MONASH University
Accident Research Centre

MOTORCYCLE SAFETY RESEARCH PROGRAM

MOTORCYCLE CRASH COUNTERMEASURES:

LITERATURE REVIEW AND

IMPLEMENTATION WORKSHOP

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Abstract
This literature review has examined many of these proposed countermeasures designed to either prevent crashes or reduce rider and pillion passenger injuries in the event of a motorcycle crash. In addition, the need for improvements to the effectiveness or methods of implementation of current countermeasures has been assessed. The countermeasures discussed include those which reduce the risk of a crash occurring:

- improvements to conspicuity
- motorcycle rider training
- awareness training for car drivers
- enforcement and licensing initiatives
- zero BAC
- restrictions on carriage of pillion passengers
- restrictions on off-road riding by young riders
- improvements to motorcycle braking
- improvements to rider field of view
- engine capacity and power restrictions
- modifications to the road environment

and those which reduce the severity of injury in crashes:

- helmets
- lower limb protection
- airbags, and
- protective clothing.

The implementation workshop discussed the advantages and disadvantages and barriers to implementation of the recommendations of the literature review.

Key Words
motorcycle, injury, road trauma,
countermeasures

EXECUTIVE SUMMARY

Although Australia continues to maintain a relatively high standard in the field of motorcycle safety, significant scope exists for the implementation of various countermeasures designed to either prevent crashes or reduce rider and pillion passenger injuries in the event of a motorcycle crash. This literature review has examined many of these proposed countermeasures. In addition, the need for improvements to the effectiveness or methods of implementation of current countermeasures is assessed.

The countermeasures discussed include those which reduce the risk of a crash occurring:

- improvements to conspicuity
- motorcycle rider training
- awareness training for car drivers
- enforcement and licensing initiatives
- zero BAC
- restrictions on carriage of pillion passengers
- restrictions on off-road riding by young riders
- improvements to motorcycle braking
- improvements to rider field of view
- engine capacity and power restrictions
- modifications to the road environment.

Countermeasures which reduce the severity of injury in crashes include:

- helmets
- protective clothing.
- lower limb protection, and
- airbags.

It was concluded that wearing reflective clothing and daytime use of running lights and headlights can increase motorcycle conspicuity. The arguments raised against mandatory use of daytime lighting were noted.

Little statistical evidence was found to show that motorcycle rider training programs reduce crash risk per km travelled. In fact, many previous studies which examined this issue were found to have suffered methodological pitfalls. Future analytical strategies were therefore recommended. There are potential benefits to motorcyclists of education and awareness campaigns which target other road users but further evaluations are needed.

Recommendations for licensing programs were examined and the difficulties concerning enforcement of these programs were noted. The role of alcohol in motorcycle crashes was discussed.

Restrictions on both the carriage of pillion passengers and off-road riding by children and adolescents were also reviewed.

Those vehicle-based countermeasures included in this review centred upon braking systems (particularly upon the benefits of anti-lock brakes). The relative importance of a rider's ability to see clearly around a motorcycle was also examined.

Further research is necessary in order to conclude the debate surrounding engine capacity and power restrictions. Improvements to road environments could be made, if their effect on other road users was considered.

In terms of countermeasures to reduce injury, potential improvements to helmet crash performance were discussed. Limitations in rider vision accorded by helmets were also examined. It was concluded that the effectiveness of lower limb protectors and airbags may be restricted to a limited range of crashes and circumstances. The benefits of protective clothing in reducing the incidence of minor injury were relatively more apparent.

During the Implementation Workshop, the participants discussed the motorcycle crash countermeasures identified by the Literature Review and identified a number of additional candidate countermeasures. The countermeasures with the highest achievability and desirability ratings were:

RECOMMENDED COUNTERMEASURE	ACHIEVABILITY	DESIRABILITY
Develop checklist for Councils for road safety auditing	++	++
Improved semi-trailer visibility	++	++
Investigate conspicuity strategies used by successful riders	++	++
Collect better crash data for conspicuity	+	++
Encouraging riders to wear protective clothing and footwear	++	++
Reducing dangers of bullbars	++	++
Improved truck under-run protection	++	++
Educate owners not to lend bikes and danger of litigation	++	+
Encourage better maintenance of brakes, suspension, clutch and throttle	++	+
Caution in use of raised pavement markers in intersections	++	+
Abrasive coating on man-hole covers and steel plates covering roadworks	++	+
Avoid use of low-friction materials where traffic might travel at roadway speeds	++	+
Discourage use of car phones	++	+
Education program on fastening and fitting helmets	++	+
Poster showing steps to check if helmet fits properly	++	+

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PART 2: IMPLEMENTATION WORKSHOP

1 INTRODUCTION

Australia continues to maintain a relatively high standard in the field of motorcycle safety (see Nairn, 1993 and Haworth, Ozanne-Smith, Fox and Brumen, 1994, in particular). In fact, a number of the research areas that are currently being actively pursued abroad, especially in North America, are not directly applicable to Australia as appropriate domestic programs have already been instituted. Compulsory use of helmets, rider training schemes and structured graduated licence requirements are three such examples where current Australian programs meet or exceed the standards being recommended for implementation elsewhere (Nairn, 1993).

However, scope for improvement still exists. The Federal Office of Road Safety (CR84, 1989) has estimated that motorcycleriders are 19 times as likely to be killed per kilometre travelled as car drivers. In 1991, the estimated number of motorcyclists admitted to hospital accounted for 13% (police records) to 17% (hospital records) of all road injury admissions. By comparison, motorcyclist fatalities in 1991 represented 12% of total road fatalities. The Victorian Road Safety Committee (1993) reported that motorcycle collisions cost the community about $149 million annually.

Figure 1 shows that both the absolute numbers of motorcycle riders and pillion passengers (motorcyclists) killed in Australia and the proportion of road fatalities that they constitute have been falling since 1984. This suggests that general road safety countermeasures and those more particularly aimed at motorcyclists may be having an impact. However, in order to know whether motorcycle crash risk has decreased, it is important to know whether the amount of motorcycle riding has changed over that period of time. This information is not readily available.

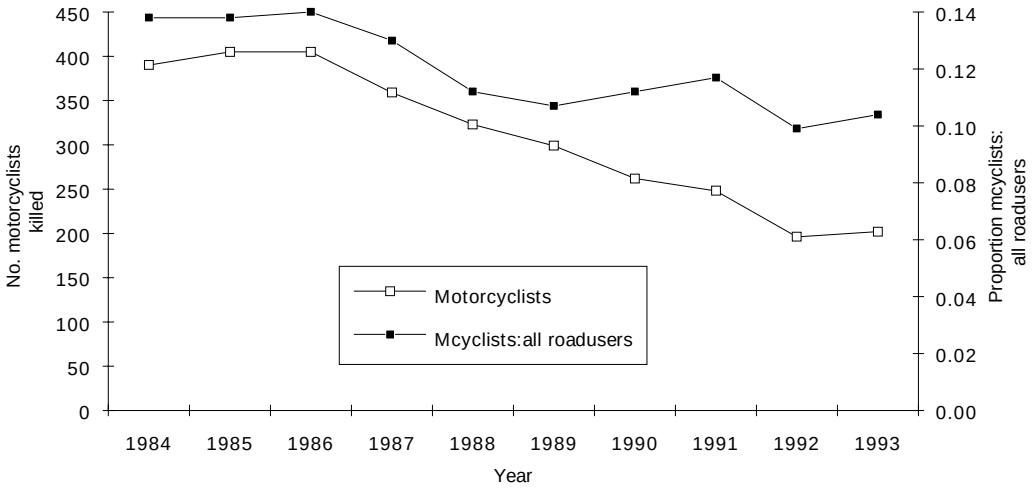

Figure 1. Motorcycle rider and pillion passenger (motorcyclists) fatalities and motorcyclist fatalities as a proportion of all road users killed in road crashes from 1984 to 1993. (Source: Federal Office of Road Safety, Road Fatality Statistics, December 1993)

The number of registered motorcycles in Australia provides some indication of the amount of motorcycling. It has been dropping since 1985 (Australian Bureau of Statistics) in a similar way to the numbers of fatalities.

The number of motorcyclists killed in road crashes in Victoria has been dropping since 1986 (see Figure 2). Since 1990, the total number of persons killed in road crashes in Victoria has dropped dramatically. Yet the number of motorcycle riders killed has not decreased as much. This suggests that different factors are affecting motorcyclists compared with other road users. Comparing Figure 1 and Figure 2 suggests that the proportion of crashes involving motorcyclists is not dropping as quickly in Victoria as in the rest of Australia.

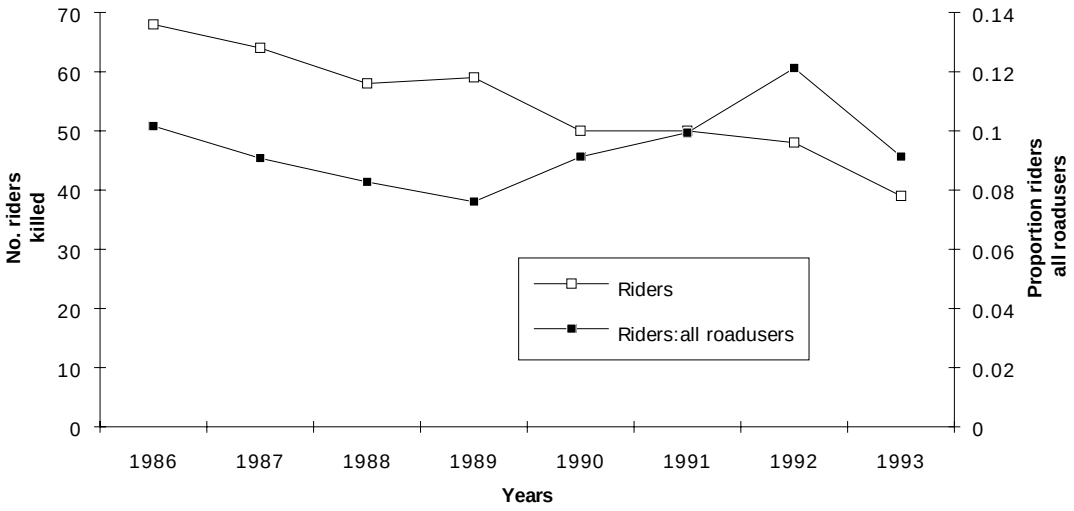

Figure 2. Number of motorcycle riders killed in road crashes in Victoria 1986-1993 and riders killed as a proportion of all roadusers killed. (Sources: Vic Roads Road Safety Facts Document and FORS Road Crash Statistics Australia)

In considering the magnitude of the problem in question one must also remember that motorcyclists are not only more prone to on-road collisions compared to other classes of road users, but that severe injury is a relatively more common result in the event of a crash involving a motorcycle. In Victorian on-road crashes reported to police, motorcycle riders have the second highest rate of injury severity, after pedestrians. About 54 percent of injured motorcycle riders are killed or admitted to hospital, whilst the comparable figure for other drivers, passengers and bicyclists is less than 40 percent. (Source: analyses of State Traffic Accident Record).

Even considering Australia's relatively high standards in the field of motorcycle safety the aforementioned statistics support claims that there is still great opportunity for improvements to be made. The need for such improvements may become more salient in the future. As many analyses have demonstrated, motorcyclists are far more likely to be injured in a collision compared to car drivers. Increased usage of motorcycles, due to increasingly crowded road systems and an escalating need for cheaper transport, will therefore bring a disproportionate increase in total road

casualties (Watson, 1990). It is anticipated that this review of literature related to motorcycle crash countermeasures may play a small part in the process of ameliorating the costs, both personal and economic, of motorcycle crash casualties.

1.1 SCOPE OF THE STUDY

Part 1 of this report presents a review of selected research from Australia and abroad which deals with proposed and current countermeasures for motorcycle crashes. Part 2 summarises a workshop which was held to discuss issues relating to implementation of the countermeasures identified by the literature review.

The countermeasures are divided into:

1. countermeasures which aim to prevent crashes occurring and,

2. countermeasures which reduce injury in the event of a crash involving a motorcycle.

The order in which the countermeasures are discussed in the literature review does not represent their relative importance. In addition, the relative efficacy of individual countermeasures may be increased by varying degrees when they are combined with other countermeasures.

PART 1: LITERATURE REVIEW

2 COUNTERMEASURES TO PREVENT CRASHES

The countermeasures to prevent motorcycle crashes reviewed here are:

- improvements to conspicuity
- motorcycle rider training
- awareness training for car drivers
- enforcement and licensing initiatives
- zero BAC
- restrictions on carriage of pillion passengers
- restrictions on off-road riding by young riders
- improvements to motorcycle braking
- improvements to rider field of view
- engine capacity and power restrictions
- modifications to the road environment.

2.1 IMPROVING CONSPICUITY

Motorcycles are smaller than cars and as such are less conspicuous and more difficult to detect. The most common multi-vehicle collision scenario is violation of a rider's right of way. Hancock, Wulf, Thom and Fassnacht (1990) discussed the contribution of the conspicuity problem to these crashes and concluded that it was considerable. Olson, Halstead-Nussloch and Sivak (1980) found that many of these crashes involved cars turning in front of oncoming motorcycles and other angle collisions at intersections.

Analyses of motorcycle crashes in Victoria and South Australia have concluded that the failure of a motorist to see the approaching motorcycle may have been responsible for between 12 percent and 21 percent of crashes (McLean et al., 1979; Williams & Hoffman, 1979; both cited in Bui, 1992).

Most studies which have concluded that motorcycle conspicuity underlies right-angle crashes have compared single and multi-vehicle motorcycle crashes. Olson (1989) cautioned that the relationship is not clear. Cercarelli, Arnold, Rosman, Sleet and Thornett (1992) noted that this procedure compares crashes with clearly different causes (car drivers' possible failure to detect a motorcyclist against motorcyclists' loss of vehicle control). In their study, Cercarelli et al. (1992) compared car-motorcycle and car-car crashes, after controlling for amount of day and night-time driving by both vehicle types. The authors hypothesised that poor motorcycle conspicuity should result in relatively more daytime car-motorcycle than car-car crashes. Their study did not support this hypothesis; the difference was negligible when the relatively greater daytime use of motorcycles than cars was taken into account. They caution that their results do not prove that there is not a conspicuity problem. It may

be that the restricted sample size and widespread daytime use of headlights at the time contributed to the lack of a significant difference.

Improving conspicuity has the potential to prevent some motorcycle crashes. Methods for improving conspicuity include use of bright coloured clothing and motorcycles and daytime use of headlights and running lights.

2.1.1 Bright coloured clothing and motorcycles

An observational study on Sydney roads revealed that most motorcycles were a dark colour whilst motorcycle riders tended to wear dark colours, with 55.9 percent wearing black coats and 13.9 percent wearing blue coats (Johansen, 1987).

The consensus view is that bright coloured clothes and motorcycles reduce the chance of collisions (Avery, 1979) . 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 bike. Night-time right angle collisions would therefore be unaffected by such a measure.

The Social Development Committee Inquiry into Motorcycle Safety in Victoria (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).

2.1.2 Daytime use of headlights and running lights

Running lights are two lights, usually placed about half a metre apart, but at the same height. They are relatively uncommon on motorcycles in Australia. As with the use of colours and fluorescence, the daytime use of running lights and headlights aims to intensify the contrast between motorcycle and background, allowing the motorcycle to be seen sooner and at greater distances compared to motorcyclists who do not employ such lights. Accordingly, Donne and Fulton (1985) and Fulton et al (1980; both cited in Ravinder, 1987) found that daytime use of running lights significantly increased the conspicuity of motorcycles.

A survey conducted on Sydney roads in 1986, before daytime lighting use was legislated, found that 65.5 percent of motorcyclists rode with headlamps operating

during daylight hours (Johansen, 1987). An observational study in Perth in 1990 also showed that 61.8 percent of motorcyclists used headlamps during the day (Cercarelli, et al., 1990; cited in Cercarelli et al., 1992).

In relation to conspicuity countermeasures in general, motorcycle riders attitudes were examined in a study in Sydney in 1987 (Ravinder, 1987). The overwhelming majority believed that it is important to ensure that the motorcyclist is visible to other road users. About 60 percent of motorcycle riders reported using headlights during the day but approximately 40 percent of respondents were worried about the amount of drainage and reduction of service life of batteries caused by daylight use of headlights. Less than half of the motorcyclists believed in the safety value of high visibility clothing. This was in accord with the very small percentage of motorcyclists observed wearing such clothing (Johansen, 1987).

Other Australian studies have generally shown a strong association between daylight headlight use and safety. Vaughan, Pettigrew and Lukin (1977) found that motorcycles without headlights on were two to three times more likely to be involved in crashes than motorcycles with headlights on. During 1986 in New South Wales, motorcyclists using headlights during daylight hours were nearly three times under involved in fatal crashes than non-headlight users (Ravinder, 1987).

While daylight use of headlights or running lights has not been required by law throughout Australia, the Federal Government has introduced Australian Design Rule 19/01 which requires hard-wiring of headlights for motorcycles manufactured after March 1992. This has been opposed by some motorcycling organisations.

In submissions to the Social Development Committee Inquiry into Motorcycle Safety in Victoria Report on Motorcycle Visibility (1992), rider groups presented several arguments against daytime running lights and headlight use (and particularly against the hard-wiring of daytime running lights). These arguments resulted in the Committee recommending that the use of daytime running lights for motorcycles remains voluntary in Victoria. A summary of these arguments and the counterarguments of the Federal Office of Road Safety are presented below.

First, arguments were presented that the use of daytime running lights may be dangerous because of an effect on other drivers' vision. Riders argued that a bright light within the driver's visual field can initiate a reflex response in which the driver ceases his or her scanning process, decreasing the possibility that a motorcyclist will be detected. In the Committee's own assessment, evidence on this point was "inconclusive" (Social Development Committee, 1992). It was also argued that daytime running lights may cause oncoming drivers to suffer the effects of glare, again reducing their ability to detect objects, including motorcyclists. However, the Federal Office of Road Safety has noted that the light intensity specified by ADR19/01 is below the glare threshold indicated by research (personal communication).

Secondly, riders presented arguments that the benefits of use of daylight running lights would be small. The Social Development Committee (1992) concluded that daytime lights had the potential to affect only about 2 percent of daytime motorcycle

casualty collisions. This assumption was based on a number of assumptions which the Federal Office of Road Safety describes as conservative. The assumptions were that:

- lights are only effective when vehicles approach each other on parallel paths. FORS notes that the angle of view is not the same as the angle between vehicle paths, people do not always stare straight ahead

- lights are only effective when the driver has an unobstructed view of the rider. FORS argues that lights may still be useful when the rider is partially obscured by traffic and detection may depend on their being seen briefly in a gap in traffic

- lights could only affect crashes in which the driver reports that the motorcycle was not seen in time to avoid the crash.

Some commentators have argued that low casualty crash statistics associated with daytime headlight use are not the result of the conspicuity measure per se, but merely a reflection of the relatively higher level of safety consciousness exhibited by riders who elected to use daytime lighting. However, a reanalysis of Vaughan et al.'s (1977) data by Kearns (1981) dismissed this objection.

Thirdly, it was argued that the legal implications of compulsory daytime running lights must also be considered as most insurers have exclusion clauses to cover non-compliance with roadworthy requirements. It is argued that, in the event of a crash involving a motorcycle with hardwired daytime running lights which had been damaged, the insurance company might find it difficult to determine whether the daytime lighting was in use at the time of the collision. However, the Insurance Council of Australia advised the Federal Office of Road Safety that there was no substance to this concern and that the insurer is obliged by law to pay if the rider could not reasonably have known that the vehicle was defective. FORS also note that the situation is the same in principle as with other mandatory lights, such as brake or tail lights and there is no indication that rules requiring these lights have caused a significant insurance problem.

Fourthly, rider organisations argued and the Social Development Committee recommended that the light intensity specifications in ADR19/01 are not sufficiently bright for Australian conditions. FORS examined the evidence cited in support of this conclusion and found that it referred to a single study involving daytime lights on a car, not a motorcycle, related to the main part of the day, rather than dawn or dusk (as interpreted by the Committee) and related to peripheral vision only. Thus, FORS concluded that this study did not question the appropriateness of the current specifications.

Another recommendation of the Social Development Committee was that the Minister for Transport request the Federal Government delay implementation of Australian Design Rule 19/01 until the report of the International Committee on Daytime Running Lights is available and its implications for Australia are examined (SDC, 1992). However, the International Committee issued a consultative document which stated that the use of daytime lights by motorcycles was not seen as an issue, being

mandatory or well-established in most European countries, rather its concern was with daytime lights for cars (FORS, personal communication).

Difficulties arising from dirt (which can reduce daytime running light intensity by 50 percent) and motorcycle power requirements (for example, hard-wired lighting might be difficult to implement on some smaller motorcycles due to limited battery charge) are also cited by rider organisations as reasons for not mandating daytime running lights (Social Development Committee, 1992).

Many riders argue that compulsory daytime lighting might confirm the existing opinion of many vehicle drivers who believe that motorcyclists are risk-takers operating outside the usual road rules. As such, riders feel that compulsory daytime lighting requirements would constitute a level of discrimination against motorcyclists (Social Development Committee, 1992).

2.2 MOTORCYCLE RIDER TRAINING

Motorcycle rider training is offered in almost all states of Australia. Pre-licence programs are compulsory in New South Wales, South Australia, Tasmania and the Australian Capital Territory whilst in Victoria, Queensland and the Northern Territory they are voluntary. Governments contribute to the funding of many of these rider training programs. In Western Australia pre-licence training is neither compulsory nor publicly funded (Road Safety Committee, 1993; Nairn, 1993).

The legislatures of thirty-nine states in the US have established motorcycle rider education programs. These programs are typically funded through motorcycle licence or registration fees. Their curriculum generally covers about sixteen hours of training, half of which are usually spent riding motorcycles on a controlled range. Several states in the US have made the successful completion of such a program a mandatory requirement for young riders seeking a motorcycle licence (Nairn, 1993).

The ultimate measure of the efficacy of any motorcycle rider training program is its impact on crash rates. However, in its inquiry into motorcycle safety in Victoria, the Parliamentary Road Safety Committee (1993) reported that motorcycle rider training has generally been found to have no effect on crash rates or, worse, that it increases the risk of riders becoming involved in a collision. For example, a US National Highway Traffic Safety Administration study demonstrates no significant differences in the crash and conviction rates over a two year period between riders subjected to no formal rider training, riders who undertake three hours of formal training and riders who undertake 20 hours of formal training. The study concluded that age, motorcycle ownership, gender, marital status and income were the statistically significant predictors of the crash rates of novice riders (cited in ibid).

Nairn (1993) provides a comprehensive discussion which reviews past research concerning motorcycle rider training programs. He concluded that:

- once results were adjusted to reflect differences in subjects age, sex, riding history, exposure and education, differences originally found between trained and untrained riding populations were determined to be insignificant

- findings about the effect of training on violation rates are unclear

- most studies have demonstrated that riders who had taken a motorcycle training course were more likely to wear protective gear (ibid).

Other studies have shown mixed results. Wood and Bowen (1987) reported on changes to motorcyclist training and licensing in Victoria and found that it had an overall positive effect and a good benefit-cost ratio. However, they were forced to conclude that the relative effects of training and testing could not be separated from the effect of the scheme as a whole. Crash numbers may have fallen because the scheme acted as a disincentive to apply for a licence, rather than by training producing safer riders.

Ridersafe, a two-level pre-licence training system, was introduced in South Australia from April 1987. It included two four-hour training sessions as part of gaining a learners permit and a four-hour training session to obtain a probationary licence. At both levels the sessions included lectures and discussions, videos and hands-on riding. An evaluation could not find any effect of the change on safety and concluded that this was because the numbers in that one State would never be sufficient to be able to demonstrate an effect, if one existed (Kloeden, Moore and McLean, 1994).

From a study of 877 Canadian motorcycle riders, Cooper and Rothe (1988) concluded that the amount and type of exposure were the most important determinants of motorcyclist crash risk; there was no evidence that formal motorcycle training was effective in reducing crash risk.

Adams, Collingwood and Job (1985) investigated a training program for Australia Post motorcycle telegram delivery staff. Injury records for the six months before and after a training course were compared. The two-day course had theoretical and practical components which covered:

- service and maintenance of a motorcycle
- riding attitude
- road craft
- identification of potential dangers and defensive riding.

Difficulties relating to non attendance, employee mobility and disturbance to the experimental design made analysis and interpretation of the program difficult. The authors concluded that:

> *while the results of the present study show no evidence that the 1982 training course changed the accident rates of those participating, a number of circumstances indicate that these results should not be taken as in any sense discouraging, but rather as a genuine failure to produce positive evidence (ibid; 18).*

The findings of Barry (1970) and Hurt (1979) suggested that experience with a particular type of motorcycle is needed to improve rider safety. Thus it would seem best if riders rode their own motorcycle during practical training programs. The current training scheme for Australia Post motorcycle riders includes practical instruction on the model of motorcycle which will be ridden for mail deliveries, fully-loaded.

McLaren (1992, cited in Langley, Begg and Reeder, 1993) reviewed sixteen studies of motorcycle training. He concluded that:

> *Formal motorcycle training or enhanced skills testing programmes of the type and standard identified are unlikely to lead to substantial or sustainable reductions in accidents or traffic violations arising through improvements in safe riding practices.*

McLaren also argued that any significant beneficial effects that did arise were more likely to be attributable to reduced exposure than to skill acquisition.

Most evaluation studies compare a group of riders who chose to undertake a course with another group who chose not to take that course. Many methodological pitfalls should be acknowledged when assessing these studies. Nairn (1993) also provides a summary of potential analytical defects which apply to many of these studies. These include:

- a lack of quality control brought about by significant differences in various training programs. Rider training programs differed from state to state, training site to training site and even different presenters at the one site may incorporate slightly different training material and techniques

- It is quite possible that riders who take training courses voluntarily differ in important respects from those who are not volunteers. For example, the former are presumably relatively more safety conscious and, therefore, might be expected to have better crash records

- difficulties concerning group comparability. Nairn (1993) warns that it is important that matched pairs of trained and untrained riders have the same sex, age, and riding history (in terms of exposure, crash statistics, etc.). Some studies have also utilised relatively small samples

- a failure to acknowledge that the act of training a rider may change factors other than basic skill levels. For example, training may change attitudes or subsequently foster increased exposure (Nairn, 1993).

In summary, while some studies have shown beneficial effects of training or training and testing schemes, they have not clearly shown that training reduces crash risk per km travelled. There is a need for better evaluations of training, particularly focussing on the competencies needed for safe riding.

2.2.1 Possibilities for improving motorcycle rider training

Simulator-based training programs for motorcyclists are currently being developed and tested. Simulators allow novice riders to "experience" dangerous situations that could not be safely incorporated in on-road training. While the technical advances needed for effective simulation of motorcycle riding are ongoing, evaluations of the effectiveness of simulator-based training in terms of reduced risk of on-road crashes are not yet available. Yuhara, Oguchi and Ochiai (1993) note that "the purpose of safe driving education by the riding simulator is to predict and forecast dangerous situations that can take place in dangerous traffic scenes and to drive defensively" (p.59).

The Australia Post (1988) study of motorcycling injuries pointed out the need for refresher training for those who had been riding for a number of years because of changes in the road rules and in the characteristics of the task. An added advantage of training programs for experienced motorcyclists is the potential to train riders who may have missed training at the recruiting or novice rider stage. Attention needs to be paid to this issue also.

While motorcycle training has focussed on crash avoidance, it can also include learning how to minimise injury if a crash cannot be avoided. Some aspects could include the use of protective clothing and safer motorcycles (eg. leg protectors). Palmer (1993) has outlined actions that a motorcyclist can take to reduce the extent of injury in an unavoidable intersection crash with a car. Unfortunately, there has been no evaluation of the usefulness of training on minimising injury.

The cost effectiveness of motorcycle rider training has been examined by Nairn (1993). Taking the Australian Capital Territory program as an example, he found that the annual cost of the pre-licence rider training scheme was $140,000. In contrast, the annual cost of motorcycle crashes in the A.C.T. is $20 million. Supposing it could be established that the program would result in only a one percent reduction in the cost of motorcycle crashes, thereby saving the Territory $200,000, then the program would be cost effective. The debate continues as to the efficacy of such programs.

2.3 AWARENESS TRAINING FOR CAR DRIVERS

There is evidence to suggest 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. Also, Weber and Otte (1980, cited by Hancock et al., 1990) working in West Germany reported that among automobile drivers involved in a collision with a motorcycle, those without a driver's license for a motorcycle were over represented. This may be because drivers who ride know where to expect motorcyclists and are better at anticipating their behaviour. Since most multi-vehicle motorcycle crashes 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 Social Development Committee Inquiry into Motorcycle Safety in Victoria (1992) recommended that programs be developed to encourage car drivers to be aware of motorcycles. The Transport Accident Commission launched an advertising campaign in 1993 featuring this message but no evaluation of its effectiveness was undertaken.

Little valid research has evaluated the efficacy of these programs. Nairn (1993; p.33) warns that in doing so two sequential questions must be addressed:

- are these campaigns reaching their target audience?

- how successful are these campaigns in effecting the desired behavioural change?

An answer to the first question may not necessarily provide evidence concerning the second.

2.4 IMPROVEMENTS IN LICENSING AND ENFORCEMENT

Licensing and enforcement measures to prevent motorcycle crashes include:

- measures to reduce the amount of unlicensed riding
- modifying rider behaviour by changing the conditions of licences
- requiring a motorcycle licence before purchasing a motorcycle

Many riders involved in on-road crashes are unlicensed or riding an unregistered motorcycle. Data from the US Department of Transportation's Fatal Accident reporting System (FARS) show that the percentage of fatally injured motorcyclists who were either unlicensed or improperly licensed between 1983 and 1989 ranged from 39 percent to 42 percent. The problem is particularly severe in California where the incidence of improperly licensed motorcyclist fatalities ranged from 39 percent to 63 percent over the same period (Nairn, 1993). Rates of valid licensure tended to be lowest amongst younger riders and those who did not own the motorcycle.

In Australia, unlicensed or unregistered riding is particularly common amongst younger motorcyclists. A recent Victorian 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.

In both countries, to differing extents, 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 country's 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.

Recent changes to licensing systems have aimed to reduce the crash involvement of novice drivers, including novice motorcyclists. The (Australian) Federal Government's Ten Point Road Safety Package includes a graduated licensing system for young drivers, the elements of which are as follows:

- zero BAC for learner drivers
- zero BAC for the first three years after obtaining a non-learners licence up to 25 years of age
- no learner permits to be issued before 16 years of age
- no probationary licence to be issued before 17 years of age (Note: the licensing age is 18 years in Victoria)
- the minimum period for a learner permit to be six months.

Increasing the learners permit age for motorcyclists above that of the minimum licence age for driving a car may help to prevent motorcycle crashes. This action removes the incentive to obtain a motorcycle learners permit in order to travel unsupervised at an early age.

Some jurisdictions have implemented limits on the length of time a motorcycle learner permit can be held. This aims to prevent riders from continuing to ride while avoiding the licence examination.

Given these recommendations for licensing restrictions, it is acknowledged that a number of practical difficulties concerning enforcement for motorcyclists do exist. Sometimes, motorcyclists will evade police driving cars by lane splitting or riding into areas where police either cannot follow or it is unsafe for them to do so. There is only a limited number of police motorcyclists.

In addition, there is a need for police to intercept riders in a safe manner, avoiding pursuits and potential crashes. Perhaps a program of checking of licensing and registration details as part of ongoing police activity (eg. random breath testing) would serve as an appropriate deterrent. Nairn (1993) argues that with current levels of technology this would be a relatively straight forward task.

The suggestion has also been made that intending purchasers of motorcycles be required to hold a current motorcycle licence. While this has the potential to decrease unlicensed riding, it would have to be implemented in such a way as to avoid problems for those learning to ride a motorcycle and to provide for registration of motorcycles for business use.

More stringent penalties, including the temporary impounding of motorcycles (or confiscation of licence plates) driven by riders who are invalidly licensed, have also been mooted. This strategy might not only deter unlicensed riders but also owners from allowing unlicensed riders to operate their motorcycles (Nairn, 1993).

2.5 ZERO BAC LIMIT

2.5.1 Alcohol in motorcycle crashes

Motorcycle riding demands greater co-ordination, balance and concentration than that required to drive a car. It is not surprising, therefore, that the effects of alcohol consumption on motorcycle riding are far more dramatic than its effects on car driving (Haworth et al, 1994).

Most studies have shown that alcohol is involved to a greater extent in motorcycle than car crashes. For example, in 1990, 33 percent of dead motorcyclists tested in Queensland exceeded 0.05% BAC compared with only 29 percent of car drivers (Queensland Transport, 1991). National crash statistics in Australia demonstrate that 41 percent of motorcycle fatalities involve blood alcohol levels above 0.05%. The comparable figure for drivers of cars and other light passenger vehicles is 29 percent (FORS, 1991; cited in Nairn, 1993).

A number of US studies show that crashed motorcyclists are more likely to have consumed alcohol compared to crashed car drivers (Soderstrom et al, 1993). For example, the rider had a measurable level of alcohol in 53 percent of US motorcycle related deaths in 1988, compared to 40 percent in all traffic fatalities (Friedman, 1991).

However, recent Victorian data suggest that the involvement of alcohol is similar in car drivers and motorcyclists. In the five-year period 1989 to 1993, 30.0 percent of motorcycle riders killed in crashes in Victoria, for whom BAC was known, exceeded 0.05%, compared with 29.1 percent of car drivers (from analyses of VIC ROADS data).

The role of alcohol does appear to increase with crash severity. In Victoria during the period 1988 to 1990, BAC was greater than 0.05% for 16 percent of motorcycle riders injured in casualty crashes but 32 percent of riders killed (VIC ROADS, 1992a).

Accordingly, research from abroad suggests that alcohol consumption also acts to increase injury severity by reducing the likelihood that a helmet will be worn. In a Californian study, Romano and McLoughlin (1991) found that fatally injured motorcycle riders with detectable BAC's were less likely to have been wearing a helmet than sober riders. Helmet wearing rates were lower among intoxicated (11 percent) than sober (38 percent) motorcycle riders admitted to a Seattle trauma centre (Luna, Maier, Sowder, Copass and Oreskovich, 1984). Overall, serious head injuries were more common among intoxicated riders compared to sober riders (74 percent vs 39 percent, respectively). For the sample as a whole, the mortality rate was four times greater for intoxicated than sober riders (23 percent vs 6 percent, respectively).

There is some evidence that crashes of alcohol-impaired riders differ from those of non impaired riders. Luna et al (1984) found that intoxicated riders were more often judged to be at fault in the crash compared to sober crash involved riders (66 percent vs 44 percent). Soderstrom, Dischinger, Shiu and Soderstrom (1993) found a similar pattern. In addition, the latter suggested that intoxicated riders were more likely to have preinjury convictions than non intoxicated riders.

The frequency of serious head injuries (AIS>=3) among unhelmeted intoxicated riders was also significantly greater than among unhelmeted sober riders (74 percent vs 48 percent). This is further evidence that the *types* of crashes in which intoxicated riders were involved may have produced relatively more severe injuries (Luna et al., 1984).

Soderstrom et al. (1993) also found that motorcyclists injured in single vehicle crashes were more likely to have used alcohol than those in multiple vehicle crashes (68.1 percent vs 42.7 percent).

Alcohol consumption among pillion passengers has also been identified as a problem (Larsen & Hardt-Madsen, 1987). In one county in Denmark, 6 of 10 pillion passengers killed had a BAC exceeding 0.08. In each case the rider was also under the influence of alcohol.

Clearly, the alcohol impaired rider presents a dangerous scenario. Given the current high level of general programs for reducing drink driving, specific countermeasures which have been suggested for motorcyclists include zero BAC for novice riders and zero BAC for all riders.

2.5.2 Zero BAC for novice riders

Many Australian states have introduced zero BAC for novice riders, in conjunction with zero BAC for novice car drivers. These restrictions are based on the assumption that novice riders and drivers are more impaired at low levels of alcohol than their more experienced counterparts. Alcohol is an additional risk factor to inexperience and age which predisposes novice riders to greater risk from the outset.

Zero BAC may also have learning effects beyond the P-plate period in terms of self-regulation and lower BACs when no longer restricted.

Victorian data demonstrates that young riders are no more likely to have a positive BAC than older riders (see Table 1). Some of this effect may be due to compliance with the restriction.

Table 1: Age and distribution of blood alcohol concentrations for motorcycle riders injured in police-reported casualty crashes in Victoria, 1988-90. (Source: VIC ROADS, 1992a)

Age (years)	Zero to 0.05	0.051 to 0.15	Over 0.15
Under 18	87%	10%	3%
18 to 26	85%	9%	6%
All ages	84%	10%	6%

2.5.3 Zero BAC for all motorcyclists

Currently, similar BAC limits apply to motorcyclists and car drivers in most Australian jurisdictions. However, it has been suggested that a zero BAC limit should apply for all motorcyclists because of the greater level of perceptual-motor skills required for safe operation of a motorcycle. Lower alcohol limits have been introduced for other drivers (mainly professional drivers) in many jurisdictions. Introduction and enforcement of such a limit is calculated as having a likely benefit-cost ratio of 3:1 (Torpey et al., 1991).

2.5.4 Other measures to reduce the role of alcohol in motorcycle crashes

- *Enforcement:* Australia's random breath testing (RBT) systems are more comprehensive and sophisticated compared to many US sobriety examination strategies (Nairn, 1993).

- *Treatment and rehabilitation:* Australia currently has stringent BAC requirements, effective points systems for tracking repeat and multiple offenders, and effective interstate cooperation regarding driving offence records. There is, therefore, a reasonable probability that hard-core drinkers among the riding population will be detected. However, whilst there is provision for licence withdrawal, treatment and rehabilitation in Australia remain relatively ineffective (ibid). Simpson and Mayhew (1990) suggest that the hard-core drinking rider (and driver) is not likely to be reached by traditional education strategies. The authors therefore argue that further research is needed to determine the nature of drink-driving prevention campaigns that might be effective with this group specifically.

- *Alcohol interlocks:* Suggestions for alcohol interlocks for motorcycles in general, and for multiple drink-riding offenders in particular, have been made. Unfortunately, at the time of writing, no direct research concerning this potential countermeasure was available.

- *Education and awareness:* It is considered by many commentators (see, for example, Nairn, 1993) that the current road safety and general anti-alcohol and drug publicity campaigns employed in Australia are of a relatively high standard. However, the issue of drink-riding is not adequately addressed.

2.6 RESTRICTIONS ON CARRIAGE OF PILLION PASSENGERS

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, 1991).

In Victoria, motorcyclists are not allowed to carry pillion passengers within the first year of licensing. It was calculated that extending this restriction from one to three years would cost about $250,000 in publicity and $1 million in enforcement. To break even, the countermeasure would need to be 18.6 percent effective in reducing injuries (Torpey et al., 1991).

2.7 RESTRICTIONS ON OFF-ROAD RIDING BY CHILDREN AND ADOLESCENTS

A significant number of motorcyclists, particularly younger ones, are injured when riding off-road (Haworth et al., 1994). A number of authors have suggested attempting to restrict or prohibit off-road motorcycle riding by children and adolescents in order to prevent crashes and thus reduce injuries.

Mason (1984) pointed out that in the case of children riding on private ground, the parent or guardian is responsible for ensuring that their children minimise the risks associated with motorcycling by wearing appropriate clothing and helmets, riding safely and using suitable bikes (if it is deemed appropriate for them to be riding at all).

Currently motorcycle clubs allow children as young as six years of age to participate in races, although there is a body of experts who feel children so young are not able to control a motorcycle satisfactorily (Sherman & McKinnon, 1984, Craft, 1979, Mason, 1984 and Wilson-MacDonald et al, 1987). It does seem that, in general, these clubs do make a reasonable effort to ensure the safety of the participants by making helmet wearing compulsory and usually designing race courses sensibly (Place, 1979; Sherman & McKinnon, 1984).

Kraus et al (1975a) suggest banning the use of motorcycles by persons less than 16 years of age in places without available riding areas. The authors comment that:

> *... with the absence of readily available recreational riding places to use the motorcycle, the young, unskilled driver turns to city streets, highways, and county roads to operate the minicycle, which is not designed for this type of use but is capable of speeds of 72 km/hr (ibid; 93).*

According to Avery (1988), paediatricians have argued that boys aged six to twelve years are

> *... developmentally incapable both physically and mentally of carrying out the complex co-ordination of movements required to handle a motorcycle in competitive events....There is growing concern both for the adverse effects of permanent brain damage and for damage to the growth points of bones (p.29).*

2.8 VEHICLE-BASED COUNTERMEASURES

Motorcycle design features can be modified to reduce the risk of a crash occurring or to reduce the severity of the resultant injury. Design features intended to prevent crashes include improved braking and improvements to rider vision. Vehicle-based countermeasures to reduce injury severity will be discussed in Section 3. These include crashbars, leg protectors and airbags.

2.8.1 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).

Further research has centred upon anti-lock braking systems suitable for motorcycles. Hurt (1987) 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 the extra cost is estimated at several hundred dollars (Nairn, 1993).

Systems which equalise braking between the front and rear brakes may be more cost-effective than the more sophisticated concept of anti-lock braking.

2.8.2 Improvements to rider vision

The ability of a rider to clearly see around the motorcycle is influenced by many factors, including mirror size and location, rider position and helmet design. Occurrences such as arm shadow may even affect a rider's field of view. Nairn (1993) warns that the provision of a good field of view may conflict with the aerodynamic and styling criteria applied to contemporary motorcycle design. For example, they note that there is no evidence in the literature to suggest that a rider's field of view rearward is well considered in the design of motorcycle rear view mirrors.

Better maintenance of motorcycles is also recommended as a potential countermeasure to reduce crash involvement. Maintenance of the brakes, suspension, clutch and throttle is particularly important.

2.9 ENGINE CAPACITY AND POWER RESTRICTIONS

In response to the perception that higher capacity motorcycles are potentially more dangerous for novices, many jurisdictions have implemented restrictions on the maximum engine capacity for novice motorcyclists (Haworth et al, 1994). However, there appears to be little current statistical evidence that a restriction on the size of a motorcycle that can be ridden by a novice favourably affects crash rates (Fabre et al, 1993; Nairn, 1993). One reason for this lack of success may be that some small capacity motorcycles, whilst satisfying 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 et al, 1994). Nairn (1993) argues this is especially relevant considering changes in motorcycle characteristics in recent years.

In contrast, Rogerson, Lambert and Allen (1992) argued against the introduction of a power-to-weight restriction. The authors found that 18.7 percent of novice riders in crashes in Victoria during the period 1987 to 1990 were not complying with the current 260cc capacity limitation. They concluded that increasing compliance with the capacity limitation would result in a greater crash rate reduction compared to a 150 kw/tonne laden power to weight ratio. It would be prudent to consider their conclusion in light of the aforementioned enforcement difficulties discussed elsewhere in this report. In sum, it appears that additional research is needed to yield valid conclusions concerning this issue, particularly in relation to an examination of whether current motorcycle design characteristics vary from those upon which existing engine capacity restrictions were originally based (Nairn, 1993).

2.10 ROAD ENVIRONMENT MODIFICATIONS

The road environment is often overlooked as a motorcycle hazard. Broadly, relevant countermeasures are concerned with improvements to highway guard railing and road surface.

Approximately 3.5 percent of motorcycle fatalities in the US in 1984 involved guardrails. Regional surveys in the Federal Republic of Germany suggested that in 1986 and 1987, approximately 15 percent of motorcycle fatalities involved crashes with guardrails (Koch & Brendicke, 1988). The injuries reported were generally severe due to the aggressive nature of guardrail design.

Experimental designs which utilise both a lower W-beam and an impact attenuator (made of neopolene that envelops the guardrail post) to protect fallen riders and pillion passengers continue to be examined in France and Germany. Specifically, Dohman (1987) reported that protective devices of these types have been installed on about 80 kilometres of guardrail in several federal states of Germany (cited in Nairn, 1993). Systematic accident studies are continuing.

In economic terms, Dohman (1987) calculated that the cost of installing this countermeasure on all guardrails in the Federal Republic of Germany would outweigh their benefit. If, however, installation was limited to approximately ten percent of guardrails known to have relatively high levels of crash involvement, a positive benefit-cost ratio would result (cited in ibid).

Mount (1987) argued for greater attention to be directed to the following traffic engineering and street maintenance factors which have potentially serious effects on motorcycles:

- *Road markings:* paint and thermoplastic markings become slippery when wet and present a relatively more significant danger to motorcycles than cars

- *Raised pavement markers*: these phenomena present an obstacle to motorcycles during turning manoeuvres and, therefore, should be used with caution within intersections

- *Man-hole covers and steel plates* used to cover roadworks are also extremely slippery. It is recommended they be treated with an abrasive coating

- *Brick paving stones*, such as glazed tiles and basalt blocks, also have low friction coefficients and should not be installed in areas where traffic might travel at roadway speeds (cited in Nairn, 1993).

3 COUNTERMEASURES TO REDUCE INJURY

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. Countermeasures have been developed which focus on reducing injuries to the head (helmets and air bags), the upper torso (air bags) and the legs (fairings and crash bars).

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).

3.1 HELMETS

The most effective intervention currently available to reduce motorcyclist injuries is the motorcycle helmet. The introduction of compulsory wearing of motorcycle helmets in Australia in the 1960s resulted in a substantial decline in serious head injuries sustained by motorcyclists (Nairn, 1993). Many contemporary analyses also address the efficacy of helmet usage. The majority of these, describing a more serious situation, focus on US States which repealed or weakened their mandatory helmet wearing laws, leading to a 40-50 percent decrease in helmet wearing rates and a subsequent increase in the frequency of serious head injuries (e.g., Chenier and Evans, 1987).

For example, these US studies found that:

- the probability of sustaining an injury while wearing a helmet is 15.1 percent compared to 22.8 percent whilst not wearing one (Kraus et al., 1975)

- the average Injury Severity Score (ISS) for crash victims wearing helmets is 9, compared to a score of 11.5 for those not wearing helmets, and the cost of treatment varies accordingly ($6,637 versus $12,109) (May and Morabito, 1989)

- the average hospital stay was 5.8 days for helmeted riders and 11.8 days for non-helmeted riders (McSwain and Belles, 1990). Other studies have shown similar effects (eg. Shankar, Ramzy, Soderstrom, Dischinger and Clark, 1992)

- a helmeted rider is one sixth as likely to die of head injury as an unhelmeted rider (Carr et al, 1981)

- non-helmeted riders were six times more likely to suffer severe brain damage compared to helmeted riders, while there was no difference in the probability of other injuries (Bachulls et al, 1988; cited in Nairn, 1993; 35)

- fatalities increased by 25-26 percent as a result of the reduction in helmet wearing (Chenier and Evans, 1987). McSwain and Belles (1990) also showed that fatality rates were higher for unhelmeted riders.

Fortunately, helmet wearing rates in Australian are high. A survey of motorcycles on Sydney roads in 1986 showed that 97.4 percent of riders and 96.0 percent of pillion passengers wore helmets (Johansen, 1987). The vast majority of these were of the full-face style. Haworth et al. (1994) found that between 6% (Police-reported crashes) and 14% (hospital admissions, both on- and off-road) of young riders in crashes in Victoria were not wearing helmets.

Such research continues to support the case for compulsory helmet usage. Head injury can be further reduced by:

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

3.1.1 Improving the crash performance of helmets

Zellmer (1993) concludes that the possibilities for enhancing helmet performance by merely increasing the energy absorption characteristics are rather low. However, he notes that an enhancement of liner deformation of 6.8 mm would give a reduction of 39.2 percent in head injury criterion (HIC). He concludes that the use of HIC in testing, rather than maximum acceleration reached, would make it easier to distinguish between poor and good helmets.

Corner, Whitney, O'Rourke and Morgan (1987) also studied the efficacy of the shell and liner properties of helmets. They concluded that the Australian Standard (AS1698) should be amended to reduce helmet liner stiffness, increase shell stiffness, improve the sliding qualities of helmets, specify full face helmets only and modify the crash performance tests to include the vulnerable facial and side areas of the head. The authors noted that although helmets prevented a significant number of potentially fatal head injuries, there continued to be cases of diffuse brain injury and brain stem damage.

In a study of 200 injury and fatal motorcycle crashes, the New South Wales Traffic Authority concluded that 35 percent of all impacts on helmets were outside the helmet test area currently specified in AS1698. Further, 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.

Based on much of this research, Nairn (1993) recommends the development of a new, more comprehensive Australian Standard for motorcycle helmets. Additional requirements should include the development of specifications to minimise the effects of tangential and frontal impacts (perhaps through enhanced energy absorption), and research into skidding resistance. Nairn (1993) also warns that such new research must be completed with a humanoid headform.

3.1.2 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. In a British study Gilchrist et al (1988, cited in Nairn, 1993) found that the range of helmet sizes currently available in the United Kingdom was insufficient to adequately match the range of head shapes and sizes. 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).

3.1.3 Rider vision

All helmets restrict to some extent the superior and peripheral vision of the rider, even when worn and fitted correctly. Hayward and Marsh (1988) concluded that a full face helmet caused a 38 percent reduction in a rider's vertical field of vision. This figure increased to 60 percent with the attachment of a sun visor and ventilation mask. The authors postulate that such a severe restriction in the vertical field of vision causes the rider to lose sight of activities which would otherwise have been seen in his or her peripheral vision when observing the mirrors and instruments (cited in Nairn, 1993).

The problem of misting and deterioration of visors and goggles has also attracted much interest. As a consequence of their design and construction, visors are relatively sensitive to surface damage, thereby reducing the clarity of a rider's vision.

Visors are also more easily subject to fogging, compared to goggles, and helmet ventilation devices are not entirely effective. Hayward and Marsh (1988) concluded that many "high mileage" riders accept the field of view limitation caused by goggles in order to get better abrasion resistance (cited in ibid).

Clearly, further research needs to be undertaken to examine whether the field of view requirements in the Australian Standard should be modified.

According to Nairn (1993) the cost of developing a generally appropriate, revised standard for motorcycle helmets is likely to be in the order of $100,000. Given that the average cost of a serious head injury has been estimated (conservatively, some would think) by the Federal Office of Road Safety at $56,000, if a new motorcycle helmet standard resulted in the prevention of merely two serious head injuries then the development would be cost effective.

3.1.4 Improving helmet wearing rates

In sum, there is ample evidence for the value of helmets. Whilst opponents of mandatary wearing laws cite arguments related to personal choice and privacy infringements, on balance many commentators consider that a worldwide effort to create mandatory wearing laws should be encouraged. Unfortunately, such laws do not (and probably would not) apply to riders on private property. This is a major shortcoming as it enables both adults and even children under licensing age to ride motorcycles, with no helmet or other protective gear, while on private property.

3.2 PROTECTIVE CLOTHING

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 to higher collision velocities ("The implications...", 1991). The Motorcycle Safety Foundation (1993) are of the view that only protective clothing specifically designed for motorcycling will continue to afford the best combination of fit and protection whilst actually riding. While most on-road motorcyclists wear protective jackets, it is estimated that only about half of these riders wear protective trousers and gloves.

Wide-flared trousers, flowing scarves and similar items should be avoided due to the possibility that they could become entangled in the motorcycle. The wearing of a jacket also reduces the rider's chance of becoming dehydrated whilst travelling in hot environments, as wind rushing over exposed skin quickens the process of dehydration.

Specifically, snug fitting gloves improve a rider's grip on the handlebars. In contrast, gloves which are too bulky may cause problems concerning the operation of the motorbike controls, whilst gloves which are too tight can restrict circulation causing the rider's hands to become cold.

Benefit-cost calculations for compulsory wearing of protective clothing by motorcyclists and pillion passengers (Torpey et al, 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.

Improvements to protective clothing have been proposed which see it playing a more "active" role in reducing injury. Toms (1990) comments that "I like the concept of turning a motorcyclist into a 'Michelin Man' in a crash. This centres the protection on the rider, and the quality of his or her protection, instead of the motorcycle. Air vests, inflatable clothing, padded plastic shielding, and semi-structural clothing - they all have merit" (p.i). However, research into the effectiveness of the "Michelin Man" concept has yet to be reported.

3.3 LOWER LIMB 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. However, such countermeasures designed to increase lower limb protection for motorcyclists have been the subject of considerable controversy (see Watson, 1990, for example). Toms (1990) comments that much of the research work in this area has been fuelled by product liability legislation, rather than the needs of motorcyclists.

These structures have generally been designed in the form of safety fairings. Importantly, Craig, Sleet and Wood (1983) observed that 'crash bars' (tubular metal protective devices) were fitted to 21 percent of patients' motorcycles and "appeared to offer no protection to the lower limbs". The authors therefore recommend that:

> *... to reduce the incidence of severe lower limb injuries it might help to provide some form of shell surrounding the legs to protect them against impacts from other vehicles which are most likely to strike the outer side of the lower leg (p.165-66).*

However, in the same study the authors warned:

> *... this form of device offers no protection against impacts after being thrown from the machine, although the resulting lower limb injuries are generally less severe. Special boots with knee protectors made from an impact-absorbent material could help to reduce the injuries if all motorcyclists would wear them - racing leathers are already known to give some protection (p.166).*

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.

In a more recent study, 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).*

However, in agreement with the conclusions of Craig et al (1983), Ouellet did state 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.

There is considerable concern that structures to provide leg protection may worsen overall rider injuries by increasing head and chest impact loads (Ouellet, 1990).

Fuel tanks can also sometimes cause damage to a rider's knees or legs (Pegg & Mayze, 1980) or pelvis (de Peretti et al, 1993). In fact, Ouellet (1990) notes that suggestions for cleaner design made by the earliest investigations of motorcycle crashworthiness have been largely ignored by recent designers. 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. Unfortunately, this advice has been largely ignored by 1980's designers, who have placed sharply humped fuel tanks directly in front of the rider's crotch and pubic bone (Ouellet, 1990).

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; for example, thick jeans and long leg boots (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). Toms (1990) comments that "reinforced, sturdy and lightweight motorcycle boots, not unlike the motocross variety, are clearly beneficial. Padded knee shield and thigh pads, like hockey and football players use, are also helpful. Styling and crash research on these concepts awaits attention" (p.ii). Relatively little attention has been given to the reduction of very common, but not severe injuries, although their total cost is likely to be considerable.

3.4 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.

Fitting an airbag to the instrument panel or the top of the petrol tank has been suggested as a method of preventing injuries by reducing the impact velocity. Airbags are one of the few restraint systems that do not obstruct the rider during normal riding. In general, airbags have been found to be most effective in 90 degree collisions with a stationary car. Oblique collisions or collisions with a moving car tend to result in the rider sliding around the side of the bag, and so little change in their velocity (Finnis, 1990; Ouellet, 1990). Unfortunately, in approximately half of a group of 129 crashes studied by Ouellet (1990) the motorcycle was found to have either yawed, lent or down-slid at the time of impact, thus reducing the effectiveness of an air bag.

Other issues involved with air bags are the need to have a very fast trigger switch because of the small distance between any sensor and the rider and the need for the switch not to be too sensitive, leading to it being triggered by minor knocks in everyday riding (e.g. potholes). In addition, the cost of fitting an air bag is a greater proportion of the cost of the motorcycle than is the case for fitting an air bag to a car. While it may be that injury reductions from an effective motorcycle air bag would result in good benefit-cost ratios, the willingness of motorcyclists to pay the additional cost is unclear.

Finnis (1990) has noted that while the conventional approach has been to design an air bag to produce a controlled deceleration of the rider, an alternative is to design the air bag to increase the exit height to ensure that the rider is ejected cleanly from the rider and clears the opposing vehicle. He cautions that this latter approach, while having some potential benefits, may result in more injuries because of hitting the ground from a greater height.

Like leg protectors then, airbags are not totally ineffective, but their effectiveness is restricted to a limited range of crashes and circumstances. Further research into controlling the ejection path is required.

3.5 FURTHER PROGRESS IN INJURY REDUCTION

Many researchers in this area have stressed the need for better knowledge about the mechanics of motorcycle crashes and the ways in which injuries are caused in order to develop more effective countermeasures. A number of approaches are being undertaken to collect this information, including motorcycle barrier research, in-depth crash investigations and computer simulations.

Toms (1990) identified a number of needs in motorcycle barrier research:

1. better motorcycle crash dummies
2. an organized and funded effort to refine the electronics and instrumentation needed to document motorcycle crash testing
3. dummy fixtures to control and align the dummy on the motorcycle before impact
4. open and honest evaluation of crash results; and
5. the opportunity to reconstruct and repeat tests to verify the repeatability and predictability of crash barrier results. (p.ii)

4 CONCLUSIONS

Although Australia continues to maintain a relatively high standard in the field of motorcycle safety, significant scope exists for the implementation of various countermeasures designed to either prevent crashes or reduce rider and pillion passenger injuries in the event of a motorcycle crash. This literature review has examined many of these proposed countermeasures.

Many proposed countermeasures to prevent crashes were suggested in the literature. It was concluded that wearing reflective clothing and daytime use of running lights and headlights can increase motorcycle conspicuity. The arguments raised against the use of daytime lighting (eg., glare effects upon the vision of other drivers) were noted.

Little statistical evidence was found to show that motorcycle rider training programs reduce crash risk per km travelled. In fact, many previous studies which examined this issue were found to have suffered methodological pitfalls. Future analytical strategies were therefore recommended. There are potential benefits to motorcyclists of education and awareness campaigns which target other road users but further evaluations are needed.

Recommendations for licensing programs were examined and the difficulties concerning enforcement of these programs were noted. The role of alcohol in motorcycle crashes was discussed at length.

Restrictions on both the carriage of pillion passengers and off-road riding by children and adolescents were also reviewed.

Those vehicle-based countermeasures included in this review centred upon braking systems (particularly upon the benefits of anti-lock brakes). The relative importance of a rider's ability to see clearly around a motorcycle was also examined.

Further research is necessary in order to settle the debate surrounding engine capacity and power restrictions. Improvements to road environments could be considered, bearing in mind their effect on other road users and benefit-cost ratios.

In terms of countermeasures to reduce injury, potential improvements to helmet crash performance were discussed. Limitations in rider vision accorded by helmets were also examined. It was concluded that lower limb protectors and airbags were not totally ineffective; rather their effectiveness is restricted to a limited range of crashes and circumstances. The benefits of protective clothing were relatively more apparent.

5. RECOMMENDATIONS

The following recommendations arose from the literature review. Some are already being undertaken in Victoria.

The recommendations to reduce crash occurrence are:

1. use of bright coloured motorcycles and clothing to improve conspicuity

2. daytime use of headlights and running lights to improve conspicuity

3. further evaluation of both motorcycle rider training and awareness training for car drivers

4. more effective enforcement of licensing and registration for motorcycles as part of ongoing Police activity (e.g. RBT)

5. consider increasing learners permit age for motorcycle to above that for car

6. limit the maximum length of time that a motorcycle learners permit may be held

7. consider requiring intending purchasers of motorcycles to hold a current motorcycle licence (although allowing for learners and business ownership)

8. more stringent penalties for riding without a licence (e.g. impounding motorcycle)

9. zero BAC for novice riders (learners and those in the first year of riding)

10. consider zero BAC for all motorcyclists if this can be shown to be warranted

11. publicity campaigns regarding the dangers of drink-riding

12. consider extending the restriction on carriage of pillion passengers from one to three years

13. educate parents and guardians about when children are old enough to be riding off-road, appropriate clothing and helmets and suitable motorcycles

14. encourage fitting of brake equalising systems or anti-lock braking

15. encourage better maintenance of brakes, suspension, clutch and throttle

16. improved enforcement of the 260cc capacity limitation for riders with a learners permit or first year on a licence

17. caution in use of raised pavement markers within intersections

18. treatment of man-hole covers and steel plates used to cover roadworks with an abrasive coating

19. avoidance of use of materials with low friction coefficients (e.g. glazed tiles and basalt blocks) in areas where traffic might travel at roadway speeds

Recommendations to reduce injury in motorcycle crashes are:

1. amendment to the Australian Standard AS1698 to reduce helmet liner stiffness, increase shell stiffness, improve the sliding qualities of helmets, specify full face helmets only, re-examine field of view requirements and modify the crash performance tests to include the facial and side areas of the head

2. preparation and implementation of an education program for riders and helmet retailers concerning fit and fastening of helmets

3. mandatory helmet wearing when rider or pillion passenger on private property

4. further investigation of the benefits and dangers of leg protection devices

5. encouragement of motorcycle designs which provide a smooth ejection path for the rider

6. encouraging riders to wear protective clothing and footwear

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PART 2: IMPLEMENTATION WORKSHOP

6 WORKSHOP AIMS AND STRUCTURE

A workshop was convened by the Monash University Accident Research Centre to discuss the recommendations of the Motorcycle Crash Countermeasures Literature Review. It was held on 31 March 1995 and involved representatives of motorcycle manufacturers and retailers, training organisations, motorcyclist organisations, Vic Roads (Road Safety and Registration and Licensing), the Transport Accident Commission, Victoria Police, Royal Automobile Club of Victoria, Australia Post, Federal Office of Road Safety, South Australian Office of Road Safety and Monash University. A list of workshop participants is provided in Appendix 1.

Given the large number of recommendations to be discussed and the specialised knowledge of participants, the morning session of the workshop was devoted to countermeasures related to the rider and other road users and the afternoon session devoted to vehicle and roadway countermeasures. The morning session was chaired by Mr Ted Vincent of Vic Roads Road Safety Division and the afternoon session by Professor Peter Vulcan of Monash University Accident Research Centre.

Workshop participants were sent a copy of the literature review and asked to consider the recommendations. The specific questions which they were asked were:

- If the recommendations have been implemented, what success do you believe they have had and how might they be improved?
- If they have not been implemented, should they?
- What are the advantages and disadvantages and barriers to implementation?

7 RIDER AND OTHER ROAD USERS COUNTERMEASURES

RECOMMENDATIONS TO REDUCE CRASH OCCURRENCE

1.* Use of brightly coloured motorcycles and clothing to improve conspicuity.

While no objections to the principle of improving conspicuity in this manner were raised, a number of current practical difficulties were raised. Chief among these difficulties is that the motorcycles which are most brightly coloured are currently the sports bikes which are believed to be the most dangerous (because of high power to weight ratios and peaky acceleration characteristics). It was not considered appropriate to recommend their purchase and use. This also has ramifications for any analysis of crash data as a function of motorcycle colour because the sports characteristics of most bright coloured bikes will probably be associated with higher crash rates.

Two other issues related to conspicuity were raised. First, that the problem of conspicuity is not confined to daytime motorcycling although many discussions assume this. Secondly, that the conspicuity of a motorcycle depends on what is behind the motorcycle to some extent. Little crash data are currently available on this issue and collection of such data would be very difficult.

2. Daytime use of headlights and running lights to improve conspicuity.

It was noted that Australian Design Rule (ADR) 19/01 requiring hard wiring of headlights on was introduced for new motorcycles from March 1992. Speakers representing motorcyclists and trainers commented that there is no Australian crash data yet available which shows a safety benefit of the introduction of ADR 19/01. Regulators commented that they are monitoring crash data to assess the effects of ADR19/01 but the data are currently unclear. The reasons for this are that the ADR is not expected to affect more than a few percent of crashes, daytime light use was not zero before ADR19/01 and that ADR19/01 takes a long time to phase in, compared with a compulsory use law. It will take a few years to collect sufficient crash data to assess the effects of the ADR by comparing changes in those motorcycle crashes which would be expected to be affected by the change with other motorcycle crashes which would not be expected to change.

The need for more detailed crash data to address conspicuity issues in general and ADR19/01 was agreed by representatives of motorcyclists, Police and road safety organisations. It was noted that the Victorian Accident Report Form does not collect information on colour, headlights, clothing etc.

* The numbering of the recommendations in Part 2 reflects that in Section 5 of Part 1.

The existence of evidence other than crash data (e.g. experimental data) to support improvements to conspicuity was noted by a number of road safety researchers.

Motorcyclist representatives and Police agreed that strategies used by the motorcycle rider can increase their conspicuity. . Police noted that the motorcyclist needs to place himself to be seen. A number of speakers stated that there is a need to find out the strategies used by successful motorcycle riders.

Motorcyclists argued that riders may need the option of turning the lights off for safety. For example, when the sun is behind the driver, they claimed that the rider needs to turn off their headlight to increase their conspicuity

General Discussion on the visibility of motorcycle riders.

There was extensive discussion of what underlies the common statement by car drivers that they 'did not see' the motorcyclist. It was queried whether this was a real perceptual problem based on the size, dark colour and/or speed of the motorcycle, whether car drivers are inattentive or whether drivers merely make this claim as a defensive reaction. It was agreed that 'did not see' was also probably a comment in car-car crashes in which the perceptual problems were not as likely to contribute to the occurrence of the crash. Car drivers not seeing pedestrians and bicyclists was also considered to be an issue.

The comment was made that probably the most useful thing to know in reducing crashes is not what the driver means by 'did not see' but what motorcyclists do that makes them 'not seen'.

One representative recommended awareness training for car drivers so that they have experience with motorcycles and know what to look for. It was suggested that perhaps learner drivers could receive training while riding as pillion passengers on motorcycles.

MUARC suggested that the TAC simulator could be used address the mechanisms involved in this phenomenon and to look at learner drivers as motorcyclists versus car drivers. Motorcyclist representatives and trainers stressed the need for realism in simulation.

3. Further evaluation of both motorcycle rider training and awareness training for car drivers.

Motorcyclist trainers acknowledged that proof of the effectiveness of motorcycle training has not been established in scientific studies. They pointed to the high risks of unlicensed riding as a form of evidence of the effectiveness of training. The point was made that training shows riders what the vehicle is capable of versus what it is not capable of, rather than training being able to control later riding behaviour.

A number of speakers noted the problem of variability between training schemes, both in quality and content. Concern was expressed that in the last decade training has

focused on low speed conditions and so is of limited relevance to the 'real' on-road conditions. The need for training to address the effects of alcohol on motorcycle riding and to deal well with cornering was stressed.

Some effects of training which were noted by motorcyclist representatives and trainers were that:

- it makes the motorcycle rider feel safer
- most motorcyclists who have taken training courses can talk about situations that they have avoided by a system or strategy they have learnt in training
- training makes people aware of other motorcyclists
- whilst training may increase exposure, it reduces the risk of injury because those who have been trained are more likely to wear protective clothing.

Representatives of the licensing authority noted that the availability of training is affected by it being cheaper to get a licence than to do training and licensing. It is more difficult in rural areas. The concern was expressed that compulsory training might lead to increased unlicensed riding.

4. More effective enforcement of licensing and registration for motorcycles as part of ongoing police activity.

The need for separate enforcement strategies for on-road and off-road riding was noted.

The question was raised whether unlicensed and unregistered riders are at higher risk of crashing because of that fact or because of the nature of the people who are involved. The Police commented that most commonly these riders are unlicensed and are inexperienced with both motorcycling and the particular bike.

There was extensive discussion of the deterrent effectiveness of RBT and speed enforcement for motorcycles. Researchers commented that RBT was designed to have maximum effectiveness in reducing drink driving by car drivers and so its design is not ideal for licence and registration enforcement or even reducing drink driving by motorcyclists.

It was proposed that Police check the licences and registration status of motorcyclists only (not other drivers) at RBT because of the large unlicensed/unregistered problem. Representatives of trainers and motorcyclists felt that this form of targeting might be acceptable to the majority of motorcyclists if extensive consultation was undertaken prior to its introduction and a leaflet explaining the reasons was given out at the time of checking. It was noted that legal motorcyclists stood to benefit from reductions in unlicensed and unregistered motorcyclists because this could prevent general increases in insurance premiums.

Researchers suggested that culpability data could be used to calculate implied exposure to assess the over involvement of unlicensed and unregistered motorcyclists in crashes.

The need to educate owners not to lend their bikes and the possible litigation that could ensue was stressed by researchers and trainers.

It was noted that the cost of registration is $28 plus $250-$400 for third party insurance, depending on the size of the bike. TAC cover for medical expenses is included but not loss of income earnings and suing is liable if the motorcycle is unregistered. The conclusion drawn was that it may be more economically viable to be unregistered if a person is only riding occasionally.

One representative described a Californian program in which experienced riders put together a program for 'unriders' (unlicensed, unregistered and/or under age) and held local campaigns. This could be an alternative or companion to the current legislation and law enforcement.

7. Consider requiring intending purchasers of motorcycles to hold a current motorcycle licence (although allowing for learners and business ownership).

A comment was made that this may not work as people returning to motorcycling may be bothered to go through the system again, despite the changes. Perhaps this could work if at time of registration, it could be found out if the owner is licensed and then make it a separate registration category if the owner is unlicensed. There is also a need to remember that the owners may not be the riders.

8. More stringent penalties for riding without a licence (eg impounding the motorcycle).

The Police noted that unlicensed and unregistered riding was very common on forest roads. At national parks, State Forest personnel intercept every vehicle and usually find at the weekends for example, there are about 28% unlicensed and 21% unregistered and on a public holiday weekend there are 55% unlicensed and 45% unregistered. Some people are very occasional motorcyclists. The Police have no doubt that unlicensed riding has increased because of the increased difficulty of getting a Learners Permit and restrictions on the length of the permit. It was noted that there seems to be an overflow of off-road riding onto the road.

The current penalties are very low: $110 on the spot fine for unlicensed rider or an unregistered bike and no demerit points are added for any of the above fines. Fortunately, the low level of penalties is not currently reducing deterrence because many people assume that the level of the penalty is much higher.

The deterrent effectiveness if being caught on a motorcycle (unregistered and/or unlicensed) led to loss of the car licence as well was queried. It was noted, however, that other general deterrence data has shown that increasing fines does not necessarily deter offenders.

9. Zero BAC for novice riders.

A loophole in current licensing regulations was identified where riders who have a full car licence are not liable to zero BAC while holding a motorcycle learners permit or a novice motorcycle licence (first three years). It was agreed that zero BAC should apply for all learners permit and novice licence holders, regardless of whatever licences were held. The possibility of some administrative difficulties was raised and so it was considered likely that this change would only be implemented if direct evidence of potential crash savings was available. The need for licence checking at RBT to enforce this requirement was noted.

10. Consider zero BAC for all motorcyclists if this can be shown to be warranted.

The Police expressed the view that zero BAC across the board for motorcyclists and car drivers would be a good idea. Rider representatives said that zero BAC for all motorcyclists would be opposed unless it also applied to car drivers.

Additional discussion of enforcement

The issue of whether common deterrence (RBT etc) is having as much effect on motorcyclists as on car drivers was raised. The Police considered that current RBT practices make it difficult for motorcyclists to avoid being tested although there is no available data on number of RBT tests by vehicle type. However, it was pointed out that most RBT is conducted at night, while most motorcycle riding occurs during the day. Researchers noted that alcohol is involved in many serious motorcycle crashes but if RBT timing does not match when these crashes occur, then perhaps RBT is not as effective for motorcyclists. MUARC noted that alcohol involvement in fatal crashes is similar for motorcyclists and car drivers in Victoria.

12. Consider extending the restriction on the carriage of pillion passengers from one to three years.

The Police noted that it is potentially a bad combination that engine capacity and pillion restrictions are lifted at the same time but rider representatives stated that they would oppose any change to current rules.

Many representatives agreed that there was a need for a better understanding of the role of pillions in crashes. The lack of exposure data for pillions was noted, and it was felt that the involvement of pillions in fatal crashes (14%) was probably considerably greater than the amount of pillion riding that occurs. Issues related to pillions which were raised included: their degree of experience, pillions leaning the wrong way, showing off to pillions, the relationship of carrying pillions and alcohol involvement, pillions being less likely to have correctly fitting helmets and protective gear.

The irregular and spontaneous nature of much pillion riding was considered to possibly reduce the effectiveness of restrictions on pillions. It was stated that HART and Stay Upright have training for committed pillions but these pillions may not be the real problem.

Engine capacity and power restrictions.

The Police proposed a graduated system in which the basic licence is to ride a motorcycle of less than 260cc and that a further licence is required to ride larger motorcycles, possibly requiring further training. The graduated nature of the Japanese motorcycle licensing system was discussed.

Trainers noted that at the moment, there is no separate moped licence and maybe there should be lesser training standards for scooters. Having no licence at all for small capacity motorcycles is not politically acceptable.

The Vic Roads study of power to weight restrictions suggested better enforcement of the 260cc limit would be more effective than a power to weight restriction. It was noted that there is a restriction in NSW of 150 kw/tonne limit through a coded colour on the registration label. The 250cc limit may no longer be appropriate due to the more powerful bikes available.

Police noted that power to weight ratio enforcement has been difficult for cars and trainers agreed that the difficulty in current enforcement means that any changes in the rules may be unproductive.

A motorcyclist representative queried whether a crash relationship exists between engine capacity and crashes. Road safety researchers noted that the relationship existed at the time that the restriction for novice riders was introduced but that the position may be less clear now. There is a need for current exposure data and a motorcycle exposure survey is being planned.

13. Educate parents and guardians about whether children are old enough to be riding off-road and to educate their children to wear appropriate clothing and helmets and use suitable motorcycles.

The Police noted that children are much more likely to ride motorcycles off-road than drive cars off-road. This flows on to them being more likely to ride motorcycles (illegally) on-road than to drive cars (illegally) on-road. There are restrictions on off-road motor bike riding but they are not enforceable or adhered to. The number of regulations is adequate but enforcement of them is a problem, especially in terms of defining them in a public place verses a 'real' off-road situation. Another problem is enforcing maintenance standards of motorcycles for example, 35% of unregistered bikes have no brakes at all.

It was argued that off-road riding is really a sport while fatalities and serious injuries are mainly from on-road riding. It was noted that Police data may give a biased view of the relative numbers of injuries sustained on- and off-road because off-road accidents are not required to be reported.

8 VEHICLE AND ROADWAY COUNTERMEASURES.

RECOMMENDATIONS TO REDUCE CRASH OCCURRENCE:

1. Encourage the fitting of brake equalising systems or anti-lock braking.

Motorcyclist representatives mentioned a number of disadvantages of equalising or anti-lock braking systems (ABS) which are limiting their use. The first is the cost, estimated at about $2,000 for ABS. Thus ABS is currently only fitted on the most expensive bikes. Simple equalising systems are cheaper but motorcyclists consider them ineffective because of the change in weight balance that occurs during braking.

There is a common feeling among motorcyclists that "a good rider in good conditions will beat anti-lock brakes". When queried, motorcyclist representatives denied that ABS or equalising systems were considered "wimpy" or "unsexy".

Concern was expressed by a manufacturer representative that anti-lock brake systems may increase crash severity by keeping the bike upright and the rider on the bike. The current systems might therefore be 'safer' and lead to fewer injuries because their instability results in the rider usually falling off the bike before the collision.

Differences between the braking of cars and motorcycles were discussed. A trainer stated that the braking abilities of the two types of vehicles are about the same in good conditions with well-maintained vehicles and experienced drivers or riders although there is a lot of variability in the study results. In wet weather cars will stop more quickly than motorcycles.

The usefulness of ABS or equalised braking for novices was discussed and it was noted that many novice crashes involve poor braking strategies. However, it was noted that these systems are not available on the sub-260 cc bikes that novices are restricted to riding.

A number of representatives were of the view that ABS or equalised braking systems were unsuitable for off road bikes for which brakes are used for purposes other than for stopping (e.g. standing up) and so the rider wants to be able to lock the brakes.

It was noted that changing from a bike with anti-lock brakes to another bike may have safety disbenefits.

2. Encourage better maintenance of brakes, suspension, clutch and throttle.

There seemed to be unanimous support for this recommendation. It was noted that there is quite a lot of literature around encouraging better maintenance (e.g. Vic Rider) but the problem is getting people to do it. Riders mistakenly believe that they can make mechanical repairs or adjustments themselves because they can see the components.

3. Improved enforcement of the 260cc capacity limitation for novice riders.

Discussion of the limitation and its effectiveness took place in the morning session. There was no support for the concern that the restriction to 250cc could be acting to limit the fitting of some safety features (which are currently available only on larger, heavier bikes).

4. Caution in the use of raised pavement markers within intersections.

5. Treatment of man-hole covers and steel plates used to cover roadworks with an abrasive coating.

6. Avoidance of the use of materials with low friction coefficients (eg glazed tiles and basalt blocks) in areas where traffic might travel at roadway speeds.

There was lengthy discussion of the hazards to motorcyclists of signs, road markings, roadside furniture.

The first issue raised was that the placement of signs, trees and poles may obscure the ability of other motorists to see motorcyclists. The height of Keep Left signs in the middle of the road was specifically mentioned and signs that you can see through were suggested.

Differing views were expressed about the use of rolled kerbing. Australia Post are objecting to the use of rolled kerbing because they believe it is contrary to the Australian Standard and riders tend to ride over it (rather than using the driveways), resulting in back injuries. However, the general view expressed was that rolled kerbing may be better for motorcyclists to hit in crashes than standard profile kerbing.

Complaints have been received by the RACV about the use of raised reflective pavement markers (RRPMs) in conjunction with pedestrian crossings, both from motorcyclists and car drivers. They believe that it is better to safety audit the crossing and the site in general to establish and remedy the problems, rather than installing RRPMs.

In the past yellow concrete blocks were placed alongside some tram lines to prevent cars obstructing the trams. The replacement of these blocks by a solid barrier has worsened the situation for motorcyclists because it is high enough to trip them over and it is unbroken, so motorcyclists cannot cross it (as breaks in the blocks at least allowed). The Motorcycle Riders' Association is against both the blocks and the solid barriers.

Specific road environment problems which were mentioned were: chicanes designed for cars which allow motorcyclists to almost travel in a straight line but can catch their pedals, problems with the visibility of some medians which are not signed, the need to take care when travelling on cobblestone roads, the wire rope fence which has been used to replace the ARMCO fence in Burke Road, Kew, motorcyclists becoming

airborne as a result of riding over a spoon drain placed on a bend and the lack of skid resistance of older road markings.

There was general agreement that local Councils design roads with cars in mind and the result is sometimes dangerous to motorcyclists. There was widespread support for a checklist for Councils to use in safety auditing. Motorcyclists felt that there were not specific motorcycle blackspots but that there are a very large number of bad road practices which are more appropriately picked up by an audit. Vic Roads noted that the new AUSTROADS guide to road safety auditing specifically mentions taking the needs of each type of road user into consideration.

The Police raised the problem of traffic signals which do not detect motorcyclists being a safety problem because the motorcyclist will eventually go through a red light and be at risk from traffic from other directions. Vic Roads responded that it is unlikely that the induction system can be technically improved to avoid the problem, which also occurs for bicyclists.

RECOMMENDATIONS TO REDUCE INJURY IN MOTORCYCLE CRASHES:

1. Amendment to the Australian Standard AS1698 to reduce helmet liner stiffness, increase shell stiffness, improve the sliding qualities of helmets, specify full face helmets only, re-examine field of view requirements and modify the crash performance tests to include the facial and side areas of the head

There was little support for the recommendation to specify full face helmets only. This arose from concern about findings regarding transmission of impact to the neck by full-face helmets and the lack of quantitative and qualitative exposure information on use of full-face versus open helmets. It was thought that perhaps there is a different type of riding by those who don't wear full-face helmets. There may be scope for improvements to the design of full-face helmets to incorporate an articulation point so that impact is not transferred to the back of the neck.

The general conclusion was to await the findings of the committee which is currently assessing possible revisions to the helmet Standard.

The role of stiffness was queried and it was explained that some liners are too stiff and so reduce the degree of impact absorption. Reducing the stiffness of liners will affect the longevity of helmets.

Widespread concern was expressed about the age of some helmets in current use. It was noted that AS1698 is quite an old standard and so there are some very old Standards-approved helmets currently in use. Perhaps helmets should have an expiry date. The Police noted that occasional riders often have very poor helmets.

There was general concern about the resale of helmets, some don't have a sticker or are damaged. Legally, any helmet can be sold if it has a Standards Approved sticker

but it was felt that it should be illegal to sell second-hand helmets because the purchaser does not know the history of a second-hand helmet and cannot see interior damage.

The safety of tinted visors was discussed. It is illegal to wear a tinted visor at night and most visors have a sticker which says "for daytime use only". However, it is acknowledged that riders do not always change visors between day and night use. The suggestion was made that it may be better to wear sunglasses under a clear visor than have a tinted visor but this is incompatible with the use of goggles. The issue of UV protection from tinted visors also needs to be addressed.

The potential for and usefulness of an ISO motorcycle helmet standard was discussed. It was queried whether this might result in cheaper and better helmets. It was noted that Snell is a worldwide standard (voluntary) but there are complaints that it may be too stringent and perhaps may be increasing stiffness and injury. Currently, almost all Australian helmets are imported with the shells being the same across the world, but the liners differing to take into account different head shapes.

2. Preparation and implementation of an education program for riders and helmet retailers concerning fit and fastening of helmets

It was noted that many riders ride with the strap undone during summer, particularly couriers. The Police noted that poor fit of helmet may relate to borrowing the bike and being unlicensed, the whole idea of riding on a whim. If this is the case, then the efficacy of the recommendation would be reduced.

Developments in strapless helmets in the US and France were noted which have an air-filled bladder system but it is unclear how well they would perform in a crash.

The extent to which retailers currently ensure that the helmet is a good fit was discussed. A manufacturer representative stated that the only person who really knows if the helmet fits properly is the rider. It was noted that rider training courses stress helmet fit, new helmets etc. It was concluded that perhaps retailers should be helping novices in the choice of helmets. A poster showing the steps to check if the helmet fits properly might be useful.

3. Mandatory helmet wearing when rider or pillion passenger on private property

While there was no disagreement with the need to wear helmets when riding on private property, considerable concern was expressed about the ability to enforce mandatory helmet wearing on private property. The Police stated that there is currently no legislation to require this and Police have no authority to go on private property. It is better to encourage people, rather than try to make it mandatory.

Occupational health and safety legislation may cover workers in terms of adequate protective gear. Unfortunately most OH&S enforcement happens after the injury has occurred.

4. Further investigation of the benefits and dangers of leg protection devices

The general comment from riders, trainers and industry was that leg protection devices were not a good idea and should be kept in the EEC. It was felt that there is a problem of entrapment by leg protection devices. Safety bars are used in low speed training at HART but are taken off for higher speed work. The Police considered that there is more benefit in protection which stays with the rider, e.g. padded knees and elbows.

5. Encouragement of motorcycle designs which provide a smooth ejection path for the rider

Most riders, trainers and industry representatives felt that modern-style motorcycles have incorporated a smooth ejection path for the rider and that removal of the front number plate helped this. However, concern was expressed about the increasing popularity of cruiser motorcycles which do have prominent protrusions, such as shaped handlebars, tank design and keys.

6. Encouraging riders to wear protective clothing and footwear

The Police expressed the view that protective clothing and footwear has to be encouraged, rather than standards developed because developing standards would increase the costs to a high level. There are currently many small manufacturers making made-to-measure items. The value of protective clothing and footwear should be publicised.

It was considered by motorcyclists that the Full Gear, Fool Gear campaign was helpful. Training organisations recommend full coverage. Fortunately the Victorian climate is much more amenable to this than in more northern states.

Additional issues raised

It was noted that a category of countermeasures which was not raised was changes to the features of other vehicles which may contribute to the occurrence of motorcycle crashes or to their severity, e.g. dark cars, bullbars (for which there do not seem to be after-market guidelines), car phones, lack of under-run protection on heavy trucks, semi-trailer turning circles and visibility of semi-trailers when turning. It was suggested that putting turning lights all the way down semi-trailers is a good idea. On the other hand, side skirts may restrict the ability of motorcyclists to see under a truck. Tinted windows make it harder to see through cars to be able to detect motorcyclists,

bicyclists and pedestrians. The use of hand-held mobile phones by car drivers contributes to the risk of crashes.

The issue of dangerous, particularly curvilinear alignments attracting motorcyclists was discussed by Vic Roads and training representatives. Examples given were the Great Ocean Road and the Yarra Boulevard. It was stated that it is necessary to take the fun out of these locations in order to reduce their attraction to motorcyclists. Speed humps in the middle of curves (marked, not slippery) may be better than chicanes for that reason. If hazards are signposted, then they may become a deterrent.

9 CONCLUSIONS: ACHIEVABILITY AND DESIRABILITY OF COUNTERMEASURES

During the Workshop, the participants discussed the motorcycle crash countermeasures identified by the Literature Review and identified a number of additional candidate countermeasures. In this section, the comments made in the Workshop are summarised into ratings of the achievability and desirability of each of the countermeasures.

The **achievability** of a countermeasure comprises the dimensions of acceptability to motorcyclists(as represented by the majority of those riders at the Workshop), cost of implementation and technical feasibility.

The **desirability** of a countermeasure corresponds largely to the extent to which the countermeasure is expected to reduce motorcyclist trauma (according to the Literature Review).

In the tables which follow, the countermeasures identified by the literature review are in bold text and the specific actions recommended by Workshop participants are italicised. In the achievability (and desirability) columns, a blank means that it was not considered achievable (or desirable), one plus sign means that it received moderate support and two crosses signifies strong support.

Table 1. Achievability and desirability of recommendations to reduce crash occurrence.

RECOMMENDATION	ACHIEVABILITY	DESIRABILITY
Develop checklist for Councils for road safety auditing	++	++
Improved semi-trailer visibility	++	++
Investigate conspicuity strategies used by successful riders	++	++
Collect better crash data for conspicuity	+	++
Educate owners not to lend bikes and danger of litigation	++	+
Encourage better maintenance of brakes, suspension, clutch and throttle	++	+
Improved enforcement of 260cc limit		+
Caution in use of raised pavement markers in intersections	++	+
Abrasive coating on man-hole covers and steel plates covering roadworks	++	+
Avoid use of low-friction materials where traffic might travel at roadway speeds	++	+
Discourage use of car phones	++	+
Daytime use of headlights and running lights	+	+
Study motorcycle rider training	+	+
Training to address effects of alcohol and deal well with cornering	+	+
More effective enforcement of licensing and registration	+	+
Police check license and registration at RBT	+	+
Educate parents about age, appropriate clothing, helmets and motorcycles	+	+
Motorcycle owners to hold riders licence	+ if exemptions, see text	+
Zero BAC for novice motorcyclists	+	+
Zero BAC for all motorcyclists		+
Improve conspicuity by bright coloured motorcycles and clothing		+
Encourage fitting of brake equalising systems or ABS		+
Pillion restrictions for three years		+
More stringent penalties for unlicensed riding	+	
Maintain engine capacity restriction, rather than introduce power-to-weight restriction	+	
Study awareness training for car drivers	not discussed	not discussed

Table 2. Achievability and desirability of recommendations to reduce injury in motorcycle crashes.

RECOMMENDATION	ACHIEVABILITY	DESIRABILITY
Encouraging riders to wear protective clothing and footwear	++	++
Reducing dangers of bullbars	++	++
Improved truck under-run protection	++	++
Education program on fastening and fitting helmets	++	+
Poster showing steps to check if helmet fits properly	++	+
Expiry date for helmets	+	+
Illegal to sell second-hand helmets	+	+
Encouragement of motorcycle designs which provide a smooth ejection path	+	+
Amend standard to reduce helmet liner stiffness, improve sliding quality etc.	await committee report on possible revisions	+
Developing standards for protective clothing and footwear		+
Amend standard to specify full-face only		+
Further investigation of leg protection devices		+

APPENDIX 1: LIST OF WORKSHOP PARTICIPANTS

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Linda Behrens*	Monash University Gippsland.
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Jill Rogers	South Australian Office of Road Safety.
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Chris Brooks	Federal Office of Road Safety.
John Goldsworthy	Federal Office of Road Safety.
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*=Participants who attended the morning session only.
#=Participants who attended the afternoon session only.