most of the motorcycles had small engine capacities and were slower than other traffic. Thus many of the crashes that were prevented were likely those of cars running into the back of slow-moving motorcycles. In addition, motorcycles make up a large proportion of motorised traffic (and injuries and fatalities) in Malaysia and so the investment in separate facilities is likely to be much more cost-beneficial than it would be in Australia (where motorcycles comprise only about 1% of traffic). There have been calls to allow low-powered scooters to use on- and off-road bicycle lanes but no rigorous evaluations have occurred.

## 7.4 BETTER DELINEATION

More motorcycle crashes occur on curved roads than straight sections of roads. While rider preference for curved roads may increase the amount of riding on these roads, another factor contributing to motorcycle crashes is other vehicles rounding a bend and straying onto the motorcycle's side of the road (or vice versa). Improved delineation has potential to reduce these crashes.

Devices installed to improve delineation can have potential disbenefits to motorcyclists and recent work has focussed on minimising these unintended effects. Paints used for road markings traditionally had lower skid resistance than the surrounding pavement, resulting in slippery surfaces and motorcycle loss of control in some instances. There are paints and other road surface treatments developed that have similar skid resistance to the surrounding pavement and it is important to ensure that such paints are used rather than inadvertently increasing risk.

Similarly, steel reflective delineators on Armco (W-beam) safety barriers have been considered to be hazardous to riders in the past. A new pliable plastic delineator has been developed (HyLyte Joint 10) and is being trialled by VicRoads on routes with a high motorcycle crash risk. VicRoads will assess the effectiveness of the new delineators in terms of safety for motorcyclists, visibility to road users, durability, ease of installation and resistance to attack by vandals.

## 7.5 MOTORCYCLE CRASH BLACKSPOT TREATMENTS

A blackspot is a location on the road network where crashes are concentrated. Blackspot programs involve a systematic process of identifying high-risk sites, the factors contributing to crashes at those sites and developing and implementing cost-effective solutions. Treatments of crash blackspots have been demonstrated to be highly effective in reducing road trauma for all vehicles, with benefits considerably greater than their costs. Well-designed blackspot programs can prevent at least 2 fatalities per year per $10M invested, with a lifetime of between 15 and 25 years depending on the type of treatment (Vulcan & Corben, 1998). The extent to which motorcycle riders benefit from overall blackspot programs has not been investigated to date.

Preliminary analysis of the first 20 treated locations showed a 58 per cent reduction in motorcycle injury crashes and an 80 per cent reduction in serious or fatal motorcycle crashes in the first 12 months. It has three components, involving road treatments; at blackspots or blacklengths with high rates of motorcycle loss-of-control crashes, at intersections with high rates of motorcycle crashes, and along popular motorcycle routes to improve the consistency of the road environment for motorcyclists.

Longer-term analyses should provide better information on crash savings and provide guidance on which types of treatments are effective in reducing crashes and crash severity.

## 7.6 CONCLUSIONS

Road improvements to prevent motorcycle crashes can be divided into those that should be common practice in all work by road managers, and other improvements that are probably only justified at motorcycle crash blackspots or high volume motorcycle routes. In terms of changing common practice, there is a need for guidelines to be developed and road managers to be educated in their importance and use.

# 8 ROAD IMPROVEMENTS TO REDUCE INJURY SEVERITY

While most road improvements produce their safety benefit by preventing crashes, others play a larger role in reducing injury severity. Many of the latter road treatments provide a more forgiving environment in the event that run-off-the-road incidents do occur (which they term 'roadside hazard management') and consist of two key strategies: the development of clear zones and modifying roadside hazards especially trees and poles, so that any impact is either totally avoided or has reduced consequences. Barriers are one approach to modifying roadside hazards.

These measures address the problem of road surface and environmental hazards as factors contributing to the over-representation of motorcycle riders in crashes.

The reader is referred to Table 1 of the Haddon matrix for an understanding of how these measures to improve motorcycle safety have been classified in relation to other measures.

## 8.1 PROVISION OF SAFE ROADSIDES

Provision of safe roadsides is an important measure to reduce injuries in crashes involving all road users, but is particularly important for motorcycle riders. While protective clothing has benefits these may be lost if the rider impacts a solid object before enough speed has been lost in movement across the ground. Secondly, objects that are frangible for a car may not be frangible for a motorcycle.

A clear zone can be defined as a set distance between the outer edge of travel lane and including the shoulder, which has been cleared of obstructions to provide a safe recovery area for straying vehicles (United States Department of Transport, 1983, cited in Wilson, Corben & Narayan, 1999).

The clear zone concept is being questioned as an effective means of preventing serious injuries in run-off-the-road crashes, especially along high-speed, high-volume routes. For the case of a 15m median width, errant vehicles will, in many common crash scenarios, be able to pass through the median and reach vehicles travelling at high speed in the opposite carriageway Delaney et al. (2002b). Also, Delaney et al. (2002a) demonstrated that there was often insufficient time for the drivers of errant of vehicles to actually commence braking, before reaching the far boundary of the 9m clear zone. In most cases, the impact speeds with rigid objects situated beyond the clear zone would clearly exceed the capacity of even the safest vehicles to protect their occupants.

Unfortunately, the deceleration characteristics of riders who have been thrown from their bikes cannot be calculated in a similar manner to those of four-wheeled vehicles. Thus, while the presence of clear zones appears to be better than their absence, the adequacy of current guidelines (or practice) for motorcycle safety is currently unknown.

In addition to providing safe roadsides for motorcycles that have left the carriageway, there is also a need to ensure sufficient clearances between the edge of the carriageway and roadside objects for motorcycles travelling along the carriageway. Motorcycles differ from other vehicles in that they overhang their wheel track by about half a metre on each side and because they lean to change direction, which markedly alters the clearance they require when travelling upright (VicRoads, 2001). Failure to account for these characteristics may result in riders colliding with poles or signs or fences that are placed too close to the edge of the pavement.

## 8.2 IMPROVED BARRIER DESIGN

Barriers are erected to prevent the occurrence of some of the most severe types of crashes e.g. head-on crashes, crashes into trees, poles and other roadside objects, and rollover crashes. As part of this outcome, collisions with barriers occur instead of more severe crashes. Thus, the measure of effectiveness of barriers is how much they reduce injuries that might have occurred in the absence of the barrier, rather than whether the barriers themselves cause injury. Unfortunately, it is impossible to measure accurately the injuries that no longer occur, so the emphasis is often on the injuries that occur in collisions with barriers.

The design philosophy for roadside barriers that has developed over many years appears to not take explicit account of the needs of motorcyclists. Roadside barriers are designed to meet established United States or European crash-testing standards which define the crash test conditions in terms of vehicle mass, speed and angle of impact, with generally no requirement to consider motorcyclists. As a consequence, the physical design and performance of barriers in collisions can be insensitive to the specific needs of motorcyclists. Of particular concern, is that the mass of a rider is about an order of magnitude less than a typical vehicle. A barrier post designed to collapse in an impact with a vehicle therefore may prove effectively rigid to a motorcyclist.

There are three general categories of barriers that have different performance characteristics and uses. Solid concrete barriers are often placed in between opposing lanes of traffic on urban freeways to prevent head-on collisions. Steel W-beam or ARMCO guardrails are often placed at the edge of the road to prevent vehicles from colliding with dangerous objects such as poles, trees and bridge supports or from travelling down steep roadsides (e.g. ditches or cliffs). Flexible barriers have four heavily tensioned steel cables fastened in parallel or criss-crossed between upright posts. They are used to control vehicles that are leaving the roadway or to separate two opposing directions of traffic on undivided roads or along medians to prevent head-on crashes and crashes with trees, poles and other rigid objects located within medians.

While little scientific evidence is available regarding the mechanisms of injuries occurring in collisions between riders and barriers, most concerns have been raised about injuries caused by the posts supporting steel guardrails and by the steel cables of flexible barriers. It is also accepted that the rigid nature of concrete barriers, and the sharp edges of guardrail barriers, also present serious injury risks to motorcyclists. The magnitude of these risks relative to the various barrier types, (or the absence of a barrier), however, has been difficult to determine due to a lack of research in this area (Candappa, Mulvihill, Corben & Lenné, 2005; Federation of European Motorcyclists' Association (FEMA), 2000).

Ibitoye, Hamouda, Wong, and Radin Umar (2009), however, have investigated the effect of W-beam guardrails on motorcyclists in the event of a crash in Malaysia to identify the danger associated with such rails. The researchers used a simulation of a motorcycle crash based on a specific motorcycle design and the Ministry of Public Works specifications for the W-beam guardrail. The resultant animation showed that speeds of 48 and 60km/hr impact will cause the motorcyclist to eject from the vehicle and somersault to land on their back, while at 32km/hr the speed is not enough to create a whole rotation and thus the motorcyclist lands on his head. Not only does the impact of landing cause significant damage but also the head acceleration during ejection (with impact speeds of 48 and 60km/h) is above the limit at which brain damage is likely to occur. Ibitoye and colleagues (2009) also found a high risk for neck and chest injuries. The results of this research overall suggest that the existent guard rails are dangerous for motorcyclists, a factor which needs to be addressed in the future to reduce injury severity in the event of a crash.

While some motorcyclists suggest that the smooth surface of concrete barriers is more motorcyclist-friendly than flexible barriers, not all agree.

They conclude that Moto.Tub and crash barrier post protectors are the most promising approaches and propose that they be trialled at road sections identified by motorcyclist groups as posing elevated risks to riders (motorways and dual carriageways with outside curve radius less than 400m, other roadways with radius less than 250m and grade-separated intersections). They note that the shrub used as a decelerator in some jurisdictions is a noxious weed in others and suggest that trialling an alternative native plant that minimises costs and ensures ease of care is possible.

# 9 MEASURES TO IMPROVE TREATMENT OF INJURIES

Many of the measures to improve treatment of injuries are common to all road users in crashes. The measures are categorized as vehicle based, road (environmental) based, and rider based.

These include:

- Automatic collision notification (vehicle based)
- Improved emergency response (access and trauma management) (environment based)
- Safer removal of helmets (rider based).

Programs for safer removal of helmets are one of the few measures that are specific to motorcycle riders.

Vulcan (1998) states that, “It is likely that more rapid notification of serious crashes through mobile telephones or automatic transmitter devices fitted to vehicles will improve the chances of survival for seriously injured persons. Improvements in emergency medical services and procedures in hospitals may also reduce deaths among critically injured victims.”

## 9.1 AUTOMATIC COLLISION NOTIFICATION

There is now general agreement in trauma management that there is a short window of opportunity – the time in which it is necessary to transport a trauma victim to skilled attention in a specialist unit accustomed to dealing with trauma in order to maximise their chances of survival (Amos, 1993). In one study, Sampalis, Lavoie, Williams, Mulder and Kalina (1993) found that total prehospital time over 60 minutes was associated with a three times greater risk of dying. This can represent a ‘golden hour’.

Champion, Augenstein, Cushing, Digges, Hunt, Larkin, Malliaris, Sacco and Siegel (1998) proposed that an Automatic Collision Notification (ACN) system has the potential to significantly improve emergency medical responses and thus, outcomes for many injured patients. The ACN would comprise a crash recorder which collects crash impact data, an automobile location system and a cellular phone system which sends the crash and location data to the emergency medical system. They note that systems with some or all of these features are currently or will soon be available. However, it may be that sending information about the likely severity of injuries directly to the emergency medical services, rather than notification per se, that has the greatest potential to improve the outcome for the injured occupants. The early response may be particularly important for crashes in rural areas. Li, Doong, Huang, Lai and Jeng (2009) found that there were more fatalities in rural areas compared with urban areas in Taiwan and recommended that one approach would be to have facilitated an earlier medical response.

## 9.2 IMPROVED EMERGENCY RESPONSE

Prompt and effective treatment may transform a potentially fatal crash into a serious injury crash. Emergency response consists of collision notification, sending a response, at-scene treatment, and in-hospital treatment.

McDermott et al. (1996) found that system inadequacies contributed relatively more to pre-hospital treatment problems and patient management inadequacies contributed relatively more to in-hospital treatment problems. The pre-hospital system inadequacies were identified as:

- too long at scene
- unduly long time to or from scene
- inappropriate triage
- no dual response (Mobile Intensive Care Ambulance (MICA) plus normal ambulance)
- attending officers not qualified in Advanced Trauma Life Support (for example, patient was not intubated or given intravenous fluids when required).

Overseas studies have shown that changes to trauma management systems (integration, coordination, and inclusiveness of providers, designation of hospitals to receive major trauma, concentration of expertise in trauma management, and agreed triage and transport protocols) can reduce the potentially preventable outcome rate from levels similar to the 36% found in Victoria to figures as low as 3% (Cales, 1984; Shackford, Mackersie, Hoyt, Baxt, Eastman, Hammill, Knotts and Virgilio, 1987; Davis et al., 1992, cited in Review of Trauma and Emergency Services – Victoria 1999).

Most of the research thus far has focussed on the possible increases in survivability of crashes due to improvements in emergency medical services. There is a need for more information about the effects of improved emergency medical services on the severity (and long-term consequences) of non-fatal crashes. The Major Trauma Management Study (Danne et al., 1998) found preventable or potentially preventable outcomes among 8% of survivors of trauma from all causes (not just road trauma) with adverse outcomes (major complications or central nervous system disability at discharge). These survivors with adverse outcomes are likely to have continuing medical and other costs.

Li and colleagues (2009) investigated the characteristics of various motorcycle crashes in Taiwan and found that a high rate of motorcycle crashes occurred in rural areas, which was related to a higher likelihood of fatality. The authors suggest that collaboration of hospital and roadway authority systems could help increase treatment at crash sites, which would reduce the risk of fatality for crashes in such areas.

## 9.3 SAFER REMOVAL OF HELMETS

There has been concern voiced by riders and paramedics that injuries may occur or be worsened in the process of removing helmets from injured riders (particularly full-faced helmets). Programs for training emergency services personnel in correct procedures for removing helmets have been developed in the United States but these are not widely known or used (Motorcycle Safety Foundation, 2001). No published evaluations of these programs were found.

## 9.4 CONCLUSIONS

Measures to improve treatment of injuries for motorcyclists include programs for safer removal of helmets as well as those that are common to all road users in crashes. Programs for training emergency services personnel in correct procedures for removing helmets have been developed in the United States but these are not widely known or used, and no published evaluations of these programs were found.

Automatic Collision Notification (CAN) is a proposed system designed to improve emergency medical responses and thus, outcomes for many injured patients. The ACN would comprise a crash recorder that collects crash impact data, an automobile location system and a cellular phone system that sends the crash and location data to the emergency medical system. Systems with some or all of these features are currently or will soon be available and it is estimated that first generation ACN technology could save up to 12% of rural fatalities. A system designed specifically for motorcyclists is currently being proposed.

Changes to trauma management systems which include the integration, coordination, and inclusiveness of providers, designation of hospitals to receive major trauma, concentration of expertise in trauma management, and agreed triage and transport protocols can reduce the potentially preventable outcome rate from levels similar to the 36%.

# 10 SELECTED RIDER AND DRIVER MEASURES TO PREVENT CRASHES

This section provides lists of selected safety measures along with an assessment of whether they have been proven to be effective for motorcycle and scooter riders or for road users in general. Then each of the measures is rated in terms of its potential to improve motorcycle safety in high-income countries and in low and middle income countries where a large proportion of vehicles are motorcycles.

**Table 2 Ratings of selected measures**

| No. | Selected measure | Proven for motorcycle riders | Not proven for motorcycle riders | Proven for general road users | Potential to improve motorcycle safety in HIE | Potential to improve motorcycle safety in LMIE with large proportion of motorcycles |
|---|---|---|---|---|---|---|
| **Possible changes to motorcycle training, licensing and testing** | | | | | | |
| 1 | Increase minimum ages for learner and provisional motorcycle licences so that they are higher than for car licences | | ü | | ü | |
| 2 | Introduce minimum periods for L and P | | ü | | ü | |
| 3 | Introduce maximum period for L | | ü | | | |
| 4 | Zero BAC to apply for all L and P riders | ü | | ü | ü | ü |
| 5 | Replace 250cc engine capacity restriction with | | ü | | ü | |

| No. | Selected measure | Proven for motorcycle riders | Not proven for motorcycle riders | Proven for general road users | Potential to improve motorcycle safety in HIE | Potential to improve motorcycle safety in LMIE with large proportion of motorcycles |
|---|---|---|---|---|---|---|
| | power-to-weight restrictions for L and P | | | | | |
| 6 | Introduce requirement for display of P plates | | | | ü | |
| 7 | Increase roadcraft training at both L and P | | ü | | | |
| 8 | Introduce compulsory training to obtain L and P | ü | | | | |
| 9 | Introduce off-road training for L, mix of on- and off-road training for P | | ü | | | |
| 10 | Introduce off-road testing for L, on-road testing for P | | ü | | | |
| 11 | Remove exemptions for older applicants | | ü | | ü | |
| 12 | Remove exemptions for applicants already holding a licence for another type of vehicle | | ü | | ü | |
| 13 | Introduce active requirement to maintain currency of a motorcycle licence to ensure that those wishing to return to riding have to regain a minimum level of skill or competence before doing so | | ü | | | |

| No. | Selected measure | Proven for motorcycle riders | Not proven for motorcycle riders | Proven for general road users | Potential to improve motorcycle safety in HIE | Potential to improve motorcycle safety in LMIE with large proportion of motorcycles |
|---|---|---|---|---|---|---|
| **Making riders easier to see** | | | | | | |
| 14 | Encourage riders to wear lighter coloured clothing and helmets (which may also be cooler) | ü (some evidence) | | | | |
| **Educating other road users** | | | | | | |
| 15 | Incorporate sharing the road into driver education and publicity materials | | ü | | | |
| **Enforcement to reduce risky behaviours** | | | | | | |
| 16 | Police to target locations and times where unlicensed riding is most common | | ü | | | |
| 17 | Police to continue enforcement of speed and other illegal behaviours by drivers to reduce risks to riders | | ü | | | ü |

**VEHICLE MEASURES TO PREVENT CRASHES**

| | Selected measure | Proven for motorcycle riders | Not proven for motorcycle riders | Proven for general road users | Potential to improve motorcycle safety | Priority for implementation (High, Medium or Low) |
|---|---|---|---|---|---|---|
| **Improve braking systems** | | | | | | |
| 18 | Encourage riders to choose motorcycles with antilock and linked braking systems | | ü | | ü | ü |
| **Making motorcycles easier to see** | | | | | | |
| 19 | Encourage riders to purchase motorcycles that are light-coloured | | ü | | ü | |
| 20 | Encourage riders to ride with lights on | ü but not clear | | ü | ü | ü |

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## APPENDIX A - Glossary

There were many different meanings for key terms. The following are some key terms and what was meant when used in this survey and throughout the report.

| Term | Meaning |
|---|---|
| Motorcycle | is a two- or three-wheeled motor vehicle. It does not include power-assisted bicycles (PABs) or electric bicycles (EBs). |
| Scooter | is a type of motorcycle which is a step-through design and often has automatic transmission. |
| Moped | is a two- or three-wheeled motor vehicle with an engine capacity not exceeding 50cc and a top speed not exceeding 50km/hour. Most (but not all) mopeds are of scooter design. |
| Motorcyclist | includes riders (those in the driving position) and passengers, unless specified. |
| Injured person | is someone admitted to hospital. |
| Speeding | includes both riding or driving above the posted speed limit and riding or driving at an inappropriate speed for the conditions. |
| Licence | includes learner permits. |
| Geographical coverage | is how much of your economy is covered by legislation or program (e.g. all of it, or some states or provinces only) |
| Commuting | is travel to and from home to work and return |
| Work travel | is travel as part of work; for example, travel to deliver goods or travel between work locations e.g. delivering mail or police riding or delivering goods |