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Title and Subtitle

Motorcycle Safety Research Literature Review: 1987 to 1991.

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Abstract

This report presents the findings and recommendations of a world-wide review of the literature on motorcycle safety research, covering the period 1987 to 1991. The literature examined was divided into a number of categories which included the following: alcohol, licensing, rider training, motorcycle design features, road environment, public education and awareness and helmet design. For each category, current research relating to countermeasures is reviewed, the success or failure of existing applications is documented, the relevance to Australia is assessed, and recommendations and directions for future research are noted.

Keywords

Environmental Adaptation, Traffic Management Treatments, Town Planning, Road Design,

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EXECUTIVE SUMMARY

This report presents the findings and recommendations of a world-wide review of the literature on motorcycle safety research, covering the period 1987 to 1991.

A comprehensive review of the literature published up to and including 1986 was prepared in 1987 by R.J.Nairn and Partners for the South Australian Department of Transport, Division of Road Safety. This report, which was well received within the road safety community at the time, was made available to FORS at the outset of this study.

It is clear from this analysis of the literature that Australia is maintaining a high standard in the field of motorcycle safety. A number of the research areas which are being most actively pursued overseas, particularly in North America, are not directly applicable to Australia because appropriate programs are already in place. Compulsory use of helmets, rider training schemes and structured licence requirements are three areas in particular where Australian programs meet or exceed the standards being recommended for implementation elsewhere.

Nevertheless, having regard for Australian conditions, there are a number of recommendations worthy of consideration. These are:

- It is recommended that FORS conduct a review of the extent to which BAC data is recorded for motorcyclists involved in collisions (including non-fatal collisions) and the manner and quality of recording that data. If there is sufficient data available, conduct an analysis of the extent of involvement of drink in motorcycle collisions. If the data is insufficient, establish an expanded or improved data gathering and reporting program in conjunction with the State authorities.

- Research is recommended to establish, for Australian conditions, the incidence of unlicensed riding and crash involvement of unlicensed riders, to quantify the need for and provide focus for enforcement and education programs.

- Further research is recommended to quantify the impact of engine capacity restrictions on accident rates of inexperienced riders. Alternatives should also be evaluated. This would provide a firm basis for the States and Territories to review their current licensing requirements.

- Australian authorities should continue to introduce, refine and evaluate pre-licence rider training schemes. This continuing evaluation is necessary to:

  - Assess whether or not a positive effect results from the programs, providing a basis for their continued operation; and

  - Identify deficiencies and areas for improvement in the content of the training courses.

  A monitoring program is recommended for these training courses, which should be carefully designed for statistical rigour, including adequate sample size, carefully matched controls, considering experience, exposure and other methodological pitfalls described later in section 4.2.2.

- It is recommended that FORS, in consultation with State authorities, establish a national accreditation scheme to ensure consistent quality of trainers and course content.

- It is recommended that FORS closely evaluate anti-lock and integrated braking systems because they appear to be a cost-effective means of improving motorcycle handling.

- It is recommended that FORS investigate the number of accidents involving serious leg injury, to determine the number of injuries which would be reduced in severity or avoided if leg protection was provided. This will give a guide to the value of pursuing further research into crash bars and other forms of leg protection.

- It is recommended that FORS investigate the number and type of injuries which may be attributable to protrusions into the ejection path. This could form the basis for a review of motorcycle design rules, with the aim of reducing the severity of injuries to riders.

- The concern expressed by motorcyclists about the impact of standard traffic engineering practices on the stability and safety of motorcycles should be addressed through education and publicity directed towards local councils and state road authorities. An appropriate program would include reference to: road marking location and material; location of raised pavement markers; location and surface type of steel covers; decorative paving; speed bump design; and routine maintenance.

- It is recommended that FORS encourage, in association with the State authorities, the development of a new, more comprehensive Australian Standard for motorcycle helmets. The additional requirements should include impact angles not currently covered, energy absorption with a humanoid form, skidding resistance and modified field of vision requirements. This would reduce the severity of injuries to helmeted motorcyclists in some instances.

- It is recommended that FORS prepare and implement an education program about correct fit and fastening, targeted at riders and helmet retailers. This would reduce the incidence of ejection of helmets in crashes.

- It is recommended that FORS consider a research project to identify the extent to which:

    - Past public education programs have reached their target audiences;
    - The attitudes and behaviour of the target audiences have been modified; and
    - Accident rates have changed as a result of the programs.

  This research could then be used to guide the development of future public awareness and education programs.

1. INTRODUCTION

In 1987, R. J. Nairn and Partners, under contract to the South Australian Department of Transport, prepared a comprehensive review of the research literature related to motorcycle safety. That work was reported in the report titled 'Motorcycle Safety Inception Study' (Nairn, 1987).

This study has been commissioned by the Federal Office of Road Safety (FORS), to review the literature which has become available since 1986. This report describes the critical review of the literature available through the major literature databases of the world, covering recent developments in motorcycle safety, as reported in the press, technical journals, and trade magazines.

1.1 Background

Since 1980, the number of people killed in motorcycle accidents in Australia has declined from almost 450 to approximately 250 in 1990. Since 1983, the rate of decline in fatalities has been almost identical to the decline in numbers of registered motorcycles. Since 1980, there has been a 39% reduction in the rate of motorcycle fatalities (per registered motorcycle), while there has been a 44% reduction in fatality rate per vehicle for non-motorcyclists. Despite this decline, motorcyclists are still 19 times more likely to have a fatal accident per kilometre travelled than other road users (FORS, 1991).

The number of people killed in motorcycle accidents in the US increased dramatically in the decades prior to 1980, achieving a peak of 5,097 fatalities in that year. In the subsequent decade, the nationwide incidence of motorcycle fatalities has declined, reaching a low of 3,105 fatalities (a drop of 39% below the decade-opening high) in 1989. Much of the decline in motorcycle fatalities observed during the 1980s can be traced to a single cause: a decline in ridership.

Between 1980 and 1989, the number of motorcycle registrations in the US dropped by 26%. At the same time, the fatality rate per ten thousand motorcycles dropped from 9.0 to 7.4, a decline of 18%. Thus the drop in accidents has outstripped the drop in registrations, suggesting that the widespread introduction of helmet laws, training programs, and public education campaigns introduced over the decade had a measurable impact on accidents.

Even so, at the end of the decade, the US National Safety Council estimated that the mileage-based death rate for motorcycle riders was more than 15 times greater than that of the overall motor-vehicle death rate. This rate, leading as it does to over 3,000 deaths per year, provides a significant impetus for motorcycle safety research and the introduction of ongoing countermeasures at the federal, state, and local levels.

In the four years through 1986 in Great Britain, the total number of deaths on the road remained almost constant at approximately 5400 per year (Lyness, 1987). In 1986, 42% were car occupants, 34% were pedestrians and 14% motorcycles. As in North America, the total number of motorcycle accidents is decreasing, but this is largely explained by a decline in motorcycle traffic. While there were 0.9 car occupant deaths per million vehicle kilometres, there were 14 motorcycle rider deaths per million vehicle kilometres, very similar to the situation reported in the US.

During the same period, the trend in Israel has been different (Moukwas, 1989). Both total ridership and accident rates have been increasing. Because of these variations in trends and conditions, it is important to critically review the background to overseas study conclusions and legislative actions, in order to determine their applicability to Australian conditions.

1.2 STUDY OBJECTIVES

The objective of this study is to conduct a comprehensive world-wide review of motorcycle safety research reported in the literature from 1987 to 1991 inclusive. It was felt that research published prior to 1986 was adequately covered in the South Australian Study (Nairn; 1987). The latest date covered in the literature searches for the present study is August, 1991.

1.3 METHODOLOGY

The first step in the process was to interrogate the major databases of the world. Databases accessed included: Literature Analysis System on Road Safety (LASORS), International Road Research Database (IRRD), Australian Road Research Database (ARRD), National Transportation Information Service (NTIS) and those databases available through Dialog Services in the US.

Key words were selected to isolate publications dealing with motorcycles and road safety. After reviewing the lists of authors and titles, abstracts were requested for those articles which appeared to be appropriate.

Two areas were excluded from the study, at the direction of FORS: helmet usage and legislation; and conspicuity. Helmets are compulsory in all Australian States and Territories, and a re-examination of the issue was not seen as warranted due to consistently high observed wearing rates. For example, Johansen (1987) reported 97% and 98% wearing rates in Sydney in the mid 1980s.

Literature related to helmet design has, however, been retained in this study due to recent design considerations with possible safety benefits. Issues relating to motorcycle conspicuity measures were excluded from the study since they have already been the subject of a separate, extensive review.

The literature search was completed during 1991. Because of the time lag between completion of research and results being published, some of the research discussed here was carried out prior to 1987, and little research completed after 1990 was available for review. While the search covered all major, appropriate sources throughout the world, it is clear that the extent of new research which has been reported during this period is limited.

Copies of publications which appeared to warrant more detailed review were requested through inter-library loan services. While we are pleased with the extent to which US and Australian publications have been covered, a number of important conference proceedings requested from Europe and Japan have not been received before this review was finalised.

1.4 THIS REPORT

For convenience, the discussion of the material examined has been divided into a number of separate categories. These are:

- The Alcohol Impaired Rider
- Licensing
- *Rider Training*
- Motorcycle Design Features
- Road Environment
- Public Education and Awareness
- Helmet design

These categories tend to correspond to promising countermeasures aimed at lowering the motorcycle accident rate. In each case, current research regarding the countermeasure is reviewed, the success or failure of existing applications is documented, the relevance to Australia is assessed, and recommendations and directions for future research (or innovative countermeasures) are noted.

2 THE ALCOHOL IMPAIRED RIDER

Accident statistics in Australia show that 41% of motorcycle accident fatalities involve blood alcohol levels above 0.05%, compared to 29% for drivers of cars and other light passenger vehicles (FORS, 1991). Other countries report a similar situation.

Although the involvement of alcohol as a factor in motorcycle fatalities has declined over the last eight years in both the US and Canada, over half of the fatally injured riders in both of these countries still show some traces of alcohol in their blood. Recent Canadian research concludes that "...drinking motorcyclists have a higher relative risk of fatal collisions than automobile drivers, particularly at high BACs." (Mayhew and Simpson, 1990).

2.1 RECENT RESEARCH FINDINGS

2.1.1 Trends

Simpson and Mayhew (1990) studied eight-year trends in the blood alcohol content of fatally injured motorcycle riders and drivers in both the United States and Canada. Between 1980 and 1988, both countries saw a steady and systematic decline in the percentage of fatally injured riders and drivers who had been drinking. In both countries, the percentage of fatally injured motorcyclists who had been drinking has been consistently higher than the percentage of fatally injured auto drivers who had been drinking.

Figure 2.1 plots the incidence of alcohol among motorcyclists fatally injured in Canada and the United States from 1980 to 1988. Although the percent of riders who had been drinking is greater in Canada over most of this period, by 1988 the incidence of drinking among fatally injured riders stood at roughly 50% in both countries. In spite of the fact that alcohol involvement has been declining as a factor in fatal crashes in recent years, Simpson and Mayhew note that "even today half of all fatally injured riders have been drinking.".

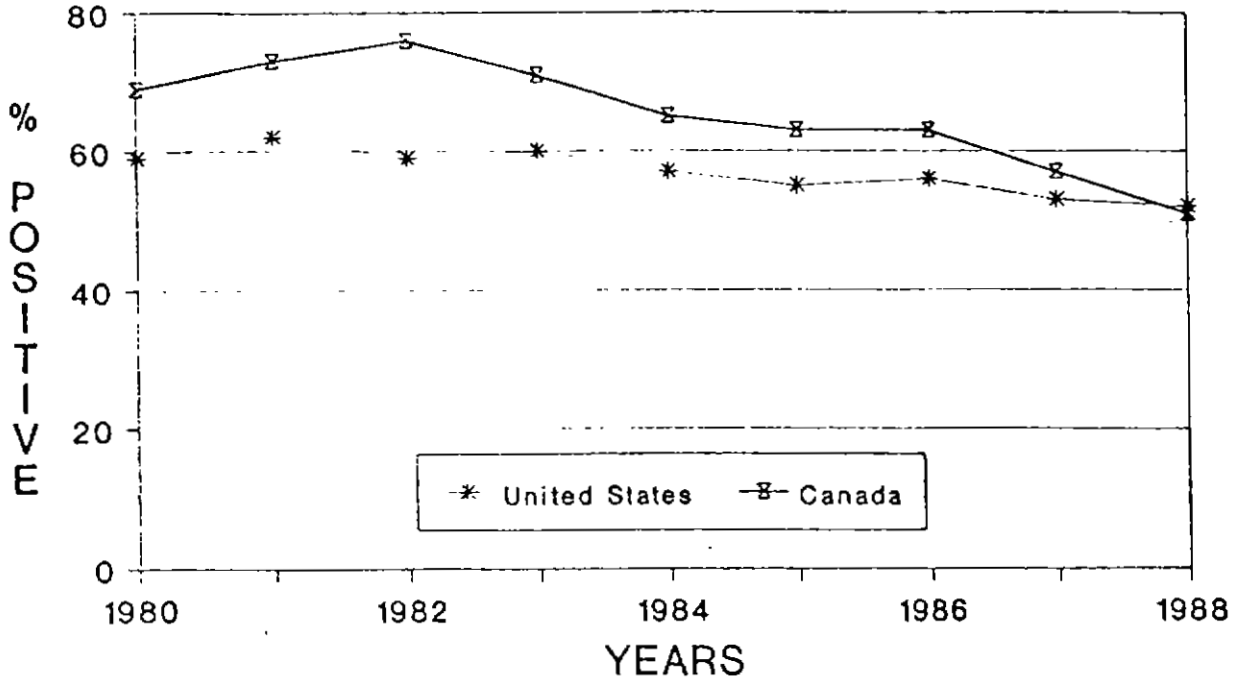
Simpson and Mayhew found little change over the years in the levels of alcohol detected among those fatally injured riders who had been drinking. At least 70% of those who had been drinking had BACs over the legally defined level of impairment (0.08% to 0.10% in most states and provinces) and nearly 50% had very high BACs (in excess of 0.15%).

2.1.2 Relative Risks

Mayhew and Simpson (1990) also investigated the possibility that the effects of alcohol are more pronounced in motorcyclists than auto drivers, given that riding a motorcycle is a more demanding task than driving an automobile. Their analysis of contemporary Canadian data revealed, for both motorcyclists and automobile drivers, increases in the relative risk of fatal collisions with increases in BAC. However, they also found that "...drinking motorcyclists are at greater risk of fatality than automobile drivers who have been drinking, especially at illegal BACs (81 mg. % and over)".

Figure 2.1

COMPARISON OF TRENDS IN ALCOHOL AMONG
MOTORCYCLISTS KILLED IN CANADA AND THE UNITED STATES
1980-88



TIRF of Canada, 1990

Source: Simpson and Mayhew, 1990.

2.2 COUNTERMEASURES

The range of countermeasures for the alcohol impaired rider cited by Simpson and Mayhew (1990) includes legislation, enforcement, education and awareness, and treatment and rehabilitation.

2.2.1 Legislation

Raising the legal drinking age has had a demonstrable impact in lowering drink driving accidents among younger drivers and motorcyclists throughout the US There is some indication that raising the age at which riders may obtain a motorcycle licence might have the same effect. For riders with driver education, the minimum licensing age is 16 in most states, but it ranges from 14 in North and South Dakota to 17 in New Jersey. Imposing zero BAC requirements on permit holders and probationary licence holders also helps to reduce fatality rates among new licensees.

2.2.2 Enforcement

Sobriety checkpoints at which officers screen all drivers and riders for signs of potential drunkenness and drug impairment have been successfully introduced in the US in recent years. In addition, a current NHTSA study (Stuster, 1990) is documenting tell-tale clues that will enable police officers to identify and apprehend impaired riders more efficiently.

2.2.3 Treatment and Rehabilitation

Simpson and Mayhew (1990) point out that the overwhelming majority of fatally injured riders who have been drinking have consumed considerable quantities of alcohol. They suggest that the hard-core drinker is not likely to be reached by traditional education and awareness programs and suggest that research is needed to determine the nature of prevention programs that might be effective with them.

2.2.4 Education and Awareness

Simpson and Mayhew (1990) credit the ongoing decline in the incidence of alcohol among fatally injured riders to both the unprecedented concern about drinking and driving that has surfaced at all levels of government and the community, and to the education and awareness programs which have sprung from this concern. They note that 30% of alcohol impaired rider fatalities had relatively low BACs (by North American legal standards). This may reflect a number of factors, such as the higher legal limits in those countries, and the extent to which riders understand the impact of drinking on their accident risk. This suggests that in those countries there still exists a need for traditional enforcement and education and awareness programs targeted at the more responsive individual and the more responsible drinker. This target group could be expected to be more responsive to such programs than the hard-core drinkers described above.

2.2.5 Alcohol Interlocks

No direct references have been found (for the study period) to research into alcohol interlocks for motorcycles in general, or those of multiple offenders.

2.3 RELEVANCE TO AUSTRALIA

2.3.1 Legislation

The directions suggested by US researchers for raising minimum legal drinking and driving ages would move the US towards the standards already in place in Australia. Australian action is supported by the North American research. Recent legislative changes is some Australian states include:

- retaining the minimum age for motorcycle learner permits at 17 years and 9 months;
- the introduction of a three year probationary licence (with a minimum age of 18 years);
- a zero BAC limit during the three year probationary licence period;
- a prohibition of carrying a pillion passenger for one year; and,
- restriction to motorcycles with engine capacity of less than 260cc for the same period.

2.3.2 Enforcement

Random breath testing (RBT) checkpoints are widely used in Australia, and are more comprehensive and sophisticated than many US sobriety checkpoints. Many US checkpoints do not use breath test equipment, but rely on tests of a motorist's fine motor skills. These include making the motorist walk a straight line, balance on one leg and touch his/her nose with an outstretched finger. This appears to increase the time required to process each motorist, compared to Australian style RBT checkpoints (Fehon, 1991).

2.3.3 Treatment and Rehabilitation

Australia has more stringent BAC requirements, a good points system for tracking multiple offenders and better interstate cooperation for driver offence records. There is therefore a higher probability of detecting hard-core drinkers among the population of riders. However, while there is provision for licence withdrawal and/or change to probationary licence status, treatment and rehabilitation remain relatively inactive.

2.3.4 Education and Awareness

The lower legal BACs in Australia address Simpson and Mayhew's (1990) findings to some extent, and it is considered that the current road safety and general anti-alcohol and drug publicity campaigns in use in Australia are of a high standard.

2.4 FUTURE RESEARCH

Mayhew and Simpson (1990) propose that future research efforts on the issue of drinking and riding should include roadside surveys aimed at documenting the drinking riding patterns of motorcyclists. They suggest, further, that research efforts should also be directed towards gathering objective data on the BACs of motorcyclists involved in accidents of different injury severity, since "reliance on studies of fatally injured motorcyclists provides only a portion of the information needed to understand the role of alcohol in collisions involving motorcyclists.".

Finally, there is a need for more rigorous documentation and evaluation of legislative, enforcement, and awareness programs aimed at reducing the incidence of alcohol impaired riding among motorcyclists, so that the more effective programs can be identified and repeated in other jurisdictions.

2.5 COST EFFECTIVENESS

The collection and collation of BAC data for all riders involved in collisions has two components. For those injured and requiring treatment at hospital, it is understood that all riders' BAC is documented. It is also standard practice, in some States at least, to test the BAC of all drivers and riders involved in collisions.

It would appear then, that with current practices or relatively minor modifications, significant data is available to study the role of alcohol in all collisions involving motorcyclists. It is estimated that an initial budget of $50,000 would enable collation and analysis of the existing data, and $20,000 per annum would permit annual monitoring revisions. This would provide a cost effective means of maintaining up to date data for monitoring the impacts over time of relevant education and enforcement programs.

2.6 RECOMMENDATIONS

It is recommended that FORS conduct a review of the extent to which BAC data is recorded for motorcyclists involved in collisions and the manner and quality of recording that data.

If there is sufficient data available, conduct an analysis of the extent of involvement of alcohol in motorcycle collisions. If the data is insufficient, establish an expanded or improved data gathering and reporting program in conjunction with the State authorities.

3 LICENSING

3.1 BACKGROUND

Most states in the US require riders to obtain a special operator's licence before operating a motorcycle on public streets and highways. There is, however, ample evidence that many motorcyclists ignore these requirements. 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 ranged from 39% to 42% between 1983 and 1989. The problem of unlicensed riders is particularly severe in California, where the incidence of improperly licensed fatalities has ranged from 39% to 63% over the same period. On the basis of interviews and licence checks conducted with 1600 motorcyclists in late 1989 and early 1990, Billheimer (1991) estimated that roughly 41% of the motorcyclists using California's roads are improperly licensed. Thus unlicensed riders comprise a disproportionate share of the state's fatally injured motorcyclists.

In a separate study, Kraus (1990) found that 39% of a sample of 3,723 motorcyclists severely or fatally injured in California in 1985-1986 were operating motorcycles they did not own. Riders who were not owners of the motorcycles were less likely to be valid licence holders than riders who owned the motorcycle they crashed (20% vs. 44%). The licensing rate of crash-involved drivers who were not owners was 15% if the owner was also unlicensed. Rates of valid licensure were lowest among young riders.

In commenting on the high incidence of unlicensed riding in California and the rest of the US, a recent National Highway Transport Safety Administration (NHTSA) paper points out that "...Riders who operate motorcycles without valid licences are, at a minimum, circumventing the skill and knowledge tests that are a major segment of a state's comprehensive motorcycle safety program.".

Anecdotal evidence gathered by the authors suggests that a similar problem exists in Australia, although not to the same extent. However, no evidence was found in the literature to support or refute this.

3.2 LICENSING REQUIREMENTS

In 1989, NHTSA and the Motorcycle Safety Foundation convened a panel of experts from the fields of operator licensing and motorcycle safety to develop a model for an optimal motorcycle operator system (Spurgeon, 1990). This system addresses issues such as:

- The perennial permit holder,
- The number of consecutive learner permit renewals,
- Rider education and licensing tie-ins,
- Provisional licences for first-time motorcycle licence holders,
- Restrictions for provisional licence holders, and
- Recommendations for knowledge and skill tests for motorcyclists.

3.2.1 Licensing Objectives

As stated by the NHTSA / MSF working groups (Spurgeon, 1990), "...the ultimate goal of a motorcycle operator licensing system is to reduce crashes, injuries, and fatalities.". Operator licensing can help reach this goal by achieving the following objectives:

- Motivate people who wish to operate motorcycles to develop the skills and acquire the knowledge necessary to ride safely,
- Control the learning process to ensure that the beginning rider gains experience in a low-risk environment,
- Assure that new riders attain an appropriate level of skill and knowledge before being granted full riding privileges, and
- Assure that experienced riders maintain an acceptable level of safety knowledge and skill throughout their riding careers.

In addition to enhancing public safety, motorcycle operator licensing also provides a means for state motor vehicle administrators to:

- Collect data regarding motorcycle rider demographics,
- Exercise legal control over motorcyclists, and
- Generate revenue to support other motorcycle safety programs.

3.2.2 Permit Parameters

A learner's permit is required for on-street operation by any rider not holding a valid motorcycle operator licence or endorsement. Since the permit is intended to encourage beginning riders to gain riding skills quickly under low-risk conditions, the NHTSA/MSF group recommends a number of restrictions:

Permit Period. To avoid the problem of the perpetual permit holder, the learner's permit should be issued for a maximum period of ninety days and may be issued only twice per applicant. A minimum permit period of 30 days is recommended to ensure that each applicant has ample time to practice riding under controlled conditions.

Permit Restrictions. To limit the beginning rider's exposure to traffic and risk of injury, the committee recommended that at least the following restrictions be applied to the learner's permit:

- Mandatory Helmet Use. Even where helmet use is not compulsory, permit holders should be required to wear approved helmets.
- Passenger Restrictions. Because of the additional rider skill required for controlling a motorcycle when carrying a passenger, permit holders should be required to ride solo.
- Zero BAC/Drug Level. Permit holders should be prohibited from riding with any amount of alcohol or drugs in their system. The committee notes that "this will allow the administration to impose sanctions on the riding privileges of youthful violators and discourage alcohol or drug use by all beginning riders during the high-risk learning period".

In addition to these minimum restrictions, the following might also be applied:

- High Visibility Clothing,
- Supervision,
- Night-time Curfews, and
- No Interstate Riding.

Rider Education. Rider education is thought to be effective in increasing the skill level of beginning motorcyclists. However, the effectiveness of these programs in reducing accident levels has yet to be conclusively demonstrated (See Section 4.0). Even so, mandatory training for licence-seeking applicants under 21 has proven feasible in many states, and the NHTSA/MSF committee recommends that "...all applicants who fail the licensing test be required to complete an approved rider education course".

3.2.3 Licence Tests

One school of thought (Fassnacht, 1988) suggests that "By their nature licensing tests assess minimum performance and knowledge that operators are deemed to need to operate a motor vehicle in traffic.". Experts disagree, however, on what constitutes a minimum level of performance and knowledge, and the extent to which training and accident avoidance skills should be incorporated in the licence test. It is generally agreed that the "lollipop test" administered by California, so called because of the "circle and stem" shape of the testing area, represents a minimum test, since it focuses only on the rider's ability to shift gears and control the motorcycle at low speeds and does not address many of the skills required to avoid accidents. As identified in past research (i.e., Hurt, et al., 1981) these skills include:

- Emergency braking in a straight line,
- Emergency braking on a curve,
- Swerving, and
- Cornering.

In the wake of the Hurt study, several more rigorous testing procedures have evolved that enable the examiner to observe the applicant's mastery of these critical skills. These testing procedures include:

- The Motorcycle Operator Skill Test (MOST), a comprehensive test which consists of eight exercises that evaluate a rider's ability to stop, negotiate various turns, swerve, and stop on a curve. The test requires some special equipment and a testing area 125 feet by 50 feet.
- The Alternate MOST is available where budget or space limitations do not allow the use of the MOST. The Alternate MOST requires a minimum of 115 by 70 feet and consists of seven exercises that evaluate a rider's ability to turn, swerve, and stop a motorcycle.
- The Motorcycle Licensing Skill Test (MLST) allows examiners to objectively measure rider performance in three critical riding tasks; turning, swerving, and braking. The test uses special equipment and requires an area of 125 x 50 feet.

Materials for each of these procedures have been tested and are available either from the Motorcycle Safety Foundation or the National Highway Traffic Safety Administration. However, extensive comparison tests conducted in New York (Billheimer, 1987) were unable to demonstrate that the more rigorous tests had an impact on the subsequent accident history of applicants passing these tests.

3.2.4 Provisional Period

The NHTSA/MSF guidelines suggest that a provisional period involving special restrictions be imposed on all first-time licensees. Under their system, the nature and duration of the provisional period would vary according to the age of the licensee and the date the licence is issued.

First time licensees between 16 and 21 years of age would be subject to the following special provisions for a period of two years:

- Mandatory helmet use;
- 0.00 BAC/Drug levels; and
- Early intervention for traffic law violators.

First time licensees older than 21 would have a six-month provisional period, during which time they would be subject to:

- Mandatory helmet use; and
- Early intervention.

3.2.5 Licensing Restrictions

Several jurisdictions in North America (Quebec in Canada and the states of Washington and North Dakota) restrict the size of motorcycle that can be operated by certain riders. In reviewing restrictive licensing practices, Mayhew and Simpson (1990) note that licensing restrictions on the size or power of the machine that can be operated by a novice rider are particularly popular outside North America, and group such restrictions into three categories:

- The British model, which involves restricting all learners and probationary or provisional riders to machines with an engine capacity of 250 cc or less (the 250 cc restriction has been reduced to 125 cc in Great Britain);
- The Japanese or multi-tiered model, which allows novice riders to become licensed on the size of machine on which the skill test is taken. Test requirements typically become more difficult as the size of machine increases; and
- The West German model, which involves different age limits for different classes (defined in terms of engine size, power and speed) of motorcycle. Riders aged 16 are restricted to the smallest class; those over 20 can operate the largest class if experience has been gained on a middle class motorcycle.

A remarkable number of combinations of licensing restrictions exist. One promising approach proposed in the earlier Australian study (R.J. Nairn and Partners, 1987) is to raise the minimum age at which a motorcycle licence can be obtained. US experience in states in which the driving age is 17 suggests that higher driving ages actually lower accident rates, and do not just postpone novice accidents by one year.

Mayhew and Simpson (1990) note that "...while there appears to be no shortage of different and innovative approaches to address 'the problem' there is a paucity of solid evidence to show precisely what the problem is that is being controlled and whether or not the restrictive practices have had the intended beneficial effect.". They observe, however, that Denmark recently rejected engine size limits because a study conducted by the Danish Road Safety Council found no conclusive evidence that such limitations led to fewer accidents among inexperienced motorcyclists. A recent West German study (Koch, 1990) also concluded that "restricting young beginner motorcycle riders to low powered machines has no favourable effects on the accident situation.".

3.3 COUNTERMEASURES

The best licensing system in the world is useless if motorcyclists avoid it by riding without obtaining a proper licence. A number of countermeasures have been suggested for increasing the proportion of validly licensed riders and reducing the crashes associated with unlicensed riders. The most obvious of these is:

- Heavier Enforcement. Licence status should be checked each time a routine stop of a motorcyclist is made. Based on the number of citations issued in California for improper motorcycle licences, it is estimated that fewer than 10% of the state's unlicensed riders were cited in any given year.

Kraus (1990) suggests a number of other countermeasures.

- Purchase Prerequisite. Requiring proof of valid licence as a prerequisite for purchasing a motorcycle would reduce the extent of unlicensed riding.

- More Stringent Penalties. Impounding motorcycles (or confiscating licence plates) driven by invalidly licensed riders for a specified period of time should reduce the amount of unlicensed riding, and it would also deter owners from allowing invalidly licensed people to operate their motorcycles. Fining or otherwise punishing motorcycle owners who lend motorcycles to invalidly licensed riders, or holding them liable for crash damages would also deter this practice.

Any attempt to impose more stringent penalties on unlicensed riders must be accompanied by heavy doses of public information and education. Billheimer (1991) found that over three-quarters of California's motorcyclists contacted in telephone interviews were unaware of the current penalties for riding without a licence. Accordingly, public information programs should focus attention on current sanctions, the problem itself, and any special enforcement programs designed to counteract it.

Kraus (1990) reasons that restrictive practices and increased sanctions can change motorcycle behaviour in either of two ways: they can avoid sanctions by obtaining the proper licence or by not riding. He reasons that sanctions applied to unlicensed riders are more likely to be effective if they reduce riding than if they merely shift unlicensed riding to licensed riding. To the extent that the measures reduce exposure, they will reduce crashes. He is less hopeful, however, that changing unlicensed riders to licensed riders without changing the amount or type of riding will have any impact on crashes, in view of the New York finding that licensing programs have not been shown to be effective in reducing crashes (New York State DMV, 1988).

3.4 RELEVANCE TO AUSTRALIA

3.4.1 Permit

It is not clear whether Australian States have restrictions on the number of consecutive permits, or a minimum permit period. These are valuable restrictions and should be investigated.

3.4.2 Permit Restriction

The NHTSA/MSF guidelines are less restrictive than the Victorian requirements. The expected introduction of Provisional Licences in ACT in late 1992 will see the ACT also exceeding the NHTSA/MSF guidelines.

The guidelines support the current push for stronger, more uniform legislation throughout Australia. The Federal Government's 10 Point Road Safety Package aims to achieve this and includes a graduated licensing system for young drivers, the elements of which are as follows:

- zero Blood Alcohol Concentration for young drivers
- zero Blood Alcohol Concentration 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
- the minimum period for a learner permit to be 6 months

3.4.3 Licensing Restrictions

There does not appear to be strong statistical evidence that a restriction on the size of a machine that can be operated by novice riders favourably affects the accident situation. However, this has been a controversial issue, and the studies reported above did not appear to specifically consider power or power to weight ratio. It may be appropriate to consider a power to weight restriction rather than an engine capacity restriction, in view of the change in motorcycle characteristics in recent years. This trend needs to be researched and quantified to establish whether the current characteristics vary from those considered when the engine size restrictions was first introduced in Australia.

3.4.4 Heavier Enforcement

Some Australian police forces already check licence status each time a driver or rider is stopped for a traffic offence. For example, in N.S.W. and Victoria, a cross check is made of current licence status and any warrants outstanding against the licensee. However, at RBT sites it is not common practice for a check against current records to be made unless the rider fails the initial breath test. With current technology, it would be relatively straightforward to check the current status of all riders stopped for whatever reason.

3.4.5 Purchase Prerequisites

Requiring proof of a valid licence as a prerequisite for purchase of a motorcycle would be difficult to enforce in practice.

A learner rider may not have access to a motorcycle as readily as a learner driver has access to a car. In this circumstance, the learner may have to purchase a motorcycle in order to learn to ride.

The licence requirement could be readily circumvented by having the motorcycle purchased in the name of a licensed rider. There would be no legal impediment to this practice.

3.4.6 More Stringent Penalties

These may be appropriate if unlicensed riding is found to be a significant problem in Australia.

3.5 FUTURE RESEARCH NEEDS

Research is needed to document the size of the population of unlicensed riders and relate testing, restrictive licence practices, mandatory training programs, and sanctions to the size of that population. The US and Canadian research described above suggests that unlicensed riders are over represented in fatality rates, but until the size and composition of the unlicensed riding population in Australia is known, it is difficult to establish exposure rates for accident studies addressing the effectiveness of various motorcycle safety measures. There is some indication that mandatory training may lead to lower licensing rates among the age group required to take training, but the evidence is sketchy at best.

3.6 COST EFFECTIVENESS

The cost of determining the rate of unlicensed riding in Australia would depend on the quality of the data available from existing records. Assuming data has been recorded in police infringement and accident records, an Australia-wide study could be conducted within a budget of $50,000. This would be a worthwhile investment if it identified targets for modified legislation or practice to reduce the incidence of crashes related to inadequate licensing.

3.7 RECOMMENDATIONS

Research is recommended to establish for Australian conditions:

- The incidence of unlicensed riding and crash involvement of unlicensed riding, to quantify the need for and provide focus for enforcement and education programs;
- Quantify the impact of engine capacity restrictions on accident rates of inexperienced riders.

4 RIDER TRAINING

4.1 BACKGROUND

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 and are generally based on the Motorcycle Safety Foundation's beginning rider education program curriculum, known as the Motorcycle Rider Course: Riding and Street Skills (MRC:RSS). This curriculum covers roughly sixteen hours of training, eight of which are spent on motorcycles on a controlled range. Several US states have made the successful completion of the MRC:RSS course mandatory for young riders seeking a motorcycle licence. The MSF has also developed an eight-hour Experienced Rider course (ERC) for veteran motorcyclists.

The Singapore government has established the Singapore Safety Driver Centre and introduced a driver training procedure based on Japanese practice. Kobayashi and Chua (1989) report a reduction in accidents caused by motorcyclists as a consequence. However, traffic conditions and accident patterns are different from those in Australia.

4.2 EVALUATIONS

4.2.1 Past Research

The ultimate measure of the effectiveness of any motorcycle training program is its impact on accident rates. In the last ten years, several states and provinces have attempted to assess the impact of motorcycle training using a matched-sample approach. These include Illinios (Satten, 1980, and Mortimer, 1984), Ontario (Jonah, et al., 1982), Wisconsin (Leung and Rading, 1987), Pennsylvania (McKnight, 1987) and British Columbia (Rothe and Cooper, 1987 and McDavid, et al., 1989).

Table 4.1 summarises the key characteristics and conclusions of seven matched-sample studies conducted during the 1980s in US and Canada. No similar studies were reported in Australia during the study period. Only one of these studies concluded that motorcycle training reduces accidents. In the most recent of the studies listed, McDavid (McDavid, et al., 1989) found that "Trained riders tend to have fewer accidents of all kinds (all motor vehicle accidents combined), fewer motorcycle accidents, and less severe motorcycle accidents. Although these differences are not large in a statistical sense, they suggest that when care is taken to carefully match trained and untrained riders, training is associated with a reduction in accidents.".

Accident Impacts. Earlier studies were not able to demonstrate that motorcycle training reduces accidents. In fact, a few of the earliest studies (Satten, 1980; Jonah, et al., 1982; and Mortimer, 1984) found that a straight comparison of trained and untrained riding populations showed that the untrained riders had lower overall accident rates. However, these differences vanished when results were adjusted to reflect differences in age, sex, riding history, exposure, and education between the trained and untrained populations. Rothe and Cooper (1987) found some evidence to suggest that trained riders had fewer accidents during their first year of riding, but their sample sizes were so small (and the variability of accidents was so high) for the period that the finding was not statistically significant. In the end, they reported that "...no conclusions may be drawn concerning the effectiveness of motorcycle rider training in reducing accidents.".

Violations. Past studies also give different results regarding the impact of training on recorded motorcycle violations. Although Mortimer (1984) found no differences in the violation rates experienced by trained and untrained riders, both Satten (1980) and Jonah, et al. (1982) found significantly fewer violations among course-takers.

Use of Protective Gear. Satten (1980), Mortimer (1984), and Rothe and Cooper (1987) all found that riders who had taken a motorcycle training course were more likely to use safety gear such as helmets and heavy reflective jackets. These findings coincide with the results of recent surveys of trained and untrained riders in California, which show consistently higher use of safety equipment among trained riders (Billheimer, 1991).

Although only one of the studies to date has concluded that motorcycle training reduces accidents, most have suffered from methodological difficulties which make it impossible to reach any firm conclusions regarding training effectiveness. These methodological difficulties have been discussed at some length in a separate paper (Billheimer, 1990) and are summarised below for the sake of convenience.

4.2.2 Potential Methodological Pitfalls

Lack of Quality Control. The seven different studies listed in Table 4.1 examine, in effect, seven different programs. Training programs differ significantly from state to state and from province to province. Unfortunately for the evaluator, there is also the possibility that a program's presentation may differ from training site to training site within a single state or province. While some states, notably California, have established rigorous quality controls, those controls are the exception. Many US programs rely heavily on volunteer labour and are reluctant or unable to exercise the control needed to guarantee consistent quality in instructors and presentations.

The Self-Selection Problem. One weakness of most evaluations of motorcycle training concerns the biasing impacts of self-selection. Riders who take training courses voluntarily are presumably more safety-conscious than riders who do not take such courses, so that trained riders might be expected to have better accident records than untrained riders. On the other hand, McDavid (1989) points out that self-selection could also bias results in the opposite direction. He claims that most motorcycle accidents go unreported, and to the extent that trained riders are more safety-conscious, therefore, they might also have a greater propensity to report minor accidents to the police, and thus figure *disproportionately* in official accident statistics.

The only way to circumvent the self-selection problem entirely is by randomly pre-assigning riders to training groups, while denying training to other riders. While the approach was used in a New York study (New York, 1987, and Buchanan, 1987) and in previous California studies of motorcycle testing (Anderson, et al. 1980 and Kelsey, et al., 1986), random assignment is not feasible in most cases, particularly where training is legally mandated for some licence-seekers under the age of 21.

Group Comparability. In establishing matched cohorts, it is important that matched pairs of trained and untrained riders have the same age, sex, and riding experience. A few earlier evaluations (e.g. Leung and Reding, 1986) compared the accident records of trained and untrained drivers without controlling for age, sex, riding experience, and exposure. Subsequent studies (Rothe and Cooper, 1987; McKnight, 1987) have shown these factors to be crucial in explaining accident and violation histories.

TABLE 4.1

PREVIOUS COMPARISON STUDIES

EVALUATING THE EFFECTIVENESS OF MOTORCYCLE TRAINING

YEAR	STUDY AUTHOR(S)	LOCALE	COMPARISON YEARS	SAMPLE SIZE	SAMPLE % FEMALE	SAMPLE AVG. AGE	MATCHING CRITERIA	INFORMATION SOURCES	CONCLUSION
1980	Satten	Illinois	--	T: 69	52%	34	Random	Phone Interviews	Higher accident rate in trained group
				U: 71	26%	31			Higher violation rate in untrained group
1982	Jonah, et al.	Ontario	4	T: 811	23.1%	27	Random	Phone Interviews; Driving Records	No difference in accident rate
				U: 1080	42.2%	21			Higher violation rates in untrained group
1984	Mortimer	Illinois	1	T: 213	8.7%	27	Gender	Mail Surveys; Site Interviews	Higher accident rate in trained group
				U: 303	4.5%	27			No difference in violation rate
1987	Leung & Reding	Wisconsin	3	T: 2,914	56.8%	29	Endorsement Date	Driving Records	No difference in accident rate
				U: 43,094	6.6%	25			Higher violation rate in untrained group
1987	McKnight	Pennsylvania	1	T: 2,424	32%	35	Age, Gender, Endorsement Date, Prior Driving Record	Mail Surveys; Driving Records	No difference in accident rate
				U: 2,148	30%	33			
1987	Rothe & Cooper	British Columbia	2	T: 418	21.9%	32	Age, Gender, Initial Insurance Data	Phone Interviews; Driving Records	No difference in accident rate
				U: 402	16.3%	32			Slightly higher violation rate in untrained group
1988	New York State	New York	2	T: 1,792*	14%	26	Random	Driving Records	No difference in accident rate
				U: 2,307*	12%	26	Pre-selection	Mail Surveys	No difference in violation rate
1989	McDavid, et al.	British Columbia	5	T: 139	0	30	Age, Gender, Location, Endorsement Date, Prior Driving Record	Driving Records	Lower accident rate in trained group
				U: 139	0	30			Insignificant difference in violation rates

T = Trained sample
U = Untrained or informally trained sample
*Number includes only licensed riders

Although age and sex are important predictors of motorcycle accident potential, these two factors alone do not provide enough of a basis for classifying matched groups of trained and untrained riders. In addition to age and sex, riding history and accident exposure (i.e. kilometres ridden) must also be considered. Trained and untrained motorcyclists of the same age and sex can differ markedly in riding experience and accident exposure.

Settling for the Easy Match. Even if evaluators recognise the need to match more than the age and sex of trained and untrained riders, there is still a danger that the matching process itself will provide a biased comparison base. When a motor vehicle registry list of licence holders is used as a basis for sampling untrained riders, it is relatively easy to match older, more experienced trainees with untrained riders having similar ages and riding histories. It is much more difficult, however, to match younger trainees with suitable cohorts in the untrained group. There are several reasons for this difficulty:

- Younger riders are more mobile and less easy to locate;
- There are proportionally fewer untrained riders in the younger age categories, in states which mandate training for younger riders; and
- Younger riders are more likely to be unlicensed and untraceable.

Unless care is taken to obtain matches for a representative sample of trained riders, the danger exists that older, more experienced riders will be over represented in the cohort groups. In one matched-pair study, (McKnight, 1987), the average trainee had 4.5 years of riding experience prior to training while the average untrained rider had 7.9 years of riding experience. The average age of trained riders was 35, while that of untrained riders was 33. It stands to reason that training is less likely to be effective on an older rider with over four years of experience than on a younger rider coming to the course with no experience whatsoever. One of the primary challenges in establishing a cohort group of untrained motorcyclists is that of finding suitable matches for the young, totally inexperienced trainee.

It is also important to note that for studies measuring relatively rare events, such as road accidents to an individual, a design which compares experimental and control groups is more reliable than longitudinal (before and after) studies.

Sample Size. In addition to using comparison groups that were not directly comparable, several past studies have involved relatively small numbers of subjects. Sample sizes in the major training studies cited in Table 4.1 appear in Table 4.2.

Table 4.2: Sample Sizes Of Studies Described In Table 4.1.

	SAMPLE SIZE		
Study	**Trained**	**Untrained**	**Years Compared**
Satten	69	79	Unspecified
McDavid, et al.	139	139	5
Mortimer	213	303	1
Rothe and Cooper	418	402	2
Jonah, et al.	811	1,080	4
McKnight	2,424	2,148	1
Leung	2,941	43,094	3

Sample sizes of under 500 which consider only one year of accident data are relatively small for their intended purpose. In reviewing a 1982 study (Jonah, et al., 1982), McKnight (1987) notes that for the sample size of under 1,000 trainees to have shown a statistically significant impact, accidents among the trained group would have to be nearly 50% lower than accidents among the untrained group. McKnight observed, with some understatement, "to anticipate an impact this great is rather optimistic.".

Sample Timing. One important but often overlooked factor in developing an unbiased sample of trained and untrained motorcyclists for the purpose of evaluating a training program, is the timing of the sample. If the sampling process requires a response to a telephone interview or a mail-out survey, and if the survey is conducted after the year in which performance is to be evaluated, any differences which might exist between the trained and untrained population are less likely to be detected by the sampling process. For example, it seems obvious that motorcyclists who have been fatally or seriously injured in accidents are not likely to be responding to surveys.

Concurrent Changes. The act of training a motorcyclist may change more than their basic skills. It may also change their attitudes and riding habits. Recent telephone surveys in California suggest, for instance, that novice motorcyclists ride twice as much after taking the course as they did before they were trained (Billheimer, 1991). While the desire to ride more may have come before taking training, and may in fact have led to the decision to take training (that is, training may have been the effect, not the cause, of the decision to ride more often), the likelihood that riding distance (and hence accident exposure) will increase following training should be factored into any evaluation of training impacts. This also reinforces the need, described above, to carefully match comparison cohorts.

4.3 RELEVANCE TO AUSTRALIA

New South Wales, South Australia, Tasmania and the Australian Capital Territory all have compulsory pre-licence rider training. Victoria, Queensland and the Northern Territory have voluntary pre-licence rider training. Western Australia has no pre-licence rider training.

Using the ACT as an example, approximately 900 individuals per year attend the one accredited training organisation, for two 4.5 hour sessions. Approximately 98% of attendees pass the course. The total cost of the course is $154, of which $60 is paid by the student and $94 is paid by the A.C.T. government.

The findings of the above studies on rider training, where valid, should be applicable to Australian situations. The methodological pitfalls described by Billheimer should provide useful input for the design of similar studies in Australia.

4.4 FUTURE RESEARCH

Although attempts to compare the subsequent records of trained and untrained riders in North American training programs have generally been inconclusive, the programs continue, overall accident rates are dropping, and more sophisticated research techniques are being applied to the evaluation task.

A long-term evaluation plan has been developed to document the effect of a statewide training program for novice riders in California (Billheimer, 1990). This plan focuses on riders in the Los Angeles area and is based on a sample of untrained riders that is carefully matched to the population of riders trained in that area on the basis of (1) age, (2) sex, (3) years riding, (4) miles ridden/year, and (5) their primary reason for riding (commuting, recreation, etc.). Riding records of the trained and untrained riders will be tracked over time to determine whether trained riders have significantly fewer accident or violations than untrained riders.

4.5 COST EFFECTIVENESS

The annual cost of the pre-licence rider training scheme in the A.C.T. is approximately $140,000. The annual cost of motorcycle accidents in A.C.T. is $20 million. If rider training in the A.C.T. can result in at least a 1% reduction in the cost of motorcycle crashes, (cost saving of $200,000), then the program is cost effective.

4.6 RECOMMENDATIONS

Australian authorities should continue to introduce, refine and evaluate pre-licence rider training schemes. This continuing evaluation is necessary to:

- Assess whether or not a positive effect continues to result from the program, providing a basis for their continuing operation
- Identify deficiencies and areas for improvement in the content of training courses.

The monitoring program should be carefully designed for statistical rigour, including adequate sample size, carefully matched controls, considering experience, exposure and the other methodological pitfalls described above.

FORS, in consultation with State authorities, should establish a national accreditation scheme to ensure consistent quality of trainers and course content.

5 MOTORCYCLE DESIGN FEATURES

For the purposes of this discussion, motorcycle design features are divided into two distinct categories:

Crash Prevention Features (e.g., anti-lock brakes, integrated braking, headlights, conspicuity aids, rear-view mirrors); and

Crash Protection Features (i.e., crashbars, leg-protectors, airbags)

5.1 CRASH PREVENTION FEATURES

Crash-prevention features of motorcycle design include the braking system, visibility aids such as rear-view mirrors and design issues (e.g., headlights, running lights, fairing width) associated with conspicuity. Because conspicuity has been separately studied by FORS, this section focuses on braking system design and visibility aids.

5.1.1 Braking systems

In 1986, members of the Transportation Research Board's (TRBs) Committee on Motorcycles and Mopeds reviewed motorcycle design features and identified three areas of potential braking system improvement (Transportation Research Circular, April, 1986):

- Special friction materials;
- Anti-lock brake systems; and
- Integrated braking systems.

Special Friction Materials

In wet weather, the collection of water on brake discs, pads, and linings may affect the performance of brake systems and increase stopping distances. The TRB committee reviewed a number of alternative brake designs using special friction materials and concluded that "...these materials may improve wet weather brake performance, under some conditions, without compromising performance in dry weather.". They noted that the direct and indirect costs involved with these materials could be prohibitive in view of the fact that motorcycles typically operated in dry weather and suggested that their use might be restricted to vehicles subjected to a high frequency of wet weather operation.

Anti-Lock Brake Systems

Past research (e.g., Hurt, 1987) has shown that many motorcyclists involved in accidents failed to use the full braking capability of their motorcycles. Fear of locking up the front wheels and capsizing is believed to be one reason that motorcyclists tend not to use their front brakes, even in emergencies. To encourage effective brake application by a wide range of riders, anti-lock brake systems (ABS) have been studied for some time, and several successful mechanical and electronic prototype systems have been developed. Donne and Cart (1987) reported that a three year field trial of seven motorcycles fitted with an anti-locking braking system was underway in Great Britain. Final results do not appear to be reported at this stage.

The chief obstacle to the widespread adoption of ABS appears to be cost. The TRB committee estimated that equipping both wheels with anti-lock brakes could add several hundred dollars to the cost of a motorcycle, and questioned whether motorcyclists would be willing to pay that amount for a device that is most useful in unusual (i.e. emergency) circumstances. BMW currently offers anti-lock brakes on its motorcycles, and it is anticipated that Japanese manufacturers will offer this feature on some of their European models in 1992.

Integrated Braking Systems

Little new research on integrated braking systems has been reported since the Nairn (1987) study, the research efforts apparently being directed more towards ABS. The following reports therefore remain appropriate.

Sheppard, et al., (1985) reported that incorrect braking is a factor in ten percent of motorcycle accidents in UK. Observations, interviews and driving test results showed a great variation in braking techniques, with most riders deviating from the practice recommended by the licensing authorities.

The TRB Committee noted that "the fact that motorcycle riders do not make effective use of the front brake has led to the study of integrated or single-point braking systems in which the operation of a single brake control results in application of both front and rear systems. An integrated braking system can help assure that the braking contribution of the front brake is utilised more effectively by some riders.".

Since some motorcycles already employ integrated braking systems, the committee went on to suggest research comparing the response and performance of existing and potential integrated systems with that of traditional dual braking systems for a range of operators under various conditions. A limited comparison of this sort was undertaken by Mortimer (1984), who found that foot-operated integrated brakes provided 70% more deceleration than foot-operated rear brakes on dry surfaces and 40% more deceleration on wet surfaces. As reported in the earlier Nairn study (R.J. Nairn and Partners, 1987), Mortimer put the case for integrated braking systems convincingly and succinctly:

"...integrated brakes when used with the front brake allow 'expert' level braking deceleration to be achieved by experienced, knowledgeable, but 'non-expert' motorcyclists. This suggests that the integrated braking system would allow substantially improved braking performance to be rapidly achieved by novice and less experienced riders. High level braking performance appears to be associated with a high degree of preparedness and experience in severe braking. Accident situations do not provide the former and most motorcyclists do not possess the latter. Integrated brakes would help to overcome these deficiencies.".

5.1.2 Visibility Aids

The ability of a rider to clearly see around the motorcycle is influenced by many factors, including size and location of mirrors, rider position, helmet design and physical agility. Motoki and Tsukisaka (1987) examined the extent of arm shadow in the field of view for various seating angles and locations of mirror. They established a method for measuring the angle of the field of view of motorcycle rear view mirrors.

The provision of a good field of view may conflict with the aerodynamic and styling criteria applied to a motorcycle design. However, there is no evidence in the literature to suggest that the field of view rearward is well considered in the design of motorcycle rear view mirrors.

5.2 CRASH PROTECTION FEATURES

Given the choices of putting a protective device on the rider (i.e. a helmet) or on the motorcycle (i.e. airbag), Ouellet (1990) comes out strongly in favour of the former, reasoning 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.". Nonetheless, certain types of protective devices have been known to be effective in certain types of crashes.

5.2.1 Air Bags

M.R. Finnis (1990) of the British Road Research Laboratory tested air bag restraint systems on three motorcycles in impacts with a stationary car and concluded that "...although these tests have not been fully successful in demonstrating the effectiveness and practicality of an airbag restraint system, they have provided encouraging evidence that air bags can greatly reduce injury in frontal impact and have provided a pointer for ways in which the performance of such systems could be greatly improved.".

In reviewing earlier motorcycle air bag research, Ouellet (1990) concluded that "...an air bag mounted in front of the rider works well in limited situations (e.g. perpendicular impacts into a stationary car) but fails when faced with the complexity of impact with a moving car and the consequent motorcycle motion.". He was also generally critical of crash studies in which an upright motorcycle is propelled against a stationary car, noting that the "...majority of motorcycle-car accidents involve both vehicles moving. Also, about half of a group of 129 accidents was found to have occurred with the motorcycle either yawing or leaning or down sliding at the time of impact.".

5.2.2 Crashbar Protection

The terms leg protector and crashbar tend to be used interchangeably in the literature. In this review the term is applied to any bar or device which is designed to prevent intrusion into the space normally occupied by a rider's leg.

In order to determine the relative effectiveness of the leg protection space afforded by contemporary crashbars, Ouellet (1987) undertook a detailed investigation of 131 accidents involving crashbar equipped motorcycles. He found 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" and that "conventional expectations of crashbar performance and leg injury mechanisms simply are not supported by the in-depth analysis of actual accident events.".

On the basis of those findings, he estimated in a subsequent study (Ouellet, 1990) that "leg protection devices mounted on the motorcycle are likely to affect at most about half of the serious leg injuries and may have the ability to affect favourably only those that result from direct crushing of the leg against the side of the motorcycle during impact.".

In spite of his scepticism, this does, nevertheless, suggest that the severity of leg injuries would be reduced in approximately 50% of accidents involving serious leg injury.

Gosnell (1990) investigated the attitudes of existing UK motorcyclists to leg protectors and reports that approximately 50% of the 600 motorcyclists responding to a structured survey questionnaire would not use leg protectors.

Like airbags then, crashbars are not totally ineffective, but their effectiveness is limited to a restricted range of accidents and circumstances.

5.2.3 Cleaner Design

Ouellet (1990) notes that suggestions for cleaner design made by the earliest investigations of motorcycle crashworthiness have been largely ignored by recent designers. While investigating the dynamics of motorcycle impacts in the early 1970s, Bothwell (1971, 1975) recommended that a sound strategy for improving motorcycle collision performance would be to smooth out the rider's ejection path, remove obstacles or make them less injurious, and remove lacerating surfaces. Unfortunately, Ouellet notes that this advice has been largely ignored by 1980s designers, who have placed sharply humped fuel tanks directly in front of the rider's crotch and pubic bone.

5.3 RELEVANCE TO AUSTRALIA

The research on improvements to motorcycle braking systems has direct relevance to Australia and should encourage FORS to press for ADR changes. It can be assumed that the vehicle mix and crash mechanism in Australia are similar to those in North America and the UK, so the research on the usefulness of crash bars and air bags reported above is considered to be relevant to Australian conditions.

5.4 FUTURE RESEARCH AREAS

5.3.1 Crash Prevention Features

The TRB Committee on Motorcycles and Mopeds (TRB Circular N302) has recommended comparing the response and performance of various existing and potential integrated braking systems with that of dual braking systems for a range of operators under various conditions. The further addition of anti-lock brakes should be tested for both braking systems, and researchers should explore the cost that operators are willing to pay for these innovative braking features.

5.3.2 Crash Protection Features

Ouellet (1990) suggests that future crash test research be linked more directly to accident investigation findings to provide more realistic representation of the behaviour of motorcycles in actual crashes. Thus, if motorcycles are yawing or sliding in half of all recorded accidents, a similar proportion of crash tests should be carried out with motorcycles yawing or sliding. In this way, conclusions drawn from crash tests will be valid for actual accident situations.

5.5 COST EFFECTIVENESS

There have been various estimates of the cost of fitting anti-lock and integrated braking systems to new production motorcycles. The most recent estimate, which is available to FORS, of the cost of fitting anti-lock and integrated braking systems to new production motorcycles is $1,200.

There are approximately 32,000 motorcycles sold annually in Australia. Therefore the total annual cost of introducing anti-lock and integrated braking systems on new motorcycles is approximately $38 million. The total annual cost of motorcycle accidents in Australia is $800 million. Therefore, on an annual basis, the introduction of the advanced braking system would be cost effective if it reduces the cost of motorcycle accidents by 5%.

5.6 RECOMMENDATIONS

It is recommended that FORS:

- Closely evaluate anti-lock and integrated braking systems because they appear to be a cost-effective means of improving motorcycle handling.
- Investigate the number of accidents involving serious leg injury, to determine the number of injuries which would be reduced in severity or avoided if leg protection was provided. This will give a guide to the value of pursuing further research into crash bars and other forms of leg protection.
- Investigate the number and type of injuries which may be attributable to protrusions into the ejection path. This could form the basis for a review of motorcycle design rules.

6 ROAD ENVIRONMENT

6.1 GUARDRAIL

The road environment itself is often overlooked as a motorcycle hazard. Of the 4,430 motorcycle fatalities in the United States in 1984, 157 (3.5%) involved guardrails. Accident analyses undertaken in France and Germany (Quincy, et al., 1988 and Domhan, 1987) suggest that rider collisions with guardrails account for a disproportionate number of fatalities on urban freeways.

Experimental designs using a lower W-beam to protect fallen motorcyclists from impact with guardrail posts have been tested in both France and Germany (see Figure 6.1). As an alternative to the lower W-beam, German researchers designed an impact attenuator made of neopolene that envelopes a guardrail post to cushion the force of any impact. Dummy tests with both the lower W-beam and an impact attenuator around the post have proven the effectiveness of both these protection measures. Domhan (1987) reports that the cost per metre of installing the attenuators was less than half of that for a continuous W-beam. Even so, he calculated that costs would outweigh benefits if attenuators were installed on all guardrails in the Federal Republic. If, however, installation was limited to roughly the ten percent of the guardrails shown by past accident history to have the higher probability of motorcycle accidents, a positive benefit-cost ratio would result.*

Since the autumn of 1984, protective devices have been installed on about 80 km of guardrail in several federal states of Germany (Domhan, 1987). Systematic accident studies are being performed to ascertain the effectiveness of these devices and to identify promising locations for additional installations.

6.2 ROAD SURFACE

Mount (1987) has made a plea for greater attention in traffic engineering and street maintenance to details which have a serious effect on motorcycles.

Items highlighted as of concern to motorcyclists include:

- Roadmarkings - paint and thermoplastic markings are very slippery when wet and present a danger to motorcycles that is much greater than for cars.
- Raised pavement markers present an obstacle to motorcycles during turning manoeuvres, and so should be used with caution within intersections.
- Man-hole covers and steel plates used to cover roadworks are also extremely slippery. The application of an abrasive coating renders them satisfactory.
- Brick paving stones such as glazed tiles and basalt blocks also have low coefficients of friction and shouldn't be used for traffic at roadway speeds.

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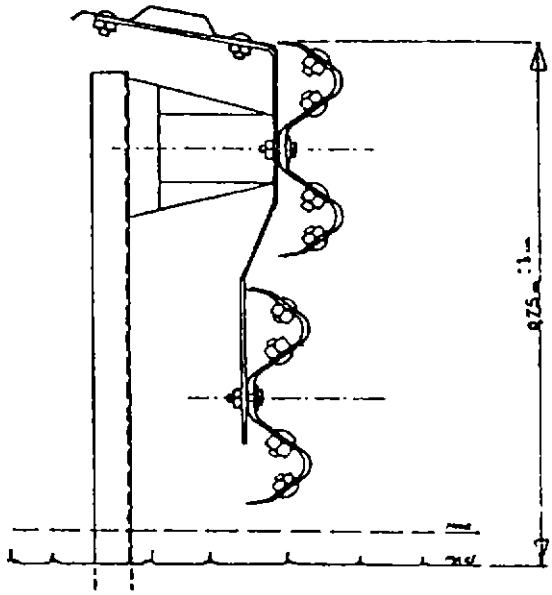
* The details of this cost-benefit calculation are not given, so it is not known how Domhan assessed the effectiveness of the guardrail attenuators in preventing fatalities. Clearly, the installation of attenuators on all guardrails will not eliminate all guardrail-related fatalities.

Figure 6.1
GUARDRAIL WITH MOTORCYCLE PROTECTION



Source: Quincy, et al., 1988.

- Speed bumps of poor design can be dangerous to motorcycles and are generally inefficient. Good design principles have been established by ARRB and TRRL.
- Loose gravel commonly gets on to the paved road surface when there are unsealed shoulders. This is a particular danger to motorcyclists at corners. It could be overcome on such roads at intersections on roads which have unsealed shoulders by sealing to a curved section of kerb and gutter.

Many of these features are being used even more frequently now than when Mount made these comments, as they are commonly included in local area traffic management schemes (LATMs) and in traffic calming schemes.

The incompatibility of motorcycles and some common traffic devices is not a peculiarly Australian problem. Similar shortcomings of roadmarkings and crash barrier posts were noted in Luxembourg by Koch (1989).

6.3 RELEVANCE TO AUSTRALIA

Australia has a well developed road safety practice and has many thousands of kilometres of guardrail. However, it is not known to what extent guardrail design has an impact on motorcycle injuries or fatalities in Australia.

Mount's comments noted above about traffic engineering practices refer specifically to the Australian situation.

6.4 FUTURE RESEARCH

It may be useful to analyse accident statistics to quantify the number of injuries and fatalities involving guardrails, to determine whether the guardrail design contributes to the severity of injuries. It would also be useful to compare the relative numbers of motorcycle and car accidents involving guardrails with their relative exposure. If the motorcycle crash rate is disproportionately high, this could point to other road features which may contribute to higher risk for motorcycles at these locations.

6.5 COST EFFECTIVENESS

The research described above into the incidence of the involvement of guardrail in motorcycle crashes would need to be completed before an assessment can be made of the cost effectiveness of possible guardrail modifications.

Many of the items mentioned with respect to traffic engineering and maintenance represent good, cost efficient practice and should be encouraged.

6.6 RECOMMENDATIONS

The concern expressed by motorcyclists about the impact of standard traffic engineering practices on the stability and safety of motorcycles should be addressed through education and publicity directed towards local councils and state road authorities. An appropriate program would include reference to: road marking location and material; location of raised pavement markers; location and surface type of steel covers; decorative paving; speed bump design; and routine maintenance.

7 PUBLIC EDUCATION AND AWARENESS

Several states and provinces in North America have undertaken extensive public awareness programs designed to market motorcycle training, increase driver awareness of motorcyclists, or promote motorcycle safety in general. Those evaluators (e.g., Billheimer, 1991) who have attempted to evaluate the effectiveness of these campaigns have been able to document increases in public awareness, but typically have been unable to demonstrate a link with lower accident rates.

7.1 PROGRAMS

A wide range of public education and awareness campaigns have grown up around broader motorcycle safety programs in various US states and Canadian provinces. These programs have been aimed at a variety of target audiences, from the novice motorcyclist to the general driving public.

Simpson and Mayhew (1990) point out that licensing authorities in most jurisdictions produce a motorcycle rider manual, and federal, state, and private agencies have produced brochures and pamphlets to encourage novice motorcyclists to become safe riders. Most states with motorcycle training programs advertise the need for training through a variety of media channels. More general public information and awareness campaigns have focused on making other road users more aware of the motorcyclists.

Many of the more successful materials produced from one jurisdiction have been picked up and used by other jurisdictions. In the mid-80s, the State of Minnesota produced a series of high-visibility TV spots warning of the dangers of motorcycling and the need to watch out for motorcyclists. These spots were adopted by other states, including California.

California, in turn, has produced a 22-minute video outlining the scope of its statewide training program which includes "breaks" for commercials advertising the need for training and motorist awareness. California has also produced a series of billboards and bumperstrips promulgating the theme "My brother (sister, father, etc.) rides, please drive carefully" (see Figure 7.1), designed both to increase driver awareness and to recast the image of the motorcyclist from an anonymous black-helmeted threat to somebody's loved one.

FIGURE 7.1

SAMPLE BUMPERSTRIP ENCOURAGING MOTORIST AWARENESS

7.2 EVALUATIONS

The evaluation of public education and awareness campaigns must necessarily address two sequential questions:

- Are these campaigns reaching their intended audience?; and
- How successful are these campaigns in effecting the desired behavioural changes?

A few evaluators have attempted to answer the first question, but there appears to be no recorded research documenting the impact of a publicity campaign on motorcycle accident rates or riding behaviour. For example, Billheimer (1991) found through a series of telephone surveys that rider awareness of the California Motorcycle Training Program increased dramatically (from 36% to 79%) over the first years of the Program's existence, largely in response to a "Tame the Iron Horse" advertising campaign. The same series of telephone surveys also found that 50% of the riders interviewed had been exposed to billboards or bumperstrips carrying the admonition "My Son (Brother, etc.) Rides, Please Drive Carefully.". However, no attempt was made to relate this awareness to motorist awareness or motorcycle-car accident rates.

7.3 RELEVANCE TO AUSTRALIA

The research reported here is directly relevant to Australian conditions. The public education and awareness programs used in Australia appear to be similar to those reported in the research literature from the US. However, there do not appear to have been reported Australian evaluations of the extent to which the programs achieve their ultimate goal of reducing motorcycle accidents, nor the extent to which motorists' awareness of motorcycles has increased.

7.4 FUTURE RESEARCH

Simpson and Mayhew (1990) suggest that the development, implementation and evaluation of motorcycle safety awareness campaigns could benefit from past successes in the field of health promotion. They note that "...the infusion of the health promotion perspective has broadened the traditional focus of traffic safety to include both the importance of lifestyle issues in determining the risk of collision and, subsequently, the utility of non-traditional methods, such as community-based approaches, for accident prevention. For example, a health promotion perspective would emphasise that skill (how well a person can drive) may be no more important than life-style factors (how a person chooses to drive) in determining accident involvement.". They go on to note that this perspective has already had a profound impact on one specific area of traffic safety - impaired driving.

7.5 COST EFFECTIVENESS

In the absence of documentation of the effectiveness of such programs, it is difficult to assess the cost effectiveness of possible future programs. Rather, additional research is recommended below to improve the understanding of this subject.

7.6 RECOMMENDATIONS

The literature does not report a great deal of new research related to public education and awareness programs. It is recommended that FORS consider a research project to identify the extent to which:

- Past programs have reached their target audiences;
- The attitudes and behaviour of the target audiences have been modified; and
- Accident rates have changed as a result of the programs.

This research could then be used to guide the development of future public awareness and education programs.

8 HELMET DESIGN

The effect of helmet usage on motorcycle fatality rates is well understood and has been documented by many authors, as reported in the Nairn (1987) study. The introduction of compulsory wearing of motorcycle helmets in Australia in the 1960s resulted in a substantial decline in serious head injuries in motorcyclists. The experience of many US states has been that the rate of serious head injuries declined when compulsory helmet laws were introduced and subsequently rose after those laws were repealed.

8.1 RECENT RESEARCH FINDINGS

In the US, many states have either not enacted or repealed laws requiring compulsory wearing of crash helmets while riding a motorcycle. As a result, there continues to be an extensive body of research into the overall effectiveness of helmets in reducing the level of serious head injuries in motorcycle crashes. For example, Bachulls, et al., (1988), in reporting a four year study at Emanuel Hospital, Portland, Oregon of 367 injured motorcyclists, found that for non-helmeted riders the incidence of severe brain damage was 600% higher and the incidence of all brain damage was 200% higher than for the helmeted rider, while there was no difference in the incidence of other injuries.

This research continues to support the case for compulsory helmet usage. Other research activities which have been reported are principally aimed at further understanding the mechanisms of helmet behaviour and performance in crashes and the effects of helmets on rider vision.

8.1.1 Crash Performance

Corner, et al. (1987) studied the sufficiency and effectiveness of the shell and liner properties of helmets. They concluded that the Australian Standard (AS1698) should be amended to reduce helmet liner stiffness, increase the shell stiffness, improve the sliding qualities of helmets, specify full face helmets only and modify the tests to include the vulnerable facial and side areas of the head. They noted that although helmets were preventing significant fatal head injuries, there continued to be cases of diffuse brain injury and brain stem damage.

A study of 200 injury and fatal motorcycle crashes by the N.S.W. Traffic Authority concluded, amongst other things, that 35% of all impacts were outside the test area specified in AS1698 and that minor oblique impacts were capable of producing injuries ranging from minor unconsciousness to severe brain injuries. The recommendations include:

- Increase the area of protection specified in AS1698,
- Develop specifications for a test to measure the ability of a helmet to minimise the effect of tangential impacts; and
- Develop specifications for a test to evaluate means of reducing the effect of frontal impacts by improving the energy absorption ability of the front of helmets.

Tzeng and Lee (1989) investigated the role of thickness and density in determining the liner's energy absorbing capability. Schaper and Grandel (1985) concluded from impact tests that many helmets available in the US had too low efficiency of energy absorbing material.

Gilchrist, et al. (1988) concluded that the current range of sizes of helmets available in the UK was insufficient to adequately match the range of head shapes and sizes. Mills and Ward (1985) had earlier shown that the position of the chin strap pivots and the fit of the helmet at the rear are important to prevent helmet rotation and loss. Mills and Gilchrist (1991) more recently quantified the performance of helmet shock absorption under various types of impacts and noted that very few impacts in practice are of a type contained in the British Standards test procedure.

Huybers (1988) reported that the "coming off" rates of helmets reported in the literature varied from 7% to 36%, and attributed this to a combination of incorrect fastening and poor fit.

Cooter, et al. (1988) have suggested that the rotation of a full-face helmet following impact on the chin guard may cause fatal damage to the brain stem. They suggested the need to reassess the structural properties of the face bar to provide greater energy absorbing properties or fail at a critical loading which would prevent excessive rotation. This may involve a compromise between facial protection and energy absorption. Krantz (1985) found a similar injury mechanism in a small number (five out of 132) of fatalities to helmeted motorcyclists.

8.1.2 Rider Vision

All helmets restrict to some extent the superior and peripheral vision of the rider. Hayward and Marsh (1988) found that a full face helmet caused a 38% reduction in vertical field of vision, which was increased to 60% with the attachment of a sun visor and ventilation mask attachments. They also found that full face helmets tend to have a better field of view in the horizontal plane than do jet-type helmets, and that there is a severe restriction of horizontal vision of 21% with the use of goggles.

They postulate that a severe restriction on vertical field of view causes the rider to lose sight of activities, which would otherwise be seen in peripheral vision when observing the mirrors and instruments.

There also continues to be interest in the problem of misting and deterioration of visors and goggles. Because of their construction, visors are relatively sensitive to surface damage. Timmerman (1985) reported on the effect of imperfect visors on clarity of vision, but no recent reference has been found to his results. Visors are also subject to fogging more easily than goggles and ventilation devices are not entirely satisfactory. Hayward and Marsh (1988) reported that many "high mileage" cyclists accept the field of vision limitation of goggles in order to get better abrasion resistance.

Visors and other attachments to helmets are not covered by the UK standard.

8.2 RELEVANCE TO AUSTRALIA

The research into the design and efficiency of helmets is of direct relevance to Australia. The Australian studies (e.g., Cooter, 1990; Corner, et al., 1987) all questioned the suitability of AS1698 to adequately test for common types of impacts.

8.3 FUTURE RESEARCH

It is understood that the Australian Standard is currently under review. This should be encouraged by FORS to include additional tests which address:

- Impacts from angles not currently considered;
- Energy absorption with a humanoid headform;
- A skidding test; and
- Modified field of vision requirements.

8.4 COST EFFECTIVENESS

The development of a modified standard for motorcycle helmets may increase the cost of helmets to the consumer. However, this need not necessarily be the case, because the standards are currently under review in a number of countries, particularly in EEC countries in preparation for 1992. It would therefore be timely to revise the standard now so that the manufacturers will be able to accommodate any uniquely Australian features with changes that will be made for the European market.

The cost of developing an appropriate, revised standard for motorcycle helmets is likely to be in the order of $100,000.

The average cost of a serious head injury has been estimated by FORS at $56,000. If a new motorcycle helmet standard results in two less serious head injuries (cost saving of up to $112,000), then the development of this standard would be cost effective.

8.5 RECOMMENDATIONS

It is recommended that FORS:

- Encourage, in association with the State authorities, the development of a new, more comprehensive Australian Standard for motorcycle helmets. The additional requirements should include impact angles not currently covered, energy absorption with a humanoid form, skidding resistance and modified field of vision requirements.
- Prepare and implement an education program about correct fit and fastening, targeted at riders and helmet retailers.

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