Motorcycle safety: a scoping study

Prepared for Road Safety Division, Department for Transport

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Executive Summary

The Department of the Environment, Transport and the Regions (DETR) (now Department for Transport (DfT)) commissioned TRL Limited to undertake a scoping study of motorcycle safety. The objectives were to review the relevant literature and research, to identify existing gaps in knowledge and to make recommendations for further research. The report was originally issued as a TRL Unpublished Project Report in November 1999. It is now being published to make the work available to a wider readership. However, no attempt has been made to update it to take account of research and statistics published during the intervening period.

The study reviewed national accident figures, which showed that motorcyclists are a particularly vulnerable group of road users. In 1997, the fatality rate for motorcyclists was 12 per 100 million vehicle km, the rate for car drivers being 0.3. Up until 1993, both motorcyclist casualties and mileage had been falling, but from 1993 until 1997 they were stable or, in the case of fatalities, had begun rise. A long term trend towards the use of machines of over 500cc engine capacity meant that by 1996 they accounted for over two thirds of the stock and nearly two thirds of fatalities. Growing proportions of casualties are to older riders, and involve bikes over 500cc on non-built up roads. Peaks in summer and weekend casualties involving such machines are consistent with a significant amount of discretionary, recreational riding. Newly licenced riders in 1997 accounted for only a small proportion of accidents though some of the older riders of bigger-engined motorcycles should perhaps be regarded as novices in terms of recent experience – especially experience on high performance machines. Overtaking and speeding are important factors associated with motorcycle accidents.

Motorcycles and motorcycling have a number of characteristics that are at least potential contributors to the high accident liability of motorcyclists. Motorcycles tend to have much higher power-to-weight ratios than cars, and increasing numbers of motorcycles are capable of very high speeds and accelerations. Being a ‘single track’ vehicle, a motorcycle can easily become unstable and capsize if braking, accelerating or a slippery road surface cause a wheel to lose adhesion. This is particularly critical if the machine is leaning to take a bend. Braking can also cause a motorcycle to change its line on a bend. Such characteristics make motorcyclists particularly vulnerable if they take bends too fast to be able to stop in the distance they can see to be clear, and to sudden changes in road surface. The need to avoid wheel-locking also means that riders may find it difficult to make best use of the brakes in other emergency situations. Longitudinal ridging or grooving of the road surface, and raised road markings, can produce steering instability.

In addition to problems of instability, motorcycles and their riders are vulnerable in other ways (e.g. lack of crash protection, vulnerable to not being seen by car drivers, vulnerable in impacts with crash barriers that have been designed for other types of vehicle). Possible countermeasures to deal with these problems include protective clothing, secondary safety systems, and use of headlamps or other measures to improve conspicuity. There are clear indications that such measures are effective or could be made so. The conspicuity problem appears to be partly associated with car drivers learning visual strategies that are not very effective at detecting motorcycles, and there is potential to address this by training – although it is not clear how effective this would be in the long term given that the basic problem may be the relative rarity of motorcycles.

One of the inherent advantages of motorcycles as a method of transport is that their narrowness and acceleration give them the ability to overtake, and to filter past other traffic, in situations where cars cannot. Also, some riders seek to satisfy sensation-seeking motives, which may lead to behaviours such as high acceleration, fast cornering and overtaking. There is a wide spectrum of motorcycle type and performance, and several categories of motorcycle use that may be associated with different types of accident and levels of risk. This, together with interactions with variables like rider age, sex, motivation, and level of exposure, implies that the ‘motorcycle safety problem’ is probably much more heterogeneous than the car safety problem, and that subsets of the problem may have to be addressed separately. One example here is that of despatch riders, who appear to have far higher accident liabilities than other motorcyclists even when mileage and other factors are taken into account.

Some of these problems can be approached by engineering the motorcycle to improve its stability under braking (e.g. antilock braking systems) or to provide protection to the rider if the machine does crash. Improving road surfaces, and using signs to warn riders of poor surfaces, also have an important part to play. Giving riders the skills, rules and knowledge necessary to identify and avoid critical situations and maximise control of the motorcycle is the challenge for training-based interventions.

Because of the stability and handling characteristics mentioned earlier, the control skills needed for motorcycling are inherently more demanding than those needed for car driving, especially in emergencies. Motorcyclists receive relatively little formal training, and opportunities for supervised on-road riding are limited. Rider training (at least for the mass of the population) must avoid placing the rider at risk, which restricts its ability to give experience of critical situations. Because of the wide spectrum of performance, riders trained on learner motorcycles then graduate to much more powerful and demanding machines without further training – and riders returning to motorcycling after a break may hold a full licence but may have had no formal training at all, and no experience of high performance machines.

The challenge for training is likely to be made more difficult by the facts that sensation-seeking motives are important for some riders, and that training concentrating on control skills may lead to more accidents if riders become over-confident. Training riders to be aware of their own limitations is desirable, and attention also needs to be given to skills associated with hazard perception, and to ways of identifying and communicating a ‘rule-base’ for safe riding.

On-road behaviour seems to be strongly associated with attitudes and motivations. Skill training should perhaps be seen as a measure that enables a rider to perform in a particular way, but which then needs to be supported by other measures to persuade the rider to behave safely. This suggests that ways need to be found of influencing attitudes and motives and, possibly, of alerting riders to the negative influence these can have on safety. There are indications that law and rule-breaking behaviours, which are associated with high accident liability, may be largely habitual and need tackling early in a riding career.

Recommendations for research based on the findings of the scoping study are made in the report.

1 Motorcycle safety: overview and summary of recommendations for research

1.1 Introduction

The Department of the Environment, Transport and the Regions (DETR) (now Department for Transport (DfT)) commissioned TRL Limited to undertake a scoping study of motorcycle safety. The objectives were: to review the relevant literature and research, to identify existing gaps in knowledge and to make recommendations for further research.

This report presents the results of the study. Section 1 gives an overview of trends in motorcycle accidents, and a brief commentary on some of the safety-relevant characteristics of motorcycling. It then brings together the recommendations for research made elsewhere in the report. Section 2 presents background information on motorcycling trends, and casualty and injury patterns. Subsequent sections review research on specific areas of motorcycle safety: Sections 3 and 4 review vehicle and environmental factors and Section 5 reviews psychological factors together with training and education. Section 6 outlines current motorcycle licensing legislation.

The report was originally issued as a TRL Unpublished Project Report in November 1999. It is now being published to make the work available to a wider readership. However, no attempt has been made to update it to take account of research and statistics published during the intervening period.

1.2 Motorcycling and motorcycle accidents: some numbers and trends

1.2.1 The motorcycle stock in Great Britain

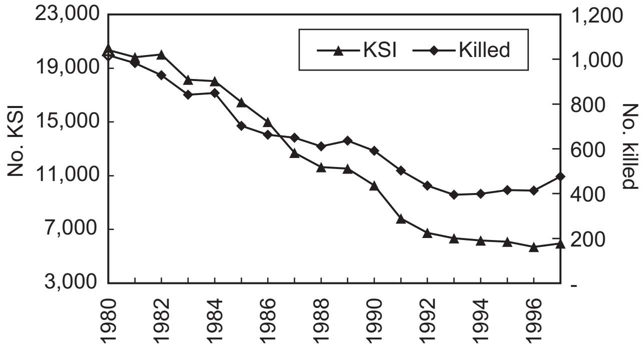
- After declining from nearly 1.5 million in 1982 to about 0.6 million in 1995, the total UK motorcycle stock started to rise in 1996.
- Numbers of newly registered motorcycles doubled between 1993 and 1997.
- The stock of motorcycles with an engine capacity over 500cc has been rising since 1987 at least, whereas the stock of smaller machines has been declining. In 1997, machines over 500cc accounted for about 72% of the total.

1.2.2 Exposure

- Total mileage travelled by motorcycles halved between 1982 and 1993, and has been steady since then.
- Mileage on non built-up roads has been increasing since 1994.
- Annual mileage increases with engine size.

1.2.3 Motorcycle accidents

- Trends in the total numbers of motorcycle casualties reported to the police are shown in Figure 5 of the report, and are also shown as follows:



- The age-distribution of motorcyclist casualties has changed dramatically over the period 1980 to 1997. In 1980, over 50% of casualties were under 20 years old, and less than 20% were aged over 30. In 1997, the situation had reversed, with less than 20% of casualties aged under 20, and over 50% aged over 30. These trends reflect large reductions in the numbers of casualties to young motorcyclists: casualties to middle-aged riders have remained fairly stable, but the number of fatalities has increased.
- Novice riders (in the sense of riders who have only recently gained a licence) now account for only a relatively small proportion of casualties. More mature riders of larger motorcycles are dominating the casualty statistics. However, it may be that a significant proportion of these riders should themselves be regarded as novices. People returning to motorcycling after a break may have little recent experience of riding, and may have no previous experience of riding a powerful machine.
- Growing proportions of casualties involve motorcycles with engines over 500cc, and occur on non built-up roads. In 1996, nearly two thirds of motorcycle fatalities were on bikes over 500cc, and such bikes comprised about two thirds of the stock.
- Sales of motor scooters are increasing, a trend that, if continued, may have significant effects on the numbers and pattern of 'powered two wheeler' accidents.
- Speeding and overtaking are important factors in motorcycle accidents. Nevertheless, a substantial proportion of serious injuries and fatalities occur at modest impact speeds, where there is an opportunity of providing crash protection.
- About 60% of GB motorcycle casualties involve collision with a car, and about 20% are 'single vehicle' accidents. Equivalent figures for fatalities are 40% and 25%.

In summary, national accident figures show that motorcyclists are a particularly vulnerable group of road users. In 1997, the fatality rate for motorcyclists was 12 per 100 million vehicle km compared with only 0.3 for car drivers. Up until 1993, both motorcyclist casualties and mileage had been falling, but from this time they have been stable or, in the case of fatalities, have begun to rise. A long term, steady trend towards the use of machines of over 500cc engine capacity has meant that by 1996 they accounted for over two thirds of the stock and nearly two thirds of fatalities. Growing proportions of casualties are to older riders, and involve bikes over 500cc on non-built up roads. Peaks in summer and weekend casualties involving such machines are consistent with a significant amount of discretionary, recreational riding. Newly licenced riders now account for only a small proportion of accidents though some of the older riders of bigger engined motorcycles should perhaps be regarded as novices in terms of recent experience – especially experience on high performance machines. Overtaking and speeding are important factors associated with motorcycle accidents.

To improve motorcycle safety, it appears that traditional types of rider-centred countermeasure aimed at learners and novices need to be supplemented by measures aimed at more mature riders of bigger-engined machines, including those returning to motorcycling after a break. A broad-based programme of other types of countermeasure also needs to be considered. Various types of countermeasure, and the research needed to develop and support them, are discussed in the following sections.

1.3 Characteristics of motorcycling

Motorcycles and motorcycling have a number of characteristics that make them qualitatively different from cars and car driving, and that are at least potential contributors to the high accident liability of motorcyclists.

1.3.1 Motorcycle stability, performance and handling

- Motorcycles tend to have much higher power-to-weight ratios than cars, and increasing numbers of motorcycles are capable of very high speeds and accelerations.
- Being a ‘single track’ vehicle, a motorcycle can easily become unstable and capsize if braking, accelerating or a slippery road surface cause a wheel to lose adhesion. This is particularly critical if the machine is leaning to take a bend. Braking can also cause a motorcycle to change its line on a bend.
- Such characteristics make motorcyclists particularly vulnerable if they take bends too fast to be able to stop in the distance they can see to be clear, and to sudden changes in road surface. The need to avoid wheel-locking also means that riders may find it difficult to make best use of the brakes in other emergency situations.
- Longitudinal ridging or grooving of the road surface, and raised road markings, can produce steering instability.

Some of these problems can be approached by engineering the motorcycle to improve its stability under braking (e.g. antilock braking systems) or to provide protection to the rider if the machine does crash. Improving road surfaces, and using signs to warn riders of poor surfaces, also have an important part to play. Giving riders the skills, rules and knowledge necessary to identify and avoid critical situations and maximise control of the motorcycle is the challenge for training-based interventions. This challenge is likely to be made more difficult by the facts that sensation-seeking motives are important for some riders, and that training concentrating on control skills may lead to more accidents if riders become overconfident.

1.3.2 Vulnerability of motorcycle and rider

In addition to problems of instability, motorcycles and their riders are vulnerable in other ways – for example:

- Lack of crash protection.
- Vulnerable to not being seen by car drivers.
- Vulnerable in impacts with crash barriers that have been designed for other types of vehicle.

Possible countermeasures here include protective clothing, secondary safety systems, use of headlamps and other measures to improve conspicuity, and changing the design of crash barriers. There are clear indications that such measures are effective or could be made so. The conspicuity problem appears to be partly associated with car drivers learning visual strategies that are not very effective at detecting motorcycles, and there is potential to address this by training – although it is not clear how effective this would be in the long term given that the basic problem may be the relative rarity of motorcycles.

1.3.3 Special capabilities and uses of motorcycles, and their associated riding behaviours

One of the inherent advantages of motorcycles as a method of transport is that their narrowness and acceleration give them the ability to overtake, and to filter past other traffic, in situations where cars cannot. Also, some riders seek to satisfy sensation-seeking motives which may lead to behaviours such as high acceleration, fast cornering and overtaking. There is a wide spectrum of motorcycle type and performance, and several categories of motorcycle use that may be associated with different types of accident and levels of risk. This, together with interactions with variables like rider age, sex, motivation, and level of exposure, implies that the ‘motorcycle safety problem’ is probably much more heterogeneous than the car safety problem, and that subsets of the problem may have to be addressed separately. One example here is that of despatch riders, who appear to have far higher accident liabilities than other motorcyclists even when mileage and other factors are taken into account.

1.3.4 Rider skills and training

Because of the stability and handling characteristics mentioned earlier, motorcycles’ control skills are inherently more demanding than those needed for car driving, especially in emergencies. Motorcyclists receive relatively little formal training, and there is little opportunity for supervised on-road riding. Rider training (at least for the mass of the population) must avoid placing the rider at risk, which restricts its ability to give experience of critical situations. Because of the wide spectrum of performance, riders trained on learner motorcycles then graduate to much more powerful and demanding machines without further training – and riders returning to motorcycling after a break may hold a full licence but may have had no training at all, and no experience of high performance machines.

To an extent, these problems were what lay behind the 1997 changes to the licensing system, and there is a need to assess how the changes have affected the training and experience of motorcyclists as they progress to more powerful machines. There is also a need to consider how training might be further improved, and to look for opportunities to evaluate the effects of training on accidents.

It appears that training concentrating on control skills can increase accidents, and that training people to be aware of their own limitations is desirable. Attention also needs to be given to skills associated with hazard perception, and to ways of identifying and communicating a ‘rule-base’ for safe riding. Ways of addressing the motivational and attitudinal aspects of motorcycle riding are also needed (see Section 1.3.5).

1.3.5 Rider attitudes and motivations

It is widely accepted that high levels of driving or riding skill are not sufficient to ensure safety. On-road behaviour seems to be strongly associated with attitudes and motivations. Skill training should perhaps be seen as a measure that enables a rider to perform in a particular way, but which then needs to be supported by other measures to persuade the rider to behave safely. This suggests that ways need to be found of influencing attitudes and motives and, possibly, of alerting riders to the damaging effects these can have on safety. There are indications that law and rule-breaking behaviours, which are associated with high accident liability, may be largely habitual and need tackling early in a rider’s career. Training and education are the obvious interventions here, but a challenge is to find ways of dealing with the fact that, for some motorcyclists, the thrill of controlling a motorcycle in demanding circumstances and the taking of risks appear to be important reasons for riding.

1.4 Summary of recommendations for research

Recommendations for research are made after each of the main sections of the report, and are brought together here. It was outside the scope of this study to undertake any form of cost-effectiveness analysis of these recommendations. Generally speaking, if a research item is judged to be useful from the point of view of motorcycle safety, it is included in the list. In deciding which of these recommendations to adopt, the likely costs and effectiveness of research and safety countermeasures will need to be taken into account, as will interactions with other aspects of transport policy.

Multivariate analysis of existing data on factors affecting the accident risk of motorcyclists

Although various studies of this subject have been made in the past, this is an area where recent changes in motorcycle usage and their effects on casualty trends need to be explored, in order to indicate the likely scope for possible countermeasures to reduce the number of motorcyclist casualties in the future.

Assessment of risk levels for motorcyclists is complicated by interactions between age, sex, experience, road type, motorcycle characteristics, exposure and other (probably less influential) factors. Such interactions also exist for other casualty groups, but the interaction between size of machine and type of road used is particularly strong in the case of motorcyclists: larger machines are ridden more often on high-speed rural roads than smaller machines. A satisfactory, unbiased assessment of the risks of motorcycling thus requires a rather sophisticated statistical methodology, using STATS19 accident data linked to DVLA on machine-type, NTS data on motorcycle use, motorcycle registration data, and national mileage estimates from the Traffic Census. Such a study should be particularly useful in informing the debate about the relation between motorcycle size and accident risk. It is strongly recommended that a study of this kind is done in close collaboration with the survey of self reported accidents described as follows.

Survey(s) of self reported accidents, attitudes and other variables

There is a need for a survey-based study or studies to investigate the following issues:

- The characteristics of motorcycle use in Britain at the time of the survey, in terms of machine size, rider experience and training, driving experience, age, sex, exposure, trip purpose and other variables, and how these have changed since 1988.
- The effects of the above variables and interactions between them on accident liability.
- The effects of the 1997 licensing changes on riders’ experience levels as they graduate to larger machines, and on accident liability.
- The effects of upgrading to larger machines on quantity and quality of exposure.
- The characteristics of returning riders and other riders of over 500cc motorcycles in terms of age, experience, training, attitudes, perceived risk, and motives.
- Self reported frequencies of potential ‘problem behaviours’ and the association between such behaviours, self-reported accidents and attitudes.
- Attitudes towards protective clothing, and safety features such as improved brakes, leg protectors, airbags and daytime use of headlamps.
- Links between perceived risk levels and variables such as experience, training, having accidents, and knowing people who have been injured.
- Incidence of particular types of accident (e.g. associated with diesel spills).
- Characteristics of people seeking advanced training.
- Links between attitudes, motivations, behaviour and accidents.

In principle a single, multipurpose survey could be undertaken, though this would probably run into difficulties with questionnaire length. An alternative would be to split the research as follows:

a A self-reported accident survey, similar to that undertaken by Taylor and Lockwood (1990). Questions would also cover the training and experience of returning riders and some attitudinal and behavioural information.

b A study of attitudes, motivations and behaviours – probably using a follow-up questionnaire sent to a sub-sample of the above survey respondents.

c A survey of samples of people who took their motorcycle tests before and after the licensing changes introduced in 1997. This would include questions about experience, training, and graduation to more powerful machines. Ideally, the sample size would be sufficient to detect effects of the changes on accident liability to be determined.

It is strongly recommended that the survey at (a) above is done in close collaboration with the analysis of existing data on motorcycle accident risk proposed above.

On-the-spot study of motorcycle accidents

On the spot studies or road accidents are currently being planned by DETR, and maximum use should be made of these to collect information, including exposure information, relevant to the questions identified in this report.

In-depth analysis of behavioural antecedents of motorcycling accidents

Motorcycles have particular capabilities and vulnerabilities that need to be incorporated in a rider's 'rule base' and 'knowledge base'. For learner and novice riders, this may be particularly difficult because of the relative lack of supervision during learner riding and the large variation in motorcycle performance and riding styles. In addition, there is the possibility that sensation-seeking motives, which appear to play an important part in motorcycling, may attract some riders to extreme departures from 'learner-style' riding early in their riding careers. For experienced car drivers returning to or taking up motorcycling, the differences between the rules/knowledge base appropriate for car driving and that needed for motorcycles (to do, for example, with poor conspicuity, and problems of stability and control while braking and cornering) may mean that such riders, too, would benefit from interventions designed to help them acquire the rules and knowledge they need to ride safely.

One way of identifying critical 'rules' that could help riders avoid accidents is via an analysis of motorcycle accident records to study the sequences of events that precede accidents. A technique for doing this has been developed at Nottingham University and applied with some promise to car accidents.

Motorcycle despatch riders

Unpublished TRL research based on a self-reported accident survey, has shown that once the effects of annual mileage, age, riding experience and training have been controlled for, despatch riders appear to have between about 3 and 6.5 times as many accidents as other motorcyclists, and between about 3 and 10 times as many injury accidents. It is recommended that follow up research should gather information from despatch riders about a range of factors not explored in the postal questionnaire, including:

- Riding style, risk taking behaviour and attitudes to risk taking.
- Perceived pressures of the job.
- Fatigue.
- Bike maintenance.
- Various aspects of exposure to risk.
- Accident (under) reporting.

The follow up research should start with qualitative interviews and groups-discussions, to attempt to develop quantitative survey instruments suitable for this difficult study.

Development and evaluation of rider training and education

There remains a need for well-designed evaluations of the effects of training on skills, knowledge, rider behaviour and accident liability.

Work is also needed to improve the content of training courses – for example by emphasising skill limitations, coverage of higher order cognitive skills, providing information on risk levels, and communicating a rules and knowledge base for safe riding. The possibilities for improving the ability of training to address attitudinal and motivational aspects should be considered here.

Research will be needed to help develop and evaluate the improvements to CBT, and other changes mentioned in the DETR response to the recent consultation exercise (DSA, 1999). The training of riders returning to motorcycling after a break may need to be addressed if they are shown to be particularly at risk and, or, to be relative novices with respect to training and experience.

In addition, other approaches to training – including the use of simulators – should be examined, particularly as ways of addressing motivational aspects of riding and the difficulties in providing on-road supervision and feedback during motorcycle training.

Turning these general recommendations into a programme of research on training will require further thought, and discussion with DETR. However, a detailed study of the content and practice of motorcycle training in Britain and abroad would be an extremely useful start. Information relevant to the improvement of training will be provided by many of the other research studies proposed here, including the self-reported accident studies.

Car drivers: skills, knowledge and attitudes

There are strong indications that part of the reason for car drivers 'looking but not seeing' motorcyclists is to do with expectancy. It appears that drivers do not expect to see motorcyclists, and may not incorporate them into the search strategies and perceptual short-cuts (e.g. perceptual templates) that they develop with experience. One potential countermeasure is improved driver training, emphasising the need for careful visual search for the unexpected. However, it is not certain that this would have a persisting benefit. If the basic problem is that motorcycles are unexpected because they are relatively uncommon, experience of this fact may dilute or negate any effect of training. Nevertheless, training on search and scanning techniques, and making drivers aware of expectancy phenomena, might have a persisting benefit.

Under high workload conditions, attention tends to focus not just on high probability cues, but also on cues perceived to be important. There are indications in the literature that car drivers tend not to give a lot of importance to the possibility of colliding with a motorcyclist. This suggests that emphasising the vulnerability of motorcyclists and their control difficulties may also be a useful component of driver training interventions.

Designing and evaluating such training interventions – starting perhaps with an evaluation of the recent DSA video – would be well worth doing.

Control skills and hazard perception

It has been shown that experienced drivers' hazard perception skills are vulnerable to increases in mental workload from other tasks. Given that the control skills for high performance motorcycles may well remain cognitively demanding for a considerable time, especially when riders are exploring the limits of their capabilities, it seems possible that hazard perception performance will be impaired.

Research is needed to explore whether this potential problem is likely to be an important characteristic of motorcycle accidents. Possible countermeasures might include improving the training of control skills, improving the knowledge and rules base to help riders avoid situations in which they are likely to become loaded with control difficulties, using licensing restrictions to control the transition between low and high performance machines, and improving the training of hazard perception skills.

Even if hazard perception is not shown to be affected, information on control problems will be useful in its own right.

Fatigue

In view of indications that there may be quite severe effects of fatigue even on short journeys, more research is needed to assess the size of the problem and the need for countermeasures (such as publicising the problem and encouraging frequent breaks).

The licensing system

Effects of the 1997 changes to the licensing system should be assessed as described under the recommendation 'Surveys of self-reported accidents, attitudes and other variables' described above.

Research is needed to estimate the size of the problem of unlicensed riding, and to develop countermeasures if needed.

As suggested under the recommendation 'Development and evaluation of rider training and education', research will be needed to help develop and evaluate the new changes to CBT and other aspects of the licensing system described in the government response to the recent consultation exercise.

Motorcycle and rider conspicuity

Further research on motorcycle conspicuity should be undertaken, to find whether modern technology allows night-time conspicuity to be improved. Coloured headlamps for motorcycles, and the consequences of fitting cars, but not motorcycles, with dim-dip headlamps, should be assessed as part of this work. The possibility of improving on the benefits of using headlamps in daytime should also be considered. Rider attitudes towards conspicuity devices should be included in the attitude study described earlier and in Section 5.8 with a view to finding ways of improving rider acceptance.

Interventions to improve car drivers visual search skills are dealt with under the recommendation 'Car drivers knowledge and attitudes' earlier in this section.

Airbags

In view of the very encouraging results from TRL and Japanese studies, development of motorcycle airbag systems should continue. One way of encouraging this would be through the development of impact test procedures for motorcycles – see item below. Rider attitudes towards airbag systems should be included in the attitude survey proposed as part of the recommendation for a survey of self-reported accidents, attitudes and other variables mentioned earlier in this section.

Leg protection

In view of the encouraging results from research by TRL and other organisations, motorcycle leg protection systems should be further developed. Again, development and adoption of a motorcycle impact test procedure would encourage this. Rider attitudes towards and beliefs about leg protection systems should be included in the attitude survey proposed earlier in this section.

Accident study results showing that current fairings are effective at reducing leg injuries should be further evaluated, and further research carried out if necessary, with a view to identifying the critical design parameters, encouraging 'best practice' in fairing design, and publicising the advantages of faired motorcycles.

Impact testing

A motorcycle impact test procedure, and an assessment programme similar to the NCAP programme should be developed and adopted. Impact test criteria would be based on loads applied to a dummy rider, leaving the method of satisfying these criteria to the manufacturer. Criteria could be based on those already shown to be achievable – e.g. by leg protectors and airbags. The BMW C1 motorcycle would be expected to demonstrate that it is possible to achieve reasonably good NMAP ratings.

Helmets

Work should continue on the development of helmet standards, to improve energy absorbing capacity, minimise induced rotational motion, and improve the evaluation of the complete helmet including chin-guard.

Protective clothing

Improved design and wider use of protective clothing could make a significant contribution to reducing the severity of motorcycle casualties. Further work should be undertaken to develop and test protective clothing, and finding ways of improving voluntary use.

Braking systems

More research is needed on the effectiveness of antilock braking systems and other systems such as combined brakes, as a way of reducing motorcycle accidents. The DETR on-the-spot study could, if suitably supported, collect useful data here, since it aims to collect exposure data as well as information about the accident.

Traffic lights

There have been suggestions that the time between green and red phases is sometimes too short to allow motorcycles to stop safety in wet weather without risking wheel lock. This may force motorcyclists either to put themselves in situations where they may have to jump a red light, or to slow down in anticipation of a lights change, resulting in conflicts with cars that do not need to slow. In other words, traffic light phasing may require motorcyclists to accelerate and brake out of phase with other traffic, increasing the potential for accidents. Further research is needed into the severity of this problem.

Road surfaces

If further information is required on the importance of diesel spills is required before remedial action can be justified, then research should be undertaken to collect this information. The self-reported accident study described earlier in this section and at Section 5.8 should be useful here, as should the on-the-spot accident study.

Likewise, further information on the importance of low-friction and raised road markings as a contributor to motorcycle accidents is probably needed, and the above studies could again provide useful information.

Crash barriers

Research is needed on the effects of wire rope fences and conventional crash barriers on motorcycle safety. Concrete crash barriers may need to be investigated too, if they are to be used more in this country.

Bus lanes

As stated in Section 4.6 the current trial use of bus lanes by motorcycles should be continued/expanded until adequate data are obtained to evaluate its effectiveness.

2 Motorcycle accidents

2.1 Numbers and trends

Information on accidents involving motorcycles is available from the STATS19 accident reporting system. The police complete a STATS19 report form for all road accidents known to them that involve at least one road vehicle and result in personal injury. This form includes information about the accident, vehicle(s) involved and casualties. Since 1989, in addition to the standard information, the police have recorded the vehicle registration mark (VRM). This has allowed the STATS19 records to be linked with information from the Driving Vehicle Licence Agency (DVLA) which includes vehicle make and model codes and engine capacity.

As would be expected, not all vehicles involved in injury accidents are successfully linked to DVLA records. Reasons for this include VRMs not recorded or wrongly recorded and vehicles that are unlicensed in order to evade Vehicle Excise Duty. The police first recorded VRMs in 1989 and for that year around 45% of all two-wheeled motor vehicles (TWMV) were not successfully matched. However, this proportion was significantly lower at around 15% from 1990 onwards. Information on engine size before 1989 is available from a special project set up to monitor the effects of the 1981 Transport Act. This involved police recording the engine capacity of motorcycles involved in accidents as part of the STATS19 form. The project ran from 1982 until 1986 with the number of co-operating police forces peaking in 1984.

To fully interpret the casualty statistics, details are needed on the numbers and ages of active motorcyclists, the characteristics of the motorcycle (e.g. engine capacity) and the average annual mileage of motorcyclists on rural and urban roads.

The numbers of active motorcyclists could be estimated in principle from DVLA information on the number of motorcyclist licences. The age and sex of the rider is also given. However, Broughton (1987) found that this significantly overestimated the number of active motorcyclists since large proportions of those with licences do not ride regularly. Another measure therefore is the number of licensed motorcycles known from vehicle licensing records. A benefit of this information is that the engine capacity of the motorcycle is known but the disbenefit is that no owner information (age, sex and mileage ridden) is available. Although a better source, this information is not perfect as some owners fail to licence their vehicles to avoid paying Vehicle Excise Duty and some owners may own more than one bike.

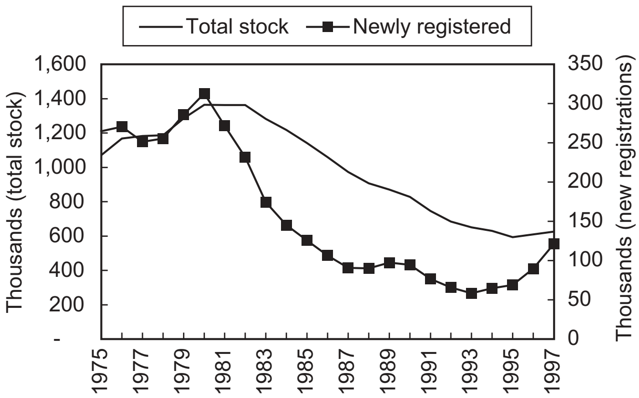
National motorcycle mileage estimates are available from roadside traffic counts (the Traffic Census) by Built-Up (BU) and Non Built-Up (NBU) roads (where the speed limit is ≤ 40 mph and >40 mph respectively). The drawback with this source is that the number of miles ridden is not known for the different engine capacities and age/sex of the rider.

An alternative source of information is the National Travel Survey which collects data on the travel habits of around 3,200 households (around 8,000 individuals) per year. Individuals complete a seven day (consecutive days) diary recording details of travel such as the purpose of the journey, the method, the distance travelled and the time of day as well as personal information (e.g. age, sex, working status). This information is invaluable in providing a picture of motorcycle use giving age-related mileage estimates and engine capacity. Its major drawback is the small sample of respondents who ride motorcycles (in line with the small number of active motorcyclists). To get the necessary level of detail, several years of data has to be aggregated and this will tend to mask changes over time.

In conclusion, the STATS19 (injury) accident data is relatively comprehensive and when linked with the vehicle licensing records provides a great deal of information about each accident. In comparison, the availability of motorcyclist exposure data is less satisfactory, with problems associated with several of the sources. Exposure data are needed to analyse the accident risks associated with different age groups of people as these risks are linked to the type of bike ridden, the experience of the rider, the number of miles ridden per year and whether the road is rural or urban.

2.1.1 The motorcycle stock

Since the introduction of the new two-part motorcycle test in 1982 and the prevention of riders learning on the more powerful motorcycles (over 125cc), the total stock of motorcycles fell by more than 50%. Figure 1 shows how this trend is altering, with the number of motorcycles newly registered doubling between 1993 and 1997. The effects of this increase are beginning to appear in the total stock series.

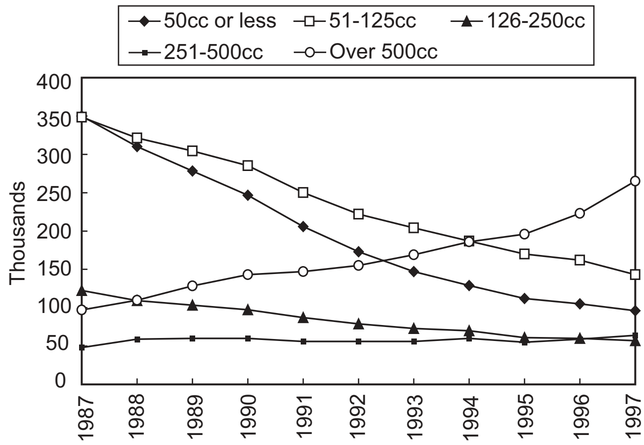


Source: Transport Statistics GB, 1998

* *New methods of estimating vehicle stock were introduced in 1992, prior years have been adjusted to reflect these changes*

Figure 1 Number of motorcycles newly registered and currently licensed*

Figure 2 shows that this growth is due to a rapid increase in the number of motorcycles with an engine capacity larger than 500cc while the number of motorcycles with an engine smaller than 250cc continues to fall. Between 1982 and 1997, all learner riders were prevented from riding bikes over 125cc. The licence changes introduced in January 1997 allow learner riders aged 21 or more to ride the larger bikes provided that an approved instructor accompanies them. This therefore suggests that the increase in motorcycle ownership is amongst those that are already qualified to ride or those that are aged 21 or more rather than being an increase in the number of unaccompanied learners on the road.

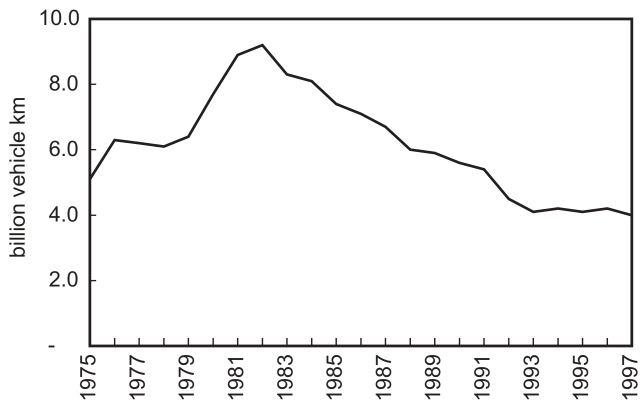


Source: Transport Statistics GB, 1998

* *New methods of estimating vehicle stock were introduced in 1992, prior years have been adjusted to reflect these changes*

Figure 2 Number of motorcycles currently licensed, by engine capacity*

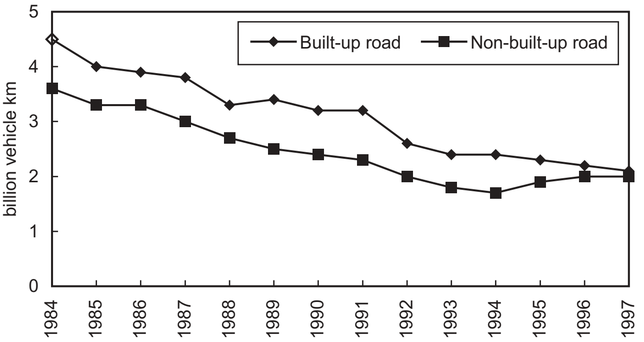
The change in distance travelled by motorcycles (estimated from traffic counts) between 1975 and 1997 is shown in Figure 3. The distance covered by motorcyclists halved between 1982 and 1993 but since then has remained relatively stable at around 4 billion vehicle-km per year. As mentioned in Section 2.1 this information is not available by engine size but Broughton (1988) showed, using journey data collected from the National Travel Survey in 1985/86, that annual motorcycle mileage increases markedly with engine capacity.



Source: Transport Statistics GB, 1998

Figure 3 Distance travelled by motorcyclists

Figure 4 shows the change in motorcycle mileage for built-up (BU) and non built-up (NBU) roads between 1984 and 1997 (estimated from roadside traffic counts on roads where the speed limit is ≤ 40 mph for BU roads and > 40 mph for NBU roads). Since 1994, the distance travelled on NBU roads has increased while the distance ridden on BU roads has continued to fall. The rise in the number of bikes registered with an engine capacity over 500cc combined with a rise in the distance travelled on NBU roads might suggest that these bikes were being used for more 'out of town' journeys. Similarly, the fall in the number of bikes with smaller engines corresponds with a fall in the number of km travelled on BU roads, suggesting a fall in the use of smaller bikes for 'in-town' journeys.

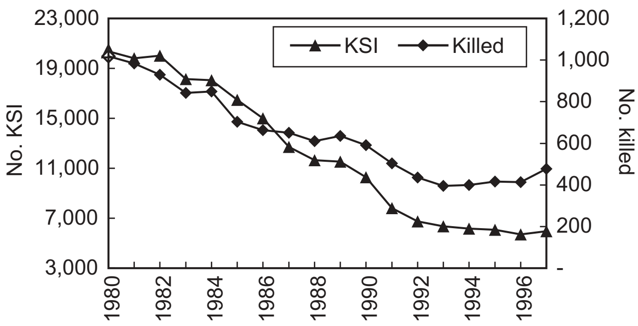


Source: Transport Statistics GB, 1998

Figure 4 Distance travelled by motorcyclists by road type

2.1.2 Key trends in motorcycle casualties

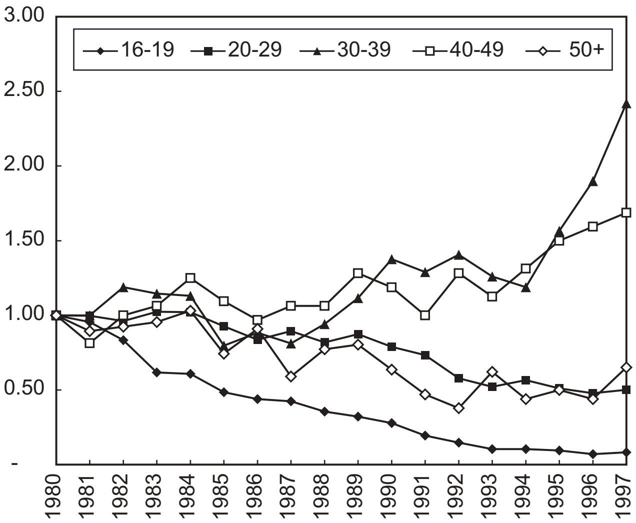
From 1980 to 1992 the number of motorcyclists killed and seriously injured fell fairly rapidly (Figure 5). Since then, the number of casualties has begun to increase again. Between 1996 and 1997, deaths and serious casualties increased by 15 and 4% respectively. As discussed in Section 2.1.1, the rise in casualties has been accompanied by a rise in the stock of motorcycles and an increase in the proportion of total motorcycle mileage on NBU roads in recent years.



Source: STATS19

Figure 5 Number of motorcyclist killed and killed and seriously injured (KSI)

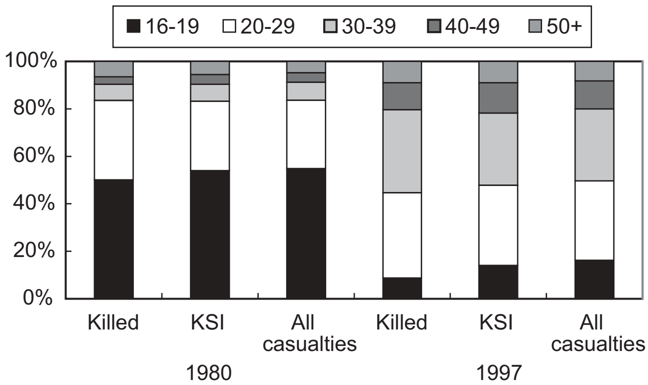
In recent years, the age distribution of casualties has also changed. Figure 6 shows the number of fatalities occurring each year relative to the number killed in 1980. The number of young rider fatalities (aged <20 years) fell by just over 90% between 1980 and 1997[1] and the number of middle-aged rider fatalities aged 30-39[2] and 40-49[3] increased by almost 2.5 times and 1.7 times respectively during the same period.



Source: STATS19

Figure 6 Motorcyclists killed, by age group
(1.00 = number of casualties in 1980)

Figure 7 shows the proportion of motorcyclist casualties in each age group for 1980 and 1997. The change in the age distribution is dramatic: in 1980 over 50% of the motorcyclist casualties were aged less than 20, but in 1997 over 50% of the casualties were over 30 years old.



Source: STATS19

Figure 7 Age of motorcyclists injured, 1980 and 1997

In 1996, almost two-thirds of all fatalities involved a bike with an engine capacity greater than 500cc. This represents a large shift: only a quarter of all fatalities involved this group of large bikes in 1984. Figure 8 shows the numbers of fatalities involving the different size machines and shows how the larger machines have come to dominate the fatal casualty statistics. In 1996 there were almost 4 times as many fatalities involving a machine with engine capacity greater than 500cc as for any other group.

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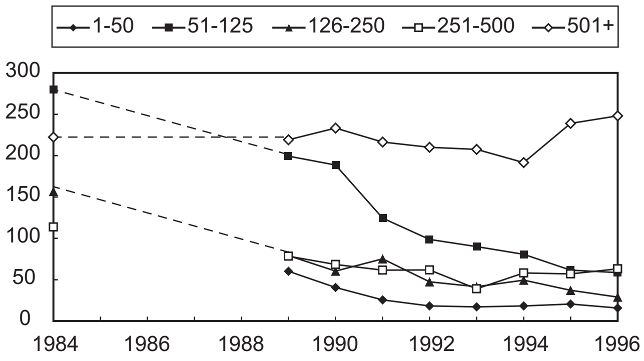
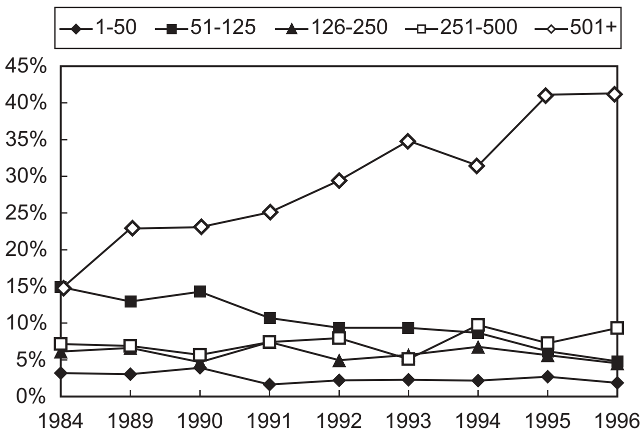
[1] *Falling from 510 to 42 fatalities.*
[2] *Increasing from 69 to 167 fatalities.*
[3] *Increasing from 32 to 54 fatalities.*



Source: STATS19 linked to DVLA records

Figure 8 Number of motorcyclists killed, by engine size of bike

Growing proportions of motorcyclist casualties are occurring on NBU roads. In 1984, under a half of fatalities were on non-built-up roads compared with almost two-thirds in 1996. This increase relates especially to the large motorcycles (greater than 500cc) as shown in Figure 9 (where 100% = fatalities on all roads). In fact an analysis of the data shows that almost two-thirds of the riders killed on the NBU roads were aged over 30 and were riding bikes with an engine capacity greater than 500cc.



Source: STATS19 linked to DVLA records

Figure 9 The proportion of total fatalities on non-built-up roads, by engine size

Casualties amongst riders of the larger bikes are very seasonal, especially on NBU roads, with a prominent peak in the summer months of June-September, presumably reflecting the higher use during these months. This demonstrates that the high numbers of casualties amongst riders of larger bikes do not arise because these machines are ridden at the time of the year when there are adverse weather conditions. In contrast, casualties amongst riders of the smaller bikes with an engine size less than 125cc do not peak in the summer. A fairly constant number of casualties occur on BU roads from January to September, and rises during the winter months.

This suggests that the smaller bikes are being ridden all year on BU roads, so are affected by the adverse weather conditions during the winter. However, the suggestion is that the use of the larger machines is far more discretionary, with riders tending to go out when weather conditions are favourable.

In 1996, the number of casualties per day in each size range of bike on built-up roads was greatest during the working week (peaking on a Friday) and was lowest at the weekend especially on a Sunday. In contrast, on the non-built-up roads, different patterns emerged for the different sizes of motorcycle. Casualties per day involving the smaller bikes with an engine size less than 125cc were highest during the week while the numbers injured while riding a bike with an engine size greater than 500cc peaked on a Sunday. If the casualty statistics are reflecting the exposure data, the suggestion must be that the recreational riders are riding larger bikes with an engine size greater than 500cc while smaller bikes with an engine size of less than 125cc are being used mainly during the working week.

2.2 Statistical studies of motorcycle accident risk

There have been a large number of studies of motorcycle accident statistics over the years, in this country and abroad. The relation between accident risk and 'size' of motorcycle has been one of the more contentious issues to be addressed by such studies. Any thorough statistical study of the factors that influence motorcycle accident risk necessarily includes size as well factors such as rider age and experience. A review of studies that have examined the relation between accident risk and size of motorcycle was published in 1997 by the TNO Road-Vehicles Research Institute in the Netherlands (TNO, 1997) 'Literature survey of motorcycle accidents with respect to the influence of engine size'. This includes all the relevant statistical studies; consequently, Section 2.2.1 examines the appropriate aspects of the TNO report, including its findings concerning the relation between size of motorcycle and accident risk. Section 2.1 brought out the contemporary significance of this relation: to what extent has the trend towards larger motorcycles (e.g. those with engine capacity exceeding 500cc) in Great Britain contributed to the recent trend of motorcycle accidents, and in particular has it contributed to the increase in fatalities?

One of the reports included in the TNO review came from a programme of research into motorcycle accidents that was conducted by TRL (Taylor and Lockwood, 1990). This is described in more detail in Section 2.2.2.

2.2.1 The TNO report

DG III of the European Commission (the Directorate General responsible for Industry) commissioned the TNO report in connection with the type approval of two- or three-wheeled vehicles: the specific question asked was whether there exists 'a relation between motorcycle accident occurrence and motorcycle engine power exceeding 74 kW'. TNO answered this by studying all reports that examined the possibility of a relation between accident risk and size of motorcycle (i.e. irrespective of whether the reports used engine power *per se* as an independent variable).

The report divided the studies under consideration into two groups:

- *direct* studies of motorcycle accidents in which data from motorcycle accidents (collected either by the police or by surveys of motorcyclists) are analysed;
- *indirect* studies of motorcycle accidents in which less direct measures of motorcycle accident risk (e.g. monthly casualty totals) are related to the introduction of new measures.

The former group is much more numerous, and directly relevant to this project. The TNO report recognises that motorcycle accident risk is influenced by several factors that can be quantified, principally a rider's age, sex and experience, the type of road and the size of machine. There is a risk that the conclusions of any particular study will mislead if the interaction of these factors is not taken into account.

The TNO report identifies the principal studies of motorcycle accident risk and provides a generally well-structured and balanced review of them, while acknowledging that many less important studies had not been reviewed in detail. Its conclusions about the general merits of the principal studies can be accepted, but there are grounds for concern relating to the report's main focus: the influence of motorcycle size on accident risk. The concerns will be discussed here because of their policy significance as well as their implications for any future study.

It should be noted that motorcycle 'size' can be quantified in various ways, but the concept relates essentially to a motorcycle's performance. Thus, the key measures include engine capacity, power, power-to-weight ratio and *laden* power-to-weight ratio. Of these four, engine capacity is the most generally available for accident-involved motorcycles; however, *laden* power-to-weight ratio (based on an average loading) is directly related to maximum acceleration and so is probably the most relevant.

Broadly, two alternative concepts of accident risk exist in the reports considered, each of which may be influenced by factors such as the rider's age and experience and the size of the machine:

a the risk of a rider being injured or killed in an accident in a specific period, e.g. one year;

b the risk of a rider being injured or killed in an accident when travelling a specific distance, e.g. one mile.

Many studies examined by TNO show that type (a) risk increases with motorcycle size, while the evidence is more equivocal in the case of type (b) risk: it appears that for this, motorcycle engine size is only influential in the case of fatal accidents (larger motorcycles have increased risk per mile ridden).

The TNO report concludes that 'there is no scientific evidence that engine size is a major factor in motorcycle accidents; engine size does not emerge as a risk factor' (Abstract, page 2) – despite reporting that various studies have found that accident risk increases with size among *fatal* accidents (page 13). The report's conclusion is based on the finding from various studies (including several which found that fatal accident risk per mile increases with size) that the type (b) risk (accidents per mile) does not increase and may tend to fall with size when non-fatal accidents are included. The high involvement of larger machines in *fatal* accidents – arguably the most significant group of accidents – is claimed to result only from their high mileage, despite the evidence presented earlier in the report that fatal accidents per mile does increase with motorcycle size.

The conclusion that engine size is not a risk factor if the higher accident involvement of bigger-engined motorcycles can be explained by their higher mileage, does not necessarily follow. Its logic depends on whether the higher mileage can be regarded as being 'caused' by bigger engines, and on the underlying aims of road safety policy. Various sources show that motorcycle mileage is greater for larger machines, reflecting the greater potential of larger machines for travelling long distances. For example, Broughton (1988) found that motorcycles of over 500 cc capacity travelled on average four times farther per year than those of up to 50 cc capacity. If a rider replaces a small machine with a larger machine, one motivation for the extra expense is likely to be the desire to travel farther, so it seems reasonable to expect that a rider's mileage will tend to rise when he or she 'upgrades'. The fact that average mileage rises with capacity does not, of course, prove that all upgrading riders automatically increase their mileage. Mileage data for a sample of riders, including many who begin to ride a larger machine, would be needed to establish the precise influence of motorcycle size on the mileage of individual riders.

For riders whose mileage does increase, the risk per year would increase even if their risk per mile was unchanged. From the national perspective of concern with the total number of road casualties, the former measure of risk is more relevant than the latter. So, even if the extra casualties associated with larger machines were entirely explained by their higher mileage, overall motorcycle safety in terms of casualties per year would be worsened by the availability of large motorcycles, and might be expected to be improved by measures that reduce the use of larger machines, such as differential taxation and graduated licensing of motorcyclists. It could be argued that accidents per year is also the most pertinent risk index from the rider's personal perspective. However, it could also be argued that the motorcycling is of benefit to the rider so long as its benefits per mile are judged (by the rider) to outweigh the accident risk per mile. Here, accidents per mile becomes the important index. In summary, the TNO conclusions about engine size might be questioned since: (a) they appear to underplay the findings of fatalities per mile increasing with engine size; (b) the higher mileages covered by bigger-engined motorcycles are themselves relevant to national road safety policy. More information on what happens to mileages when riders upgrade to bigger motorcycles is needed. The well established finding that accidents per mile for car drivers and motorcyclists decreases as mileage increases, and Taylor and Lockwood's 1990 finding that under-reporting of accidents decreases as engine size increases, also needs to be borne in mind when considering the effect of engine size on accidents.

There is one issue that the TNO report does not address: is it reasonable to expect that *final* answers to questions about the factors that influence motorcycle accident risk actually exist? As shown in Section 2.1.2, motorcycling is a highly dynamic component of the British road transport system, with major changes over recent years in the characteristics of the vehicle fleet, the user population and the types of journey made. If motorcycle accident risk is principally determined by the laws of physics then final answers should exist – although they may be difficult to identify. If, however, the main influences are behavioural then the relation could well change as motorcyclists' motivation and behaviour evolve.

2.2.2 Other research on the factors affecting accident liability

In 1990, TRL published a research report that investigated the factors affecting the accident liabilities of motorcyclists (Taylor and Lockwood, 1990). Generalised linear modelling techniques were applied to data from a self-reported postal questionnaire to determine the relationship between motorcyclists' accident liability and the basic characteristics of the riders and their riding (such as age, sex, riding experience, engine capacity, distance travelled, and road type). It should be noted that by definition this study excludes fatalities and so the model concerned was biased towards the less serious accidents. In addition, damage only accidents were included which are excluded from the STATS19 casualty statistics described in Section 2.1. Taylor and Lockwood found that predicted accident frequency decreased rapidly with increasing age and riding experience and increased with increasing mileage ridden, riding predominantly in built-up areas and riding in the winter. In addition, for those riding predominantly in non built-up areas, riders of bikes with an engine size larger than 500cc had a lower predicted accident frequency than other riders. As discussed in Section 2.2.1, the relation between accident liability and engine capacity has been the subject of much analysis and debate. Given the changes in motorcycling that have occurred since Taylor and Lockwood collected their data in 1988 it would be valuable to conduct another self reported accident study. This would be similar to Taylor and Lockwood's, but focused on issues that are of particular interest today.

In addition to the TNO report, a detailed literature review concerning motorcycle engine size and safety was reported in Canada (Mayhew and Simpson, 1989). This study concluded that the relationship between motorcycle engine size/power and collision involvement remains elusive, largely as a result of difficulties in obtaining adequate measures of exposure. Nevertheless, the weight of evidence did not support the contention that size/power is a risk factor for accident involvement.

Motorcycle despatch riders

One of the inherent advantages of motorcycles as a method of transport is that their narrowness and acceleration give them the ability to overtake, and to filter past other traffic, in situations where cars cannot. Also, some riders seek to satisfy sensation-seeking motives which may lead to behaviours such as high acceleration, fast cornering and overtaking. There is a wide spectrum of motorcycle type and performance, and several categories of motorcycle use that may be associated with different types of accident and levels of risk. This, together with interactions with variables like rider age, sex, motivation, and level of exposure, implies that the 'motorcycle safety problem' is probably much more heterogeneous than the car safety problem, and that subsets of the problem may have to be addressed separately. One example here is that of despatch riders. An unpublished TRL research study focused on the accident liability of a particular subgroup, that of despatch riders. Again based on a self-reported accident survey, this research showed that once the effects of annual mileage, age, riding experience and training have been controlled for, despatch riders appear to have between about 3 and 6.5 times as many accidents as other motorcyclists, and between about 3 and 10 times as many injury accidents. A recommendation for follow-up work to gather information from despatch riders about a range of factors not explored in the postal questionnaire is included in Section 2.4.

2.3 Accident causes and mechanisms and injury patterns

2.3.1 Introduction

In order to make any mode of transport safer it is first necessary to gain a proper understanding of the ways in which accidents happen and the causes of injury. Then it may be possible to take action to reduce the likelihood of accidents occurring and to minimise the severity of the injuries sustained.

In examining the available statistics it was evident that the UK has not investigated motorcycle accidents in-detail since the early eighties. Thus, in order to provide a review of more recent trends it has been necessary to include studies from other European countries. Nevertheless, this section begins with an examination of evidence from Road Accidents Great Britain, 1997 (DETR, 1998) so that these general statistics may be compared with the more detailed studies.

2.3.2 National (GB) trends

Table 1 provides the overall pattern of casualties during 1997 for two wheeled motor vehicles. Injuries are categorised into slight, serious and fatal and by object struck. The figures are taken from Road Accidents Great Britain 1997, and the injuries are classified such that, slight is treated in hospital but not detained, serious is detained in hospital for one or more nights, and fatal is defined as death occurred within 30 days of the accident. The most frequent cause of an injury accident was a collision with a car, 63%, followed by accidents in which there was no impact with another vehicle, 19%. Other causes of note were hitting more than one vehicle, 7%, and hitting a light goods vehicle, 4%; hitting a pedestrian, a heavy goods vehicle or a bus was a relatively rare occurrence and all accounted for less than 2% of TWMV casualties. The overall trend and the trends for slight and serious injury were very similar but interestingly the

Table 1 Number of TWMVs (Two-Wheel Motor Vehicle) casualties (n) arising from accidents in Great Britain (1997)

TWMV collision partner	*Total*		*Slight*		*Serious*		*Fatal*	
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Alone	4,523	18.5	3,079	17.1	1,319	22.2	125	24.6
Pedestrian	388	1.6	340	1.9	45	0.8	3	0.6
Bicycle	181	0.7	151	0.8	30	0.5	0	0.0
TWMV	405	1.7	299	1.7	103	1.7	3	0.6
Car	15,317	62.7	11,712	65.2	3,406	57.4	199	39.1
LGV [1]	995	4.1	739	4.1	235	4.0	21	4.1
HGV [2]	442	1.8	290	1.6	121	2.0	31	6.1
Bus/Coach	194	0.8	132	0.7	47	0.8	15	3.0
Other	187	0.8	108	0.6	70	1.2	9	1.8
>1 other vehicle	1,788	7.3	1,127	6.3	558	9.4	103	20.2
Total	24420	100	17977	100	5934	100	509	100

Source: STATS19.

TWMV category comprises motorcycles, motorcycle combinations, motor scooters and mopeds.

[1] LGV = Light Goods Vehicle.

[2] HGV = Heavy Goods Vehicle.

pattern for fatal cases was somewhat different. A collision with a car caused 39% of fatal casualties, whereas solo accidents caused 25% and collisions with more than one vehicle caused 20% of fatal casualties.

How these trends vary with location is shown in Tables 2 and 3, which compare TWMV casualties in built-up and non built-up areas. Built-up areas were defined by roads with a speed limit of 40mile/h (64km/h) or less and non-built-up areas by roads with a speed limit of greater than 40mile/h (64km/h). Not surprisingly the proportion of casualties resulting from collisions with pedestrians tends to be greater in built–up areas, with the proportion 2% in built-up areas, compared with only 0.2% in non built-up areas. Casualties arising from multiple collisions are more likely in non-built up areas both overall and for fatal casualties, with 11% and 25% in these categories respectively, compared with 6% and 12% in non built-up locations. This is contrary to what may be expected given that there are likely to be more junctions and greater traffic density in built-up areas.

Vehicle speeds are likely to be greater in a non built-up area and therefore, it is not surprising that solo accident are more than twice as likely to occur, with 31% of casualties in non built-up areas compared with 14% in built up areas. However, it is surprising that the risk of fatal injury in a solo accident in a non built-up area is less than that for a built-up area. A possible explanation is that roadside furniture (street lamps, trees etc.) is more prevalent in built-up areas and that those who lose control then collide with such obstacles.

Table 4 differentiates the situation in the whole country between motorcycles and mopeds, and analyses their collision partners in terms of the number of accidents in 1997. It should be noted that Table 4 shows accidents and thus the numbers differ from Table 1, which indicates casualties, some accidents will result in more than one casualty.

Table 4 indicates that there is a slight trend for mopeds to be less likely to collide with a pedestrian, less likely to have a solo accident, but more likely to collide with a car

Table 2 Number of TWMVs (Two-Wheel Motor Vehicle) casualties (n) arising from accidents in built-up areas in Great Britain (1997)

TWMV collision partner	*Total*		*Slight*		*Serious*		*Fatal*	
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Alone	2,369	13.5	1761	12.7	555	15.9	53	27.8
Pedestrian	374	2.1	332	2.4	39	1.1	3	1.6
Bicycle	152	0.9	133	1.0	19	0.5	0	0.0
TWMV	209	1.2	176	1.3	33	0.9	0	0.0
Car	12,139	69.2	9,735	70.3	2,318	66.3	86	45.0
LGV	782	4.5	612	4.4	160	4.6	10	5.2
HGV	250	1.4	178	1.3	63	1.8	9	4.7
Bus/Coach	148	0.8	110	0.8	31	0.9	7	3.7
Other	104	0.6	75	0.5	28	0.8	1	0.5
>1 other vehicle	1,011	5.8	738	5.3	251	7.2	22	11.5
Total	17538	100	13850	100	3497	100	191	100

Source: STATS19.

Built-up areas are defined by roads with a speed limit of 40mile/h or less. Non built-up areas are defined by roads with a speed limit over 40mile/h.

Table 3 Number of TWMVs (Two-Wheel Motor Vehicle) casualties (n) arising from accidents in non built-up areas in Great Britain (1997)

TWMV collision partner	*Total*		*Slight*		*Serious*		*Fatal*	
	n	*%*	*n*	*%*	*n*	*%*	*n*	*%*
Alone	2,154	31.3	1318	31.9	764	31.4	72	22.6
Pedestrian	14	0.2	8	0.2	6	0.3	0	0.0
Bicycle	29	0.4	18	0.4	11	0.5	0	0.0
TWMV	196	2.9	123	3.0	70	2.9	3	0.9
Car	3,178	46.2	1,977	47.9	1,088	44.7	113	35.5
LGV	213	3.1	127	31	75	3.1	11	3.5
HGV	192	2.8	112	2.7	58	2.4	22	6.9
Bus/Coach	46	0.7	22	0.5	16	0.7	8	2.5
Other	83	1.2	33	0.8	42	1.7	8	2.5
>1 other vehicle	777	11.3	389	9.4	307	12.6	81	25.5
Total	6882	100	4127	100	2437	100	318	100

Source: STATS19.
Non built-up areas are defined by roads with a speed limit over 40mile/h.

Table 4 Collision partners of motorcycles and mopeds arising from accidents in Great Britain (1997)

TWMV collision partner	*Total*		*Motorcycle*		*Moped*	
	n	*%*	*n*	*%*	*n*	*%*
Alone	4,172	18.2	3817	18.4	355	15.9
Pedestrian	1,323	5.8	1214	5.9	109	4.9
Bicycle	380	1.7	327	1.6	53	2.4
Moped	35	0.2	24	0.1	11	0.5
Motorcycle	264	1.2	240	1.2	24	1.1
Car	14,976	65.3	13456	65.0	1,520	68.0
Bus/Coach	199	0.9	181	0.9	18	0.8
LGV	970	4.2	876	4.2	94	4.2
HGV	435	1.9	399	1.9	36	1.6
Other	175	0.8	160	0.8	15	0.7
Total	22929	100	20694	100	2235	100

Source: Road Accidents Great Britain, 1997.
n = number of accidents.

or a bicycle. Overall, 65% of TWMV accidents in 1997 occurred when the TWMV was in collision with a car, and 18% of accidents involved no other vehicle.

Over the past two decades, there has been a reduction in TWMV casualties. However, this must be considered in relation to the fact that in 1980 there were some 300,000 new motorcycles sold in UK compared with only some 40,000 in 1994. Thus, although, motorcycle injuries have greatly reduced, this is largely explained by the reduction in number of machines in use. However, the trend now is for greater motorcycle use in Great Britain, with a corresponding increase of some 16% in the number of fatal cases between 1995 and 1997.

2.3.3 Object struck by the motorcycle

2.3.3.1 General

The European Enhanced Vehicle-safety Committee (EEVC) review of motorcycle safety (1993) identified that the object struck most frequently, in a half to two thirds of collisions, was a car, and in a quarter to one third of accidents where the struck object was known, the motorcycle did not impact with any other vehicle. Carre and Filou (1994), found that the great majority of two wheeler injury accidents, 70%, involved another vehicle (1093 out of 1554 accidents in the sample) and this was generally a car.

A much more recent German study, Otte *et al.* (1998), showed that little has changed; some 60% of accidents were collisions with cars and 27% involved only the motorcycle. A different study by Otte (1989) showed that most motor scooter accidents occur within built-up areas, 89% compared with 79% for motorcycles. As a result there are more scooter accidents at junctions, 57% compared with 51% for motorcycles. Otte noted that it is surprising that 33% of scooter accidents involved the scooter alone, compared with only 21% for motorcycles.

That the figures have remained comparable over such a long period suggests that in spite of changes to the motorcycle the accident pattern has not altered substantially. Therefore, in designing protection for motorcyclists it is obviously sensible to concentrate on collisions with cars and on contact with the road; this is particularly relevant to helmets and secondary safety features such as leg protection and airbags.

2.3.3.2 Collisions with crash barriers

Brailly (1998), studied French accidents whereby a motorcyclist has collided with a crash barrier. The results showed that the risk of fatality per accident is five times as great as the national rate for all motorcycle accidents. The study was in two parts and comprised an analysis of national statistics recorded between 1993 and 1996 and a site analysis of 240 accidents that occurred on non-urban roads and involved at least one motorcyclist and an impact with a crash barrier. The study showed that a yearly average of 63 fatals, 114 serious and 118 slight cases resulted from impacts into a crash barrier. These account for 8% of all motorcycle fatalities and 13% of fatalities on rural (outside of towns) roads. More than 30% of the fatalities amongst motorcyclists killed by hitting an obstacle on roads outside of towns were caused by motorcycles impacting crash barriers.

The most frequent location of these accidents was on tight bends with a radius of typically less than 250m. Accidents on bends took place mainly on the outside lane irrespective of the direction of the bend (left or right hand) and irrespective of the road category. However, accidents with barriers were far more frequent on right-hand than on left-hand bends (opposite for GB) irrespective of road category and there was no evidence to suggest that motorcyclists were more at risk on roads leading onto motorways, where it is a common practice to put a barrier, than on other types of road.

An analysis of the accidents showed that the rider contacted the barrier in about a half of the cases but was considered not to have contacted the barrier in about a third. This shows that a shield covering the barrier may be beneficial for about 50% of motorcycle accidents into a barrier. Safety zones at areas of high risk were also proposed. This study is an important indicator for the current unrest amongst motorcyclists as to the danger of barriers.

2.3.4 Motorcycle speed

The EEVC report on motorcycle safety (1993) showed that the mean motorcycle impact speed was not high and was in the range 30 to 45km/h, moreover, the mean impact speed for the car was very low and typically 15km/h. Moped impact speeds tended to be lower and the median was typically 30km/h or less.

As with all vehicle collisions, the risk and seriousness of injury increases with impact speed. Nevertheless 90% of all injuries tended to occur at less than 60km/h and some 85% of AIS I to 3 injuries at less than 50km/h. Otte *et al.* (1998), from a study of 402 motorcycle accidents in the Hannover region, showed that the mean speed of the motorcycle was 40km/h and that 80% of collisions occurred at an impact speed of 62km/h or less for the motorcycle. Otte et al. (1998) also showed that there is frequently a second impact, 143 cases, and that 80% of these occurred below 41km/h. Furthermore, the study by Otte et al. (1998) showed that scooters have a lower relative impact speed than motorcycles with 80% of accidents occurring at less than 40km/h compared with motorcycles for which 50% occurred at a relative speed of greater than 40km/h.

It is clear that the majority of motorcycle collisions continue to take place at relatively low speeds and, although injury severity increases with impact speed, a substantial proportion of serious injuries and fatalities occur at modest speeds where there is an opportunity of providing protection.

2.3.5 Impact configuration

Because a motorcycle is generally relatively light in relation to the object it is impacting, and loses stability once struck, the dynamics of motorcycle collisions tend to be more complex than for four wheel vehicles. The rider’s trajectory is more complex and variable than that of a vehicle occupant. After impact the bike tends to rotate about the impact point, so that evidence relating to the points of impact on both motorcycle and struck vehicle tends to be more reliable than information about the angle between bike and struck vehicle immediately before impact. The EEVC report (1993) quoted Otte et al. (1981) and Whitaker (1980), who both found that over 80% of impacts are within ±20 degrees of the front of the motorcycle.

Accident investigators tend to categorise impact directions by clock face angles, which limits the accuracy of angular information to 30 degree slots. Thus precise directional distributions are often not available. Also quoted in the EEVC report (1993) is Sporner *et al.* (1989) who found the angular distribution shown in Figure 10, which is repeated here to show the difference between light (including mopeds) and heavy motorcycles. There is a high concentration around the motorcycle front. Larger and heavier motorcycles in particular are likely to collide frontally with another vehicle, while the slower mopeds are relatively more likely to be hit by the opposing vehicle from the side or rear. Sporner *et al.* (1989*)* also found that the first contact area was the front wheel in 39% of cases, plus front

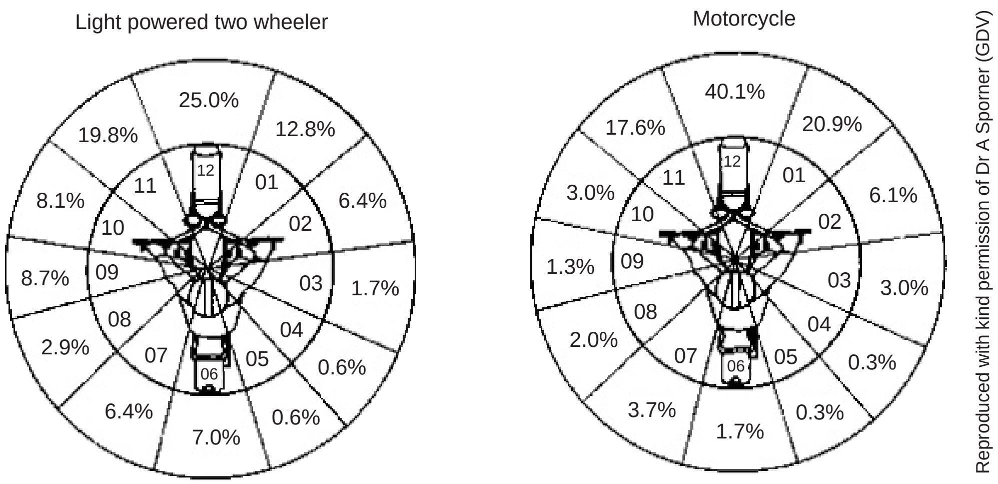


Figure 10 Angular distribution of first impact (Sporner *et al*., 1989)

wheel/fork in a further 27%, the engine, tank and rider's leg in 29%, and the motorcycle rear in only 5%.

A statistical analysis was made on the basis of an INRETS file containing 1/50th of the injury accidents that occurred in France in 1991 and 1992 (Carre and Filou, 1994). The accidents involving a two-wheeler represent 26% of all the accidents recorded in this sample (1,448 / 5,664). The 1,557 two-wheelers have been divided into four categories, according to the type of vehicle: bicycles (235), mopeds (624), light motorcycles (155) and powerful motorcycles (543).

The individual manoeuvre at the moment of the accident and the part of the vehicle struck in the collision tended to characterise the type of two-wheeler within the group as a whole. For mopeds, the characteristic manoeuvre was a change of direction, 17%, and they were generally hit in the front, 68%. Light and heavy motorcycles were frequently involved in an accident when overtaking, 15% and 17% respectively; the more powerful motorcycles were more often impacted in several places, 23%, or on their right side (left for GB) 8%.

The differences between riders of high-power motorcycles and the two-wheeler rider group as a whole were significant. This first group was more frequently involved in single-vehicle accidents, 15%, and in accidents with more than two vehicles, 27%. The accidents were due to loss of control, 16%, and occurred on a motorway, 7%, or a major road, 22%; there was doubtless a correlation between these results and the speeds at which these motorcycles were driven.

Otte's team (1998) has very recently investigated and reconstructed a sample of 402 motorcycle traffic accidents in the Hannover region. Accidents were categorised by type and location, and related to MAIS and head injury by AIS. They found that the most frequent occurrences were with the motorcycle running obliquely into the front or rear corner of the car (or other four-wheeled vehicle) 23.7%, the bike and car in frontal impact with each other 16% and the motorcycle impacting the side of the car 5.2%. Accidents not involving a collision with a four-wheeled vehicle were grouped together and include cases where the motorcycle simply lost control; this group accounted for 38% of the total.

It should be noted that AIS is the Abbreviated Injury Scale a system used to classify injuries according to the severity, regardless of the location of the injury. It is an integer scale from 0 to 6 where AIS 0 is uninjured and AIS 6 is unsurviveable. MAIS (maximum AIS) is the value of AIS for the most severe injury for a casualty.

The EEVC report (1993) concluded that there was a preponderance of serious injuries produced with the motorcycle either at roughly 90 degrees to the face of the impacted vehicle, or at relatively small angles to it; as when the motorcyclist runs into the side of a vehicle pulling out or overtaking, or when a vehicle runs into the side of a motorcycle. More recent analysis by Otte *et al.* (1998) agreed only in part with these findings. Otte *et al.* indicated that some 55% of accidents where the MAIS was 2 or greater occurred in impacts where the motorcycle impacted the four wheeled vehicle at roughly 90 degrees to the side or at a slightly more oblique angle into the front or rear corner. Twenty four percent of this group were a result of car impacts into the side of the motorcycle.

Otte has provided the only recent study of motorcycle accidents and there is a clear need for more accident studies. Moreover, the available data related only to injury accidents. It is also desirable to know about accidents in which injury was avoided in order to identify those aspects, which might prevent injury. In particular, there is a lack of reliable information on impact angles, though in the literature generally there seems to be a fairly clear distinction between glancing and head-on impacts. But, whatever the initial heading angle, it is clear that the impact points are concentrated at the front of the motorcycle, acting primarily within the front quadrant. This is supported by Carre and Filou (1994) who found that two-wheeler accidents were characterised by their extreme severity and that the most serious types of accident were caused by head-on collisions, loss of control and overtaking.

The EEVC report showed that over 90% of casualties with serious injuries sustained them while still in contact with their machine, and that only 10% occurred during body contact with the road, kerb or ground. This offers hope that it may be possible to reduce injuries by appropriate design of the machine with secondary safety features such as airbags and leg protection.

2.3.5.1 Solo Accidents: motorcycles and mopeds

The EEVC report (1993) found that a quarter to a third of all motorcycle accidents were solo accidents without collision with another vehicle. Again the only recent report is that of Otte *et al.* (1998) who found that some 19% were in this category both for the UK and Germany. This is a large proportion of accidents, albeit slightly lower than previously indicated. It should be noted that these figures include situations where the motorcyclist was avoiding collision with another vehicle, so not all solo accidents can be ascribed to the fault of the motorcyclist. Scooters have a greater solo accident rate at 33% (Otte *et al*., 1998).

Carre and Filou (1994) studied trends in TWMV accidents in France. They found that despite a trend for improvement during the years of the study, a specific characteristic of motorcycle accidents was the prevalence and the severity of accidents in which the motorcycle was the only vehicle involved. More than one third of the motorcyclists killed, 39%, were in this type of accident. For moped riders, the proportion of deaths in this type of accident was half as much (17%).

Nearly 30% of all solo accidents involved the motorcycle falling over onto the road surface, generally after a loss of road adhesion. In nearly all of these cases the injuries caused were not very serious with an AIS less than three.

2.3.6 Patterns of injury

2.3.6.1 General injury distribution and rider trajectory

The EEVC report (1993) concluded that the most frequently seriously injured parts of the body were the legs, 40 to 60% of all injuries, the head, typically 25% and the arms 20%. Eighty percent of casualties suffered some injury to the leg, 56% to the arm and 48 % to the head. However, the head injuries were more serious, at an average AIS score of 2.4, than leg injuries, AIS 1.9, or arm injuries, AIS 1.5. Thoracic and pelvic injuries were not frequent, but those recorded were often severe. Thus it was concluded that prevention of head injuries was a high priority, but nevertheless it was also thought important to pay attention to leg and arm injuries.

It is interesting to compare these conclusions with the findings of Otte's recent study, (1998). However, Otte's study describes a database that comprises data from three centres, Hannover, Munich and Glasgow. The database was compiled for 'COST 327' where the emphasis was on motorcyclists who had sustained a head impact although this database is frequently compared with a more random sample of cases collected by the Hannover team.

In the COST 327 database, collision type 1 (motorcycle comes across path of car resulting in an impact to the side of the bike) was infrequent and generally only the legs and arms were injured. This indicates that if the car struck the side of a motorcycle then the main injuries were to the extremities. In frontal collisions (collision type 2), all of the casualties suffered a head injury usually from impact with various parts of the car such as the bonnet, windscreen and the roof. Some 67% of riders in collision with the rear of a car (collision type 5) suffered a head and neck injury and 100% in collision with the front suffered a head injury. A leg injury was most likely to be sustained in collisions where the motorcycle struck the side of a car at 90 degrees (collision type 3) or where the motorcycle struck the front or rear corner of a car obliquely (collision type 4). In these accidents 90% and 95% of riders, respectively, suffered a leg injury and the leg was often caught between the motorcycle and the car, when the motorcycle swung toward the car during the impact, or between the motorcycle and the road surface. Collisions with objects (collision type 7) were characterised by frequent head and leg injuries.

In the Hannover database, 18.4% of helmeted riders sustained a head injury and 12.7% suffered a neck injury, whereas in the COST data base 55.6% suffered a head injury and 20% sustained a neck injury. This is to be expected given that the main criterion for inclusion in the COST database was evidence of a head impact, though not necessarily an injury. However, what is interesting is that in both databases, well over 70% of riders sustained a leg injury, which indicates that leg injuries are a very frequent occurrence regardless of the overall injury distribution.

Also of particular interest is that in the COST database, 80% of those motorcyclists with an injury MAIS 3 or greater sustained a head injury. Fatally injured casualties tended to have multiple injuries, having 72.7% with head injuries, 36.4% with neck injuries and 63.6% with thorax injuries; the cause of death was usually attributed to the head injury. This is consistent with a previous TRL study (Whitaker, 1980), which showed that over 80% of fatalities were as a result of head injuries.

Otte *et al*. (1998) also showed that scooter riders have a greater risk of head injuries, 24%, than motorcycles riders, 18%, but the severity was generally lower for scooter riders 3.7% AIS2 and greater, compared with 9.2% for motorcycle riders.

Little information has been published since the EEVC review as to the trajectory of the motorcyclist during an impact. The review described a study by Otte *et al*. (1982) which found that when the motorcyclist was in collision with a four-wheeled vehicle it was relatively rare for the rider to be thrown over the vehicle without impact (8.8% of cases), though in a further 11.4% of cases the rider landed upon the vehicle, rather than impacting it fully. In 54% of cases, there was direct impact of the rider with the vehicle. Situations where the motorcyclist had already fallen prior to impact by another vehicle accounted for 21.2% of all cases.

Overall, from the studies it appears that leg injuries occur mainly when the leg becomes trapped between the motorcycle and the car in acute angled impacts, and in impacts to the front and rear where the legs are likely to make direct contact with the opposing vehicle. Head injuries occur in head-on impacts where the motorcycle is at roughly 90 degrees to the front or side of the target vehicle, usually a car, and the rider is thrown forward over the handlebars into the side, front or rear of the vehicle.

It is clear that head and leg injuries are the two most important body regions for injury prevention and reduction, therefore they are considered separately below. Arm injuries are frequent and are generally less serious, although they can cause permanent disability: as yet no effective way to address the problem has been proposed, beyond the limited protection offered by good clothing.

2.3.7 Head injuries

2.3.7.1 The effect of speed, object struck and head impact location on injury type and severity

In 1981, work carried out by Vallée *et al.* (1981) showed that although the highest proportion of collisions were with cars, in fact they account for only 33% of the objects struck by the rider's head – 40% for moped riders and 22% for motorcyclists – this is because the rider's head often does not strike the collision vehicle, but the trajectory of the rider after collision brings the head into contact with other objects, often the road, motorcycle or roadside furniture.

Vallée *et al.* (1981) also showed that moped riders were substantially more likely to strike some part of a car, probably because the impact speed is generally lower and, therefore, the rider is less likely to be thrown over the car. This is consistent with the findings of research by Sporner *et al.* (1990) who noted that, for 90 degree impacts into the side of a car, the motorcyclist's head is at a very similar level to the roof edge or cant rail of the car. The seriousness of the head injury can be very dependent on just where the head strikes, or whether the rider is launched above the car cant-rail, and this depends on the design of the bike. A moped is usually a step-through and the rider is less likely to be launched into the air by this design.

More recently, Otte *et al*. (1998) analysed types of head injury, and showed that 43.5% of head injuries were soft tissue, 10.4% were concussion, 13.1% were fractures, and brain injuries (other than concussion) accounted for 27.8%. With respect to the estimated speed of head impact for each type of injury, 80% of soft tissue injuries occurred at a head impact speed of up to 55km/h and 80% of concussions at 70km/h or less. These injuries were therefore are characterised by a low head impact speed, whereas 80% of fractures were sustained at speeds of up to 90km/h, with 60% occurring at above 40km/h.

Otte *et al*. (1998) also examined the link between injury location and head impact speed and showed that lateral head impact occurred mainly at high impact speeds, with 80% in the range 50km/h to 93km/h; there were no lateral impacts below 50km/h. Facial injuries occurred at lower speeds, 80% at 74km/h or below.

Object shape influenced the injury type. Most (70%-75%) of the soft tissue injuries and concussions were caused by round objects whereas almost 80% of other brain injuries, such as haematoma, cerebral contusions and cerebral compressions were caused by round and flat objects; edge objects caused only 3.1% of this injury type. It should be noted that, of all those casualties who suffered a head impact, 55% sustained a head injury and 20% a neck injury.

2.3.8 Leg injuries

Since the EEVC 1993 report, the only study that describes the problems of leg injuries is that of Otte (1994). Much of what is contained below is from Otte's report but it is important to give a very brief extract from the EEVC report for comparison, as follows:

> *'Mackay (1985) suggests two general mechanisms of leg injury, direct impact with the other vehicle and crushing between the motorcycle and the other vehicle, and this distinction between a direct blow and trapping between the two vehicles is clear in many injury studies, for example Hurt et al. (1981) and Nyquist et al. (1985), who document the production of rider nearside lower leg injuries due to trapping between motorcycle and the other vehicle, or the pinching action experienced when the cycle 'slaps' against the car.'*

However, many of the above studies are somewhat old and the only recent study is that of Otte. Therefore, this was examined in detail to determine how the current patterns of leg injuries differ from those described above. Otte completed this study to analyse the risk to motorcyclists of leg injuries in accidents and to find the opportunities for leg protection by comparing risks for those injured on machines with and without leg fairings. Each injury was analysed by type, leg area and severity (AIS) and correlated to the impact situation with impact direction, impulse angle, load and characteristics of kinematic behaviour; 258 motorcycle accidents with cars were analysed for leg injuries.

The statistics show that motorcycling in Germany is becoming safer and devices such as crash helmets and protective clothes contribute towards this reduction in the injury risk. However, whilst improvements in helmets have contributed to a reduction in head injuries, there is no reduction apparent for the leg injuries. Otte's study confirms previous findings that some 60% of the motorcyclists in accidents sustained leg injuries, mostly fractures of injury severity AIS 2-3.

To establish the leg protection given by fairings, leg injuries were analysed by type, severity and location. Motorcycle collisions with a car, or solo accidents and collisions with solid objects, were included in the analysis although collisions with trucks were excluded because of the variation and complexity of the mechanisms involved.

The results of the analysis showed that the injury severity of the legs was reduced by the presence of a leg fairing. Of casualties riding with a fairing 28.3% sustained a leg injury compared with 33.7% for those without a fairing and furthermore the severity of the leg injuries that did occur was less, with only 14.2% with a fracture on the faired machines compared with 23% on the unfaired motorcycles.

This trend of reduced fracture risk for motorcyclists using machines with leg fairings is repeated in all collisions with cars, solo accidents and for various collision types. Otte claims that these statistics show that even standard fairings provide substantial protection to the legs.

The presence of fairings had little effect on the overall incidence of head and thorax injuries; 19.3% with and 18.1% without fairings for the head and 25.9% with and 22.8% without fairings for the thorax. However, Otte makes the point that a change in the rider kinematics is observed with leg fairings and this accounts for the different distribution of injuries among the collision types.

Otte also quantified the likely benefits for leg injuries. It was estimated that an overall reduction of 21.1% of leg injury costs could be achieved with leg protection. The most costly collision types were type 1 (motorcycle comes across path of car resulting in an impact to the side of the bike) and type 2 (motorcycle collides with front of another vehicle) for which an estimated reduction of 31.7% could be achieved. However, the greatest benefit, 34.6%, would be for type 5 collisions (motorcycle collides with rear of another vehicle) and 6 (another vehicle collides with rear of motorcycle).

Constructional suggestions for leg protectors included recommendations for the foot to be covered from the side and front and the design of protection to include the elimination of compression effects. It was also stated that the tibia must be protected in the front by an energy absorbing element although the rider must be free to leave the motorcycle during the impact.

2.3.8.1 Pillion passengers

Since the EEVC report, nothing has been published on the risk for pillion passengers thus an extract is included as follows:

> *'The presence of a pillion passenger is likely to have an important effect on the outcome of a collision. In general, the rider is likely to receive more severe injuries due to the load caused by the passenger's momentum, while the pillion is likely to receive less severe injuries, especially to the head, because of the cushioning effect of the rider in front, and possibly in some circumstances because the passenger is launched*

upwards by the back of the rider and thus flies over the impacted vehicle (Grandel 1987, Otte 1989). However, Otte (1989) also notes that, on the whole, injury levels to riders accompanied by pillion passengers are actually lower than those to solo riders, and he attributes this to lower average impact speeds for rider/passenger combinations than for solo riders.'

2.4 Conclusions and recommendations

The most important findings from Section 2 can be summarised as:

i There have been significant reductions in the number of casualties for those aged under 20 and the number of casualties involving the small bikes (of less than 125cc) since the late 1980s/early 1990s. 39% of the casualties involved a bike with an engine size less than 125cc in 1996 compared with 66% in 1984 which suggests that learner riders account for a smaller proportion of casualties compared with 12 years ago.

ii In contrast, since 1993 growing numbers of casualties have been in the age range 30-39, the majority are presumably fully licensed since over three-quarters were riding a bike with an engine size greater than 125cc in 1996. The riders of larger motorbikes (with an engine size greater than 500cc) are dominating the casualty statistics with high proportions of fatalities occurring on NBU roads during the summer months.

iii The risk of a motorcyclist being killed or injured in a road accident depends on various factors, the principal ones being:

- a the rider's age and sex;
- b the type of road (e.g. urban or rural);
- c the characteristics of the motorcycle (e.g. power or engine capacity);
- d the exposure (normally quantified as the mileage ridden).

iv The assessment of risk levels is complicated by interaction of these and other (probably less influential) factors. Such interactions also exist for other casualty groups, but the interaction between size of machine and type of road used is particularly strong in the case of motorcyclists: larger machines are ridden more often on high-speed rural roads than smaller machines (Broughton *et al.*). The complex ways in which the motorcyclist casualty rate depends upon these means that Section 2.1.2 could only hint at the underlying causes for the evolution of the casualty trends.

v A satisfactory, unbiased assessment of the risks of motorcycling thus requires a rather sophisticated statistical methodology. Although, various studies of this subject have been made in the past (discussed in Section 2.2) this is an area where recent developments could usefully be considered, especially given the changes in motorcycle usage reported and inferred here.

vi In Great Britain in 1997, 65% of TWMV casualty accidents were with a car and 18% were solo accidents. This reflects the high exposure of TWMV to cars, which was particularly evident in built-up areas. Collisions with a car accounted for 39% of TWMV fatal casualties in 1997. German statistics show similar figures, with about 54% to 60% of collisions (depending on the study) occurring with a car and between 19% and 27% being solo accidents.

vii These two accident types are prominent in both sources, and have remained comparable over a long period, suggesting that in spite of changes to the motorcycle, the accident pattern remains the same. Therefore, in designing protection for motorcyclists it is sensible to concentrate on collisions with cars and on contact with the road; this is particularly relevant to helmet and secondary safety features such as leg protection and airbags.

viii As with all vehicle collisions, the risk and seriousness of injury increases with impact speed. Nevertheless, 90% of all injuries tended to occur at less than 60km/h and some 85% of AIS I to 3 injuries at less than 50km/h. The majority of motorcycle collisions continue to occur at relatively low speeds and, although injury severity increases with impact speed, a substantial proportion of serious injuries and fatalities occur at modest speeds where there is an opportunity of providing protection.

ix Research has shown that there was preponderance of serious injuries produced when the motorcycle impacted another vehicle, either at roughly 90 degrees to the face, or at a relatively small angle. This may occur when the motorcyclist impacts the side of a vehicle pulling out or overtaking, or when a vehicle impacts the side of a motorcycle.

x A recent study (COST 327) showed that 80% of motorcyclists with an injury MAIS 3 or greater sustained a head injury. Fatally injured casualties tended to have multiple injuries, with 72.7% having head injuries, 36.4% neck injuries and 63.6% thorax injuries; the cause of death was usually attributed to the head injury. This is consistent with a previous study, which showed that over 80% of fatalities were as a result of head injuries.

xi The COST study also showed that some 70% of riders sustained a leg injury. A German study showed that the injury severity of the legs is reduced by the presence of a leg fairing. Of casualties riding with a fairing 28.3% sustained a leg injury compared with 33.7% for those without a fairing. The severity of the leg injuries that did occur was less, with only 14.2% sustaining a fracture on the faired machines compared with 23% on the standard motorcycles. Furthermore the study quantified the benefits of leg protection and recommended that motorcycles be so fitted.

Recommendations for research: Motorcycle accidents

Multivariate analysis of existing data on factors affecting the accident risk of motorcyclists

Although various studies of this subject have been made in the past, this is an area where recent changes in motorcycle usage and their effects on casualty trends need to be explored, in order to indicate the likely scope for possible countermeasures to reduce the number of motorcyclist casualties in the future.

Assessment of risk levels for motorcyclists is complicated by interactions between age, sex, experience, road type, motorcycle characteristics, exposure and other (probably less influential) factors. Such interactions also exist for other casualty groups, but the interaction between size of machine and type of road used is particularly strong in the case of motorcyclists: larger machines are ridden more often on high-speed rural roads than smaller machines. A satisfactory, unbiased assessment of the risks of motorcycling thus requires a rather sophisticated statistical methodology, using STATS19 accident data linked to DVLA on machine-type, NTS data on motorcycle use, motorcycle registration data, and national mileage estimates from the Traffic Census. Such a study should be particularly useful in informing the debate about the relation between motorcycle size and accident risk and it is strongly recommended that such a study, if undertaken, is done in close collaboration with the survey of self reported accidents mentioned at Section 2.2.2. This survey is described more fully in Section 5 along with associated survey research on the motorcycle rider.

Motorcycle despatch riders

Unpublished TRL research based on a self-reported accident survey, has shown that once the effects of annual mileage, age, riding experience and training have been controlled for, despatch riders appear to have between about 3 and 6.5 times as many accidents as other motorcyclists, and between about 3 and 10 times as many injury accidents. Follow up research should be undertaken to gather information from despatch riders about a range of factors not explored in the postal questionnaire, including:

- Riding style, risk taking behaviour and attitudes to risk taking.
- Perceived pressures of the job.
- Fatigue.
- Bike maintenance.
- Various aspects of exposure to risk.
- Accident (under) reporting.

This research should start with qualitative interviews and groups-discussions, to attempt to develop quantitative survey instruments suitable for this difficult study.

The recommendations for further research in the areas concerning vehicle factors and protective equipment to reduce injury are discussed at the end of Section 3.

3 Vehicle factors and protective equipment

3.1 Braking: problems and systems

For many types of vehicle incorrect or inappropriate brake application is not critical under most circumstances. With two-wheeled motor vehicles a mistake by the rider that leads to either wheel being over-braked will cause the machine to skid, become unstable and capsize. The incidence of skidding in personal injury accidents is substantially greater for motorcycles (TWMV) than for other vehicles: in 1997, skidding occurred in 28% of accidents in the wet involving a TWMV compared with 20% for other vehicles (DETR, 1998).

It has been shown that many motorcyclists brake incorrectly, and this is thought to be a contributory factor in many motorcycle accidents. An old study by Sheppard *et al.* (1985) researched the way in which motorcyclists brake by observing their behaviour at road junctions. They found that when braking normally, 36% of riders used only the rear brake and 11% used only the front brake. Even in an emergency 19% still used only the rear brake and 35% used only the front brake. This practice leads to accidents that could easily be prevented as was shown by Maclean *et al.* who found that 30% of accidents studied could have been avoided if the full available braking had been used.

Anti-lock brakes (ABS) are designed to prevent wheel locking and thus provide motorcyclists with the confidence to use the brakes up to the limit of the friction available, without fear of falling to the ground. ABS also reduces stopping distance in wet and icy conditions. A few machines are now offered with anti-lock brakes.

In spite of track tests that show ABS to be very advantageous some accident studies have shown that the benefits may not be as extensive as the track tests had indicated. However, further research to identify the effects of ABS more clearly should be considered. The sample should contain enough machines with and without ABS to allow reasonable statistical power, and the study designed to take exposure into account.

3.2 Conspicuity

3.2.1 Introduction

Not seeing a motorcycle has been reported to be a common cause of motorcycle accidents during both the hours of daylight and at night, and this has been the case for many years and in many countries. In the early eighties TRL reported on a series of experiments to determine ways of improving the conspicuity of motorcyclists and motorcycles (Donne and Fulton, 1985).

The reasons for inadequate conspicuity are very different during the day and at night and potential solutions need to be evaluated separately. The ideal measure of the effectiveness of a conspicuity aid would be a reduction in accidents following its widespread use. However, this is not a practical basis for experiment because of the difficulties of scale and maintaining experimental control. Therefore the research which TRL has conducted for daytime conspicuity was based on a laboratory trial, a pedestrian field trial and a ‘road-glimpse’ trial. For night-time conspicuity a series of lighting arrangements were assessed by peripheral detection, vehicle identification and speed judgement. This research remains the most comprehensive study available and is reported here briefly as a basis for comparison with more recent findings.

3.2.2 Daytime conspicuity

3.2.2.1 Laboratory trial and results

The laboratory trial consisted of observers looking at photographic slides of the control (a motorcycle and rider with no fluorescent treatment) and six different types of fluorescent treatment to a motorcycle and rider in a traffic scene. The time taken for each observer to identify the motorcycle was the test measure. This intended as a rough sorting procedure and the results, given in Table 5, show that a fluorescent jacket and a fluorescent waistcoat were substantially better than the control. A fluorescent helmet also appeared to be better, but by only a small margin.

Table 5 Mean detection times for options using fluorescent material – laboratory method

Experimental option	*Mean detection time (seconds)*
Control – not fluorescent	1.090
Legshields – fluorescent from front	1.048
Jacket – completely fluorescent	0.896*
Headlamp cover – fluorescent from front	1.070
Helmet – covered in fluorescent material	1.008
Waistcoat – completely fluorescent	0.880*
Sleeves – completely fluorescent	1.116

***** *Denotes significantly better than control (p<0.05)*

3.2.2.2 Pedestrian trial and results

For the pedestrian trial, the motorcycle and rider were positioned in a side street at a distance of 25m from a junction. Two interviewers waited at each side of the junction such that the motorcycle was not visible and they questioned pedestrians who had crossed the street and who had looked to check for the presence of traffic. The pedestrians were asked if they had noticed a motorcycle in the street as they crossed. The assessment was based on the proportion of positive responses for each conspicuity arrangement.

Trials were run using several types of standard headlamp, daytime running lamps, fluorescent jacket/waistcoat and helmet and a control. In total 18,000 pedestrians were involved at different sites and in different weather conditions. Table 6 gives a summary of the results and shows that a fluorescent jacket/waistcoat and a pair of daytime running lamps were the most effective aids to conspicuity. A single daytime running lamp and a large headlamp were considerably better than the control and each of these was assessed in the road glimpse trial.

NB. In most cases the results in Table 6 are given as a range of values because the conspicuity aid was evaluated at different sites and on different occasions at each site. Where only one value is quoted, the conspicuity aid was evaluated on different occasions but at the same site.

3.2.2.3 Road glimpse trial and results

Subjects were asked to identify the nearest approaching vehicle whilst seated in the driving seat of a parked car and allowed a brief glimpse of the road ahead through a shutter (see Figure 11). The road conditions varied between no traffic and incidental traffic. Sometimes the test motorcycle displayed one of the 4 conspicuity aids, while at others it was in the control condition. Table 7 gives the results and shows that the 40W large headlamp (dipped), the pair of daytime running lamps and the fluorescent jacket were all significantly better than the control.

Table 6 Summary of results from pedestrian field trials

Experimental option	*Detection rate %*
Control	7.1 – 26.5
Fluorescent helmet#	15.2
Fluorescent jacket/waistcoat	22.5*
Small dipped headlamp 100mm dia	
18W tungsten#	17.3
40W tungsten	3.9 – 29.5
40W tungsten (flashing)	11.2 – 20.7
Large dipped headlamp 180mm dia	
24W and 40’ tungsten	21.5 – 29.7+
40W tungsten (flashing)	13.2 – 26.0+
55W halogen	8.1 – 20.7+
Single daytime running lamp	
10W tungsten	21.0 – 28.4+
15W tungsten	12.1 – 33.3+
Pair of daytime running lamps	
6W tungsten	30.8 – 38.0*
10W tungsten	14.2 – 31.9*
15W tungsten	18.7 – 44.7*

**denotes significantly better than control (p<0.05)*
+denotes significantly better than control in some trials only
#tested at one site only

3.2.3 Night-time conspicuity

3.2.3.1 Interpretation

At night ‘not seen’ may be interpreted in different ways. A motorcycle has only one headlamp which, as a provider of visual cues, has several drawbacks. These can be classified as:

i insufficiently bright to attract attention particularly when competing with pairs of powerful lights on other vehicles;

ii in complex traffic a single light may be not be identified as belonging to a motorcycle;

iii a single light provides poor cues to speed and location compared with two lights as spaced on 4-wheeled vehicles.

3.2.3.2 Experimental conditions

The above aspects were assessed using a variety of lighting arrangements. (In all the tests the headlamp was dipped: the control was a dipped 40W headlamp).

These were:

i 55W quartz – halogen;

ii 40W tungsten + steady daytime lights;

iii 40W tungsten + flashing daytime lights;

iv 40W tungsten and fluorescent striplights (mounted vertically);

v 40W tungsten and illuminated leg weather shields.

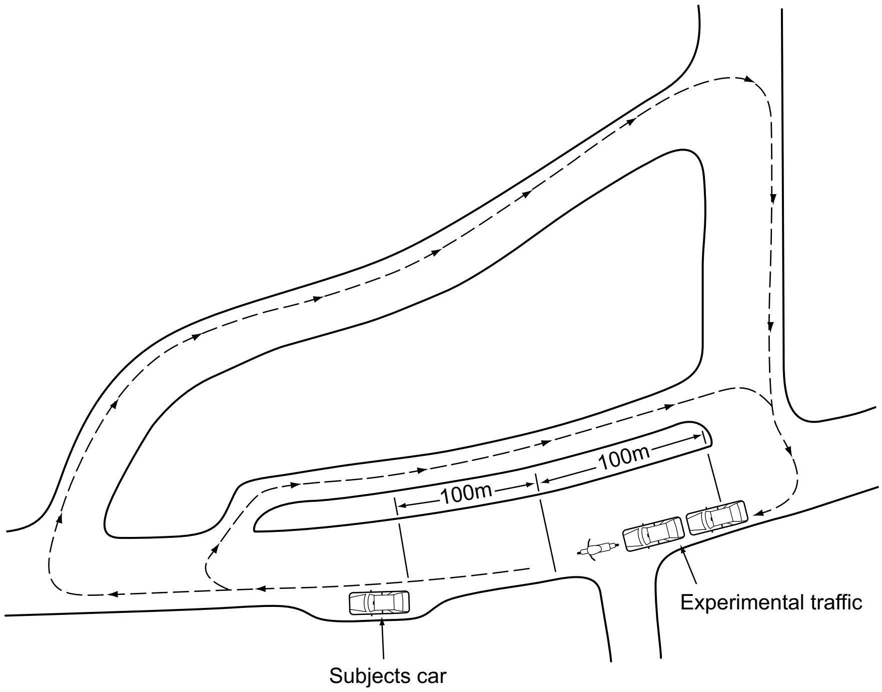


Figure 11 Experimental site for 'road glimpse' trials

Table 7 Mean values of ranks – 'Road glimpse' trials

Experimental option	*Mean values of ranks+*	*% correct*
Control	2.68	53.6
40W, 180mm diameter headlamp	3.22*	64.4
1 x 15W daytime running-lamp (glass-halogen)	2.90	58.0
2 x 15W daytime running-lamp (tungsten)	3.11*	62.2
Fluorescent jacket	2.99*	60.0

** Denotes significantly better than control (p<0.05).*
+ 5 denotes always seen, 0 denotes never seen.

Also used in conjunction with the standard headlamps were amber daytime running lamps wired to remain permanently lit or both flashing. Three different trials were conducted. These were designed to assess detection distance, vehicle identification and speed judgement. The trials took place on the test track at TRL under high-quality sodium street lighting and on dark but clear winter evenings.

3.2.3.3 Peripheral detection trial

Observers were asked to count numbers on a random display occupying their central view. They were then requested to indicate when they were aware of a test vehicle approaching at 60^o to their line of sight. The distance at which the approaching vehicle was detected was used as the measure of detectability of the lighting arrangement.

3.2.3.4 Vehicle identification trial

Observers were given brief glimpses of groups of approaching traffic constituted in different ways and asked to identify the leading vehicle. Sometimes the test motorcycle was the leading vehicle. The test measure was the proportion of correct responses and was compared with the control.

3.2.3.5 Speed judgement trial

Judgement of speed and location were examined in two experiments. In both the tests, vehicles travelled towards observers at a predetermined speed between 40km/h and 90km/h. In one experiment the vehicle was obscured from view when at a distance of 46m from the observer who was asked to indicate when the vehicle would arrive. In the second experiment observers were asked simply to estimate the approach speeds of the test vehicle, again at a distance of 46m, but with unrestricted observation.

3.2.3.6 Results

The results of the detection and identification trials are summarised in Table 8 and show that the simplest and most effective aid to night-time conspicuity is a 55W quartz halogen headlamp. It was a clear winner in the detection trial and was bettered only by striplights and leg shields in combination with itself in the identification trial.

There are conspicuity aids which, if used extensively, could reduce the number of motorcycle accidents substantially both during the daytime and night-time. The simple expedient of fitting a 55W quartz halogen headlamp to all motorcycles is one solution.

3.2.4 Other studies

Thomson of New Zealand concluded, from his research of accident studies, that compulsory use of motorcycle headlights should be favoured and that if introduced in New Zealand, they would have a benefit to cost ratio

Table 8 Summary of the identification and detection trials

Night-time mean conspicuity aid	*Mean identification factor (Max 1.0)*	*Detection distance m*
Car	–	346
55W Quartz-halogen headlamp		
– with striplights	0.92	Not tested
– with legshields	0.90	
55W Quartz-halogen headlamp	0.79	305
40W Tungsten headlamp	0.76	139
All other arrangements	<0.79	<170

exceeding one (Thomson, 1980). Further research by Thomson showed that the following factors should be accounted for in conspicuity research:

- sky illumination levels;
- traffic density and type of traffic;
- type of background;
- speeds of the motorcycle;
- luminance contrast ratio;
- headlight output.

It is interesting to note that the TRL research did account for most of these.

Thomson drew attention to the importance of the position of the motorcyclist in the driver's visual field, and the interaction of this with time of day/night – perceptual facts consistent with Willams' 1976 analysis of Australian motorcycle accidents. Thomson also cited research suggesting that expectancy was an important determinant of whether a motorcyclist is seen by another road user. Objects such as motorcycles with a relatively low probability of being encountered are less likely to be detected than more common objects such as cars. Thomson suggested that the use of headlamps on the motorcycle might help to overcome this expectancy phenomenon.

The effects of mental workload and attention-sharing on detection of visual targets was also discussed by Thomson, again with the suggestion that increasing the motorcycle's conspicuity might assist drivers in coping with this problem.

A literature review on the perception of the presence of motorcycles conducted in the Netherlands by Noordzij (1997) supported Thomson's 1980 conclusions. The literature indicated that perceiving motorcycles is more difficult than perceiving cars and that the failure to perceive motorcyclists is partially due to the fact that other motorists attach little importance to the presence (or possible presence) of motorcycles. Also, it was found that there was little problem with perceiving a motorcycle at short distances in the daytime. Noordzij suggested that the perception of motorcyclists at night could be improved by using retroflecting material on the bike which emphasises the contour of the motorcycle and by using yellow light for better perception of motorcycles both in the daytime and at night.

Other research, documented by Thomson (1980), has analysed accidents by motorcycle headlight usage and field of view in daylight conditions. The research demonstrated that there was a higher percentage of accidents involving motorcycles with their headlights off compared to motorcycles with the headlights on. There were also more accidents involving motorcycles with their headlights off when the bike was in the other driver's *peripheral* visual field compared to motorcycles with their headlights off when the bike was in the other driver's *central* visual field. However, there was only a marginal difference between the percentage of accidents involving motorcycles with their headlights on when the bike was in the other driver's *peripheral* visual field and the percentage of accidents involving motorcycles with their headlights on when the bike was in the other driver's *central* visual field. In fact, the percentage of accidents involving motorcycles with their headlights on when the bike was in the other driver's peripheral field were slightly less compared to when the bike was in the other driver's central field. This suggests that headlight use increases the perception of motorcycles by other vehicle users and that when the motorcycle appears in the peripheral visual field (where perception seems to be most difficult) to a level which is comparable with when the motorcycle appears in the central visual field.

Researchers at the University of Sussex have conducted a series of studies on motorcycle conspicuity (Hole and Tyrrell, 1995; Hole *et al.*, 1996; Langham, 1995). These studies involved showing participants a series of slides or videos of traffic scenes. The findings indicated the beneficial effect of headlights in helping car drivers to detect distant motorcycles, especially in visually cluttered environments. It was also found that repeated exposure to headlight-using motorcyclists significantly delayed detection of an unlit motorcyclist, indicating that although the use of headlights increases the conspicuity of riders and improves the probability that they will be detected by drivers of other vehicles, it may place those who do not use headlights at increased risk. Colour and patterning of clothing was also examined, the results indicating that dark clothing was superior whether the headlight was on or off. The results were interpreted in terms of luminance contrast between target and background, which is well-known to be an important determinant of visibility. Although a rigorous evaluation of these results is beyond the scope of the present review, it seems likely that the effect of dark clothing on conspicuity *when the headlight is on* may have been over-emphasised by the experimental technique used in these trials. It is true that dark clothing will increase the luminance contrast between the headlamp and its background but, on the road, the contrast will be very high even without the dark clothing. The video and slides-based presentations will not have been able to reproduce the actual luminance contrast, and may have detected an effect of clothing colour that would not be present on the road.

Langham (1995) replicated the findings of the above studies and also investigated the effect of cognitive style on detection of a motorcyclist. Cognitive style in this context referred to 'the ability to break up an organised visual field in order to keep part of it separate from the rest of that field' as measured by the Embedded Figures Test (EFT) (Wapner and Demick, 1991). Those with lower abilities as measured by this test fall into a cognitive style category called *field dependent* (FD) and those with higher abilities are called *field independent* (FI). Participants were drivers who viewed video scenes of traffic and determined whether a motorcyclist was present in those scenes. It was found that cognitive style had a significant effect on whether a motorcycle was detected. Field dependent (FD) drivers were worse at detecting motorcycles compared to field independent (FI) drivers in both cluttered and uncluttered environments and also when headlights were on and when they were off. For both FD and FI drivers, headlight use increased conspicuity of a motorcycle, especially at greater distances. This improvement in conspicuity was greatest for cluttered environments and for FD participants compared to FI participants. Having headlights on increased conspicuity to FD drivers to a level that brought them closer to the detection capabilities of FI drivers.

Unpublished research by Langham and Hole has shown that although lack of conspicuity (i.e. as defined in terms of target size and luminance contrast) may well be one reason for the ‘looked-but-failed-to-see’ (LBFS) error, other factors are also important. They conducted a laboratory based study where participants watched video clips of an approaching vehicle in a traffic scene, as viewed from the perspective of a driver at an intersection. Participants were shown either a real motorcycle (control condition), or an animated shape: a vertical moving bar (to represent a motorcycle), a horizontal moving bar (to represent a car) or a vertical mosaic distortion (conveying a sense of motion without form). Participants were asked to search for a motorcycle or for any motor vehicle and their reaction times were measured as well as whether they thought they were being deceived.

It was found that experienced drivers, as compared to inexperienced or non-drivers, reacted faster, and were more likely to be deceived by the animated shapes, believing that they were vehicles. This was the case so long as the search instructions matched the shape orientation (i.e. if asked to search for a motorcycle and presented with a vertical bar). Inexperienced drivers generally noticed the deception immediately. These results suggest that experienced drivers form some basic internal representation of each type of vehicle, and use these as a perceptual shortcut, perceiving targets as motorcycles if they match the internal prototypical shape for motorcycles. Other results showed that detection times were longer when participants were not told which type of vehicle to expect. The researchers suggested that with experience, drivers develop shorter reaction times at junctions and only extract a minimal amount of information from complex traffic scenes based on prior expectancies about what they are likely to see. Visual search failures at intersections may be due to expected prototypical shapes being for cars and larger vehicles with primarily horizontal dimensions. When a motorcycle appears in the visual field, the vertical dimension may not match the expected horizontal prototype and therefore it goes undetected.

These findings are an example of the expectancy phenomenon discussed by Thomson (1980). The question for motorcycle safety is, what can be done about it beyond attempting to compensate by increasing the physical conspicuity of motorcycles. The answer might appear to be improved driver training, emphasising the need for careful visual search for the unexpected. However, it is far from clear whether this would have a persisting benefit. The basic problem is that motorcycles are unexpected because they are relatively uncommon, and experience of this fact may tend to dilute or negate any effect of training. Nevertheless, training on search and scanning techniques, emphasising the importance of not driving into the path of a motorcycle, and making drivers aware of expectancy phenomena, might have a persisting benefit. Designing and evaluating such training interventions – starting perhaps with an evaluation of the recent DSA video – would be well worth doing.

In a more recent study, Hole *et al.* (1996) stated that bright clothing and headlights may not always improve conspicuity. However, in this study slides were used for the experiment and the results may have been influenced by the limitations of this technique.

In many countries use of headlamps during the daytime is compulsory for powered two wheelers. This is so in Austria, Belgium, Switzerland, Germany and Spain for motorcycles with a capacity greater than 125cc.

Bijleveld (1997) has recently analysed Austrian accident data and concluded that use of headlights gave a 35% reduction in motorcyclists severely injured from collisions with cars during the daytime. This is a conclusive result and is a very pertinent finding in support of the need for improved conspicuity.

It is recommended that conspicuity be further researched to find a means of improving on the benefits of the use of the headlamp. Currently coloured lamps, although illegal, are fashionable among motorcyclists who believe that they offer improved conspicuity compared with the conventional headlamp. One potential advantage is that this colour-coding of motorcycles may make it easier for other road users to identify a motorcycle against a complex background of other lights. Night-time conspicuity should also be reassessed to determine if the original TRL findings may be more readily implemented with more modern technology.

Designing and evaluating training interventions for car drivers along the lines discussed above, and starting perhaps with an evaluation of the recent DSA video – is also recommended.

Rider attitudes towards conspicuity aids are discussed in Section 5.3.1.2.

3.3 Vehicle secondary safety systems

3.3.1 Method of assessment and ISO 13232

In the last few years improving passive safety has been one of the basic aims of accident research on two-wheeled motorised vehicles. The main problem is the wide range of possible outcomes of a two-wheeler accident, arising from the complex possibilities of the sequence of motion of both rider and motorcycle, and the injury mechanisms involved, which differ very considerably from those seen in car accidents.

To describe a motorcycle collision with a car or other opposing vehicle, five crucial impact variables need to be defined: motorcycle speed, car speed, motorcycle contact point, car contact point, relative heading angle. Because of this complexity it is not surprising that very few studies are available which have examined all five of these variables. As a result there is often some confusion in discussion of accident research, and some unavoidable speculation in some aspects of the studies. It is therefore of critical importance to the successful development of any safety device that it is tested, not only in the impact configurations likely to give rise to the sort of injuries that the device is designed to prevent in real accidents, but also in other configurations to ensure that there is no increase in the risk of other types of injuries.

Because of the need to examine motorcycle safety in this critical way an ISO Standard was developed, ISO 13232, and published in 1996. This comprises eight parts starting with accident data collection and analysis, which is used to identify the seven most important impact configurations. The remaining parts define the specialised motorcycle dummy components, test methods, assessment of potential injury from the dummy measurements, computer analysis and reporting. Of particular relevance for this report is the ISO calculation of normalised injury costs that can be expressed as a percent change.

3.3.2 Airbags

3.3.2.1 Background

In impacts head on to the motorcycle, 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).

The first crash tests with airbags on motorcycles were published in 1973 (Hirsch and Bothwell, 1973). The airbag, which was rare at that time even in the car sector, was meant to act as a restraint system. So that it could fulfil this requirement, airbag volumes of up to 120 litres were used. The results were not entirely satisfactory but gave a clear indication that an airbag system could be beneficial.

In the early 1990s tests were completed in the UK in which three different types of motor cycle were fitted with an airbag (Happian-Smith and Chinn, 1990). The aim was to achieve maximum restraint by the airbag and as great a reduction in the motorcyclist's speed as possible. The results show that full restraint was not possible above a speed of 30mile/h, though reducing the rider's velocity and controlling his trajectory could still be beneficial.

However, of more importance are two recent papers describing the development of an airbag system specifically for the motorcycles to which they were fitted.

3.3.2.2 Development of an airbag system for a Norton Commander: TRL project

On behalf of the DETR, this project completed the development and testing of a purpose built motorcycle airbag restraint system at Transport Research Laboratory in 1996 (Okello and Chinn, 1996; Chinn *et al.*, 1997). The system was developed in structured phases involving mathematical modelling, system manufacture, and then development and evaluation in a series of tests on a Norton motorcycle. The tests ranged from static fire to sled tests and finally full scale impacts. A Hybrid III dummy was used throughout the programme and a wide range of parameters were assessed. Results of the sled and full scale impact tests show kinetic energy reduction of between 79% and 100% and low neck-injury measurements compared with tolerance limits. Firing of an airbag is an important part of the system and TRL has undertaken research to determine the characteristics of a trigger system by the use of theoretical and experimental data. This includes data obtained from accelerometers mounted at different locations on a motorcycle during 'rough riding' tests.

As part of the programme TRL commissioned Lotus Engineering to design, manufacture and supply a purpose built airbag system for a large, touring Norton Commander motorcycle for impact testing. The programme started with MADYMO computer simulation of rider kinematics at impact, using load and acceleration impact test data information supplied by TRL, to determine the most suitable location of an airbag on the motorcycle and also to assess the system characteristics. Parametric studies determined the optimum airbag size and shape including tethering, suitable fire times, rate of inflation and pressure. This was followed by the design and manufacture of an airbag module mounted at the rear of the modified fuel tank, consisting mainly of an un-coated polyester airbag and a hybrid inflator. Knee bolsters designed to control the rider trajectory but retain the energy absorbing properties defined in the TRL leg protection specification were also mounted into the motorcycle front fairing.

The test phases of the programme included firing the airbag system statically to assess its performance and integrity during deployment. This was followed by a series of sled tests to develop the system and consider the effects of an out of position rider, for example crouching or prone riders, as well as simulating angled impacts. This was followed by the full scale crash tests in which a free-wheeling Norton Commander motorcycle, fitted with an airbag system, was impacted into stationary and moving cars at different speeds, angles and directions to assess performance of the airbag in as many road accident conditions as possible.

It is well known that the performance of an airbag system depends critically upon the time at which the airbag is deployed during the impact and this in turn depends upon the characteristics of the firing switch. For this reason, the airbag system in these tests was fired remotely with a delay at impact based on the motorcycle fore/aft deceleration pulse obtained from equivalent standard test. The design of the tests was in accordance with ISO DIS 13232 (ISO, 1996).

The characteristics of an airbag switch must be chosen so that the bag is deployed efficiently during an accident but does not deploy when the motorcycle is being ridden even when this is over an extremely uneven surface such as potholes or a kerbstone or very rough terrain. Motorcycle vibrations during such extreme circumstances were evaluated, and the results of this research were used in the development of the system.

The Norton Commander motorcycle was chosen as the test bed for which the airbag system was to be developed. It was a large touring machine, 221 kg, with a full glass-fibre fairing and was representative in weight and size of the larger machines on the market. Although the system was developed specifically for this machine it was intended that the development would formulate principles which are readily applicable to other machines of this class and may, in general, be applicable to many motorcycles of conventional design.

The main objective, and therefore the main function of the system, was to protect the rider in impacts, approximately head-on to the motorcycle, into moving and stationary vehicles. Additionally, the system should be of some benefit in a range of other impact configurations but it must not be of serious detriment to the rider in any configuration. It should be noted that approximately 75% of motorcycle accidents occur at motorcycle impact speeds of up to 48km/h, and 96% up to 64km/h (40mile/h), and that 93% of the serious and fatal head injuries occur at speeds of up to 64km/h (40mile/h) (Whitaker, 1980; Sporner *et al*., 1989). It should also be noted that the majority of fatal and serious head and chest injuries occur in impacts approximately head-on to the motorcycle and that in the majority of accidents with an opposing vehicle, the speed of the opposing vehicle is 25km/h (15mile/h) or less. It was decided, therefore, to aim to optimise the airbag system performance for impacts approximately head-on to the motorcycle into stationary and slow moving vehicles (up to 25km/h), with the additional requirement that injury potential in head-on impacts at speeds up to 64km/h (40mile/h) be reduced.

It was intended that the overall performance of the system would be judged against the performance of a standard motorcycle and that the criteria for the optimised case, which was a 50th percentile single rider in normal seating position travelling at 48km/h, head-on into the side of a stationary vehicle, should be:

- That the kinetic energy at the plane of initial impact be reduced by at least 70%.
- That the instrumentation measurements for the head, neck and chest should be substantially reduced.

Results of the trajectory analysis obtained from the tests show that the airbag was effective in reducing the rider velocities at impact. This is illustrated by the results of a test in which a motorcycle at 48km/h impacts the side of a car moving at 24km/h at an angle of 225°. Head velocity was reduced by 64%, the chest velocity was reduced by 75%.

Kinetic Energy Assessment – The rider trajectory analysis of the full scale impact tests showed that the dummy was fully restrained by the airbag with significant reduction in rider forward velocity and corresponding kinetic energy reduction of between 79% and 100%.

It should be noted that the injury results indicated by the tests with the standard motorcycle were lower than might have been expected. The Norton Commander motorcycle used in these tests was a large touring machine with a full glass-fibre fairing. The design of the Norton fairing provides partial protection to the rider during the critical impact period. It is clear from both observation and test results that the fairing design is an important factor in protecting the rider and therefore needs to be considered seriously by the manufacturer during the design stage.

In summary TRL's airbag tests with the Norton Commander demonstrated:

1 The airbag module, purposely designed and built for the Norton Commander motorcycle, is a novel system for which the computer simulation was successfully used to determine the system parameters. Design, optimisation and manufacture of a system tailored for a specific motorcycle was considered paramount to the success of the system. The process of development starting with computer simulation and proceeding through design, development and evaluation using static fire tests, sled tests and finally full scale tests and aiming for clearly defined performance targets has proved very efficient and effective.

2 The sled test results showed that the airbag system fully restrained the rider with 100% reduction in rider kinetic energy for all test conditions assessed.

3 The sled test results and those of the full scale impact tests analysed to date comply fully with the design and performance criteria defined at the beginning of the programme and thus confirm the successful performance of the airbag system to date.

4 Full-scale impact test results analysed to date indicate that the dummy has been successfully arrested by the airbag. Rider forward velocities are greatly reduced with a corresponding reduction in kinetic energy of between 79% and 100%.

5 All of the neck results for airbag tests reported in TRL's study were significantly less than the tolerance values, and the majority were low compared to those recorded in standard tests. They show considerable improvements over previous airbag research, which commented adversely on the potential for increased neck injuries.

6 The TRL full scale impact test data and the motorcycle rough ride and misuse results, indicate that a fire time is possible within the limits imposed by the requirements for total airbag deployment time. Full mapping of sensor operation at threshold impact speeds in different configurations will be required to develop a commercial system.

7 ISO DIS 13232 defines a system of calculating the normalised in jury costs for a range of seven impact pairs. This method was applied to the five pairs of ISO tests in the programme and the results showed that the airbag system reduced these costs by over 80%: a further indication of the success of the system.

Figure 12 Impact at 90° without and with the TRL/Lotus Engineering airbag system

3.3.2.3 An airbag system for a Honda Gold Wing: Honda project

A similar study by Iijima of Honda Research (Iijima *et al*., 1998), of airbags mounted in a large touring motorcycle, Honda Gold Wing, demonstrated that the airbag was beneficial in four cases, harmful in two cases and had little or no effect in three cases.

Iijima *et al*. (1998) showed the benefits of an airbag and risk by body region in terms of average change of AIS (Abbreviated Injury Scale) across all the impact test configurations and for the entire impact sequence. The main benefits and risks demonstrated were to the head and neck. For the head, and for these impact configurations, the injury benefits were much larger than the injury risks; whereas for the neck, the injury risks were greater – although overall there was still a net benefit. When considering this result it should be borne in mind that the Hybrid III MATD dummy neck is substantially stiffer in flexion and extension than a human neck, so that the study probably over estimated the true risk for the neck and underestimated the benefit to the head. A stiff neck will indicate greater neck strain and hence injuries than one that is correct. Conversely a stiff neck will reduce the head contact velocity and hence acceleration for a given impact test, especially if the chest is restrained before the head contact is achieved. Thus, the benefit of the airbag will be underestimated.

Iijima's study also showed the total average injury benefit and risk in terms of average change in normalised injury costs across all test pairs and accounting for frequency of occurrence of these impact configurations in accidents. The results indicated that the injury benefits were very much greater than the injury risks. This is an encouraging result for a device that was described as an exploratory study.

Iijima completed an impact to the front of a stationery car (impact configuration 115-0/30) with the dummy leaned 45 degrees forward to investigate airbag-to-dummy contact effects in this riding position. This test indicated that there was no significant difference in the injury outcome compared with the test in the normal riding position because even though the dummy neck extension and moment increased this was not sufficient to indicate a difference in injury potential.

The overall average positive and negative changes, i.e. injury benefits and risks in terms of Normalised Injury costs, for the 200 simulations taking into account frequency of occurrence for the primary impact period indicated an injury benefit during the primary impact.

Overall, then, these initial results are encouraging, and it indicates that with further research a fully-practical and affordable safety device could be developed that will reduce injuries to motorcycle-users, especially head and chest injuries.

3.3.3 Leg protecting devices

3.3.3.1 Crash bars

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-for example a fairing designed to prevent intrusion into the spaces normally occupied by the rider's legs.

Importantly, Craig *et al.* (1983) observed that 'crash bars' (tube protective devices) were fitted to 21% 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'.

However, in the same study the authors warned that 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.

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

In a more recent study, Ouellet (1987) investigated 131 crashes involving crashbar equipped motorcycles. He agreed with the conclusions of Craig *et al.* (1983) and stated that leg protection devices may have the ability to affect favourably those serious leg injuries, which result from direct crushing of the rider's leg against the side of the motorcycle during impact. Nairn (1993) contended that the severity of leg injuries would be reduced in approximately 50% of the crashes which involved serious leg injury if leg protection were to be fitted.

There is considerable concern that structures to provide leg protection may increase overall rider injuries by increasing head and chest impact loads (Ouellet, 1990). However, Otte (1998) showed that a fairing can protect the legs without these problems (Section 2.3.8).

It can be seen from the statistics reported in Section 2 that certain accident groups show a greater probability of leg injuries than others. These are accidents in which the force is directed into the motorcyclist's leg. Here the direction of the force against the motorcyclist's leg is more important than the direction of the force against the motor cycle. The most severe injuries result from the direct force loading, and injuries to the lower extremities caused by contacts during the flight phase are only of secondary importance.

3.3.3.2 Specially designed leg-protecting fairings

Experimental testing to study different kinds of leg protection have been conducted since the 1970s, and this is fully reported in the EEVC report 1993, and summarised as follows:

TRL (Chinn, 1984; Chinn and Macaulay, 1986; Chinn *et al.*, 1989; Chinn and Hopes, 1985) tested one design of leg protector in 36 full-scale impact tests with three different models of motorcycle. The detailed design of the protection was varied for each model, but the underlying principles were the same in each case, with an energy-absorbing component on each side of the bike. This was placed well in front of the rider's legs and attached strongly to the frame, but with a facility to break away at very high forces, and had a softer knee pad immediately in front of the knees. When compared with a standard machine the tests showed a benefit from leg protection in 61% of cases, no effect in 28% and a detriment in only 11%. Overall, this study concluded that properly designed leg protection could have substantial benefits.

In contrast to this, a study by the International Motorcycle Manufacturers Association (IMMA) carried out 34 full-scale tests, again using three different models of motorcycle. Here too the leg protectors differed somewhat for each machine, but were essentially similar in design. This design contained the energy absorbing and knee protection elements found in the protectors of the first study, but the whole device was considerably more massive and had a blunter profile. Interestingly, these tests used specially-developed dummies with frangible legs. In the latest series of tests, measurements of head accelerations and leg bone breakage were expressed in an overall analysis relating the injury potential to a cost to society. The conclusions were that out of 8 pairs of tests the leg protection was beneficial in 3 pairs and detrimental in 5 pairs. Overall, the study concluded that leg protection increased the net risk of head and leg injuries. Even so, it is interesting that better results for leg injuries overall were obtained in a later design which was lighter and less blunt than the others.

Subsequent to this report both IMMA and TRL pursued their investigations using methods defined by ISO 13232. In particular the use of a motorcycle anthropometric dummy, based upon a Hybrid III and fitted with frangible legs and on-board instrumentation. The IMMA investigations (Rogers and Zellner, 1998) described tests and analysis of seven test pairs, tests in which the standard Kawasaki GPZ was compared with one fitted with leg protection. The device was found to be beneficial in two cases made no difference in one and was detrimental in four comparisons. Overall the practical tests showed a disadvantage for leg protection.

However, ISO 13232 requires a computer analysis of 200 accident configurations. These results are described by Kebschull *et al*. *(*1998). The results from the simulation of 200 accidents showed that leg protection was potentially harmful in 17% of accidents and potentially beneficial in 26%.

TRL tested the most recent leg protection, fitted to a Kawaski, in two pairs of tests and showed that there were overall substantial benefits. These results from various organisations clearly vary as to the potential benefits of leg protection. However, when considered in conjunction with the evidence from Otte's accident findings, see Section 2, overall the results suggest that with further development leg protection could become greatly beneficial.

3.3.3.3 Special designs of motorcycle

BMW have launched a TWMV, designated the C1, that is a departure from conventional designs. It is based upon a Scooter layout but also has a 'roof' whereby the frame is extended from the rear at the base of the seat base over the rider's head and joins with the front. Figure 13 is a picture of the C1 and shows that it is similar in design to the Quasar, built and sold in the UK in the 1980s but only in very small numbers.

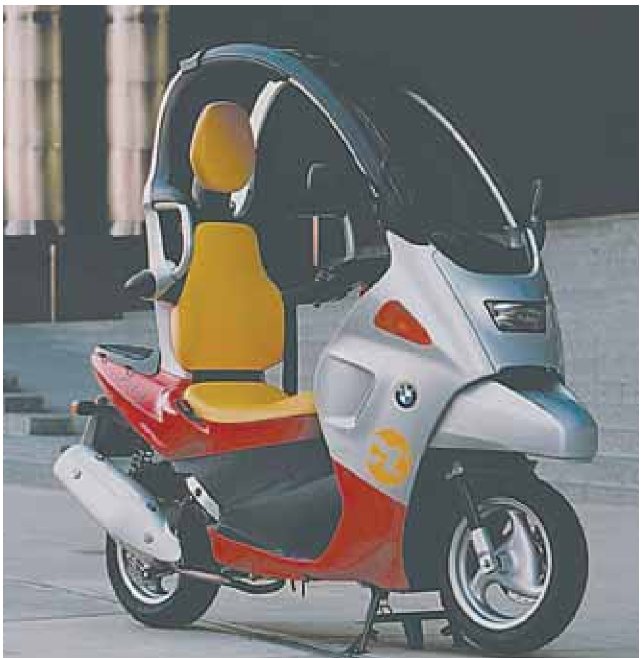


Figure 13 The BMW C1

Figure 14 is a skeletal drawing of the C1 (Kalliske *et al.*, 1998) and shows that the frame of the C1 and the roof are of integral construction. The intention is to provide two wheeler transport with greatly improved safety and improved weather protection. The rider is restrained by the use of seat belts and a tuned crumple zone at the front and is further protected in a roll over by the special frame construction that acts as a roll-bar. The main safety features are:

- Aluminium safety frame with integrated protective roll bars that comply with FMVSS 216 roof crush test.
- Three point lap and diagonal seat belts that comply with ECE-R14.
- Safety seat to prevent ‘submarining’.
- Side bars in the shoulder area to prevent sideways slip and intrusion.
- Deformable energy absorbing front element.
- Front suspension with pitch compensation.
- Tempered safety glass windshield.

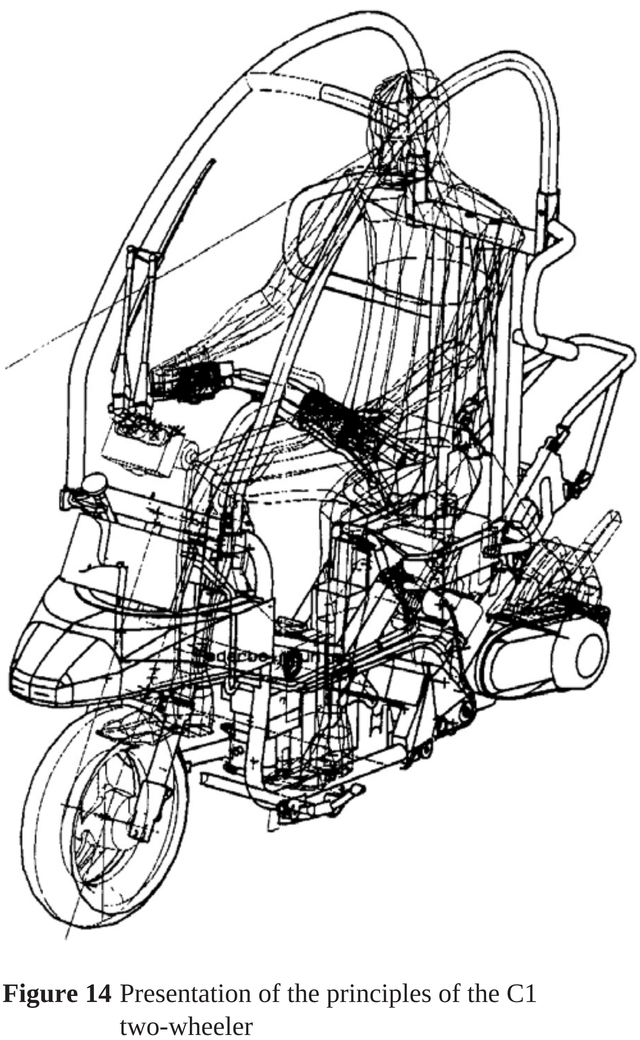


Figure 14 Presentation of the principles of the C1 two-wheeler

Kalliske *et al.* (1998) of BAST have evaluated the performance of the C1 in a series of impact tests and computer simulations. The C1 was evaluated in six impact configurations of which two were in accordance with ISO 13232. Of the remainder, two were impacts into the rear of a car: one into a rigid barrier and the other, a C1 with a pillion, into the side of a car. Specific results are not given but the paper comments that for impacts frontal to the C1, the HIC (Head Injury Criterion) was always well below the human tolerance, the neck momentum was reduced by about 50% compared with measurements from a dummy on a conventional two wheeler and the neck force was similar. The chest and hip strain were higher than for a conventional machine but these were similar to what is expected from a belted occupant and were well below human tolerance levels. Lower extremities, leg forces, were very low and only about 1/12th of the values normally measured for a two-wheeler. Similar results were found for the impacts into the side of the C1 and, although the hip measurements were greater, they were still below recommended tolerance levels. Head contact with the ground did not occur in these tests although it was thought to be possible.

Computer simulation was used to evaluate the HPC (analogous to HIC), head acceleration and GAMBIT (Generalised Acceleration Model for Brain Injury Tolerance) the C1 and a conventional scooter, in all seven ISO configurations. The results, although not quoted, indicated that in all configurations these measurements were very much lower for the C1 than for a conventional scooter. In conclusion BMW AG believe that this type of vehicle is much safer than a conventional two wheeler and will provide future road users with a very convenient and safe form of transport.

3.4 Helmets and protective clothing

3.4.1 Introduction

Apart from a helmet, the clothing worn by motorcyclists varies from only plimsolls and shorts in hot climates to a complete set of clothing, often of leather or wax impregnated cotton material. Standards exist for helmets in most countries, but only in Sweden does a standard exist for motorcyclists’ clothing. This section reviews first helmets and then protective clothing.

The message that helmets are currently effective but could be improved is explained with reference largely to the COST 327 Literature Review on Motorcycle Helmets and Head Injuries 1997. The COST 327 action is over half completed and will provide comprehensive recommendations on how helmets can be improved. This will have been based upon a better understanding of head injury mechanisms from the accident data collected as part of the study and how such knowledge may be used to improve test methods and, in turn, helmet Standards.

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 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. Most motorcyclists, though not moped riders, in Northern

European countries wear protective jackets although it estimated that only about half of these riders wear protective trousers and gloves. Riders in hot countries in Southern European frequently wear only ordinary clothing, including shorts and plimsolls, that offers no protection.

It is interesting to note, as a prelude to the information below, that cost-benefit 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% effective to reach break even point. These calculations were based on police-reported accidents. 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.

The potential for different types of clothing to protect a rider have so far not been clearly identified in a single document. This chapter attempts to rectify this by bringing together the available knowledge. Injuries which good clothing could protect against are identified and the accident mechanisms described. Different materials and the different types of construction currently used are discussed and the most efficacious of these are identified and described. A CEN standard for protective clothing is currently being prepared and it is hoped that this will cater for the main requirements outlined here.

3.4.2 Helmets

3.4.2.1 Current helmets: reported benefits and problems

The following are extracts from the COST 327 Literature review and serve as a guide to the current situation.

There has been much studied and written on the effect of helmet law repeal and reinstatement in various States in the USA. However, as noted by de Wolf (1986), this type of study evaluates the effect of the repeal of helmet use laws on (in this instance) the motorcycle fatality rate. It does not evaluate the effectiveness of motorcycle safety helmets because there is no direct comparison between helmeted and unhelmeted riders. This is largely true of all such studies and for that reason they are not discussed here except to say that in almost all cases of repeal the incidence of head injury, fatal and otherwise, increased.

Hurt *et al.* (1981) surveyed over 900 injured motorcycle riders, of which 60% were non-helmet wearers and 40% helmet wearers. The analysis of injuries at the critical to fatal threshold, showed that 3.5% of helmeted riders were above this threshold, compared with 8.2% above this threshold for the non-wearers. It can be concluded from this that the risk of death is more than halved if a helmet is worn. In his conclusions Hurt states that ‘helmeted riders and passengers showed significantly lower head and neck injury for all types of injury at all levels of severity’.

Otte *et al.* (1984) studied 272 motorcyclists injured in road accidents around the Hanover area. Non-helmeted riders accounted for 72.5% of the total injuries and yet this group were outnumbered (by how many is not stated) by the helmet wearers. Overall (including figures from a previous study) Otte *et al.* claim that 70% of non-helmeted riders suffer head injuries whereas only 45% of helmeted riders sustain head injuries.

3.4.2.2 Open versus full face helmets

For some years there has been an increasing tendency for riders to wear a full-face (integral) helmet rather than an open face (Jet) helmet, largely in the belief that greater protection is afforded by the full-face helmet. However, a full-face helmet is heavier, and it may also increase the tendency for the visor to mist over. It is particularly important that the benefits of open-faced helmets are quantified because these are more likely to be worn by moped riders.

Otte and Felten (1991) analysed 598 accidents in which a full-face helmet had been worn and found that the highest percentage of impacts, 34.6%, were in the chin region and that persons who experienced a chin impact were far more likely to have suffered severe head injuries. Otte noted that a frequent side effect of a chin impact is fracture of the base of the skull; Harm’s (1984) analysis shows that skull base fracture is an injury slightly more likely to occur with a full-faced than an open-faced helmet, a finding which is consistent with Otte’s. Overall the risk of facial injury is greatly reduced with a full-faced helmet, but the risk of skull-base fractures may be increased.

However, of more statistical significance is Hurt *et al*. analysis (1981) of 900 motorcycle accidents which shows that the advantage of injury reduction increased significantly with increased helmet use although a full-face helmet offers greater protection without any disadvantage from increased weight.

This study is particularly important because the number of riders wearing a helmet was approximately the same as those not wearing a helmet. In addition, the distribution of open faced and full faced helmet types was such that the results could be compared statistically.

3.4.2.3 Improving helmet protection

Hopes and Chinn (1989) investigated the effect of helmet shell and liner stiffness on the ability of a helmet to protect the head. Helmets made to pass British Standard BS6658 were compared with helmets similar in size and shape, but with liners of different stiffness, ranging from well below to above that of the standard liner: shells with increased stiffness were also tested at stiffnesses 1.5 and 1.8 times that of the standard helmet. All possible combinations were tested. The conclusions were that the stiffer the liner or shell, the higher the peak acceleration and HIC from a given drop height.

The standard helmet was considered to be too stiff and too resilient. For example, when impacted at 6.7m/s the peak resultant acceleration was 305g and the HIC was 3351. A helmet with a standard shell but a lower density liner gave results of 189g and 1825 HIC. The standard helmet does not absorb energy efficiently in an impact of the sort of severity that a rider may be able to survive. At an impact speed of 6.7m/s a HIC of 3351 was measured, and yet only 70% of the energy absorbing capacity of the liner was used. It was not until the impact velocity was raised to 12.5m/s that nearly 100% of the energy absorbing capacity was used, but at this velocity the HIC became nearly 9000, almost certainly unsurvivable. Helmet shells are also too resilient, so that they rebound and thereby increase the total acceleration.

In the same study an experimental helmet was made from an aluminium shell, which had little resilience, and a low-density liner. This was tested at 6.7m/s giving a peak acceleration of 102g and a HIC of 602 compared with the 305g and HIC of 3351 of a standard helmet. This experimental helmet has a greatly superior performance, but the materials would be insufficiently durable for a practical helmet. Nevertheless, it indicates the sort of improvement that might be possible. Gilchrist and Mills (1987) have also studied the effect of materials on helmet efficacy and their conclusions are similar to those of Hopes and Chinn.

Overall, it seems that helmets are too stiff and too resilient. However, while the use of peak acceleration alone as a standard criterion can control the stiffness of a helmet, it cannot ensure that the helmet absorbs energy efficiently, and the use of a time-dependent criteria such as HIC is essential for this purpose.

3.4.2.4 Helmet standards

That current helmets afford good protection is in no doubt, but it is clear that there is much room for improvement and the route is through improved standards. Efficient energy absorption with the optimum impulse, minimum tendency to induce rotational motion and a comprehensive evaluation of the whole helmet including the chin guard of a full face helmet are features for which standards should require tests. Currently only the British Standard 6658 includes tests for rotation and the chin guard.

3.4.3 Protective clothing

3.4.3.1 Injury prevention and reduction

It is essential to understand what protective clothing can and cannot protect against. It is desirable that some indication should be given to prospective purchasers of clothing that will indicate to what extent the clothing will achieve protection as follows:

a Prevention of most laceration and abrasion injuries that occur when a rider slides on the road surface after falling off.

b Prevention of contamination of open fractures by road dirt.

c Reduction in the severity of contusions and fractures, with the prevention of some fractures and joint damage.

d Reduction in the severity (or prevention) of muscle stripping and degloving injuries, particularly to the lower leg and hands.

e Prevention of accidents by maximising the conspicuity of the rider.

f Prevention of accidents by maintaining the rider in good physiological and psychological condition by keeping the rider dry, warm, comfortable and alert.

3.4.3.2 Limitations of the protection offered by clothing

Some accidents involve mechanisms and forces on the body that clothing cannot, so far as is known, significantly mitigate. These include:

a Severe bending, crushing and torsional forces to the lower limbs, which occur in particular when the leg becomes trapped between the motorcycle and another vehicle or the road.

b Massive penetrating injuries on any part of the body.

c High energy impacts on the chest or abdomen causing injuries through shock waves, and severe bending forces such as when the torso strikes an upright post.

Theoretical calculations suggest that the necessary thickness and mass of an effective rib cage or spinal column protector is such that they cannot be incorporated in motorcycle clothing using current technology.

The collation of data from crash damaged suits enables the determination of the strength required by particular areas of garments to remain intact in accidents. Figure 15 shows the areas of abrasion recorded from 20 consecutive suits examined in a study by Woods, (EEVC 1993)

Other evidence supports these findings. 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 and 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 and 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'. 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.

3.4.3.3 Physiological stress and clothing

Stress: Types and reduction

The discomfort caused by physiological stress is important because it can increase the likelihood that a rider might have an accident. It can cause:

a Impaired sensation and thus perception and a reduction in the accuracy of the control of actions.

b Dulled responses and increased reaction times.

c Impaired motor responses.

d Increased fatigue.

Physiological stress occurs when physiological work has to be done to counter the discomfort, when there is a homeostatic physiological response to the changes the physical factors have caused in the body, or when a task is continued to the point when fatigue occurs. Robertson and Porter (1987), who showed that riders suffered the following stresses quantified these problems in a survey:

a 60% reported muscular stress.

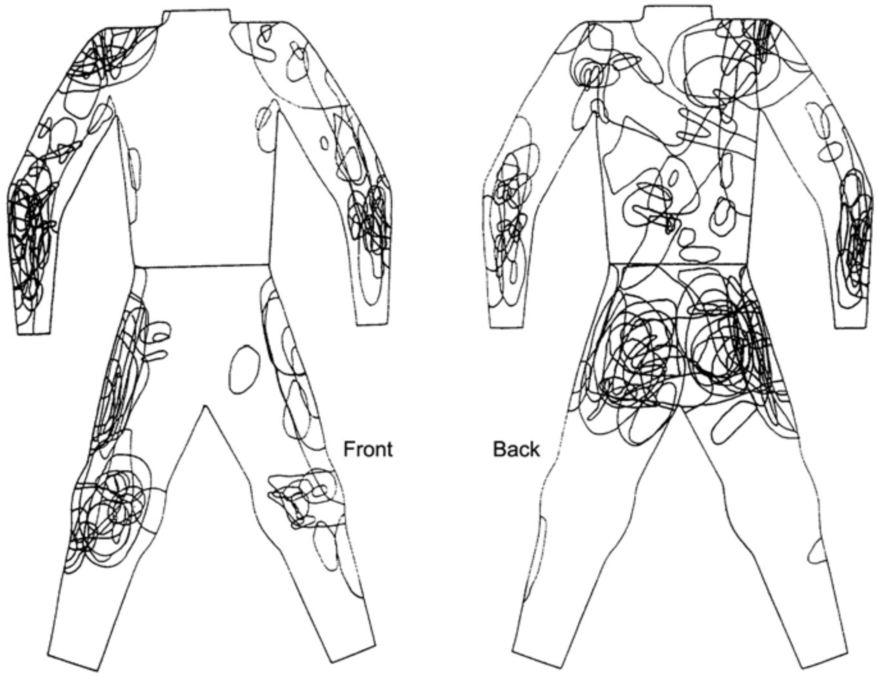
b 33% reported thermal stress.

c 27% reported noise stress.

d 22% reported vibration stress.

The clothing worn can both increase and reduce these problems and therefore correct choice is essential for improved safety.

Source: EEVC, 1993



Reproduced with kind permission of Dr R I Woods (University of Cambridge)

Figure 15 Areas of abrasion damage from 20 accident-damaged leather suits

3.4.3.4 Preventable physiological stress: cold stress

Clothing effectiveness in preventing cold stress is directly related to the thickness of the insulating air layer and the stillness of the air in it. Therefore, clothing should permit neither wind entry nor forced convection to be caused by wind buffeting. The protection needed against cold stress depends on the riding conditions and riding duration. Data is available from measurements on motorcyclists riding at motorway speeds (around 110km/h) in the UK (Woods, 1983, 1986).

A third of the basal heat production of riders can be lost from the neck and face if they are not adequately protected in cold conditions. Except for the nose, around the eyes and where the helmet is a close fit, all the skin should be covered with at least 10mm of insulation contained within a completely windproof cover (Woods 1982). To provide adequate protection the lower edges of the garment must be inside the body oversuit and should be designed to allow the head to turn fully for traffic observation.

The hands are kept warm by blood flowing to them, and the bloodflow is halted either by nervous control from the brain if the whole body becomes cold, or by a local response if the hands themselves become cold. For the hands to remain warm the body must be at or above normal temperature, and the insulation over the hands must keep the skin warm (Woods, 1982): under these conditions the hands sweat slightly.

Foot heat supply and blood flow control is similar to that of the hands. The motorcyclist's shins are more subject to cooling than the forearms, which are more active. If the shins become cold, foot blood flow is negligible. Insulation for the feet generally has to be within the impact protective layers of the boots. It is very important that significant pressure is not exerted on the foot or ankle skin as this will also halt bloodflow.

3.4.3.5 Wet stress

Many garments on sale are ineffective at preventing wet stress, though knowledge is available to do this. The most suitable overgarment materials (for example, some polymeric coatings) will provide water vapour permeability when the outer surface is wet. These fabrics are available in high visibility fluorescent colours, which should be used to provide high conspicuity under the poor visibility conditions of wet weather.

3.4.3.6 Vibration and noise stress

Some protection against vibration can be provided in boots and gloves by incorporating gel or foam materials in areas that contact the motorcycle (materials used in industrial clothing for this purpose may be suitable). Clothing should be designed so that it does not flap or vibrate in the airstream created during riding, particularly near the helmet.

3.4.3.7 Heat stress

Little attention has been paid to designing clothing that will minimise heat stress in motorcyclists, but this is important if riders are to be able to wear impact protective clothing in warm conditions, particularly in the south of Europe. Significant progress has been made in the design of military and industrial clothing for use in hot situations, particularly when mechanical and chemical protection are also required. The following points are of relevance to the design of motorcycling clothing:

a It is unlikely that air-conditioned clothing with a pumped cool air supply will be practical for motorcyclists.

b The available cooling mechanisms are the windflow generated by the rider's motion and his sweating mechanism. Potential points for air to enter clothing are those with air pressure on them. These are the forward facing parts of the body such as the torso, wrists, forearms and legs. Air exit points may be placed wherever the internal pressure in the clothing exceeds the external pressure. The air must flow freely over the skin to evaporate sweat.

c Entry and exit points, and permeable or ventilated materials, should not compromise the impact protection offered by the clothing.

d Perforated leather, woven or knitted aramid fibre fabrics without coatings and coated net materials are available that have adequate tensile strength and abrasion resistance.

e Infra-red absorbed and reflectance by the outer layers of clothing are important and particularly so in hot climates where long wavelength rays can be emitted by the road surface. Clothing should be designed to reflect, not absorb, if the rider is to be kept cool.

3.4.3.8 The selection of clothing for particular uses

The selection of single items of clothing and their combined use should be based on the following considerations:

a Clothing must be able to protect against, wet, cold and heat even when these occur for long periods.

b If the hazard is a single event such as a collision the likelihood of it occurring should be assessed. Falls and impacts are common in all types of riding (including off-road) except on motorways. The severity of the collisions is dependent on the surface impacted. However because it is not possible to control where a rider will travel at any one time, the clothing must satisfy all requirements.

c A set of clothing may be bought by a rider from different sources. It is therefore important that advice should be given on compatible items. For example there should not be a gap between boots and trousers. The outermost layer should always be of high conspicuity even in wet weather.

d Clothing should be designed to ensure that all tasks required of a motorcyclist are easily accomplished and in particular movement must not be restricted.

e Riders need a way of knowing the conditions for which an item of clothing is suitable, and with which other items it is compatible.

3.5 Conclusions and recommendations

The main findings from the preceding section can be summarised as:

i Accident studies have shown that the benefits of ABS may not be as extensive as indicated by track tests. However, further research to identify the effects of ABS more clearly should be considered. The sample should contain enough machines with and without ABS to allow reasonable statistical power, and the study designed to take exposure into account.

ii Conspicuity, detection and identification trials by TRL showed that the simplest and most effective aid to day-time and night-time conspicuity is a 55W quartz halogen headlamp. An Austrian accident study showed that day-time use of headlamps reduced the incidence of severe casualties caused by impacts with a car by 35%, thus confirming TRL's research results.

iii Testing of an airbag restraint system fitted to a Norton Commander motorcycle, found that the results of the sled and full scale impact tests showed a kinetic energy reduction of between 79% and 100%, as well as low neck-injury measurements compared with tolerance limits. This airbag system reduced injury costs by over 80%: a further indication of the potential benefit of such a system. Another set of tests on a motorcycle airbag restraint system also indicated that the injury benefits were very much greater than the injury risks.

iv Accident statistics show that certain accident groups show a greater probability of leg injuries than others. Leg protection studies have shown that such devices can protect the legs in accidents but sometimes there are disadvantages for other body regions. Overall, it appears likely that satisfactory leg protection could be developed with further research.

v BMW AG have launched a radically designed two-wheeler, which incorporates a safety frame around the rider, three-point seatbelt, side bars, an energy-absorbing front, improved suspension and a safety glass windshield. BMW has shown in testing that this type of vehicle is considerably safer than conventional two-wheelers and may provide users with a safer type of two-wheeled transport.

vi Research has shown that wearing a helmet reduces the risk of death in an accident by about half. However, there is considerable scope for the improvement of helmet safety. Research has found that present helmets are too stiff and too resilient, with the maximum energy absorption of the liner occurring at high impact velocities where the probability of death is high. Helmet shells and liners should be less stiff in order to provide maximum energy absorption at lower, more prevalent, impact velocities where the benefit of a wearing a helmet can be more effectively realised.

vii A CEN Standard has been issued that specifies the requirements for body protectors when used inside protective clothing. Generally, clothing and footwear worn should protect the rider from environmental stresses, as well as providing adequate protection in the event of an accident. It is important that the clothing is of sufficient thickness to prevent burns and abrasions, especially to the lower extremities and on areas that are likely to contact other surfaces during an accident (e.g. elbows and knees). The clothing worn should maximise rider physiological comfort, conspicuity and safety.

Recommendations for research: Vehicle factors and protective equipment:

Braking systems

More research is needed on the effectiveness of antilock braking systems and other systems such as combined brakes, as a way of reducing motorcycle accidents. The

DETR on-the-spot study could, if suitably supported, collect useful data here, since it aims to collect exposure data as well as information about the accident.

Motorcycle and rider conspicuity

Further research on motorcycle conspicuity should be undertaken to find whether modern technology allows night-time conspicuity to be improved. Coloured headlamps for motorcycles, and the consequences of fitting cars, but not motorcycles, with dim-dip headlamps, should be assessed as part of this work. The possibility of improving on the benefits of using headlamps in daytime should also be considered. Rider attitudes towards conspicuity devices should be included in the attitude study described in Section 5.8 with a view to finding ways of improving rider acceptance.

Interventions to improve car drivers' visual search skills should be dealt with under recommendation 'Car drivers' knowledge and attitudes' in Section 5.8.

Airbags

In view of the very encouraging results from TRL and Japanese studies, development of motorcycle airbag systems should continue. One way of encouraging this would be through the development of impact test procedures for motorcycles – see item below. Rider attitudes towards airbag systems should be included in the attitude survey proposed in Section 5.8.

Leg protectors

In view of the encouraging results from research by TRL and other organisations, motorcycle leg protection systems should be further developed. Again, development and adoption of a motorcycle impact test procedure would encourage this. Rider attitudes towards and beliefs about leg protection systems should be included in the attitude survey proposed in Section 5.8.

Accident study results showing that current fairings are effective at reducing leg injuries should be further evaluated, and further research carried out if necessary, with a view to identifying the critical design parameters, encouraging 'best practice' in fairing design, and publicising the advantages of faired motorcycles.

Impact testing

A motorcycle impact test procedure, and an assessment programme (NMAP?) similar to the NCAP programme should be developed and adopted. Impact test criteria would be based on loads applied to a dummy rider, leaving the method of satisfying these criteria to the manufacturer. Criteria could be based on those already shown to be achievable – e.g. by leg protectors and airbags. The BMW C1 motorcycle would be expected to demonstrate that it is possible to achieve reasonably good NMAP ratings.

Helmets

Work should continue on the development of helmet standards, to improve energy absorbing capacity, minimise induced rotational motion, and improve the evaluation of the complete helmet including chin-guard.

Protective clothing

Improved design and wider use of protective clothing could make a significant contribution to reducing the severity of motorcycle casualties. Further work should be undertaken to develop and test protective clothing, and finding ways of improving voluntary use.

4 Road environment factors

4.1 Introduction

As shown in the previous sections, the mechanisms for motorcycle accidents and motorcyclist injuries are very different from those that apply to other road users; this difference is no less apparent in the interaction of the motorcyclist and the road environment. Indeed some features, such as crash barriers, which are designed to improve safety for two-track vehicles (four wheels or more) are potentially very disadvantageous for the one-track two-wheeled rider.

This section reviews the problems of particular concern related to the road surface, road markings, traffic signals and crash barriers; in some cases possible solutions and ideas for further research are recommended. The section concludes with a short comment on the findings of an experiment allowing motorcyclists to use bus lanes.

4.2 Road surface

The following road surface conditions may present a hazard to motorcyclists:

- slippery surfaces;
- repaired patches on the road;
- unevenness;
- road markings;
- longitudinal parallel grooves;
- use of cobbles;
- drain covers and gratings.

Sudden changes in road surface friction which may provoke instability in one-track vehicles can be caused by patches of diesel and oil on the road and in some areas by spillage of grease from standing buses. Instability can also occur when the road has been repaired by the use of bitumen, tar or other smooth sealants (Schweers and Brendicke 1993). Bitumen is a material used frequently in modern road repair and it is used mainly to fill and patch fissures by a process known as over-banding, to repair minor damage, or to seal the edges of a patch repair. Bitumen is normally used in strips parallel and diagonal to the direction of the road and sometimes for more extensive road repairs to which the motorcyclist is particularly vulnerable.

The danger that bitumen causes to motorcycles has been shown by numerous measurements and a series of tests which attempted to determine the physical movements of the vehicle when crossing bitumen compared with crossing tarmac road surfaces (Schweers and Brendicke 1993). Skid resistance measurements showed a much lower value of friction for wet bitumen (m = 0.25) compared with wet tarmac (m = 0.8). In practical terms, the crossing of bitumen causes considerable steering reactions, both when riding in a leaning attitude and when braking whilst riding upright.

The crossing of wet bitumen whilst leaning leads to the following effects:

- the motorcycle deviates rapidly from the chosen path, in a sideways drifting motion;
- the speed of deviation was determined to be 20º/sec, a value considered to be unsafe, since even very experienced riders rarely exceed 20º/sec on normal roads;
- typical/average riders cannot respond to such rapid unexpected movements of the motorcycle, and tend to slide either into the opposing lane or possibly into roadside furniture.

The process of braking when crossing bitumen results in:

- for an emergency stop from 50km/h, the stopping distance on wet bitumen is more than double the distance on wet tarmac;
- a patch of bitumen 0.5 m wide can increase the stopping distance of a motorcycle equipped with ABS (speed approx. 60km/h) by more than 20%. This because the ABS adjusts to the very slippery conditions and then cannot react sufficiently quickly to restore the adjustment to what is appropriate to the conventional surface to prevent the extended distance;
- a patch of bitumen 1m wide can increase the stopping distance by 45% (same conditions);
- the danger of locking wheels increases;
- thus the risk of suffering an accident or a collision is substantially increased.

Consequently, extensive repair work using a plain bitumen surface should be avoided and sealing patches should be as small as possible (Schweers and Brendicke 1993).

Parallel longitudinal grooves in the road surface can induce instability and are therefore an additional hazard to motorcycling. So far, this has not been examined scientifically, though the problem is well known to those responsible for roads. Mechanical planing of the surface prior to resurfacing can cause temporary grooving, and in some countries grooves are used to reduce the risk of aquaplaning. In Germany, road sections with grooves are often subjected to speed limits for motorcycles. However, a speed limit imposed on motorcycles alone needs to be considered carefully. Although, the risk of an accident may decrease by limiting the riding speed, the homogeneity of the traffic stream will be disturbed by this partial limit, possibly resulting in an additional risk for motorcyclists.

There is insufficient knowledge of the effects of parallel grooves on motorcycles, and more research is needed to establish whether or not they should be prohibited and appropriate warning signs should be used.

The use of cobbled surfaces should be confined to areas where there is a need for traffic calming and speed reduction, particularly in inner-city areas. However, traffic calming schemes can themselves be unintentionally hazardous to motorcyclists if they are designed with four-wheel vehicles in mind and without due consideration of two wheelers. In particular, changes in surface level and texture need to be clearly visible. Warning signs should be installed to warn of changed surfaces and of road humps or ‘sleeping policemen’, so that motorcyclists know to take particular care when crossing these sections.

4.3 Road markings

Road markings can affect the riding dynamics of motorcycles considerably, depending on the quality of the markings and the weather conditions. Poorly designed or located markings can cause wobbling, ‘crabbing’ whereby the motorcycle longitudinal axis is at an angle to the direction of travel. Surface water results in a loss of road grip (Weidele and Breuer 1989). It is especially this loss of adhesion between the tyres and the road that causes problems for motorcycle riders. Thus the potential leaning angle of approximately 45°at a velocity of 40km/h in good weather and road conditions is reduced to 40° when crossing dry markings, and may deteriorate to as little as 25° when crossing wet road markings. In addition to that, the stopping distance doubles on wet road markings compared with that on dry unmarked roadways (tarmac).

The crossing of profiled road markings causes strong steering impulses leading to deviations from the nominal track of about 100mm. In addition to this, profiled road markings cause one-track vehicles to weave, and at high speed they can even induce sustained weaving with little or no attenuation.

Surface water may be retained by profiled markings, causing loss of adhesion or even aquaplaning. In conjunction with the influence of air resistance this may cause the front wheel to rise, losing friction between the front tyre and the road.

For two-wheelers, each of the above factors increases the risk of an accident or a collision (Koch 1989, Institut fur Zweiradsicherheit 1988, Paulmann and Breuer, not dated). Giving thought to the problems that wet road markings can cause for motorcycles when designing road signs can reduce these risks:

- In wet conditions, marking foils cause a considerable reduction in road adhesion, and should be used rarely. The respective road sections can be equipped with warning roadside signs to replace the foils. Extensive road markings should be incorporated into the surrounding road surface in order to reduce the potential for an abrupt change in friction. Abrasion or grinding off of thick road markings should be avoided if it results in a substantial change in friction. Also, thick road markings should be limited to a maximum height of 2mm above the road surface.
- Unmarked zones should interrupt thick continuous line markings to reduce the potential for skidding in wet conditions.
- Profiled markings should be no more than 7 mm above the road surface.

- Metal road studs should be positioned with unequal gaps to prevent motorcycles from weaving.
- Road markings that are known to have a frictional coefficient very different from the surrounding road surface should be renewed.

4.4 Traffic signals

The timings of traffic lights at intersections, junctions and pedestrian crossings are set according to the acceleration and deceleration potential of two-track vehicles (four wheels or more). This is especially true for the time gaps between red and green phases.

Under good road and weather conditions, motorcycle riders are able to decelerate as well as two-track vehicles and have no trouble stopping when a traffic signal changes phase. Under bad road and/or weather conditions, however, the period of time between green and red phases is sometimes too short for one-track vehicles to brake sufficiently sharply without risk.

The problems of deceleration of motorcycles at traffic lights have not yet been examined scientifically and there is a need for further research in this field, especially at isolated traffic lights on country roads. One possible solution may be an appropriate speed limit for all vehicles, as well as the adoption of a realistically achievable phase timing for motorcyclists.

4.5 Crash barriers and fences

The road environment is often overlooked as a motorcycle hazard. In particular, devices such as crash barriers that are fitted to protect road users generally can be harmful to motorcyclists.

Approximately 3.5% 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% of motorcycle fatalities involved crashes with guardrails (Koch and Brendicke, 1988). The injuries reported were generally severe due to the aggressive nature of guardrail design.

Much more recently, Brailly (1998) has studied accidents in France where a motorcyclist had collided with a crash barrier. The results showed that the risk of fatality per accident is five times as great as the national rate for all motorcycle accidents and that collisions with crash barriers account for 8% of all motorcycle fatalities and 13% of fatalities on rural (outside of towns) roads. The report strongly recommends that the use of a shield on barriers. Also recommended is the introduction of a safety zone near the hard shoulder on left-hand bends (right-hand bends for countries driving on the left) with a radius of less than 250m. A wider section for the hard shoulder on the right of right hand bends (left of left hand bends GB) should also be introduced before the protective barrier in the centre. The shield may reduce the fatalities by up to a half.

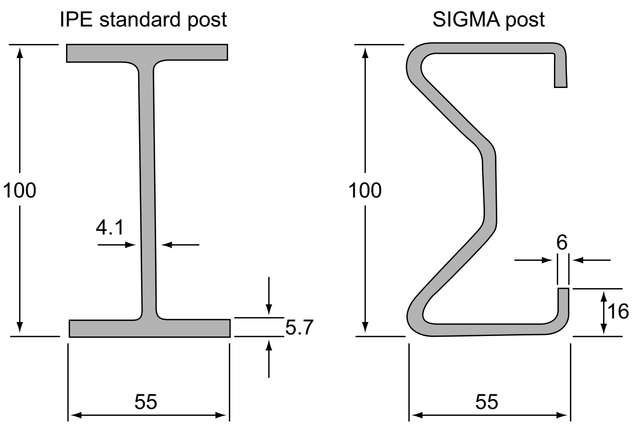
Experimental designs that utilise both a lower W-beam and an impact attenuator (made of neoprene that envelops the guardrail post) to protect fallen riders and pillion passengers continue to be examined in France and Germany. Specifically, Dohman (1987) reported that protective devices of these types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

Roadside furniture is frequently a hazard to motorcyclists, nevertheless safety fences or crash barriers are of particular relevance because they provide valuable safety protection in preventing vehicles from crossing into opposing traffic or leaving the road. They work perfectly well for four wheeled vehicles, although they can present a severe hazard to motorcyclists.

An analysis of motorcycle accidents involving crash barriers revealed that 15% of all fatalities are caused by direct impact of the rider’s body against the crash barrier. Domhan (1987) found that, among 50 motorcycle riders who suffered a collision with crash barriers, 3 were killed, 31 were seriously injured and 16 were slightly injured. There are several different designs of barrier and, in general, testing of their effectiveness is limited to four-wheel vehicles. This means that potential problems for two-wheel riders may not be identified. Most safety fences in current use consist of horizontal steel beams (‘tensioned corrugated beams’ or ‘open box beams’) supported on vertical posts. These are designed to break away when impacted by a car or larger vehicle, but there is increasing use of concrete barriers. Wire rope fences are also coming into use.

Possible and effective ways of reducing motorcycle casualties caused by crash barriers are: the dismantling of unnecessary crash barriers; for steel beam fences, the use of so called Sigma posts instead of the standard IPE-100 posts; covering posts with energy-absorbing protectors; and the addition of a second spar.

The most significant feature of Sigma-posts is that they have a considerably less aggressive outline compared with IPE-100-posts (Figure 16), a property which greatly reduces the probability of a serious injury in an impact. The addition of a lower spar prevents direct impact or contact between the motorcycle rider and the post itself. This feature seems to be especially effective where road layout encourages angles of acute lean and high riding speeds and, consequently, high impact speeds against the barrier.



Source: EEVC, 1993

Figure 16 Sigma posts compared with standard posts

Padding of the barrier face with some form of protective padding seems unlikely to be practical or cost-beneficial, but covering the crash barrier support posts with energy-absorbing material can produce a clear reduction of injury severity. Domhan (1987) reports that in comparable accident situations the injury severity could be reduced from AIS = 4 to AIS = 1 or 2 by the use of crash barrier protectors. Domhan also analysed the cost-benefit of equipping German crash barriers with safety features. He examined two possible solutions: the covering of crash barrier posts with energy absorbing material and fixing a second spar to the original crash barrier. Results show that equipping all crash barriers with additional safety features will incur high costs, which are unlikely to be outweighed by the saving in injuries. This is true for both of the above types of safety measure. However, if account is taken of the fact that motorcycle accidents are likely to be concentrated on certain sections of road and the improvements are implemented only at these points then the results of Domhan's study change considerably. It is known that between 20% and 40% of all motorcycle accidents with heavy bodily impacts into a crash barrier are confined to 10% of the crash barrier, typically on bends. If this 10% can be identified and then only this part of the barrier is provided with protective material then the benefit becomes greater than 4 times the cost.

Thus, the reduction in accident costs that can be achieved increases with an increasing accident frequency in the given road sections. Domhan also found that although the addition of a lower spar reduced injuries by preventing contact with the post, the addition of energy absorbing protectors provided greater injury reduction, and hence was more cost beneficial, if second spars were added to the original one-beam barrier.

The AIS of a rider impacting a post covered with an energy absorber is approximately half that from equivalent impacts into an uncovered post. The case for cushioning posts should be examined for conditions existing in other countries to determine whether or not it is worth doing elsewhere.

The effects on motorcycle safety of concrete or wire rope safety fences or barriers do not seem to have been studied. The concrete barriers seem likely to spread the load on a rider more widely than with either a steel beam or several wire ropes, but the concrete is less yielding and the wire ropes more yielding than the beam. Although the major benefit of safety fences stems from the containment of four-wheel vehicles, the implications of the different designs for motorcyclists deserve more attention.

4.6 Motorcycle use of bus lanes

Motorcyclists were allowed to use most bus lanes in Bristol from June 1995. TRL were asked to survey five sites on the bus lanes to assess the potential problems and benefits. Video cameras were used and the total survey time was 72 hours.

The results of this TRL survey are unpublished. However, it was found that a substantial majority of motorcyclists used the bus lanes on three of the five sites. The conclusion of the survey was that motorcyclists preferred bus lanes to general traffic lanes, except where they were approaching the end of a bus lane, or where they needed to be in one of the outer lanes to be correctly positioned at the next junction. Accidents were also studied and in the three year 'before' period there were 40 motorcycle injury accidents. In the six-month 'after' period there were 6 motorcycle accidents of which only two were on roads covered by the study; thus statistical conclusions were not possible.

This is an interesting venture and has the potential to increase motorcycle traffic flow and simultaneously reduce the accident rate.

4.7 Conclusions and recommendations

It has been shown that:

i When wet, bitumen has a low coefficient of friction and can therefore cause motorcycles to become unstable. Bitumen is frequently used to repair cracks and other damage to roads.

ii Parallel longitudinal grooves in the road surface can also induce instability and are therefore an additional hazard to motorcycling. However, there is insufficient knowledge of the effects of parallel grooves on motorcycles and more research is needed to establish whether they should be prohibited. Moreover, a satisfactory alternative should be sought.

iii In wet conditions, some road markings, in the UK and in other European countries cause a considerable reduction in road adhesion. Abrading or grinding away of thick road markings should be avoided if it results in a substantial change in friction. Unmarked zones should interrupt thick continuous line markings to reduce the potential for skidding in wet conditions. Metal road studs should be positioned with unequal gaps to prevent motorcycles from weaving.

iv Motorcyclists are much more at risk of injury in accident if a barrier is struck. A recent French study (1998) showed that, in such cases, the risk of fatality per accident is five times as great as the national rate for all motorcycle accidents and that collisions with barriers account for 8% of all motorcycle fatalities and 13% of fatalities on rural roads. Solutions proposed were the use of a shield on barriers and the introduction of a safety zone near the hard shoulder on left-hand bends (right-hand bends for countries driving on the left) with a radius of less than 250 metres. Similar accident problems have been identified in Germany and the solution, now implemented, is for a different design of post and for the post to be covered with an energy absorbing material.

v The effects on motorcycle safety of concrete barriers and wire rope fences have not been studied and neither has the problem of conventional barriers been studied in the UK.

vi Traffic signal phasing may not account for the problems of motorcycle stability during braking and accelerating in the wet. Motorcyclists maybe unable to maintain their position in the traffic flow and this needs to be investigated.

Recommendations for research: Road environment factors

Traffic lights

There have been suggestions that the time between green and red phases is sometimes too short to allow motorcycles to stop safely in wet weather without risking wheel lock. This may force motorcyclists either to put themselves in a situation where they may have to jump a red light, or to slow down in anticipation of a lights change, resulting in conflicts with cars that do not need to slow. In other words, traffic light phasing may require motorcyclists to accelerate and brake out of phase with other traffic, increasing the potential for accidents. Further research is needed into the severity of this problem.

Road surfaces

If further information is required on the importance of diesel spills before remedial action can be justified, then research should be undertaken to collect this information. The self-reported accident study described in Section 5.8 should be useful here, as should the on-the-spot accident study mentioned in the same Section.

Likewise, further information on the importance of road markings as a contributor to accidents is probably needed, and the above studies could again provide useful information.

Crash barriers

Research is needed on the effects of wire rope fences and conventional crash barriers on motorcycle safety. Concrete crash barriers may need to be investigated too, if they are to be used more in this country.

Bus lanes

As stated in Section 4.6 the current trial use of bus lanes by motorcycles should be continued/expanded until adequate data are obtained to evaluate its effectiveness.

5 The rider

Section 2 of this report looked at the statistics of motorcycling accidents and casualties, and how these vary by age, engine size, type of road, exposure, and so on. This section reviews studies of the human element in the man-machine-environment system that have attempted to gain an understanding of the mechanisms that influence the accident involvement of motorcyclists.

As well as studies of on-road behaviour, there have been many investigations of ‘internal’ aspects such as risk and hazard perception, attitudes and opinions, and motivational factors, as well as a number of recent attempts to model the attitude-behaviour relationships. These topics will be considered in turn.

5.1 Rider behaviour

5.1.1 Speed

Research into motorcyclists’ speeding behaviour has shown that excessive speed is a frequent behavioural trait (Hurdle, 1997). Mannering and Grodsky (1995) reported that 70% of a sample of 1,373 U.S. motorcyclists reported riding at over 100mph on public roads, with nearly 40% of these riders looking forward to doing so again. In addition, 80% reported riding over the speed limit when not fearing detection. Carroll and Waller (1980) found that speed appears to be a major factor in motorcycle accidents, and compared to crash involved cars, motorcycle crashes occur at higher speeds. Statistics from Germany (StBA, 1995) also indicate that the main reason for accident involvement for both older and younger riders is speeding. Not surprisingly riders of motorcycles with larger engines and ‘racing design’ motorcycles appear to speed more than riders of motorcycles with smaller engines and street design motorcycles (Kraus *et al*., 1992). Wells (1986) has shown that it was not necessarily breaking the speed limit but also riding too fast for the prevailing conditions which was associated with motorcyclists’ accidents at road junctions. Younger riders have been found more likely to speed than older riders (Kraus *et al*., 1992).

5.1.2 Close following

Thomson (1982) reviewed Australian motorcycle accidents and found that, compared to car drivers, motorcyclists made more errors in close following, both in day and night-time conditions. However, statistics from Germany (StBA, 1995) showed that close following as a factor in accidents was less pronounced among motorcycle riders than drivers of cars. However, the German statistics show that, when the motorcycle rider was at fault, close following accounts for more accidents than did right of way violations and drink-riding. According to the German statistics accidents due to close following appeared to be more pronounced among younger riders when relative accident frequencies per 10,000 vehicles are used.

5.1.3 Overtaking

Statistics from Germany (StBA, 1995) show that the proportion of accidents related to overtaking is higher for motorcyclists than for car drivers. Overtaking accidents are also more pronounced among younger (18-25 years of age) compared to older (>25 years of age) motorcyclists. These findings suggest that overtaking behaviour should also be targeted in road safety countermeasures for motorcyclists.

5.1.4 Conspicuity devices and protective clothing

Countermeasures to increase motorcyclist and motorcycle conspicuity are bright/reflective clothing, or clothing with reflective patches, high visibility helmets and daytime riding lights. A number of studies from a decade or more ago provide information on the level of usage of such measures-though it should be noted that changes in availability, fashion, economics and rider awareness of the benefits may have changed the situation substantially since then. Gosnell (1990) found in a survey conducted in Britain that only 36% of riders stated that they wore reflective or fluorescent clothing when riding. Those who did use reflective clothing were more likely to be older rather than younger riders. It was found that 47% of riders over 35 years reported wearing reflective clothing. Ravinder (1988) found in an Australian survey that riders tended to prefer dark jackets with 56% of riders in his sample reporting wearing black jackets and 14% reporting wearing blue jackets. Less than 6% of the sample reported wearing bright coloured jackets, such as yellow.

With regard to helmets, Youngblood (1980) found that next to white, the most popular colours for motorcyclists in the United States were red, blue, and black, comprising a 42% grouping of low visibility colours. In addition, 59% of riders said that their helmet displayed no reflective material. Of those who had reflective material on their helmets, 24% had it on the back and sides, 12% had it on the back only and 5% had it on the sides only. Youngblood suggested that conspicuity advocates should take note of these findings.

It would appear, however, that riders are (or, at least, were) more likely to use daytime riding lights. Gosnell (1990) reported that 61% of riders stated they used daytime riding lights and this was found to be most pronounced in high mileage riders, older riders (35 years +) and riders of larger machines. Similar results from Ravinder (1988) showed that 62% of riders mentioned that they used daytime riding lights, with less experienced riders being more likely to use daytime lights than more experienced riders.

A study by Walters (1982) provided some insight into the use of protective clothing. The study found that 35% of riders could be classified as using a motorcycle for practical reasons, 48% could be classified as those who were enthusiasts and rode for pleasure and 10% could be classified as irresponsible and whose behaviour was considered by others to be immature and irresponsible. It was found that rider ‘enthusiasts’ were more likely to report the use of protective clothing than were ‘practical’ and ‘irresponsible’ riders.

5.1.5 Behaviour at road junctions

Wells (1986) observed 651 motorcyclists’ behaviour at five different types of junction: crossroads with and without traffic lights, T-junctions with and without traffic lights, and roundabouts. It was found that fewer faults associated with making rear observations occurred at crossroad junctions with traffic lights, than at crossroad junctions without traffic lights. Fewer riders also made signalling and speed faults (inappropriate signalling or not signalling; travelling too fast for the conditions) at junctions with traffic lights than at those without traffic lights. Rear observation and signalling faults were the most frequent behaviours at both types of crossroad junction. A somewhat less frequent fault was concerned with the ‘safety gap’. Faults in this category were largely due to motorcyclists’ squeezing through between two lanes of traffic. There was more opportunity to do this at junctions with traffic lights because of the greater likelihood of stationary traffic.

At T-junctions and roundabouts, it was found that the most common faults were associated with rear observation, speed and signalling. More faults occurred at T-junctions without traffic lights than at those with traffic lights. However, safety gap faults were judged serious or more dangerous when the junction had no traffic lights. ‘Lane swap’ faults were more common on approaches to roundabouts than they were on approaches to traffic lights (changes from lane one to the other which are usually made by the rider to move up through a line of moving traffic, but could also be due to motorcycle riders being unsure of the appropriate lane for their manoeuvre at a roundabout).

For all types of manoeuvre (right and left hand turns and going straight on), rear observation, signalling, road positioning and speed were common problems. However, if the motorcyclist was going straight on, faults of rear observation and signalling were less common. This was attributed to the lower need for signalling and rear observation when going straight on over a junction. Signalling faults when turning were usually due to the appropriate signal being omitted. A small number of faults were due to signalling too late. Most of the faults when going straight on were due to rapid deceleration without giving a necessary arm signal to following traffic. Speed faults and faults of road positioning were more common when the motorcyclists were going straight on than when they were turning left or right.

One problem with this study was that the criterion for rear observation faults was absence of observable head turning movements. Many motorcyclists use their mirrors when looking behind them and, therefore, it may have been difficult to observed whether they had correctly made rear observations. Although many riders were observed moving their heads to look behind them (on motorcycles without mirrors) and a few others were positively identified as having used their mirrors, those who had mirrors and were not judged to have used them may nevertheless have had reasonably good observation of following traffic.

Unpublished research conducted by TRL has examined motorcyclists’ exposure to accident risk and identified the aspects of behaviour which lead to accidents at road junctions using the STATS19 database supplemented by site studies using video recording data. They acquired data on corner cutting and weaving through traffic of 417 motorcycles involved in ‘interactions’. These were defined as ‘a situation involving a motorcycle and at least one other vehicle or pedestrian in which a collision would probably have occurred if any of the road users concerned had not seen each other and subsequently altered their normal course in the road’. Interactions involving corner cutting were common at unclassified T-junctions, where traffic flows were low. The amount of weaving observed was lower, with only 18% of motorcyclists being involved in a weaving interaction. In addition, it was found that there were more interactions when motorcyclists turned right as opposed to turning left or going straight on and this pattern reflected two-wheeler accidents recorded in the national statistics. Very few interactions were observed when the motorcyclists were turning left or going straight on. A measure was developed of accidents per million traverses of a junction to assess the risk to two-wheelers (these included both powered two wheelers and bicycles). A higher accident rate was found for roundabouts than for T-junctions when using both the study data and national data. In addition, the rate of severe accidents was higher at roundabouts than at T-junctions.

5.1.6 Impairment through stress

Responses to ‘stressors’ involve the whole body. Physiological changes are part of this response, and psychological and behavioural changes may also occur. For example, the discomfort felt by physiological stress can increase accident risk because it can dull responses and increase reaction times, impair motor responses, increase fatigue and impair perception. Robertson and Porter (1987) found that 60% of motorcycle riders reported muscular stress, 33% thermal stress, 27% noise stress, and 22% vibration stress. Stressors causing these types of stress reactions can be reduced by rider clothing. For example, protection from vibration may be offered by boots and gloves with foam materials in areas, which are in contact with the motorcycle, and cold stress can be reduced by insulated clothing.

Little is known about the effects of stress on specific rider behaviours. However, theory indicates that the effects of stress may be quite different for different individuals. This is in line with a ‘transactional’ approach to stress, in which stress is seen as a condition that results when person-environment ‘transactions’ lead to a perceived discrepancy between the demands of a situation and the resources available to cope with those demands (Lazarus, 1966; Folkman and Lazarus, 1985). Thus, it is not the magnitude of the demands which determines stress, but the perceived demands of the situation together with the perceived ability to cope. Therefore, when faced with the same demands, there may be significant individual differences between people because of differences in the ability to cope.

Research in relation to motorcyclists’ stress is required which, firstly, investigates the environmental and situational cues that evoke stress responses. Secondly, the effects of these cues need to be understood in relation to different individuals with different coping strategies. Thirdly, consideration needs to be given to the behavioural responses and individual coping strategies which are associated with these road-environment stressors. An understanding of these rider-road environment transactions, should assist the development and implementation of suitable countermeasures. These might include better designed road systems which reduce perceived demands, or the development of training schemes which help riders to cope with the perceived demands of on-road situations through the introduction of new coping mechanisms. It is clear, also, that interaction with other traffic can be regarded as a stressor. However, individual components or tasks involved in the traffic situation that may influence perceived demands, and their relation to individual coping strategies, have received little attention.

5.1.7 Impairment through fatigue

It was noted above that stress can increase fatigue. Fatigue has also been associated with squinting of the eyes, heavy helmets (Aldman *et al*., 1977) and long journey times (Travers and Jennings, 1980). Well designed visors and lightweight helmets are possible countermeasures here. Fatigue is also related to drinking and is one aspect of drink-driving that can impair behaviour. A study by Travers and Jennings (1980) investigated the effects of fatigue on motorcyclists’ reaction time and decision making ability. They monitored riders’ pulse rates during a 12 mile route and compared reaction times after the ride with those from a control group. After having completed the 12 mile route, riders had significantly longer reaction times and choice reaction times compared to the control group. A significant association was also found between distance travelled and reaction time. These results indicated that fatigue can cause reaction time and decision-making ability to deteriorate as distance travelled increased. The implication for road safety was that long journeys should be planned to include frequent rests.

5.1.8 Impairment through alcohol

Evidence concerning alcohol-related motorcycling accidents is mixed. Some research has shown that only a minority of motorcycle accidents are alcohol-related (Raeder and Negri, 1969; Newman, 1976; Vaughan, 1976). However, other research has shown that a high proportion of motorcycling accidents are alcohol-related (Williams and Hoffmann, 1979; Lacey and Carroll, 1980; Ouellet *et al*., 1987; Iowa Department of Transportation, 1988; Fell and Nash, 1989; Holubowyez *et al*., 1992; Soderstrom *et al*., 1993). In addition, Masaaki (1989) found that 32% of moped riders and 15% of motorcycle riders, stopped by the police at various checkpoints, were driving under the influence of alcohol. It may be important when deciding which evidence is more valid that under-reporting by the police has been documented (e.g. Baker, 1975). The behavioural manifestation of alcohol impaired riding in the United States was reported by Ouellet *et al*. (1987) who found that motorcycle riders who drank were more prone to operator error, to simply run off the road and to crash at higher speeds. They were less likely to have worn a helmet, and hence more likely to be fatally injured than non-drinking motorcyclists. This is supported by Soderstrom *et al*. (1993) who found that motorcyclists convicted for drinking and driving, compared to those without convictions for drinking and driving, were more likely to also have been convicted for speeding and reckless driving. Motorcycle riders involved in alcohol-related crashes are more likely to be younger and more likely to be male (Williams and Hoffmann, 1979; Lacey and Carroll, 1980; Holubowyez *et al*., 1992; StBA, 1995). Finally, it has been well established that alcohol-related motorcycle accidents occur more frequently at night, at weekends, in rural areas and as single vehicle accidents (Williams and Hoffmann, 1979; Lacey and Carroll, 1980; Holubowyez *et al*., 1992).

It should be noted that the studies cited above come from several countries and cover a long period of time;

none being particularly recent. Their application to the current situation in the UK is therefore unclear. However, given what is known about the effects of alcohol, the demands of motorcycle riding, and the vulnerability of motorcyclists to injury, it is obvious that riders are extremely vulnerable to the effects of alcohol.

5.2 Risk and hazard perception

5.2.1 Risk perception

The literature on motorcycling and risk has mainly been concerned with *objective risk* rather than *perceived risk*, and there are only a limited number of studies relating to the perception of risk in motorcyclists.

Mannering and Grodsky (1995) pointed out the factors that may tend to bias an individual's perception of risk. These were:

- *Unwarranted optimism:* those who are more optimistic of their riding skill and likelihood of accident involvement are more likely to perceive a lower risk.
- *Anchoring bias:* this refers to tendencies to anchor risk estimates around the notion of overall risk based on riding experiences and general knowledge of overall accident risk. Therefore, involvement in training courses or previous accidents may be likely to affect estimates of perceived risk.
- *Availability bias:* this refers to the assessment of risk based upon disproportionate information. As a result, appropriate probabilities of risk may not be assigned to events which have been disproportionately experienced or recalled.
- *Deliberate under-estimates of risk:* this is the tendency to justify risk-taking behaviour by under-estimating risk deliberately.
- *Under-estimate the variance in accident risk:* this is the over-estimation of lower probability events and the under-estimation of higher probability events.

Mannering and Grodsky (1995) used these influencing factors to offer an explanation of their findings from a survey of 1,373 U.S. motorcycle riders ranging in age from 19 to 81 years. They surveyed motorcyclists' perceived likelihood of being involved in an accident in the next 10 years. Three categories of perceived risk of an accident were used: 'low risk', 'medium risk', and 'high risk'. It was found that respondents' mean estimates of annual accident probability was 4%, which was close to the national average annual accident probability per registered motorcycle in the U.S. A variety of individual differences were also found. Firstly, younger riders (<25 years of age) were more likely to perceive their risk as medium or high than were riders aged 40 years and over. Mannering and Grodsky suggested that it was through education programmes or experiences in learning to ride that younger riders had some sense of the dangers they face. Alternatively, they suggested that biases might be playing a role for older riders. For example, older riders may have felt the need to justify their continued involvement in an activity considered by some to be immature, by estimating a lower risk of an accident. It should be noted, of course, that we do not necessarily have to invoke bias as an explanation of age-related variation in perceptual risk since age-related variation in actual risk is well documented.

Secondly, in Mannering and Grodsky's study female riders were less likely to perceive themselves in the high risk category than were male riders. Exposure was also found to affect perceptions of risk. The higher mileage riders perceived a greater likelihood of accident involvement than did lower mileage drivers. It was suggested, therefore, that riders have a reasonable grasp of the exposure factor that can influence accident involvement.

Two experience variables were found to be important indicators of perceived risk. These were years of riding experience and a non-licensed rider indicator. Risk estimates were found to decrease with increasing years of riding experience. It was suggested that this may reflect the perceived value of experience in reducing accident risk, overconfidence in experienced riders, or it may be the result of a bias resulting from a deliberate underestimation of risk to justify the continued involvement in an inherently risky activity. Riders who were non-licensed were more likely to perceive a low risk or a high risk rather than a medium risk.

Riders who reported riding above the speed limit when not fearing detection tended to have a relatively high level of perceived risk. It was suggested that this indicated increased speed as being recognised as risk increasing. Riders who reported often riding between two lanes of cars were also more likely to select the high risk category, which indicated that riders perceive dangers in such activities. Finally, attitudes favouring fast riding were associated with higher perceptions of risk.

Another study by Leaman and Fitch (1986) asked 72 British motorcyclists aged between 17-28 years to estimate the risk of having an accident and the risk of being killed in an accident in the next two years. It was found that riders tended to under-estimate the probability of an accident, but riders who knew someone who had suffered a serious motorcycle accident perceived a higher risk of being involved in an accident themselves than riders who did not. For perceived fatality risk, however, it was found that riders over-estimated the risk compared with the national statistical probability. In addition, perceived fatality risk was directly related to the participants' own yearly accident rate, their total number of accidents, and the knowledge of someone involved in a serious accident. From their results, Leaman and Fitch suggested that prior knowledge of a serious accident is the single most important factor in motorcyclists' perceptions of risk. This is supported by Chesham *et al.* (1992) who surveyed motorcyclists' beliefs and behaviour using the Theory of Reasoned Action and the Health Belief Model and found that the only predictor of perceived risk was whether the rider had known a friend or relative killed in a motorcycling accident.

Other studies related to the perception of risk have come from Germany. One, by Rheinberg *et al.* (1986), interviewed 105 male motorcyclists aged between 18-55 years of age. They were able to differentiate between 'sporty-risky' riding styles and 'defensive' riding styles based upon a factor analysis of various scales on which participants rated their own manner of riding. They found that in comparison with motorcyclists with defensive behaviour, motorcyclists with sporty behaviour tended to give a lower assessment of the general probability of accidents, the probability of having an accident oneself and the probability of serious consequences as a result of an accident.

Another study, by Schulz and Kerwien (1990), used 129 male motorcyclists who were shown videos of 14 traffic situations, which varied according to:

- weather conditions;
- road conditions;
- locations (e.g. town, country, motorway, or mountains);
- times of day;
- having a passenger on the pillion; and
- group riding.

For each of these scenes, participants had to estimate the accident probability and the severity of the resulting consequences. In addition, they were given a pre-determined description of risky behaviour, which they could chose to accept or reject given the various traffic situations. They also had to rate the attractiveness and the perceived dangerousness of this risky behaviour.

The results showed that riders in the younger age group (18-20 years) were less able than older drivers to perceive the situation-imminent dangers in all traffic situations. In addition, in nearly all situations these younger motorcyclists assessed the accident probability as being lower than did the older rider groups. The ratings of the severity of the consequences of an accident were similar for all age groups, with the estimated level of damage being rated as high in each case.

For the dangerousness of the risky behaviour, it was generally found that the 21-25 year old group gave higher assessments. It was suggested that lower dangerousness assessments are sometimes accompanied by an increased feeling of ‘being in control’ which may be rooted in an over-estimation of capabilities.

The attractiveness ratings for risky behaviour showed that younger motorcyclists attributed a higher value to the benefits of dangerous behaviour than did older riders. It was suggested that lower dangerousness assessments and increased attraction for risky behaviour lead to a motorcyclist showing a higher tendency towards risky behaviour in traffic situations. This was supported by the finding that the risky behaviour option was chosen more often by the younger rider group. This greater acceptance of risk by the younger age group was explained by the finding that younger motorcyclists were of the opinion that they are expected to behave in a risky manner by other drivers in their peer group. In other words, the behaviour of younger riders was largely determined by *role expectations*. On the other hand, it was also found that younger riders regarded their own behaviour as a standard for other riders.

Schulz and Kerwien (1990) suggested that these findings provide evidence that acceptance of risk can be traced back to a psychological cost-benefit calculation between attractiveness and dangerousness. In other words, risk acceptance in motorcyclists depends upon the degree of incentive to behave in a risky manner and the degree of estimated danger, with risky traffic behaviour being caused by high positively valued attractions and by too low an assessment of the danger.

5.2.2 Perception of hazards

The finding that the younger riders in the Schulz and Kerwien study were less able to perceive the situation-imminent dangers in various traffic situations than older riders, suggests that there could be much of relevance in the growing literature on hazard perception in car drivers. Traditionally, driver and rider training has tended to pay more attention to control skills than to higher order cognitive skills such as those related to the anticipation, detection and assessment of hazards. Following an early study by Peltz and Krupat (1974), there has been much interest in hazard perception as a predictor of accidents at a theoretical level, but this has received only limited support at an empirical level. However, more recent studies based on relatively large samples have given some evidence of a link between hazard perception skills and accidents (Hull and Christie, 1993; McKenna and Horswill, 1999).

Despite the interest in the topic regarding car drivers, only one instance could be found in the literature of an investigation exploring the hazard perception skills of motorcyclists. This was a recent study by Underwood and Chapman (1998), which compared the hazard perception skills of motorcyclists with those of car drivers, and hypothesised that motorcyclists would have superior hazard detection skills.

The sample consisted of 20 motorcyclists with a mean age of 36 years and 16 years riding experience, 20 car drivers with a mean age of 27 years and 9 years driving experience, and 20 novice car drivers with a mean age of 18 years and 0.16 years driving experience.

Participants watched 13 video clips of traffic scenes on urban, suburban and rural roads. They were instructed to press a button when they identified a potential hazard (anything that would cause the driver or rider to consider performing an evasive manoeuvre such as braking, decelerating or steering away from the hazard to avoid a collision). The fixations on each hazard were measured by using an eye movement tracker. The following measures were taken:

- percentage of hazards identified and reaction times;
- the time to first fixation of the hazard;
- duration of the first fixation;
- number of fixations on the hazard;
- the total gaze on the hazard; and
- the fixation to response interval: this measure provided an estimate of the decision time once attention had been attracted to a hazard.

The three subject groups did not differ on measures of percentage of hazards identified, time to first fixation of the hazard, and total gaze on the hazard.

An effect of road type was found with a marginal effect of driver type for reaction time. Older, experienced drivers responded slower than motorcyclists did when hazards appeared. Hazards in suburban areas were responded to most slowly, followed by hazards in rural areas and then hazards in urban areas.

There was also a significant effect of road type for the duration of the first fixation with a marginal effect of driver type. No interaction was found. Older drivers had had shorter fixation than novice drivers, and rural hazards attracted longer fixation than urban hazards, which in turn attracted longer fixations than suburban hazards.

There was an effect of driver type and road type on the number of fixations on the hazard. Novice drivers made fewer fixations than older drivers and motorcycle riders. Urban hazards attracted fewer fixations than suburban hazards and they in turn attracted fewer fixations than rural hazards.

For the final measure, the estimate of decision (i.e. Interval between fixation and response) there was an effect of road type and an interaction between road type and driver type. Urban hazards required shorter decision times than both suburban and rural hazards, and there were differences between drivers only for suburban roads. Experienced drivers required longer decision intervals than motorcyclists.

The results of this study suggest that motorcyclists have slightly faster reaction times in identifying hazards than car drivers, although there was no difference in the overall percentage of hazards identified. This might be explained by motorcyclists having slightly superior abilities, which come with mastering a less stable vehicle. In other words, the experience of riding a vehicle that places them more at risk of an accident may help motorcyclists to develop faster hazard identification skills. However, motorcyclists may also have slightly faster hazard identification skills owing to factors that caused them to choose to ride a motorcycle. The fact that many of the motorcyclists used in this study had experience of driving a car, while the car drivers had no experience of riding a motorcycle is a further complication when it comes to explaining why motorcyclists were found to have slightly faster reaction times to potential hazards. In this context it is worthy of note that the Taylor and Lockwood (1990) study showed that experience of driving a car had a beneficial effect on the accident liability of motorcyclists. A further explanation of the faster reaction to hazards shown by motorcyclists might have to do with their internalised criterion of what constitutes a potential hazard. Because motorcycles are more difficult than cars to control in an emergency, and because motorcycle riders are much more vulnerable to injury than car drivers, it seems likely that a developing situation on the road will become a potential hazard for a motorcyclist (and require the motorcyclist to consider evasive action) sooner than would be the case for a car driver.

It is surprising that motorcyclists have figured so rarely in studies of hazard perception. It would seem a fruitful area for further research, not just in attempts to gain more insight into the factors that influence accident liability, but also to develop training materials that focus on high order skills.

5.3 Attitudes and opinions

5.3.1 Attitudes towards countermeasures

5.3.1.1 Leg protectors and protective clothing

Research suggests that motorcycle riders tend to have negative attitudes towards the use of leg protectors. A survey of 600 motorcyclists in Great Britain by Gosnell (1990) found that 37% of riders ‘would choose to use leg protectors’ compared to 51% who would not. Of those saying they would use leg protectors most were older riders (25 years +), female riders, and inexperienced motorcyclists with less than 1 years riding experience. Similar results were found when motorcyclists were asked: ‘should all new machines be fitted with leg protectors’. 36% were in favour of all new machines being fitted with leg protectors and 50% were not in favour. Again the older motorcyclist, the female motorcyclist and the inexperienced motorcyclist were more supportive of this measure. However approximately half of the respondents had previously mentioned in the interview that they knew nothing about leg protectors. Therefore, riders may have had misplaced conceptions and not realised the safety benefits. This suggests that if leg protectors were to be considered as an optional or a mandatory safety measure on motorcycles, more information should be made available to motorcyclists regarding their purpose and effectiveness.

Concerning protective clothing, Walters (1982) found that 48% of her sample of 100 motorcyclists could be classified under a category called ‘rider enthusiasts’ who believed that wearing leathers as a means of protection was an acceptable part of maintaining their ‘self-image’. On the other hand, measures such as reflective clothing (see below) were perceived as detracting from their self-image.

5.3.1.2 Conspicuity devices

A study by Ravinder (1988) surveyed 496 active motorcyclists in Sydney, Australia and found 91% of motorcyclists believed that ‘one of the most important aspects of safe riding is to ensure that the motorcyclist is visible’. However they disagreed about the relative usefulness of various conspicuity devices. Most riders (83%) believed that daytime running lights would increase their conspicuity and 85% believed that given the appropriate legislation they would always use daytime running lights. However 40% believed that daytime running lights would decrease the life of the battery. Less experienced riders (0-15 years experience) tended to have more positive attitudes towards the use of daytime running lights than did experienced riders (16-30+ years). About half the riders (49%) agreed that if riders wore reflective clothing it would reduce the number of motorcycle accidents. Younger riders (26-35 years) believed less strongly in the safety value of reflective clothing than did older riders (46-55 years), and 37% did not wear reflective clothing because they believed ‘it does not look good’.

Similar results were reported by Gosnell (1990). It was found that 68% of riders and 80% of riders over 35 years stated that all new machines should be fitted with daytime running lights. However, fewer riders agreed with wearing reflective clothing, with 59% of riders (74% of older riders) stating that all riders should wear reflective clothing.

Hobbs *et al*. (1986) reported different results. More motorcyclists (79%) believed that ‘bikers should wear clothing which makes them easily seen’ than believed that ‘motorcyclists should use their headlights in daylight’ (57%). However, the majority of riders agreed that ‘anyone who doesn’t use a headlamp in wet weather is mad’. In addition, most riders disagreed with the statement that ‘what bikers wear makes no difference to whether drivers of other vehicles see them’. Just over half of riders believed that ‘bikers should not have to make all the efforts to be seen’ and that other road users should also make an effort. Also, it was found that only 15% agreed with the statement, ‘if you ride wearing brightly coloured clothing, others will laugh at you’, suggesting that the majority believed that reflective clothing did not detract from their ‘self-image’.

A study by Walters (1982) found that 35% of the sample of 100 motorcyclists could be classified under a category called ‘practical riders’. Such riders cited lack of conspicuity as a cause of accidents. In addition, 48% of the sample could be classified under a category called ‘rider enthusiasts’ who acknowledged that while reflective clothing was ‘a good thing’, they refused to wear it themselves because it was perceived to be ‘silly’ or because it detracted from the individual’s ‘self-image’. However the use of dipped headlights as a means of conspicuity was perceived to be an acceptable part of maintaining the ‘self-image’ for these riders.

5.3.1.3 Rider training

As mentioned above, Walters (1982) found that 35% of the sample of 100 motorcyclists could be classified under a category called ‘practical riders’. 44% of riders in this category had received formal training and perceived it as being beneficial. Among the riders who had not received any training, there was an appreciation that it would be beneficial and would ‘pinpoint errors in riding which would otherwise go unobserved’. Most were in favour of training courses that would last 10-12 hours. Another 48% of riders could be classified as ‘rider enthusiasts’. 75% of these riders believed that experience is the important factor in developing safe riding behaviour and that it is difficult to teach such safe behaviour through training. Only 16% of these riders had experienced any formal training and many had received informal training from friends and/or relatives. A minority of ‘rider enthusiasts’ believed that training could be useful, but only for the case of the ‘17 year old who is learning to ride and is irresponsible’.

Hobbs *et al*. (1986) presented motorcyclists with a variety of items relating to training and testing in their survey of riders in Great Britain. Contrary to the beliefs of the ‘rider enthusiast’ the majority of riders in their sample disagreed with the statements: ‘The best way to learn how to ride is to fall off’; ‘A true motorcyclist shouldn’t need any bike training’; and ‘bike rider training is a waste of time’. On the other hand, most riders agreed with the statements: ‘Training makes you more aware of danger on the road’ (81%); ‘Training makes bikers safer’ (74%); and ‘Bike training is worth the money’ (65%). It was also found that most motorcyclists believed ‘More training should be available for riders’ (80%) and that ‘The official bike riding test should be tough’ (80%). However, there were mixed beliefs regarding the statements: ‘Official bike tests are a poor measure of a rider’s ability’; ‘You have to be a good rider to get your full licence’; and ‘Training courses for bikers attract less confident riders’.

It was also found that almost all riders agreed that ‘Everyone should know how to control a bike properly before riding on the road’. Most riders believed that ‘All bikers should take a test to show they are safe riders’ (83%) and most also believed that ‘All bikers should have to take some training’ (76%) (which has of course been compulsory for all learner riders since the introduction of CBT). In addition, most riders (78%) agreed that ‘A lot of bikers on the road now would have benefited from training’.

There were significant effects of age on responses to the following six attitude statements. For each statement, younger riders (<19 years of age) expressed less safe responses than older riders:

1 Everyone should know how to control a bike properly before riding on the road.

2 The best way to learn how to ride is to fall off.

3 All bikers should have to take some training.

4 Bike training is worth the money.

5 Training courses for bikers attract less confident riders.

6 A lot of bikers on the road now would have benefited from training.

Hobbs *et al*. (1986) also assessed what motorcycle riders believed should be in a motorcycle training course for novice riders. The results suggest that the development of road safety, motorcycle maintenance and machine control skills are thought of as important. This research was conducted pre-CBT and it would be interesting to assess the attitudes of riders, making age comparisons, post-CBT.

Nolen and Gregersen (1989) report similar results to those found by Hobbs *et al.* They found in a survey of 662 randomly chosen owners of motorcyclists in Great Britain, aged 18-25 years, that 75% had never participated in any form of further training for motorcyclists. Despite this, most had positive attitudes towards the effects of extension courses on road safety. The intention to participate in extension courses was found to decrease with increasing fee. The kind of compensation that was most attractive to motorcyclists was the reduction in insurance for taking a course. Brake training and training in realising danger and risks in traffic were the items which were considered to be of most importance in a training course whilst theory of traffic regulations was considered to have a low priority. In addition, the survey found the following results:

- *Subjective riding skill:* Positive attitudes and intentions towards further training were more pronounced in those with low subjective riding skill.
- *Subjective way of riding:* Positive attitudes and intentions towards further training were more pronounced in those with a subjectively defensive way of riding.

- *Previous participation in extension courses:* Positive attitudes and intentions towards further training were more pronounced in those who previously participated in further riding courses.
- *Opinions on the effects of further training upon accident risk:* Positive attitudes and intentions towards further training were more pronounced in those who believed extension courses result in lower accident risk.
- *Motorcycle competition:* Positive attitudes and intentions towards further training were more pronounced in those who did not participate in any kind of motorcycle competitions.
- *Incidents with motorcycles:* Positive attitudes and intentions towards further training were more pronounced in those who had met with some kind of incident during the last year when riding a motorcycle in traffic.

5.3.1.4 Legislation

Walters (1982) found that ‘practical riders’ tended to comply with traffic law and the rules of safe riding. When such rules were broken, these riders said the main reason was to reduce anxiety (e.g. break the speed limit to reduce the anxiety of being late for work). ‘Rider enthusiasts’ had attitudes which condoned speeding through busy urban areas but not on long straights of motorway road. Riders breaking traffic rules in this category reported that they did so to generate a feeling of excitement. Rider enthusiasts also acknowledged the importance of courtesy and correct riding procedures as a factor in safe riding, but they reported instances of breaching such practices.

Gosnell (1990) found that, in general, motorcyclists did not believe that they ‘are being legislated off the road’. Only 27% of riders in his sample agreed with this statement compared to 50% who disagreed and 23% who were uncertain. Of those agreeing with this statement most were riders of larger bikes (51% of riders of machines over 400cc), were riders in the 25-34 age group (39%) and were more experienced riders with over 3 years experience (35%). Large percentages of riders, however, both agreed (53%) and disagreed (41%) with a law to restrict riders who have just obtained their full licence from riding machines over 400cc or over 50bhp. Older riders and female riders were more likely to agree with the law than younger riders and male riders.

Hobbs *et al*. (1986) found that riders’ attitudes towards police and legislation were largely positive. Relatively large proportions of riders disagreed with the attitude statements: ‘The police are biased against bikers’ (46% disagreed and 26% agreed); and ‘The police stop bikers to annoy them’ (56% disagreed and 22% agreed). In addition, relatively large proportions of riders agreed with the attitude statements: ‘If bikers obey the law when riding, the traffic police won’t touch them’ (55% agreed and 28% disagreed); and ‘There is a good relationship between police motorcyclists and bikers’ (36% agreed and 16% disagreed). However, for the latter statement, a large percentage of riders were uncertain (48%).

Similar to the results reported by Gosnell (1990), Hobbs *et al*. (1986) found that, in general, motorcyclists did not believe that they ‘are being legislated off the road’. Only 31% of riders agreed with this statement compared to 42% who disagreed and 27% who were uncertain.

Hobbs *et al*. (1986) also found mixed beliefs regarding the attitude statement: ‘Penalties for traffic offences are harsher for bikers than drivers’. 21% of riders agreed with the statement and 28% disagreed, with the majority of riders (51%) being uncertain. Finally, and rather disconcertingly, they found that most riders believed that ‘Legislation makes no difference to the number of bike accidents’ (44% agreed and 19% disagreed).

Age comparisons in the Hobbs *et al*. (1986) study showed that for all items regarding the police and legislation, younger riders (<19 years of age) had more negative attitudes, with the exception of ‘Legislation makes no difference to the number of bike accidents’ where no age effect was found. These negative attitudes towards the police and legislation may possibly be attributed to younger riders’ desire to rebel against authority.

Research on attitudes to violations has shown that compared to older riders, younger riders appear more likely to believe that having fun is a benefit of law and rule breaking behaviour, and less likely to perceive the risk of an accident as a barrier (Rutter *et al*., 1995). Gender also seems to have a significant effect, with males reporting fewer negative views concerning the outcomes of drinking and driving and speeding than for females. Gender has also been found to be mediated by beliefs about taking care, with males being more likely than females to have negative beliefs. In addition, males are less likely to perceive feeling safe as a benefit of law and rule breaking compared to females and perceive risk of an accident as a barrier (Rutter *et al*., 1995).

5.3.2 Attitudes about motorcyclists and other road users

Little research has been conducted into the attitudes and perceptions of motorcyclists towards motorcyclists. One study, Walters (1982) found that ‘practical riders’ had unfavourable attitudes towards group riding whilst ‘rider enthusiasts’ were more likely to favour group riding, perceiving this as part of the social element of riding.

Such issues were also investigated by Hobbs *et al*. (1986). They found that riders were likely to support motorcyclists in general. For example, most riders (54%) disagreed that ‘Many bikers are hooligans’ and only a minority of riders agreed with this statement (28%). Most riders (78%) disagreed that ‘Bikers deserve their bad image’ with only 7% agreeing with this statement. A significant age effect was found for these two statements, with younger riders (<19 years of age) being more inclined to disagree compared to older riders (>19 years of age). In addition, most riders (67%) agreed that ‘Bikers are always treated as second class citizens’ with only 20% agreeing with this statement. A significant effect of age was again found, with more younger riders agreeing compared to older riders.

Hobbs *et al*. (1986) also found that most riders (79%) believed that ‘Many bikers don’t realise the risks in bike riding’. Only 12% disagreed with this statement. Age effects showed that older riders were more likely than younger riders to agree with this statement. In addition, most riders agreed with the statement ‘Most bikers know when it is safe to go fast’ (52% agreed compared to 32% who disagreed). The age effect showed that younger riders were more likely to agree compared to older riders.

Finally, Hobbs *et al*. (1986) found that nearly all respondents (90%) agreed that ‘It’s not the bike that is dangerous, it is the way it is ridden’, and most (58%) agreed that ‘Bikers should ride defensively’. Only 5% and 21% of respondents disagreed with these statements respectively. However, it was found that most riders believed that ‘A safer bike makes a safer rider’ (63% agreed compared to 29% who disagreed). Age effects showed that more older riders than younger riders agreed that ‘A safer bike makes a safer rider’. No age effects were found for the remaining two statements.

The small amount of research that has examined motorcyclists’ attitudes to other vehicle road users generally shows that riders believe drivers of other vehicles are inconsiderate to motorcyclists on the road. Hobbs *et al*. (1986) found that most motorcyclists in their sample (70%) believed that ‘Motorists are inconsiderate to bikers’. Only a minority disagreed with this attitude statement (14%). Even more riders believed that ‘A lot of car drivers make life difficult for bikers’ (82%). Only 12% disagreed with this. A relative large proportion of riders also agreed that ‘Car drivers just don’t care about bikers’ safety’ (43%) and that ‘Car drivers need educating more than bikers’ (53%). 33% and 20% disagreed with these statements respectively. Despite the majority of riders believing that car drivers are inconsiderate to motorcyclists, the majority (64%) also believed that ‘The majority of car drivers are sensible’ and only a minority disagreed with this statement (21%).

Age group comparisons showed a significant effect for the attitude statements: ‘Motorists are inconsiderate to bikers’; ‘A lot of car drivers make life difficult for bikers’; and ‘Car drivers just don’t care about bikers’ safety’. Younger riders (<19 years of age) were more likely to agree and less likely to disagree with these statements than older riders, suggesting that very few teenagers held a favourable attitude towards the behaviour of some car drivers. There were no age effects for the attitude statements: ‘Car drivers need educating more than bikers’ and ‘The majority of car drivers are sensible’.

Walters (1982) found that ‘practical riders’ and ‘rider enthusiasts’ both commonly believed that the main causes of accidents stemmed from the behaviour of other road users. They tended to claim that a number of potential accidents arose from motorists who do not provide sufficient room for motorcyclists when they have to avoid obstacles on the road (e.g. parked cars). Also, they expressed that no matter how careful they were while riding, they were highly susceptible to accidents because of the behaviour of other road users. They believed that accidents could be avoided if other road users were made more aware of the vulnerability of motorcyclists and exercised more care.

‘Practical’ motorcyclists also perceived riding to be hazardous and many stated that they did not ride in the winter months and that in poor weather conditions they use other modes of transport. Also, they perceived the hazards involved in riding as anxiety provoking and this was cited as a reason for changing modes of transport in the near future.

5.3.3 Attitudes towards accident involvement

As discussed in the previous section Walters (1982) found in Wales that ‘practical riders’ and ‘rider enthusiasts’ believed that accidents stemmed from the behaviour of other road users. In addition, speed, human error and bad road surfaces were cited by such riders as a cause of accidents. However, for rider enthusiasts, speed itself was not perceived as a major cause and it was a typical attitude that they could ride fast but safely. Rider enthusiasts also believed that the majority of motorcycle accidents are the result of lack of experience on the part of the rider and their accident rates showed that most of their accidents occurred in their early stages of learning to ride. Related to this finding was that ‘trial and error’ was an important part of learning to ride rather than training.

Hobbs *et al.* (1986) study conducted in Great Britain also assessed attitudes towards motorcycle accidents, specifically accident avoidance. It was found that the majority of motorcyclists (52%) agreed that ‘Only I can reduce my chances of having a bike accident’. However, a substantial proportion of the riders also disagreed with this attitude statement (40%). Many riders (47%) disagreed with the statement that ‘It’s up to the biker to avoid accidents’. However, a substantial minority (42%) agreed with this statement. These results suggest that about half of riders believe *only they* can take responsibility to reduce their own accident risk, a large amount also believed that other road users have a responsibility. Age effects showed that more older riders (>19 years of age) believed that ‘It is up to the biker to avoid accidents’ compared to younger riders, who were more likely to disagree with the statement. There were no age effects for the attitude statement: ‘Only I can reduce my chances of having a bike accident’. This may suggest that both older and younger riders take responsibility to reduce *their own* accident risk, but younger riders are more likely to believe that it should not be the sole responsibility of motorcyclists to avoid accidents and other road users should take into consideration motorcyclists vulnerability. This is supported by the findings of Schulz and Kerwien (1990) who found that owing to younger riders under-estimating the dangerousness of a variety of traffic situations and over-estimating their control capabilities, they tended to think that the responsibility for a potential accident rests with other drivers and not themselves.

2.3 Motivations

2.3.1 Fifteen motivational factors

Schulz *et al.* (1991) suggested that there are twelve significant motivational aspects of motorcycle riding. In addition to these, a further three motivations for motorcycle riding can be found in the literature. The fifteen are described briefly as follows:

● Hedonism
For many riders, motorcycling is coupled with positive emotions such as joy, fun and pleasure. The desire for pleasurable experiences from motorcycling has been labelled hedonism (Battmann, 1984; Koch, 1990). Schulz *et al.* (1989) found that in a sample of 202 German motorcyclists, hedonism motives were the most influential of all the motivations investigated. Similarly in the UK, Hobbs *et al.* (1986) found that the majority of riders in their sample stated that their main motivation for riding was the enjoyment they obtained from the activity.

● Escapism
Motorcycle riding can involve a flight from everyday reality or an escape from civilisation (Nowak, 1979). The escapism motive includes aspects such as self-discovery, putting oneself in a good mood, forgetting everyday worries and ‘letting off steam’. Schulz *et al.* (1989) found that some riders believed that it was important to achieve an empathy with the bike, to be in touch with nature and one’s surroundings, to experience freedom and to ‘let off steam’.

● Dynamic aspects of biking
Motivations relating to this category are the experience of acceleration, speed, power, mobility and cornering and they are related to the physics of the motorcycle (Rheinberg *et al.*, 1986; Schulz *et al.*, 1989).

● Performance aspects of biking
This is linked to the sporting side of riding and includes the motives to master the vehicle and cope with the physical and psychological demands of riding, and also testing the performance limits of oneself and the machine (Rheinberg *et al.*, 1986; Schulz *et al.*, 1989). Other research by Walters (1982) found that rider enthusiasts were motivated by riding a motorcycle to its full capability. It may also be expected that such riders choose to ride sports type motorcycles due to the importance they place on the performance motives.

● Exhibition riding
This motivation implies that competent riding is not always a ‘self-fulfilling goal’ and a certain amount of showing-off is intended, particularly when riding is viewed as a sport. Brendicke (1991) found that younger riders were more likely than older riders to state that they like to perform their riding skills in public. He suggested that motorcycle riding offers a possibility, especially for younger riders, to demonstrate riding skills to other road users. He also pointed out that the demonstration of riding skill in-traffic can be associated with a high exposure to risks due to extreme ways of riding.

● Rivalry
Motivations relating to this category include being faster and better than others. Schulz *et al.* (1991) state that this competitive nature is linked to the performance motive and the sporting nature of riding. In addition, the permanent need to assert oneself against other road users has been attributed to some riders of motorcycles (Dellen and Bliersbach, 1978; Brendicke, 1991).

● Thrill and adventure seeking
Such motivations are associated with a need to seek out risky situations and activities and to experience a subjectively optimal and pleasant state of physiological arousal (Zuckerman, 1984). Researchers have suggested a link between the dynamic aspects of motorcycle riding and thrill seeking (Dellen and Bliersbach, 1978; Brendicke, 1991). In addition, thrill seeking has been found to be associated with younger age groups. Hobbs *et al.* (1986) found that 81% of riders in their sample believed that there is a thrill in motorcycle riding and 66% believed that motorcycling could sometimes be frightening. Although motorcyclists generally believe that there is a thrill in riding a motorcycle, the thrilling aspect may not be directly related to risk taking. Hobbs *et al.* (1986), for example, found that although a large proportion of motorcyclists agreed that there is a thrill in motorcycling, 72% disagreed with the statement, ‘you have to take your chances when riding a bike’. One possibility here is that the thrill comes from perceived mastery of risks by ones own skill (see Control Beliefs below).

● Flow effects
Riders can be motivated to achieve ‘flow states’ where ‘attention is narrowed down to a limited field, the self loses meaning, nothing disturbs the flow of action and complete control over the course of events seems to be present in highly practised, intrinsically motivated and competently executed activities’ (Csikszentmihalyi, 1988). Hobbs *et al.*, (1986) found that 87% of riders agreed with the attitude statement: ‘I like to feel part of the machine which I am riding’, and this applied to both younger and older riders. While finding that younger riders were more motivated to achieve flow states compared to older riders, Brendicke (1991) found that older riders were also highly motivated.

● Identifying with the bike
For some riders, the motorcycle becomes an important part of their lives. Brendicke (1991) found that many riders have had ‘a lot of good experiences with their bike and it is a good friend to them’. Hobbs *et al.* (1986) found that 62% of riders believed that riding is a way of life. The motivation to increase self-esteem has been attributed to such riders (Dellen and Bliersbach, 1978) and it has been suggested that this is particularly the case for young adolescent age groups who use the motorcycle to compensate for uncertainties in their developing years (Schulz *et al.*, 1991), while for older age groups they may be using the motorcycle to regain their youth and the experiences which they had when riding at an earlier age (the ‘born-again bikers’ effect).

● Safety behaviour
These are motives that are directed to gains in safety through active behaviour such as wearing protective equipment or efforts to safe riding behaviour in traffic. Schulz et al. (1989) found that defensive riding was rated as important by riders of touring machines compared to riders of normal, sport, enduro and chopper motorcycles.

● Control beliefs

The motive of control is attributed to riders who believe their riding qualifications are perfect. These people believe that they can control themselves, the vehicle, other road users and the situation all of the time. Schulz and Kerwien (1990) suggested that control beliefs may be rooted in an over-estimation of capabilities, and pointed out that such unrealistic control beliefs can be partially counteracted by safety motives.

● Social aspects

These motives derive from the desire to form part of a group and the involvement in group activities (e.g. conversations on biking). Schulz (1990) found that motorcycles play an important role in the social status of juvenile riders and the motorcycle is a linking element within the peer group. Also, Brendicke (1991) found that many riders ride a motorcycle in order to spend more time with people with similar interests, and this applied to both younger and older riders. Brendicke (1991), therefore, suggests that motorcycle riding offers an opportunity for social contacts, the motorcycle itself serving as an instrument of contact, a common basis and topic for discussion.

● Economic aspects

Economic reasons appear to be strong motivators to ride motorcycles. Many motorcyclists express the view that they ride motorcycles because they are cheap to run. Hobbs *et al.* (1986) found that 67% of their sample stated economy as a motivation to ride motorcycles. Economy motivations were more pronounced among young female, compared to young male riders, and featured highly among females of all ages, whilst for male riders, economy motivations were more pronounced among older male riders compared to younger male riders. It should be noted that trends in motorcycle use, i.e. with increasing use of larger engined bikes for recreational rather than utilisation purposes, appear to indicate that economic aspects today are rather different from what they were in 1986.

● Independence

Hobbs *et al.*, (1986) showed that 39% of riders gave independence as a motive for riding a motorcycle. As a motive, independence seems to apply to female riders more than male riders. In addition, there seems to be no effect of age in independence motives for female riders, whilst for male riders there is an age effect with younger males being more likely to express independence as a motive compared to older males.

● Convenience

For some motorcyclists convenience motives form their perception of motorcycling. Such motives include ‘easy to park’ and ‘manoeuvrability in traffic’. Hobbs *et al.* (1986) reported that 36% of riders mentioned ‘easy in traffic’ (manoeuvrability) and 34% expressed ‘easy to park’ as motives for riding. Convenience motives were more pronounced in riders over the age of 25. Walters (1982) also showed that this was one of the main advantages for groups of ‘practical riders’.

5.4.2 Classifications of motivations

Two investigations have found that the motivations of motorcycle riders can be grouped into three distinct categories. In the first, Schulz *et al.* (1991) conducted a survey of 376 motorcyclists’ motivations to ride. Items on the survey questionnaire measured the scales of escapism, hedonism, flow, identification with the bike, social aspects, dynamic aspects, performance aspects, exhibition riding, thrill seeking, rivalry, control beliefs and safety behaviour. Inter-correlations between the scales showed that these 12 motivational aspects could be grouped into three broad categories:

1 biking for pleasure (escapism, hedonism, flow, identification with the bike, social aspects);

2 biking as a fast competitive sport (dynamic aspects, performance aspects, exhibition riding, thrill seeking and rivalry); and

3 control over the motorbike (control beliefs and safety behaviour).

Their analysis of rider motivations by age and type of motorcycle revealed that:

Analysis by age:

- Younger riders were more influenced by riding pleasure (with the exception of social aspect where there were no significant differences).
- Younger riders were more influenced by exhibition riding, rivalry and thrill seeking motives compared to older age groups. However no significant age effects of dynamic aspects or performance aspects.
- Younger riders were less influenced by safety behaviour motives compared to these other motives and compared to older drivers.
- Younger riders had weaker control beliefs than older age groups.

Analysis by motorcycle type:

- Riders with specialised motorcycles (choppers, sport bikes, and enduros) were more motivated in driving for pleasure.
- Riders of sports bikes were more influenced by dynamic aspects and exhibition motives compared to riders of other motorcycle types.
- Riders of sports bikes and enduros were more influenced by performance aspects and thrill and adventure seeking compared to riders of other motorcycle types.
- Riders of sport and touring bikes had higher control beliefs compared to riders of other motorcycles.

The conclusions drawn from this study were that the type of bike chosen by riders provides clear information on the bikers’ motives, the experiences they seek and their concept of riding. However, Schulz *et al.* (1991) pointed out that this is only the case when riders can choose the bike they want (i.e. they may have constraints placed upon their choice of bike – such as money) and, therefore, a variability in the motives within each group (machine type) has to be assumed. One implication is that persuasive communications, tailored to the motivational requirements of the general rider of each motorcycle type, could be provided when buying a motorcycle in an attempt to encourage safe riding behaviour. Other interventions, such as large scale media campaigns, could also be tailored to the motivational requirements of riders of particular motorcycle types.

The second investigation that grouped riders motivations into categories was a study by Walters (1982), who conducted 100 in-depth interviews of motorcyclists in Wales to investigate their motivations and attitudes towards riding. She found that 35% of the sample could be classified as those who use a motorcycle for practical reasons, 48% could be classified as those who were enthusiasts and ride for pleasure and 10% could be classified as irresponsible and whose behaviour was considered by others to be immature and irresponsible. Only 7% of the sample could not be classified by these categories.

Motorcyclists who used a motorcycle for practical reasons perceived the main advantages to be economical to run and convenient to use and park. This group of riders was mostly female, and tended to ride smaller bikes for the purpose of short journeys and for travelling to and from work. In addition, such riders disliked the level of arousal generated in the course of riding, and tended to be cautious in their approach to riding in terms of their handling and their use of speed.

Motorcycle enthusiasts were likely to be younger riders, who used their motorcycles for work and also pleasure, and older riders, who had ridden a motorcycle for a long period of time and typically owned a car as an alternative mode of transport. Enthusiasts were found to accept the risk involved in riding, but unlike practical riders, tended to perceive it as a challenge rather than a deterrent. They were motivated by the excitement, exhilaration, and sense of freedom and control which they believed could not be obtained from driving a car. Riders in this category also claimed to be confident in their ability to handle the motorcycle correctly.

Irresponsible riders were found to have a lack of awareness of the risk in motorcycling, were overconfident, and perceived themselves as ‘invincible’. Gaining attention, excitement and independence were cited as motivations to behave in such a manner. Such riders were young, typically 17-18 years old. Walters (1982) suggested that training for these riders may be dysfunctional, since making safety rules more explicit may cause these young riders to deliberately set out to break them.

5.5 Attitude-behaviour models

5.5.1 Theoretical models

The theoretical models that have been used most extensively in motorcycling research are the Theory of Reasoned Action (TRA) of Fishbein and Ajzen (1975), its recent extension, the Theory of Planned Behaviour (TPB - Ajzen, 1988), and the Health Belief Model (HBM) of Becker and his colleagues (Janz and Becker, 1984).

The Theory of Reasoned Action provides a conceptual and empirical account of the relationships between beliefs, attitudes, intentions and behaviours. The theory predicts that a person’s *intention* to perform a behaviour is the immediate determinant of that action. The stronger the intention to engage in a particular behaviour, the more likely it is that the behaviour will be performed. The TRA posits that behavioural intentions are a function of two basic components:

- *attitude towards the behaviour* – this is viewed as a personal factor and it is determined by what the individual believes the outcome of performing the behaviour will be (behavioural beliefs) and the positive or negative evaluation of those outcomes (outcome evaluation).
- *subjective norms* – these are a social influence and they are the person’s perception of the social pressures put on him to perform or to not perform the behaviour in question (normative beliefs), weighted by their motivation to comply with these normative beliefs.

The TPB extends the conceptual framework of the TRA to include a further component:

- *perceived behavioural control* – this is the perceived ease or difficulty of performing the behaviour and reflects the perceived likelihood of encountering inhibiting and facilitating factors (control frequency beliefs) weighted by the perceived power of those factors to facilitate or inhibit behaviour (control power beliefs).

Work by Parker and associates (Parker *et al*., 1995) has developed the model further by adding the aspects of personal norm, affect, habit and personal identity to the theory’s three core components, although this has only been used in studies of car drivers, not motorcyclists.

In the Health Belief Model it is proposed that safety related behaviours are accounted for by means of three belief ‘dimensions’: vulnerability, severity and benefits and barriers. Within the context of motorcycling, vulnerability is concerned with how likely riders believe they are to have accidents; severity concerns the perceived seriousness of the consequences of accidents; and benefits and barriers are the perceived rewards and costs of safe and unsafe riding behaviours. Although the Health Belief Model offers a slightly different theoretical perspective than the TRA/TPB, a considerable degree of overlap between the two theories can be seen. Recent work on the Health Belief Model has led to the inclusion of three additional factors, locus of control; habit; and social support.

5.5.2 Attitude-behaviour modelling in motorcycle research

Although a large part of the research on attitude-behaviour modelling has focused on car drivers, psychological models have been used in motorcycle research to study safety helmet use, and the social psychological determinants of safe and unsafe motorcycle riding.

Allegrante *et al*. (1980) used the TRA to identify the attitudinal factors that predict behavioural intention to wear a helmet. They found that the TRA predicted 53% of the total variance in behavioural intentions to wear a helmet. It was found that the attitude component of the TRA received the greatest weight in predicting behavioural intentions rather than the subjective norm component. Further analysis revealed differences between intenders and non-intenders to wear a helmet in two attitudinal factors:

- Safety: riders with the intention to wear a helmet had stronger safety beliefs compared to non-intenders (e.g. 'wearing a helmet would prevent head injury and increase visibility and feelings of safety'); and
- Comfort-convenience: riders with the intention to wear a helmet were less likely to express the inconvenience and discomfort possibly associated with helmet use (e.g. 'wearing a helmet would make me feel uncomfortable, hot and impair vision and hearing').

However, no differences were found between intenders and non-intenders in a third attitudinal category, 'social image'. This factor included beliefs such as 'wearing a helmet would make me…. look foolish to other motorcyclists/ appear less adventurous/ look less sexy'.

Rutter and associates (Chesham *et al*., 1991; Chesham *et al*., 1992; Rutter and Quine, 1994; Rutter *et al*., 1993; Rutter *et al*., 1995) have investigated the social psychological determinants of the behaviours associated with accident involvement using the conceptual frameworks of the TRA and the Health-Belief Model (HBM). They attempted to identify the structure of these determinants, how they relate to age and sex factors, and to identify areas within the structure where intervention will have an optimum effect in encouraging motorcyclists to comply voluntarily with safety guidelines.

Rutter and associates conducted a postal survey of 4,100 motorcycle riders. Questionnaires were sent out at two time intervals, twelve months apart. Respondents completed a questionnaire based either on the TRA or the HBM. Each questionnaire comprised the five sections:

1 Safe riding: this examined riders' beliefs.

2 The rider and the machine: this obtained details regarding the machine, the respondents' riding career and current behaviour.

3 Spills and accidents: asking details of mishaps on the road in the preceding twelve months.

4 Bikes and biking: a test of knowledge about riding and the road.

5 Demographic variables: age, gender.

The only difference between the TRA and the HBM questionnaire was in the first section. In the TRA version, questions about beliefs, outcome evaluations and normative beliefs were asked, while in the HBM version, questions about perceived vulnerability, perceived severity and benefits and barriers towards safe riding behaviour were asked.

It was found that between time 1 and time 2 of the survey, 14% of the sample had at least one accident. Young riders, less experienced riders and riders who had received some form of training were more likely to report accidents than were older riders, more experienced riders, and riders who had not received any training. However there were no effects of gender or size of machine. In relation to riding behaviours, it was found that speeding, breaking traffic laws, breaking the highway code, riding too close and losing concentration were associated with accident involvement.

Principal component analysis revealed that with the exception of losing concentration, the above behaviours grouped together and accounted for more variance in accident involvement than any other factor. This factor was termed 'law and rule breaking behaviour'.

Multiple regression analysis revealed that both demographic and psychological variables significantly predicted law and rule breaking behaviour. Age, gender, experience and formal training were all significant predictors of law and rule breaking. These variables accounted for a quarter of the variance, and riders who were young, male, inexperienced and formally trained were more likely to report law and rule breaking behaviour.

Law and rule breaking behaviour was also predicted by the psychological components. For the TRA data, two behavioural belief factors were found to predict law and rule breaking. These were:

1 '*obeying law and rules*', which consisted of beliefs such as 'following the highway code', 'obeying traffic laws', 'not speeding' and 'doing as taught'; and

2 '*taking care*', which consisted of beliefs such as 'concentrating properly', maintaining the bike' and 'showing consideration'.

For the HBM data, five factors were found to predict law and rule breaking. These were:

- '*perceived vulnerability*';
- three benefit factors ('*feeling safe*', '*having fun*', and '*good bike performance*; and
- one barrier factor ('*risk of accident*').

At time 1 the demographic and psychological variables, together with a measure of bike size accounted for 41% of variance for law and rule-breaking behaviour for the TRA data and 44% of variance for the HBM data. At time two the same components, supplemented with a measure of exposure and past behaviour (i.e. reported law and rule-breaking at time 1), accounted for 63% of variance for both the TRA and HBM.

Path analyses were conducted to investigate the mediation of demographic variables by the psychological belief variables. It was found for the TRA data that age and gender had direct influences on behaviour, but were also mediated through the psychological components. Age was mediated by beliefs about obeying the law and rules, with younger riders being more likely to have negative beliefs compared to older riders. Gender was mediated by beliefs about taking care, with males being more likely to have negative beliefs compared to females. Education also led indirectly to behaviour, through beliefs about taking care.

For the HBM data, it was found that age and gender again had direct and mediated paths to behaviour. Age was mediated by the barrier of risk of accident and the benefit of having fun. Compared to older riders, younger riders were more likely to believe that having fun is a benefit of law and rule breaking and less likely to perceive the risk of an accident as a barrier. Gender was mediated by the benefit of feeling safe and the benefit of barrier risk of accident. Males were less likely than females to perceive feeling safe as a benefit of law and rule breaking and risk of an accident as a barrier. Also, experience and training had direct influences on behaviour and were not mediated by psychological variables. The perceived vulnerability factor no longer predicted law and rule breaking when the demographic variables were being taken into account in the path analysis, suggesting that the effects of perceived vulnerability were completely captured by the demographic variables.

Finally, the path analysis revealed that prior behaviour (i.e. behaviour measured at time 1) was the single largest contributor in predicting current behaviour (i.e. behaviour measured at time 2). In addition, the effect of prior behaviour on current behaviour was found to be direct and not mediated through the beliefs of riders (attitude towards the behaviour or barriers and benefits of the behaviour). These findings have led Rutter and associates to suggest that law and rule breaking is largely habitual in nature and that for training and education programmes to succeed, they must be applied early in the motorcyclists riding career before ‘bad’ riding habits have been fully developed. The psychological components which have been found to predict prior law and rule breaking behaviour are the expectancy-value components of the TRA and the HBM (behavioural beliefs and outcome evaluations for the TRA and perceived barriers and benefits for the HBM). Therefore, by influencing these psychological components via persuasive communications and attitude training early in a motorcyclist’s career, it may be possible to minimise the effect of habitual law and rule-breaking behaviours which are, in turn, associated with accident involvement.

The research findings reported by Rutter and associates have a number of implications. Firstly, they showed that motorcyclists’ beliefs predicted accident related behaviour (‘law and rule breaking’). For the TRA, beliefs regarding obeying the law and rules of safe riding and taking care predicted law and rule breaking. Those who were more likely to believe that they should follow the highway code, obey traffic laws, not speed and ride as they were taught were less likely to speed, break traffic laws, break the highway code and ride too close to other vehicles. Those who were more likely to believe that they should concentrate properly, maintain their bike and show consideration to other road users were less likely to engage in these behaviours. For the HBM, perceived vulnerability, the benefit factors of feeling safe, having fun and good bike performance, and the barrier factor risk of accident predicted law and rule breaking. Those riders who had higher perceived vulnerability believed that a benefit of motorcycling was feeling safe and a barrier of motorcycling was risk of having an accident were less likely to engage in law and rule breaking behaviours compared to those who did not hold such beliefs. Also, those riders who believed that the benefits of motorcycling were having fun and having good bike performance were more likely to engage in law and rule breaking.

A second implication of the research was that the effects of demographic factors were mediated through the psychological components of the TRA and the HBM. Although age and gender had direct relationships with law and rule breaking, they were at least partially mediated through social psychological factors. Rutter *et al*. (1995) therefore suggested that the beliefs and attitudes which youth brings with it are an important part of being a young rider, and the indication is that social psychological variables have a role to play in accident involvement.

An interesting finding was that normative beliefs (a component of subjective norm in the TRA) did not significantly predict law and rule breaking, while in the TPB studies by Parker and associates, subjective norm was a significant predictor of various driver violations. An explanation for this may be that the TPB studies by Parker and associates were concerned with car drivers, and a fundamental difference between motorcycles and cars may be in the opportunity for direct social pressure from passengers. Rutter *et al*. (1995) point out that neither perceptions of vulnerability or normative beliefs were the important predictors of behaviour, but it was the expectancy-value of the behaviour which was the crucial predictor of law and rule breaking, in other words, the barriers and benefits of the HBM and the outcomes and the behavioural beliefs of the TRA. Therefore, the most reliable predictors of motorcyclists’ law and rule breaking came from the components which the two models shared.

5.5.3 Methodological considerations

There are a number of theoretical and methodological issues to consider regarding the research on the TRA/TPB and the HBM, outlined above. The major issue for studies concerning the TRA/TPB is that they are limited to the prediction of behavioural intention rather than the actual commission of road traffic violations. While there are grounds for believing that stated intentions are predictive of actual behaviour in the driving domain, there is to date only limited empirical evidence to support this position.

A further criticism of research in this area is its reliance on *self-reports* of riding behaviours, and attitudes towards those behaviours. The first problem encountered is the degree to which self-reported behaviour is related to objective measures of behaviour. Any data based on self-reports may be subject to social desirability effects, in that respondents may deliberately under-report the frequency of their violations or their law and rule breaking behaviour in order to convey a favourable image. Social desirability effects may also operate when respondents provide their answers to measures of attitude.

5.5.4 Changing attitudes or changing behaviour?

Research into attitude-behavioural models has provided reasonably detailed information on the attitudinal components that determine or, at least, are associated with behavioural intentions, which in turn are assumed to determine behaviour. As discussed above, the relative weightings for the attitudinal components of the TRA/TPB and the HBM differ depending on the behaviour in question. These weightings even differ within the seemingly homogenous area of speeding (Stradling and Parker, 1997). Knowledge of these components and their weightings provide clues as to the specific messages which intervention campaigns should use for different behaviours[4]. Such countermeasures are directed at altering attitudes to alter behaviour. Previous research in the area of attitude training is discussed in detail in Section 5.7 (Chesham *et al*., 1992; Parker *et al*., 1996; Meadows and Stradling, 1999). The results of such research indicate that there is little evidence concerning the impact on behaviour of attitude-change strategies. However, such studies have generally been laboratory based and a number of differences exist between short term laboratory campaigns and real life media campaigns. In addition, attitude training has had some impact on preventing the development of negative attitudes towards road traffic violations (Meadows and Stradling, 1999). If a strong habit component exists for the execution of a particular behaviour, as the work by Rutter and associates would suggest, then this may provide clues as to why attitude training has had little impact. Drivers/riders may revert to their habitual driving/riding practices despite small changes in attitudes, and these attitudinal changes may themselves revert to as they were before attitude intervention after the continued habitual behaviour.

Burgess (1998) has also argued that changing attitudes does not necessarily change behaviour, but that changes in behaviour have been shown to reliably change attitudes. He cites Howarth (1988) who states:

> *'It has been frequently demonstrated that attitudes are easier to change than behaviour and that a verbally expressed belief…may not be reflected in any increase in the related and easily observed behaviour. In contrast it has been frequently demonstrated that changes in behaviour, induced by environmental pressure, can lead to a change in verbally expressed attitudes, usually in the direction which justifies the new form of behaviour'*.

The implication is that if behavioural restrictions are imposed so that behaviour is 'forced' to be safer, then attitudes are likely to change in a direction geared towards safety also. Behavioural restrictions can be imposed by providing more enforcement and new legislation. Legislation requiring mandatory use of reflective clothing, for example, may alter motorcyclists' behaviour, making them more likely to wear highly conspicuous clothing, and thus attitudes towards this safety measure will become more positive. However, as Burgess suggests, unless increased enforcement levels are undertaken over a prolonged period of time, an individual's behaviour will be less likely to change and it will revert back to match the habitual behaviour.

Thus, if one accepts the view that changing behaviour brings about changes in attitude, then interventions such as enforcement or engineering restrictions (e.g. traffic calming or modifications to the motorcycle itself) would be more appropriate. On the other hand, if one accepts the view that changing attitudes brings about changes in behaviour, then interventions such as media campaigns and educational material would be more appropriate. These approaches may differ depending on different violations or behaviours. For example, behaviours that are more permissive or are largely influenced by habit may require more restrictions on behaviour. However, it may be unwise to overlook the benefits of promoting attitudinal change in influencing behaviour.

Petty and Cacioppo (1986) postulated in their Elaboration Likelihood Model, that there were two routes to attitude change (discussed in Section 5.7), one that elicits cognitive restructuring and one that does not. The authors suggested that attitude-change that elicits cognitive restructuring will result in changes in attitude and behaviour, while attitude-change that does not elicit cognitive restructuring may lead to attitude change but not behavioural change. Therefore, attitude-change strategies may be useful in promoting safety behaviour if they involve changing the cognitive structure of individuals in which attitudes are arranged. Also, in many instances, it may be more appropriate to use a combination of attitude-change strategies and behavioural restrictions. For example, publicity may prepare people for changes in legislation and promote acceptance of those changes. Parker *et al*. (1996) have used this argument to account for the compliance with the introduction of compulsory seat belt legislation for drivers and front seat passengers in 1983.

5.6 Motorcycle training and education

5.6.1 Skills training

5.6.1.1 Training in the UK and Europe

As outlined in Section 6, later in the report, current UK legislation requires that all learner motorcyclists must attend and successfully complete a course of Compulsory Basic Training (CBT), before being allowed to ride any motorbike on the road. Successful completion of CBT allows the rider to ride on the road with L-plates for a maximum of three years before being required to take and pass the final DSA motorcycle test in order to gain a full motorcycle licence.

Pre CBT

Prior to the introduction of CBT, motorcycle training courses were widely available on a national basis under the auspices of the Royal Automobile Club and Auto Cycle Union (the RAC/ACU scheme) or the National Training Scheme (NTS). Motorcyclists participated in these courses on a voluntary basis. Wells (1982) estimated the take-up of voluntary motorcycle training to be rather low, with only 10-15% of novice riders opting to take any formal training. The effects of a widespread advertising campaign, incorporating television, radio and poster advertisements were investigated. Whilst initial response to the adverts was very favourable (measured by the telephone enquiries seeking further details of the advertised course), the resulting participation on the course was very low.

To encourage take up of the available training, part of the Transport Act 1981 limited learner motorcyclists to a machine of less that 125cc, and required riders to take and

[4] Assuming, that is, that there is a causal link running from attitudes to behaviours.

pass both a Part 1 and Part 2 motorcycle test. The first test (Part 1) was broadly comparable to the current CBT training in being an off-road skills test. Those who passed the Part 1 test were allowed to ride on the road. The second test (Part 2) was the equivalent of the current DSA motorcycle test; successfully passing this test gained the rider their full motorcycle licence. However, unlike the current DSA 'pursuit' test, the Part 2 test was conducted with examiners assessing riders' on-road riding skills whilst on foot themselves. Riders were required to take and pass the Part 2 test within the two years following successful completion of the Part 1 test.

A review of the effects of the 1981 legislation (Department of Transport, 1986; cited by Clayton and Sudlow, 1987) suggested that positive benefits had been seen, both in an expansion of training facilities throughout Great Britain, and in a sharp rise in the Part 2 Test pass rate from 50 to 75%. Despite this, it was estimated that less than one third of learner motorcyclists were taking any training. Instead, it appeared that many were simply giving up motorcycling when the period for taking the full test expired (Clayton and Sudlow, 1987).

Despite the apparent apathy for training amongst learner riders, a survey by Gosnell (1990), conducted before compulsory basic training (CBT) was introduced, indicated that most motorcyclists believed all motorcyclists should take some form of training. In this respect, respondents expressed strong support for compulsory training before learner riders are allowed on the road.

Compulsory Basic Training (CBT)

CBT is a compulsory, one-day course, introduced in 1990 in an attempt to reduce the high accident rate amongst inexperienced riders. The course, which may only be provided by Approved Training Bodies (ATBs), aims to cover basic skills and knowledge relating to safe motorcycle operation, and is in five sections:

- an introduction to the course;
- practical on-site training;
- practical on-site riding;
- practical on-road training; and
- practical on-road riding.

Exemptions to CBT were initially allowed for people wishing to ride a motorcycle with a pre-1990 full car licence incorporating a provisional motorcycle entitlement, or a provisional moped licence. However in January 1997 this exemption was removed making CBT compulsory for all learner riders.

The level of mandatory training within individual countries varies greatly around the world. In Europe, EU directives set out minimum requirements for the *testing* of novice riders, but not for the form or level of *training* required. Consequently, some European countries require riders to attend compulsory training with no unaccompanied on-road riding before the test is taken (e.g. Austria, Germany, Denmark, Luxembourg, Netherlands, Norway and Sweden), whilst others require riders to attend a programme of compulsory training followed by a period of unaccompanied riding before the test is taken (e.g. Belgium, Great Britain and Finland). Other countries have no legal requirement for any training to be completed before taking the licence test.

5.6.1.2 The effectiveness of skill training

The DETR Road Safety Strategy (1997) stated that there is 'every reason to assume it [CBT] has played some part in the reduction of motorcycle casualties in the 1990s', though reductions in the numbers of motorcyclists have obviously had a major effect (see Section 2.1.1).

No scientific evaluation of the effects of CBT on accidents has been carried out, and as CBT is compulsory, it would not now be possible to compare the accident involvement of trained and untrained riders. Furthermore, no published evidence existed to demonstrate whether CBT is effective in improving riders' knowledge or skill.

The only published evaluation of CBT investigated the attitudes and opinions of both trainers and trainees to the course (Thompson, 1994), found generally positive attitudes towards CBT among both groups, though riders tended to consider it easy and expensive.

A particular problem identified by Thompson's survey was that nearly two thirds of riders admitted to riding on the road before completing a course of CBT. Moreover the study concluded that this was significantly more prevalent among 'older' riders (over 30 years old) than among 'younger' riders (under 19). Reasons given by respondents for this illegal riding were mainly to do with ignorance of CBT's existence or misunderstanding the requirement to complete CBT before riding on the road. For those who knew and understood the regulations regarding completion of CBT and chose to ride illegally, the major reasons given related to:

- cost;
- 'not getting around to it' or too inconvenient;
- not intending to ride a bike for very long;
- wanting to practise.

Whether similar numbers are still riding on the road before completing a course of CBT is not known. It might be expected that, almost a decade after its introduction, awareness of CBT would be greater. It is not known how many riders choose to ride unlicensed, and why they do so. Research to estimate the size of the problem and investigate possible countermeasures would seem worthwhile, especially as such riders seem likely to be uninsured, and outside the influence of at least some types of safety legislation.

A more recent study (Brookes and Arthur, 1997) used qualitative interviews with riders of different age groups and levels of experience to investigate attitudes towards various motorcycling issues, including training. The study found that riders of all age groups viewed existing training as 'not relevant enough'. Although some elements were appreciated as a 'good start', CBT in particular was seen as 'falling short of the mark'. This was especially due to its failure to address risk-taking behaviour, discussed later in Section 5.6.1.3.

Few scientific evaluations have been conducted in other countries to assess the effectiveness of compulsory training interventions. More attempts have been made to evaluate the effectiveness of the more widely available voluntary training courses. However, considering the number of training courses provided around the world, it has been observed (e.g. Kloeden *et al.*, 1994) that the actual number of published evaluations of training programs is ‘disappointingly few’.

Despite a widely held view that rider training and licensing measures ought to have important benefits for motorcycle safety, the findings of evaluative studies have not demonstrated this to be the case. Reviewing 20 studies Kloeden *et al.* (1994) concluded that ‘the results of overseas research in this area, although inconsistent, seem to indicate a small positive safety benefit associated with such programs, even if only through deterring potential riders from riding’. In an earlier review, Simpson and Mayhew (1990) concluded that ‘very little support for the beneficial impact of education/training can be found in the evaluation literature’.

This lack of strong evidence that training is effective may be at least partly a result of methodological shortcomings. In Kloeden *et al.* review, 12 of the 20 studies were judged to meet only a minimum acceptable standard, while the remaining 8 were dismissed as failing to provide useful information towards the review due to ‘inadequate study design or analysis’. Various methodological problems were identified, including:

a Small sample sizes
Given that accidents are relatively rare events, the sample sizes required by evaluative studies if they are to have adequate statistical power – i.e. if they are to be able to detect reliably differences between trained and untrained groups – are very large. With many studies, even the initial sample size is too small to be relied upon to detect anything but large effects on accident rates – a problem made worse by the fact that substantial proportions of participants may withdraw before the study is completed.

b Poor control groups
A potential problem with any evaluation of voluntary training, is that of comparability between experimental (trained), and control (untrained) groups.

It has long been recognised that individuals voluntarily attending training courses are ‘self-selecting’ individuals, who may differ from those not taking up the training in ways that affect their accident risk.

c Attrition
Studies avoiding the problem of ‘self-selection’ by randomly allocating riders to a training condition may be at a heightened risk of attrition, since riders allocated to training may not be well motivated to complete it. The resulting differential dropout from the training and control samples may compromise any comparison of their subsequent accident rates. The few studies attempting randomisation were judged in the Kloeden *et al.* review to be failing to address this issue satisfactorily, hence their findings were deemed questionable.

d Accident data
A further methodological point mentioned by Kloeden *et al.* concerns the fact that self-reported accident studies cannot capture both fatal, and some serious injuries. The authors argue that this may restrict the potential effects of training that the studies are able to detect. (It should be said, though, that the numbers of such injuries in any manageable-sized survey will be small, and that self-report surveys are the only way in which individuals’ experience and exposure data can be collected).

e Long exposure intervals
An additional concern to be raised in relation to some studies relates to the use of a long exposure period as a way of increasing the accidents in the sample. Kloeden *et al.* highlighted the fact that some of the studies contained within their review had attempted this to compensate for a small sample size.

The authors argued that any effects of training are likely to be most evident in a relatively short period of time after training, especially with novice riders and that, as riding experience increases, any differences between trained and untrained riders would be expected to decrease. As a result, studies examining accident involvement over a longer period of time may have a decreased likelihood of finding any training effect. In fact, the extent to which this is a problem is unclear. Given the very steep reduction in accident liability as experience is gained during the first years of riding (Taylor and Lockwood, 1990), it does seem likely that the main effects of training ought to be felt (if at all) during this period. However, there are counter-arguments that training ought to have a long term effect, particularly if it establishes good riding habits and inhibits the formation of bad ones.

f Inclusion of more experienced riders
Finally, some studies have included experienced riders in addition to novice riders. On the argument that skills training is most likely to have its greatest effect among riders with limited experience of motorcycling, the inclusion of experienced riders may limit the size of any effect found. Again, there is a counter-argument that experienced riders may benefit greatly from training; in reality, much will no doubt depend on the design and target population of the particular training course.

Examples of evaluation attempts

Despite the methodological weaknesses of the evaluations identified and outlined in the Kloeden *et al.* review, the remainder of this section highlights some examples of the studies conducted in various countries.

Kloeden *et al.* study evaluated the effectiveness of a compulsory training program introduced in South Australia in 1987. To apply for the compulsory ‘*Ridersafe*’ course, potential riders were required to be at least 16.5 years old and have passed a theory test.

The course consisted of two, four-hour sessions held on separate days. Areas covered within the course included:

- Starting the motorcycle and using the controls.
- Turning and braking.

- Defensive riding.
- Gear changing.
- Braking in corners.
- Counter steering.

Each was addressed using a combination of group discussion, video, and practical riding on the driving range.

At the end of the second session riders judged by instructors as competent received their learner permits, allowing them to ride on the road with L-plates before taking the test. Riders judged not to be competent were asked to return and repeat the course at no extra cost.

As *Ridersafe* was phased into different postcode areas of South Australia at different times, an automatic control group was immediately available. The researchers addressed many of the methodological problems discussed above but the sample size available to the study was too small to allow reliable detection of differences in accident rate between the two groups of less than 30%. It should not be surprising, therefore, that no statistically significant effect of the course on accidents was found.

In an evaluation of the British Columbia Safety Council's 37-hour motorcycle safety training programme in Canada, McDavid *et al.* (1989) examined five years of accident data from course attendees and an untrained control group. Attempts were made to match the two groups on many variables including sex (all were males), age, month licence gained, and accident record two years prior to the experimental period.

The results showed that between-group differences in the frequency and severity of accidents were not statistically significant. Additionally the study measured moving violations committed by both groups, as these generally occur more frequently than accidents. Whilst training was associated with a reduction in violations after licensing, again this effect was not statistically significant.

Mortimer (1984, 1988) conducted an evaluation of the US Motorcycle Safety Foundation's '*Motorcycle Rider Course*'. Self-reported accidents of a sample (n= 516) of riders voluntarily attending the course were compared with those of a control group of motorcycle riders approached while visiting a local dealership.

When the results were controlled for age and years licensed, it was found that those who had attended the course did *not* have a significantly reduced number of accidents, number of recorded violations, damage cost per mile, or medical treatment cost per mile. The study did find that both the mean cost of damage to the motorcycle, and the mean cost of medical treatment per accident, were significantly lower for those attending the course. The lower medical cost might have been explained by a further finding indicating that riders attending the course made more use of protective clothing (e.g. helmets, which were not compulsory in the State where the study was carried out). This finding may, however, be a result of the trained riders being self-selecting volunteers, rather than a beneficial effect of training on the wearing of protective clothing.

Jonah *et al.* (1982) used a telephone-based self-reported accident survey to compare a sample of motorcyclists who successfully completed a four-day training course in Ontario with a sample of other riders. Since random assignment was not possible, multivariate analysis was used to control for between-sample differences. Once this had been done, there was no significant difference in accident liability between the two groups. The trained riders were significantly less likely than the others to have committed a traffic violation. This may have resulted from the training, but the authors point out that it might be a result of 'safety conscious' riders being likely to both volunteer for training and to adopt safe riding behaviours.

Raymond and Tatum (1977) evaluated the effectiveness of the voluntary RAC motorcycle training scheme in the UK. The training course consisted of 24 hours of instruction, half held in the classroom and half carried out on the driving range or in real traffic. In contrast with many other studies Raymond and Tatum found significant differences in numbers of accidents between the two groups when exposure (distance travelled by motorcycle) was controlled for. However, the differences were in the 'wrong' direction, with trained riders having significantly more accidents than their untrained counterparts.

From this discussion, it is clear that the effectiveness of training as a way of reducing subsequent accident rates remains unproven. This may in part be a consequence of the formidable problems facing the research designer in this field. As a result, there remains a need for further well-designed evaluations investigating the effect of rider training on accident involvement.

It would appear that evaluative research has been largely restricted to the pursuit of evidence for reductions in accident rates, without attempting to address whether skill courses succeed in their intermediate goals of improving rider skill. Part of the reason for this is, no doubt, the fact that there is only limited knowledge of which rider skills are linked to safety.

Clayton and Sudlow (1987) did investigate the effectiveness of a specially developed one-day training course in the UK. Just over two hundred learner motorcyclists with no or minimal on-road riding experience were recruited. Of these, half underwent the 8 hour off-road training course, whilst the other half received no training. They were assessed by:

- a skills test (conducted the day after the trained group had received the training);
- a multiple-choice test of motorcycle knowledge and safety (administered immediately before training); and
- a 25 question attitude battery covering motorcycling, training and safety (administered immediately after training had been received).

The same tests were conducted again, eight weeks later.

Both groups significantly improved their performance on the skills test between the first and second testing, but trained riders committed significantly fewer errors than the untrained group on each occasion. The major difference between the groups' scores was attributed to the control group's poorer performance on tasks involving rear observation, particularly during right turn manoeuvres, and their ability to maintain the balance of the machine and rider.

There was no statistically significant effect of the training on knowledge or attitudes.

5.6.1.3 Possible explanations of the lack of proven effects of training on accidents

As discussed above, one possible explanation of the lack of a proven effect of training on accidents concerns limitations in the assessment studies themselves. An alternative explanation is that current training is truly ineffective as a way of reducing accidents. There are several possibilities outlined here:

Skills are not being learned by the riders

One possibility is that training is ineffective at imparting the intended skills. Training can, of course, improve skill, but there is little actual evidence on the effectiveness of motorcycle training in this regard and, in particular, on whether any superiority of trained riders persists. Clayton and Sudlow (1987) provided evidence of an effect persisting over eight weeks, but there would appear to be a need for further investigation of this area, and of factors that may improve or impede the effectiveness of training.

Ford and Alverson-Eiland (1991) discussed several such factors. These included poor co-ordination, difficulty learning new motor skills, weather conditions, inadequate instruction, and anxiety. The study investigated anxiety, which is known to affect task performance and skill acquisition (e.g. Spielberger, 1983). No statistically significant effects of anxiety were found, thought there was a suggestion that anxious riders did less well at acquiring skills, and were more likely to drop out of the training.

Training does not address skills related to accident involvement

Another possible explanation of the lack of a proven effect of training on accidents is simply that the skills addressed during training are not those critical to safe riding.

In a review of motorcycle training's effectiveness, Simpson and Mayhew (1990) highlighted the importance of this issue stating 'if no measurable impact of training [on accidents] is observed it raises other critical questions, including the extent to which what is being taught is relevant to the safe operation of the vehicle'.

In view of such uncertainty, it would seem to be extremely desirable to identify those skills that are particularly important for safe riding. An analysis of the behavioural antecedents to accidents could be useful here, as a way of identifying skills and rules that could be taught to novice riders. Such is study is proposed in Section 5.8.

Task analysis is another possible approach. Jonah and Dawson (1979) cited studies by McKnight and Heywood (1974) and McPherson and McKnight (1976) in which a motorcycle test, based on a task analysis of safe motorcyclist behaviour, was developed. The Motorcycle Operator Skill Test (MOST), differed from the standard motorcycle licence test in operation in the US at the time. It was developed following their contention that for a test to be a 'valid measure of critical on-road operating skills' its development should begin with a task analysis of the skills necessary for safe on-road operation of a motorcycle.

The resulting test contained nine exercises of increasing complexity, including starting on an incline, turning right and left, avoiding obstacles and, stopping on curves. The validity of the test was measured by comparing scores on the test with ratings of the riders' performance as made by independent 'experts'. The scores were found to be significantly correlated, indicating at least a degree of validity.

In an evaluation of the test conducted by Jonah and Dawson (1979) it was found that, as hoped, experienced riders scored higher on the test than inexperienced riders. However riders previously attending a skills training course were actually assessed as having less skill than untrained riders. Furthermore this difference remained even after controlling for experience.

Despite some methodological difficulties, the study does provide an example of a possible mismatch between safe riding skills as identified by task analysis and skills addressed in training. Interestingly, though, Jonah *et al.* (1981) assessed the predictive validity of the MOST, and found no effect of test performance on subsequent accident involvement.

Driver and rider training, certainly basic pre-test training, tends to emphasise control skills and to neglect higher order cognitive skills such as those related to the anticipation, detection and assessment of hazards. There are many indications in the literature of the likely importance of such skills. In the past establishing a firm link with accidents proved elusive but there are now several studies of car drivers indicating that such a link does exist (Currie 1969; Peltz and Krupat 1974; Quimby and Watts 1981; Quimby *et al.* 1986; Hull and Christie 1993; McKenna and Horswill 1999). In a review of this area Lester (1991) stated 'the higher order cognitive and risk perception skills together with attitudinal and social factors are clearly associated with accident liability'. A large-scale prospective study involving over 80,000 driving test candidates has been conducted in Victoria, Australia, and preliminary analyses appear to confirm the existence of a relation between hazard perception scores and accidents (Hull, personal communication 1999).

Further components related to accident involvement include factors relating to risk taking behaviour. Koch and Brendicke (1990), cited by Brookes and Arthur (1997), have pointed out that training needs to deal with the contradiction that 'what we teach asks for an *avoidance* of risk taking whereas young people in society *validate* and *reward* risk taking'.

Many researchers (e.g. Simpson and Mayhew, 1990; Chesham, Rutter and Quine, 1991, 1992; Koch, 1987) have expressed concern about the relative weight given to skills training as opposed to knowledge and attitudes. Rothe and Cooper (1987), cited in Simpson and Mayhew (1990), concluded that a 'lack of riding skill is not the major problem. Attitudes, personality and awareness of others are'. Additionally there is wide support for the need for training or other interventions to address the factors influencing drivers' choice of riding style, including motivations and lifestyle as discussed in relation to the earlier point

Skills are not being translated into on-road riding behaviour

Even if (a) riders are learning the skills contained within training courses and (b) these are the skills needed for safe riding, it may be that riders then choose to behave differently during their normal riding.

Theories of driving behaviour (e.g. Michon, 1985) have outlined the importance of driver motivations in influencing the driving style the individual chooses to adopt. Additionally, research has suggested that factors including lifestyle (Keskinen *et al.*, 1992) and attitudes have an important influence on driving behaviour.

The qualitative interviews conducted by Brookes and Arthur (1997) found that riders identified risky behaviour as both the cause of danger *and* the major appeal of motorcycling. Indeed the study, which also interviewed 'pre-riders' aged 15-18 years who neither rode a bike or drove a car, found that the major distinguishing feature between those who were intending to gain a motorcycle licence and those with no such desire was the value placed on danger and risk taking.

The older and more experienced riders interviewed believed that young riders may sometimes deliberately ignore sound training advice in favour of sensation seeking, boundary testing, and motivations to impress others. Indeed, the novice riders did not deny this and described some less risky riding styles as 'boring'.

Similar findings have been outlined in Section 5.4.1 Brendicke (1991) found attitudes including 'without a certain amount of thrill, motorcycle riding is boring' to be particularly strong among groups of younger riders. Hobbs *et al.* (1986) found that 81% of riders in their sample believed that there is a thrill in motorcycling riding. However, the study also found that 72% disagreed with the statement 'you have to take your chances when riding a bike'. Hobbs *et al.* concluded that riders motivated by the thrill of riding might not actually be adopting increased risk taking behaviour during riding. Nevertheless the potential problems of thrill-seeking motives are clear, and further research is required in order to make explicit the link between such motivations and riding behaviour.

Other research into the training of car drivers has highlighted potentially negative effects of acquiring increased control skill through training. For example, there have been reports of accidents increasing following skid training (e.g. Glad, 1988; Keskinen *et al.*, 1992). It appears that falsely optimistic self-assessments of ability to control the vehicle, perhaps combined with motives to explore these new-found abilities, may lead drivers into trouble. Using training to make drivers aware of their own limitations appears to be a more fruitful approach (Gregersen, 1996).

5.6.1.4 Alternative approaches to training

The above discussion implies that the lack of proven training effects may be more than just a case of poor evaluations. Instead it is possible that training is failing to have a demonstrable effect on subsequent accident involvement due (a) to inappropriate design or content of training and/or (b) to inherent limitations in what training alone can achieve. Indeed, it has been suggested (Cloke *et al.*, 1999) that driver training ought to be seen as a measure that enables a driver to perform in a particular way, but which may then need to be supported by other measures to persuade the driver to make use of the training.

As well as generally improving the content of training courses – e.g. to emphasise skill limitations, improve coverage of higher order cognitive skills, provide information on risk, and communicate a safe-riding 'rule-base' – other types of intervention seem worth pursuing further. One is the use of simulator-based training for motorcycles, discussed below. Another is the use of training, education or publicity to attempt to change attitudes, which is dealt with in Section 5.7.

Simulators

Brookes and Arthur (1997) argued that simulation provides the best potential training method to address the interplay between riders' motivations to experience exhilaration, and motivations to remain accident free:

'The delivery mechanism must offer experience of the sources of danger from road use. It must address emotive and sensation-seeking aspects of motorcycling which appear to create and sustain risk-taking propensities. Trainees should be exposed to an investigation of riding behaviours and their consequences in a safe, valid environment: a simulation which could promote safety by simultaneously providing and examining excitement.'

As demonstrated within their interviews, something about the dynamics of controlling a motorcycle appeals to riders. The same aspects possibly motivate riders to take risks. Therefore, the authors argue that these aspects need to be adequately captured within any computer-based intervention, thus allowing the novice rider to actively 'buy into' the safe messages advocated within the training. Brookes and Arthur conclude by outlining the need for research to explore the link between riders' motivations for motorcycling and their need for risk-taking, before truly effective simulations can be designed.

Exactly how such a simulation approach to training would work in practice is not entirely clear. This is partly because the risks and motivations (and indeed the control skills) associated with on-road riding would not be fully simulated. Even if they were, the problem of how to modify skills and motives would still have to be solved. Also the possibility that the simulator would produce unwanted reinforcement of thrill-seeking behaviours would need to be addressed. In addition, there are the obvious cost-related difficulties of using high-fidelity simulators in mass training programmes. Nevertheless, even a relatively low-fidelity simulator might at least provide an opportunity for instructors and pupils to discuss motivational issues. This would seem to be worth investigating further.

Yuhara *et al.* (1993) also argue for the use of simulators in motorcycle training, since they allow training in understanding traffic situations, hazard perception and avoidance, and safe riding skills, without having to expose the learner to road hazards.

A further potential advantage of simulation is that it offers a way of overcoming one of the inherent problems in motorcycle training – that of giving adequate on-road supervision and instructor feedback.

5.7 Changing attitudes

5.7.1 Attitude-change and motorcycle riders

Research discussed earlier in this section suggests that rider motivations and attitudes are associated with unsafe riding behaviours and accident involvement. One possible reason why rider training has not been shown to be effective is that training courses have not dealt effectively with these psychological variables. As well as influencing riders' on-going choices of riding behaviour, attitudes also appear to be influential in the formation of habitual behaviours – and research (Chesham *et al*., 1991; Chesham *et al*., 1992; Rutter and Quine, 1994; Rutter *et al.*, 1993; Rutter *et al.*, 1995) has indicated that both safe and unsafe behaviours are largely habitual in nature. Indeed, Chesham *et al.* (1992) concluded that behavioural change interventions that seek to improve the accident liability of motorcyclists should (a) be based on detailed analysis of the factors important in the formation of riding habits and (b) be applied as early as possible in this process of habit formation.

Rutter and associates (discussed in Section 5.5.2) showed that expectancy-value components of the Theory of Reasoned Action (TRA) and the Health Beliefs Model (HBM) appear to be implicated in the formation of riding habits. These components are behavioural beliefs and outcome evaluations for the TRA and perceived barriers and benefits for the HBM.

Chesham *et al*. (1993) suggested that Petty and Cacioppo's 'Elaboration Likelihood Model' (ELM) of persuasion provides a useful methodological framework for examining changes in attitude, since it aims to engineer attitudes that are resistant to change and predictive of behaviour. According to the ELM, there are two routes to attitude change through persuasive communications. The 'central route' requires that an individual actively processes the persuasive messages and elaborates upon these by generating additional 'issue relevant' thoughts. The 'peripheral route' does not involve the active cognitive processing of persuasive communications and, according to the ELM, leads only to temporary changes in attitudes that are likely to be affected by peer group pressure and other influences, and unlikely to affect behaviour. In other words, the model predicts that people have to be encouraged to think about the persuasive message if useful changes in attitude are to be achieved.

Chesham *et al*. (1993) suggested that the ELM provides two explanations for the [apparent] ineffectiveness of existing motorcycle training. First, it could be due to conventional training having no impact at all on the attitudes of riders. Secondly, the ineffectiveness could be due to training producing only 'peripheral' changes in attitudes.

The researchers tested these hypothesises by evaluating an existing motorcycle training course which set out to persuade 30 young male novice riders of the value of five safe riding behaviours. The course had a statistically significant effect on participants' attitudes, changing them for the better (i.e. geared towards greater safety) for three of the five behaviours. However, the attitude changes were classified as peripheral and, therefore, as unlikely to be long lasting or predictive of behaviour. One of the indicators that the attitude changes were peripheral was the fact that the training course did not increase the number of reasons that participants were able to give for the safe riding behaviours

The reasons that participants gave for the safe riding behaviours were used to generate 'persuasive communications', which were then evaluated by two further groups of participants. One group rated their likely effectiveness, and the other group was used to find out how much 'issue-relevant thinking' was stimulated by each message. Several types of message were used, appealing to difficulty in stopping, injury risk, and the law as arguments not to speed. Differences between them in terms of (a) their judged effectiveness and (b) the amounts of 'issue-relevant thought' each type of message induced, suggested that it is important to evaluate potential attitude messages in order to produce messages likely to lead to 'central-route' attitude change.

The Chesham *et al*. (1992) study included no measures of behaviour or behavioural intention, or of any attitude change produced by the persuasive messages generated during the study. The study did not attempt to test the ELM predictions that 'central-route' attitude changes, characterised by 'issue-relevant thinking', are enduring and predictive of behaviour. Nor did it test the ELM prediction that the attitude shifts produced by the training course would be short term and unlikely to lead to behaviour change.

5.7.2 Other relevant attitude-change research

Other studies related to changing attitudes and behaviours in road users are described by Parker *et al*. (1996) and Meadows and Stradling (1999). Although these studies assessed the effectiveness of attitude change strategies for car drivers, the findings may be useful in two ways. First, they may be in principle transferable to motorcyclists and so be relevant to the improvement of rider training programmes and/or educational campaigns. Secondly, they may suggest where future research is needed to cope with differences between car drivers and motorcycle riders.

Parker *et al.* (1996) assessed the effectiveness of video-based interventions grounded in the TPB and directed at changing attitudes towards speeding on residential roads. The TPB components assessed were normative beliefs, behavioural beliefs, perceived behavioural control and anticipated regret.

The videos produced significant changes in normative beliefs and anticipated regret, but not in behavioural beliefs. A change in perceived behavioural control was found, but in the 'wrong' direction. People who watched the anticipated regret video had less favourable attitudes towards speeding. Despite that fact that some beliefs and attitudes were changed, there was no statistically significant effect on behavioural intentions.

This lack of an effect of attitude change on behavioural intentions could be seen as a heavy blow to the practical utility of the TPB. Indeed, some researchers summarise the present state of knowledge as indicating that behaviour change leads to attitude change, rather than vice versa (e.g. Burgess, 1998). Parker *et al*. (1996) suggested, however, that a full-scale media campaign to which people are exposed repeatedly over many months may be more effective at changing attitudes and behaviour than the videos used in the study (which were seen only twice). It is also relevant to note that each group of participants was exposed to only one of the videos – whereas a media campaign could seek to influence every TPB predictor variable for each person. Parker *et al*. also suggested that:

- The persuasive communications used in the study may be more useful than the directly measured attitude change (or lack of it) would indicate, since they may produce a shift from a pre-contemplative to a contemplative state of mind, in which people start to consider that they ought to change their behaviour.
- Intentions to speed may be more resistant to change than are other behavioural intentions, because drivers' attitudes towards speeding are more permissive than towards any other violation.

Nevertheless, the authors did entertain the possibility that the main benefit of attitude change may be to prepare people to accept other interventions – such as enforcement – that seek to have a direct influence on behaviour.

A study by Meadows and Stradling (1999) evaluated the effects of two resource-packs on learner drivers' attitudes to road safety. One pack informed driving instructors as to the best way to improve learner drivers' attitudes (*instructor pack*). The other pack was worked through by the students in between driving lessons (*learner pack).*

Four groups were compared, one receiving both resource packs, one receiving the experimental learner pack plus a control instructor pack, one receiving a control learner pack plus an experimental instructor pack and one receiving both control resource packs.

The researchers concluded that the resource packs had a small but positive effect on learners' attitudes, intentions and current speeding behaviour. It should be noted, however, that participants were also receiving their normal driving instruction during the period when the resource packs were being used. It is possible, therefore, that the behaviour change was produced by the driving instruction, with the resource packs having the effect of making participants more ready to accept their instructor's advice on speeding.

For learner motorcycle riders, such resources may be useful in curbing speeding and other behaviours related to accidents. However, it will be necessary to tailor them specifically to motorcycling. Clearly, a better understanding of the links between attitudes and behaviour would be useful in helping to formulate policy on improving motorcycle safety.

5.8 Conclusions and recommendations

As with car driver training, the effectiveness of motorcycle training as a way of reducing riders' subsequent accident involvement is not proven. It is not clear how much this is due to the difficulty of designing evaluative studies, and how much to a true lack of effectiveness of training. One implication of this uncertainty is that good evaluations of training are still needed. However, it seems certain that the potential effectiveness of current training is limited by a number of factors:

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

In addition, the particular control-difficulties faced by a motorcycle rider in a developing emergency are difficult to train for without placing the trainee at risk, and it seems highly plausible that many motorcycle riders have this fact brought home to them in the moments before their first accident. New training methods, possibly involving simulators, and improved training content to provide the knowledge and rules base needed to help riders both avoid and deal with emergency situations, need to be sought here.

A further important characteristic of motorcycle training is that many riders returning to motorcycling after a break have had no formal training. Those with training are likely to have been trained on lightweight, low-powered machines that bear little resemblance to the modern over-500cc machines that are increasingly dominating the motorcycle stock. Whether this is a serious safety problem is not known, and one of the objectives of the self-reported accident survey proposed later in this section is to obtain further information on this point. The before and after evaluation of the 1997 licensing changes should also throw some light on the importance of managing the transition between learner motorcycles and high performance machines. If it is found, or judged, to be serious, there could be a case for considering compulsory training for such riders.

The likely importance of motivations and attitudes in influencing whether riders put their safe riding skills into practice implies that measures are needed to influence these factors. It may be possible to make progress here by training – possibly with the help of simulators, or by using new training materials. However, educational and publicity material may be needed to change attitudes. The appeal of motorcycling to sensation-seeking motives may prove particularly difficult to tackle. It would seem highly desirable to find ways of (a) training riders to seek sensation safely and (b) promoting and harnessing other pleasures of riding. How effectively this could be done, remains to be seen.

It seems likely, as argued by Simpson and Mayhew (1990), that a lack of skills contributes to accident involvement in combination with the other factors discussed above. Further studies to develop and evaluate skills training would be valuable, perhaps associated with the work on new training methods mentioned above.

Associations between attitudes, riding behaviours and accidents suggest that measures to change riders' attitudes might improve motorcycle safety – either by influencing behaviour directly, or by supporting other influences on behaviour.

Given that one potential effect of attitude change is to encourage riders to form safe rather than unsafe riding *habits*, it would appear desirable to influence attitudes during the earliest stages of a rider's career.

Traditional training courses do not concentrate on rider attitudes, and there is some evidence that if they do achieve changes in attitudes, these are likely to be transient and not influence behaviour. This may be at least a partial explanation of the lack of a proven safety-benefit of training.

Research – for example the work on the ELM – suggests ways of designing interventions so that they are effective in inducing attitude change. For example, the ELM predicts that if changes in attitude are to be long lasting and resistant to short term decay and other influences, there needs to be *active* processing of messages contained in persuasive communications, which should generate issue-relevant thought.

Attitude models such as the TPB and the HBM can be used to identify those components of attitudes and related variables that are most strongly predictive of behavioural intentions. In the road safety field, most of this work has involved car drivers and there is a need to do more research to understand the attitudinal structure of motorcyclists.

Standard applications of attitude modelling in the road safety field attempt to predict behaviour (or, rather, behavioural intention) only in a cross-sectional sense. The results are often interpreted as identifying attitude components that, if changed, would lead to behavioural change but in fact, the models do not yield any direct evidence on this. Some researchers hold that the causal link runs not from attitudes to behaviour, but in the opposite direction. The main benefit of attitude change may turn out to be that of persuading people to accept other means of bringing about behavioural changes. More work is needed to elucidate this point.

Recommendations for research: The rider

Survey(s) of self reported accidents, attitudes and other variables

There is a need for a survey-based study or studies to investigate the following issues:

- The characteristics of motorcycle use in Britain, in terms of machine size, rider experience and training, driving experience, age, sex, exposure, trip purpose and other variables, and how these have changed since 1988.
- The effects of the above variables and interactions between them on accident liability.
- The effects of the 1997 licensing changes on riders' experience levels as they graduate to larger machines, and on accident liability.
- The effects of upgrading to larger machines on quantity and quality of exposure.
- The characteristics of returning riders and other riders of over 500cc motorcycles in terms of age, experience, training, attitudes, perceived risk, and motives.
- Self reported frequencies of potential 'problem behaviours' and the association between such behaviours, self-reported accidents and attitudes.
- Attitudes towards protective clothing, and safety features such as improved brakes, leg protectors, airbags and daytime use of headlamps.
- Links between perceived risk levels and variables such as experience, training, having accidents, and knowing people who have been injured.
- Incidence of particular types of accident (e.g. associated with diesel spills).
- Characteristics of people seeking advanced training
- Links between attitudes, motivations, behaviour and accidents.

In principle a single, multipurpose survey could be undertaken, though this would probably run into difficulties with questionnaire length. An alternative would be to split the research as follows:

a A self-reported accident survey, similar to that undertaken by Taylor and Lockwood (1990). Questions would also cover the training and experience of returning riders and some attitudinal and behavioural information.

b A study of attitudes, motivations and behaviours – probably using a follow-up questionnaire sent to a sub-sample of the above survey respondents.

c A survey of samples of people who took their motorcycle tests before and after the licensing changes introduced in 1997. This would include questions about experience, training, and graduation to more powerful machines. Ideally, the sample size would be sufficient to detect effects of the changes on accident liability to be determined.

It is strongly recommended that the survey at (a) above is done in close collaboration with the analysis of existing data on motorcycle accident risk proposed in Section 2.4.

On-the-spot study of motorcycle accidents

On the spot studies of road accidents are currently being planned by DETR, and maximum use should be made of these to collect information, including exposure information, relevant to the questions identified in this report.

In-depth analysis of behavioural antecedents of motorcycling accidents

Motorcycles have particular capabilities and vulnerabilities that need to be incorporated in a rider's 'rule base' and 'knowledge base'. For learner and novice riders, this may be particularly difficult because of the relative lack of supervision during learner riding and the large variation in motorcycle performance and riding styles. In addition, there is the possibility that sensation-seeking motives, which appear to play an important part in motorcycling, may attract some riders to extreme departures from 'learner-style' riding early in their riding careers. For experienced car drivers returning to or taking up motorcycling, the differences between the rules/knowledge base appropriate for car driving and that needed for motorcycles (to do, for example, with poor conspicuity, and problems of stability and control while braking and cornering) may mean that such riders, too, would benefit from interventions designed to help them acquire the rules and knowledge they need to ride safely.

One way of identifying critical 'rules' that could help riders avoid accidents is via an analysis of motorcycle accident records to study the sequences of events that precede accidents. A technique for doing this has been developed at Nottingham University and applied with some promise to car accidents.

Development and evaluation of rider training and education

There remains a need for well-designed evaluations of the effects of training on skills, knowledge, rider behaviour and accident liability.

Work is also needed to improve the content of training courses – for example by emphasising skill limitations, coverage of higher order cognitive skills, providing information on risk levels, and communicating a rules and knowledge base for safe riding. The possibilities for improving the ability of training to address attitudinal and motivational aspects should be considered here.

Research will be needed to help develop and evaluate the improvements to CBT, and other changes mentioned in the DETR response to the recent consultation exercise (DSA, 1999). The training of riders returning to motorcycling after a break may need to be addressed if they are shown to be particularly at risk and, or, to be relative novices with respect to training and experience.

In addition, other approaches to training – including the use of simulators – should be examined, particularly as ways of addressing motivational aspects of riding and the difficulties in providing on-road supervision and feedback during motorcycle training.

Turning these general recommendations into a programme of research on training will require further thought, and discussion with Government. However, a detailed study of the content and practice of motorcycle training in Britain and abroad would be an extremely useful start. Information relevant to the improvement of training will be provided by many of the other research studies proposed here, including the self-reported accident studies.

Car drivers' knowledge and attitudes

There are strong indications that part of the reason for car drivers 'looking but not seeing' motorcyclists is to do with expectancy. It appears that drivers do not expect to see motorcyclists, and may not incorporate them into the search strategies and perceptual short-cuts (e.g. perceptual templates) that they develop with experience. One potential countermeasure is improved driver training, emphasising the need for careful visual search for the unexpected. However, it is not certain that this would have a persisting benefit. If the basic problem is that motorcycles are unexpected because they are relatively uncommon, experience of this fact may act to dilute or negate any effect of training. Nevertheless, training on search and scanning techniques, and making drivers aware of expectancy phenomena, might have a persisting benefit. Under high workload conditions, attention tends to focus not just on high probability cues, but also on cues perceived to be important. There are indications in the literature that car drivers tend not to attach a lot of importance to the possibility of colliding with a motorcyclist. This suggests that emphasising the vulnerability of motorcyclists and their control difficulties may also be a useful component of driver training interventions.

Designing and evaluating such training interventions – starting perhaps with an evaluation of the recent DSA video – would be well worth doing.

Control skills and hazard perception

It has been shown that experienced drivers' hazard perception skills are vulnerable to increases in mental workload from other tasks. Given that the control skills for high performance motorcycles may well remain cognitively demanding for a considerable time, especially when riders are exploring the limits of their capabilities, it seems possible that hazard perception performance will be impaired.

Research is needed to explore whether this potential problem is likely to be an important characteristic of motorcycle accidents. Possible countermeasures might include improving the training of control skills, improving the knowledge and rules base to help riders avoid situations in which they are likely to become loaded with control difficulties, using licensing restrictions to control the transition between low and high performance machines, and improving the training of hazard perception skills.

Even if hazard perception is not shown to be affected, information on control problems will be useful in its own right.

Fatigue

In view of indications that there may be quite severe effects of fatigue even on short journeys, more research is needed to assess the size of the problem and the need for countermeasures (such as publicising the problem and encouraging frequent breaks).

6 Legislation

6.1 Entitlements and procedures

The Driving Standards Agency's (DSA) Motorcycling Manual outlines the legal requirements with which motorcyclists must comply before they are allowed to ride their vehicles on public roads in Great Britain. Issues covered are the law governing driving licences for motorcyclists, the types of licence and requirements for their attainment, Compulsory Basic Training (CBT), the situation regarding mopeds and foreign licence holders. The manual states the following:

6.1.1 Legal requirements

To ride a motorcycle on public roads in Great Britain it is a requirement that motorcyclists are at least 17 years of age (16 years for moped riders) and have a valid driving licence which specifies motorcycle entitlements (Category A). At present, category A entitlements are permitted if the rider holds a full motorcycle licence, a full car licence[5], a full moped licence[6] or a provisional driving licence with provisional motorcycle entitlement.

6.1.2 Provisional motorcycle entitlements

Provisional motorcycle entitlements allow the motorcyclist to ride a motorcycle up to 125cc with an engine power up to 11kW. Learner riders are also allowed to ride with a sidecar so long as the power to weight ratio does not exceed 0.16kW/kg. In addition, learner riders have to abide by other provisional licence restrictions which include the attachment of L plates to the vehicle (D plates in Wales), the restriction of motorway use and the restriction of carrying a pillion passenger.

Provisional licence entitlements for motorcyclists only last two years. The motorcyclist must pass the theory and the practical test before the two year period expires. If the motorcyclist does not pass these tests within two years of obtaining provisional entitlement then he/she has to wait one year before regaining motorcycle entitlement. This restriction was imposed in 1982 and its introduction was to provide learner riders with an incentive to train and pass the test and to eliminate the 'permanent learner'.

6.1.3 Compulsory Basic Training (CBT)

CBT was introduced in 1990 to help reduce the high accident rate among inexperienced motorcyclists and from January 1997 it became compulsory for all learner motorcyclists, including those who were previously exempt due to their holding a pre-1990 full car licence with provisional motorcycle entitlement or provisional moped licence. There has been no scientific evaluation of the effects of CBT on casualty reductions. However, the DETR Road Safety Strategy (1997) points out that there is every reason to assume it has played some part in the reduction of motorcycle casualties in the 1990s.

The CBT course has five components which have to be taken in sequence. These components are (1) an initial introduction which makes the rider aware of the safety issues involved in motorcycling and includes an eyesight test; (2) practical on-site training; (3) practical on-site riding; (4) practical on-road training; and (5) practical on-road riding.

The CBT course aims to:

- Make the rider familiar with the motorcycle and its controls.
- Train the rider to control the motorcycle, operate its controls and perform the Observation – Signal – Manoeuvre (OSM) routine and the Position – Speed – Look (PSL) routine.
- Train the rider to ride defensively and to anticipate the actions of other road users.
- Train the rider to use rear observation at appropriate times, to assume the correct road position when riding, to avoid tail-gating, and to be aware of, and ride with respect to, varying weather conditions and types of road surfaces.
- Train the rider how to cope with a range of hazards including traffic lights, roundabouts, junctions, pedestrian crossings, gradients, bends and obstructions.

At the end of the course the rider is given a brief theory lesson which covers:

- The effect on riding behaviour of drink, fatigue, illness, drugs, and so on.
- How to reduce the risk of an accident.
- Courtesy and consideration towards other road users.

The training course costs around £60-£70 and must be completed before learner riders are allowed on the public road. When learner motorcyclists have completed this course they are awarded with a DL196 form which is required before they are allowed to take the practical test.

6.1.4 Types of licence

Also introduced in January 1997 were two types of full motorcycle licence that entitle the motorcyclist to ride without L plates (or D plates in Wales), carry a passenger and use motorways:

1 Light motorcycle licence (Category A1):

The Category A1 licence entitles the use of any motorcycle up to 125cc with a power output of up to 11kW (14.6 bhp). To obtain this type of licence the motorcyclist must have passed his/her practical test on a motorcycle of between 75 and 125cc.

2 Standard motorcycle licence (Category A):

For category A motorcycles there is a two stage graduated licence scheme. After passing the practical test, riders attain stage 1 entitlements. Riders at this stage have a limited motorcycle licence which encompasses machines up to 25kW (33 bhp) and a power to weight ratio not exceeding 0.16 kW/kg. For the motorcyclist to qualify for stage 2 entitlements, he/she must gain two years motorcycling experience. Riders with stage 2 entitlements have a licence with no power restrictions and are allowed to ride motorcycles of all types. To obtain this type of licence the motorcyclist must have passed his/her practical test on a motorcycle of over 120 but not larger than 125cc and capable of at least 100kph.

6.1.5 Accelerated access

The applicant is permitted to take an additional test to provide unrestricted category A entitlements if he/she reaches the age of 21 before the two year qualifying period is complete. The additional test must be taken on a motorcycle with a power output of at least 35kW (46.6 bhp). Practice for the test is allowed on motorcycles more

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[5] *This automatically provides provisional motorcycle entitlement.*

[6] *This provides provisional motorcycle entitlement if the motorcyclist is at least 17 years old.*

powerful than those permitted by a limited motorcycle licence providing the motorcyclist is accompanied at all times by an approved instructor on another motorcycle and in radio contact; wears fluorescent or reflective clothing, has L plates fitted to the motorcycle, and follows provisional licence restrictions.

6.1.6 Direct access

The applicant is permitted to take one test which allows direct access to the unrestricted category A entitlements if he/she is at least 21 years of age. The test must be taken on a motorcycle of at least 35kW (46.6 bhp) and the applicant is allowed to practice on a motorcycle of any size. However, if practising on a motorcycle which exceeds UK learner specification the motorcyclist must follow the same restrictions as for accelerated access above.

6.1.7 The Theory Test

Since January 1997 motorcyclists have not been allowed to book a practical test until they have passed the theory test. For both categories A and A1 the theory test comprises of 35 questions with the pass cut off at 30 correct written responses. When the motorcyclist passes the theory test he/she is awarded with a certificate which is valid for two years. However, riders who have already passed a theory test for driving a car are exempt from the motorcycle theory test, with approximately 90% of riders being so exempt (DSA, 1999).

6.1.8 Moped riders

To ride mopeds on the public roads in Great Britain the rider must be at least 16 years of age and hold a valid driving licence which entitles him/her to ride mopeds (category P). Category P entitlements are permitted for riders aged 16-17 years if the rider holds a full moped licence or a provisional moped licence. For riders aged 17 years and over a full car or motorcycle licence and provisional driving licence will also permit category P entitlement. The provisional moped entitlement allows the rider to ride a machine up to 250kg in weight, up to 50cc with a maximum design speed which does not exceed 30mph, and can be moved by pedals if the moped was registered before 1977. The full moped entitlement, in addition, allows the rider to ride without L plates and to carry a pillion passenger. Accelerated and direct access and the two year qualifying period which apply to motorcycles are not applicable to mopeds.

6.1.9 Foreign riders

In Great Britain tourists and new residents with a foreign licence *(non-EC)* or an *International Driving Permit (IDP)* are allowed to ride motorcycles or mopeds on public roads for up to one year so long as the licence or IDP is valid, it insures the entitlement for the type of motorcycle the rider intends to ride, and the rider is aged 17 or above. If the rider does not have the correct entitlements or has been in Great Britain for over the one year period, he/she must apply for a UK licence before riding. These riders then have only provisional entitlements and must follow the procedure outlined above.

Foreign riders with *EU* licences can ride in the UK until their licence expires. In 1991 harmonisation of the law governing driving licences in EU countries was achieved whereby the Second Directive on driving licences was adopted. This provided obligatory categories for driving licences with defined sub-categories. Therefore, licences from these countries can be exchanged for a UK licence within a one year period of entering Britain without the need to take theoretical and practical tests. However, if the EU licence provides motorcycle entitlement which was granted automatically when the rider passed his/her test in another vehicle (e.g. car) then riders are only given full moped entitlement and provisional motorcycle entitlement. In this instance, theory and practical tests are required to obtain full category A entitlement.

6.2 Posted speed limits

In Great Britain the speed limits for motorcycle and moped riders are as follows:

	Speed limit	
Road category	*km/h*	*Mph*
Motorway	112	70
Dual carriageway	112	70
Rural roads	96	60
Urban roads	48	30

For motorcycles using a side car, alterations in these posted speeds are as follows:

	Speed limit	
Road category	*km/h*	*Mph*
Motorway	96	60
Rural roads	80	50

6.3 Compulsory helmet wearing

Helmet wearing for motorcyclists and moped riders became compulsory in Great Britain in 1973. All helmets sold in the UK, both full-face helmets and open-face helmets, must have a BSI kitemark and comply with British Standard BS6658.

6.4 New licensing policy: the DSA ‘Safer motorcycling’ consultation paper

A recent paper by the DSA (1999), ‘Safer Motorcycling’, reported on the results of a consultation exercise and proposed new policy for licensing of learner riders, untrained learner riders and the theory test for learner riders.

6.4.1 The consultation exercise

In July 1998 the DSA issued a consultation paper, ‘Provisional Licences for learner Motorcyclists’, which sought views on licensing arrangements for learner riders from motorcycle interest groups, road safety interests, the police and those concerned with operating the criminal justice system. The consultation issues were:

- How long should a provisional licence be valid for?
- Should extra training or a test-attempt affect the period?
- Should there be a disqualification period for learner riders who do not reach test standard within a prescribed period?
- How would permanent learners be deterred if learner riders were issued with ‘until age 70 years’ licences?
- Should any new arrangements apply equally to all learner riders regardless of the type of licence that they held?
- Should a person who holds a full licence for riding one type of machine take training when learning to ride another type of machine?

1,500 copies of the consultation paper were issued to the various groups and 67 responses were received. Responses included the following consistent themes:

- the current two year provisional period for motorcyclists should not be relaxed unless safety could be safeguarded;
- any change to the limited two year provisional period should exclude the risk of a ‘permanent learner’ culture, and ensure that all learners were properly trained and tested;
- learners should be encouraged to obtain a full licence within two years;
- new arrangements should apply equally to all learner riders regardless of the type of licence they hold.

Other comments from the consultees were that:

- a further training obligation would be more appropriate than a one year disqualification period when test standards are not reached within two years, since riding standards are likely to decline in the one year period when the person cannot ride a motorcycle;
- the current CBT course does not ensure properly trained learners;
- if holders of full motorcycle licences are to take further training for riding different types of machine, then training should be delivered which is relevant to the type of machine the person wants to ride;
- improvements to current arrangements should not have to wait for primary legislation;
- attention should be given to people with full motorcycling licences returning to motorcycling after several years and the driving standards of other motor vehicle users.

6.4.2 The government response to the consultation exercise

1 Licensing arrangements for learner riders

The DSA Safer Motorcycling paper outlined Ministers intentions for licensing arrangements for learner riders. It stated that Ministers intend to develop arrangements that:

- Meet the objectives of the current two year rule for provisional motorcycle licences.
- Apply fairly.
- Are simple to understand and administer.

As a result of the consultation exercise, the DSA Safer Motorcycling paper proposed that the following licensing arrangements should apply for learner riders and that due to the development of training courses and systems changes at DVLA and DSA, implementation before April 2000 would not be practical:

- provisional motorcycle licences would be issued until the age of 70 years;
- learner riders would still need a CBT certificate to ride on the road;
- the CBT course would be enhanced and different courses would be prescribed for learners using different types of motorcycle;
- a CBT certificate would be valid for 2 years; and
- a rider who had not passed a test by the end of this two year period would need to complete another CBT course to continue using the licence on the road.

In addition, a number of other arrangements were proposed which related to current learner riders who would have already obtained a CBT certificate which would be valid for three years. The arrangements would also apply to those who had lost their provisional entitlements because they had not passed a test with two years of obtaining provisional status. First, it was proposed that the changes above would not affect the three year period in which previously issued CBT certificates are valid, but if learner riders have not passed their test within the three year period then they would be required to take another CBT course for which the certificate would be valid for two years. Secondly, it was proposed that learner riders who had lost their provisional entitlements because they had not passed a test with two years of obtaining provisional status could apply to DVLA to have their licence reinstated immediately. In addition, if these riders were to still have a valid CBT certificate, then they could use the new licence for the remainder of the three year period, but they would need to take the new CBT course to continue riding on the road if they did not pass a test before their original CBT certificate expired.

The DSA Safer Motorcycling paper also reported Ministers desire for (1) an inclusive approach for developing modernised training arrangements, including the aspects of current good practice within the motorcycle training industry; (2) those involved in motorcycling to offer development training to persons returning to motorcycling in an attempt to address the concerns about safety of the born-again biker; and (3) the development of a voluntary register of qualified motorcycle instructors to provide an accredited source of instructors for conducting post-CBT training, training for riders with full motorcycling licences returning to motorcycling and persons who ride motorcycles as part of their work. However, in the long term a statutory register of professional motorcycle instructors is the aim, so that learner motorcyclists paying for the service could be assured about the professional standards of the training.

2 Untrained riders

The DSA Safer Motorcycling paper pointed out that although riders of mopeds with a provisional moped licence have to follow the same procedures as learner motorcyclists, a full moped licence is provided on a full car licence where there are no CBT requirements. It also stated that riding a moped requires different skills from driving a car and therefore, it proposed that the practice of issuing a full moped licence as a result of passing a car test should cease, although a full moped licence would continue to be issued with a full motorcycle licence.

In addition, the DSA Safer Motorcycling paper stated that in 1997, approximately 14,600 persons aged under 17 took CBT using a moped and that 13,500 persons aged 17 years and older took CBT using a moped. It was reported that the younger riders were presumably taking training for the type of machine they intended to initially ride, but the use of mopeds for CBT may ultimately lead to inappropriately trained motorcycle riders. First, those riders aged under 17 years could switch to a motorcycle with no further training. Secondly, those aged 17 years and above also have the opportunity to switch to riding motorcycles in the future and may have found it easier to satisfy the CBT obligation using a moped. However, only very few moped riders reach the test standard, with 250 practical tests being conducted annually.

3 The theory and practical tests

The DSA Safer Motorcycling paper considered how the exemption of motorcyclists from taking the motorcycle theory test, due to the rider having a full car licence, operates. It stated that, since the introduction of the theory test, the proportion of motorcycle test candidates reporting that they had studied the Highway Code has fallen from 73% to 54%. In addition, the average pass rate for the motorcycle practical test (70%) is higher than for the practical car driving test (48%), although the pass rate for the theory test is lower (54% compared to 61%). Also, with 150 motorcycle-specific questions in the question pool and an average of 15 such questions in each motorcycle theory test paper, the consultation paper recommended that holding a full car licence should no longer provide an exemption from the motorcycle theory test (and vice versa).

Finally, the Safer Motorcycling paper considered the lack of appreciation from other vehicle users regarding the vulnerability of motorcyclists and outlined supporting measures to improve the safety of motorcycling. Firstly, the question bank for car driver theory tests had included 110 questions on the subject of vulnerable road users since July 1998, and every test paper includes 4 questions on the topic. Secondly, since April 1999 the questions relating to vulnerable road users in the question bank for the theory tests taken by learner lorry and bus drivers have increased to contain 120 questions, of which 33 relate to motorcycling, and such questions are included in every test paper. Thirdly, since May 1999 the practical car test was increased by ten minutes to enable, among other aspects, a broader assessment of behaviour towards vulnerable road users. Also, since May 1999, the marking procedure for the practical car driving test has become stricter so that candidates who commit more than 15 minor faults fail the test. This procedure recognises driving weaknesses across a range of competences including the lack of skill and awareness towards vulnerable road users. In addition, there are two videos produced by the DSA which deal with vulnerability issues. The first is called ‘Just Didn’t See You’, and was issued to motorcycle training bodies to show their pupils. The other is called ‘Moving Targets’, which has been made available to all car driving instructors to show their pupils. Finally, issues relating to vulnerable road users will be covered by training syllabuses currently being developed as part of a scheme for better trained LGC and PCV drivers.

6.5 Conclusions and recommendations

This section has provided a summary of motorcycling legislation and possible new licensing changes. Recommendations for research in the area of legislation are as follows.

Recommendations for research: Legislation

The licensing system

Effects of the 1997 changes to the licensing system should be assessed as described under recommendation ‘Surveys of self-reported accidents, attitudes and other variables’ in Section 5.8.

Research is needed to estimate the size of the problem of unlicensed riding, and to develop countermeasures if needed.

As suggested under recommendation ‘Development and evaluation of rider training and education’ in Section 5.8, research will be needed to help develop and evaluate the new changes to CBT and other aspects of the licensing system described in the Government response to the consultation exercise.

7 Acknowledgements

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Abstract

Statistics show that motorcyclists are more at risk per mile ridden than any other type of road user. In addition, although the number of road accident fatalities has decreased in recent years, the number of motorcyclist fatalities has risen and the distribution of casualties has changed. TRL Limited was commissioned by the then Department of the Environment, Transport and the Regions to undertake a scoping study of motorcycle safety. This included a review of literature and current research, with a view to identifying areas where further research was needed. The report of the study was produced in unpublished form in November 1999, but is now published to make the work available to a wider readership.

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