VULNERABLE RIDERS

Safety implications of motorcycling in the European Union

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The European Transport Safety Council

The European Transport Safety Council (ETSC) is an international non-governmental organisation which was formed in 1993 in response to the persistent and unacceptably high European road casualty toll and public concern about individual transport tragedies. Cutting across national and sectoral interests, ETSC provides an impartial source of advice on transport safety matters to the European Commission, the European Parliament and, where appropriate, to national governments and organisations concerned with safety throughout Europe.

The Council brings together experts of international reputation and representatives of a wide range of national and international organisations with transport safety interests to exchange experience and knowledge and to identify and promote research-based contributions to transport safety.

CONTENTS

1. Powered Two Wheelers in the European Community

Motorcycling encompasses a number of types of vehicles and in recent years this has been reflected in the increased use of the term Powered Two Wheeler (PTW). This includes:

- Low performance mopeds (50cc vehicles with a maximum design speed of 25 km/h);
- Mopeds ('AM' category, 50cc vehicles with a maximum design speed of 45 km/h);
- Light motorcycles ('A1' category, maximum capacity of 125cc with a maximum power of 11 kW;
- Motorcycles (category 'A' limited, with a maximum power of 25 kW; category 'A', with a maximum power above 25 kW).

These vehicles can also appear in different forms. Mopeds can appear as small motorcycles but they are commonly seen also as scooters. The same is true of light motorcycles of 125cc, manufactured in both scooter and motorcycle form. There is also a new and growing trend to produce high power scooters, capable of long distances. Finally there are provisions that allow for car drivers as holders of a category "B" licence to also use a light motorcycle or moped under current European law. Some EU member states have not endorsed this option, taking the view that motorcycle use should require a specific licence. This review uses the term PTW to apply to all four categories of machines as described above.

There has been a steady rise in PTW new registrations in Europe between 1994 and 2000. Since then, the number of registrations has flattened out, although in 2005 there was a 5% increase in new registrations compared to the previous year (Figure 1).

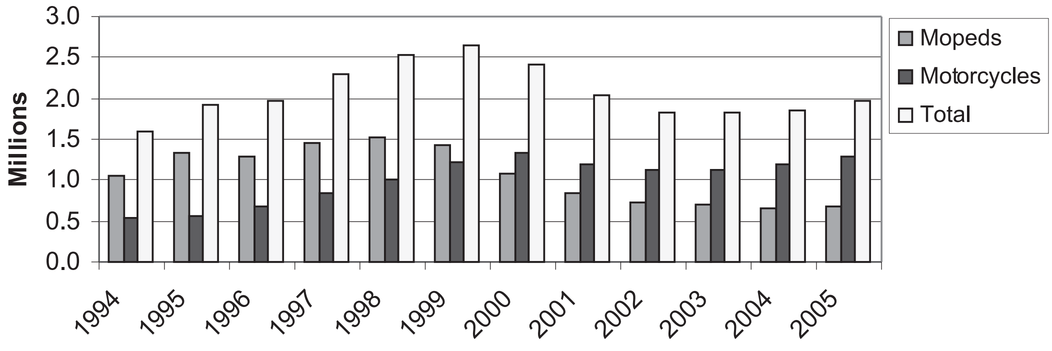

Figure 1 Total PTW new registration in the EU15 (source ACEM)

The SafetyNet project reported that the number of deaths among PTW users in EU14 (EU-15 without Germany) countries decreased by 13.5% between 1993 and 2002 (Yannis, 2005), despite the fact that PTW registrations have grown. PTW fatalities account for approximately 20% of the total number of road fatalities; in addition, the fatality rate of PTW users is not declining at the same rate as that of car occupants. Whilst all modes of transport will inevitably carry some risk, a dedicated and thorough investigation of potential safety measures, specifically aimed at PTWs is overdue. The principles of PTW crash epidemiology and causation need to be understood to identify the most promising fields for targeted measures and further research needs. In conjunction with this, it should be recognised that increase in congestion has increased the popularity of PTWs.

In recent years there has been much discussion about whether or not a PTW user falls into the category of vulnerable road user or not. Both PTW users and cyclists (when wearing a helmet) are to some extent protected. The same arguments can be advanced in relation to protective clothing. Despite its imperfections, we regard PTW users as vulnerable road users alongside cyclists and pedestrians due to the absence of a protective cage.

2. Collisions involving PTWs

2.1. Crash databases

There are a number of crash databases being used within the European Community:

- The CARE[1] (**C**ommunity database on **A**ccidents on the **R**oads in **E**urope) database collects information regarding collisions that result in death or injury. National datasets are integrated into the CARE database in their original national structure, with confidential data omitted. Transformation rules are implemented in the CARE database in order to try and increase data compatibility and thus enhance the functioning of the system.
- SafetyNet[2] is an Integrated Project funded by the European Commission and aims to build the framework of a European Road Safety Observatory, which will be the primary focus for road safety data and knowledge. The Observatory will support all aspects of road and vehicle safety policy development at European and national levels and make new proposals for common European approaches. It will extend the CARE database to incorporate the new EU Member States and will develop new fatal and in-depth crash databases.
- The MAIDS (Motorcycle Accident In-Depth Study) database, co-funded by the European Commission, is the only one dedicated to PTW crashes. It was created by the MAIDS project and included an in-depth, case control study of PTW collisions during the period 1999-2000 in France, Germany, Netherlands, Spain and Italy.

In 1997 the European Commission commissioned TNO to conduct a review of the relationship between the motorcycle power and road safety (Ruijs and Berkhout, 1997). The research was undertaken in the context of plans at that time to impose a power limit. The research was in two parts, the first a review of existing research and the second a report on whether further work would be justified. TNO came to the conclusion that further work was not justified. Many factors affect crash risk including age, experience, exposure, road conditions and the attitude of the user. There was no evidence to suggest that a powerful motorcycle is intrinsically less safe than a less powerful one.

The MAIDS study used a standardised methodology, whereby 921 collisions were investigated using 2,000 variables including human, environmental and vehicle factors. For comparison a further 923 control cases were examined. Some of the major findings of the MAIDS study were:

i. The primary crash contributory factor was human error - in 37% of cases on the part of the PTW rider and in 50% of cases due to the OV (other vehicle) driver. For the remaining 13% of cases the crashes could be attributed to poor road design or maintenance, weather related issues and technical malfunctions.
ii. Among the secondary contributory factors, PTW riders failed to see the OV (opposing vehicle) and they also made a large number of faulty decisions, i.e., they chose a poor or incorrect collision avoidance strategy.
iii. In comparison to the exposure data, unlicensed PTW riders, illegally operating a PTW for which a licence is required, have a significantly increased risk of being crash-involved.
iv. Among the primary contributing factors, over 70% of the OV driver errors were due to the failure to perceive the PTW, although OV drivers holding PTW licences were less likely to commit such a perceptual failure.
v. 71% of all PTW riders attempted some form of collision avoidance immediately prior to impact. Of these, 31% experienced some type of loss of control during the manoeuvre.
vi. 90% of the PTW riders wore helmets. However, 9% of these helmets came off the wearer's head at some time, due to improper fastening or helmet damage during the crash.
vii. 55% of PTW rider and passenger injuries were to the upper and lower extremities. The majority of these were minor injuries, e.g. abrasions, lacerations and contusions. Appropriate clothing was found to reduce, but not completely eliminate, many of these minor injuries.
viii. Roadside barriers presented an infrequent but substantial danger to PTW riders, causing serious lower extremity and spinal injuries as well as serious head injuries.

1 http://ec.europa.eu/transport/roadsafety/road_safety_observatory/care_en.htm.
2 www.erso.eu.

2.2. The influence of exposure on accident data

Generally, there is a lack of precise exposure data about PTW users. It may be assumed that there is a significant difference between Southern and Northern EU countries concerning PTW use: Greece, Italy and Portugal are the only countries where more fatal collisions are recorded inside than outside urban areas. These are also the countries with the highest PTW ownership rate - between 35 and 75 PTWs per 1,000 inhabitants (Stefan, Hoeglinger and Machata, 2003). Typically, the patterns of weekly distribution of PTW collisions do not differ between working days and weekends. On the other hand, there are countries like Austria, Belgium and the Netherlands where more collisions occur at weekends. In a third group of countries, e.g. France and the UK, more PTW collisions are observed during the week.

It should be noted, however, that the comparability of national exposure data is often limited because of inconsistencies among the definitions (road network, vehicle categories), characteristics (different use of transport modes in different countries, e.g. mopeds and motorcycles) and factors such as weather (long summers or mild winters can affect exposure). A recent ETSC report (2006) suggested a number of improvements in the way in which crash data are collected and utilised and a number of these are particularly relevant to PTW safety. For example, the underreporting of collisions and the absence of collection of damage only statistics could significantly affect the validity of crash databases. In addition, the introduction of a common methodology across Europe for the collection of crash statistics would enable countries to benefit from shared knowledge on the effectiveness of safety remedial measures. Finally, the report suggests that exposure data in each EU country should be collected by qualified institutions, using a uniform methodology and published annually.

2.3. Crash severity

The distribution of crash severity is very diverse across Europe, but within some countries there are definite patterns which are usually dependent on the way in which PTWs are used. For example, Italy demonstrates year-round use of PTWs, particularly in urban areas and thus lateral collisions are the most frequent (up to 60%). Less frequent, but more severe are single vehicle crashes (e.g. run off the road) and head-on collisions which are more likely to occur on rural roads. A report by the German insurance institutes' association (Kramlich and Sporner, 2000) reported that single vehicle crashes represent only 22% of PTW injury accidents, but 36% of deaths. Conversely, collisions with passenger cars were the most frequent (62% of crashes) but less severe (45% of deaths). Collisions with trucks and busses resulted in the most severe crashes (6% of injuries vs. 12% of deaths).

2.4. Injury types

According to an EEVC report (1994), 80% of PTW casualties suffer injuries to their legs, 56% to their arms and 46% to the head. Head injuries are, of course, more serious, with an average AIS[3] score of 2.4, compared to leg injuries (AIS 1.9) or arm injuries (AIS 1.5). Thoracic and pelvic injuries were not frequent, but those recorded were often severe.

A more recent study (Otte et al., 1998) considered collision types with regard to various injury patterns, and showed that over 70% of riders sustained a leg injury. Also, 80% of those riders with an injury AIS of at least 3 sustained a head injury and the cause of death was usually attributed to the head injury. Otte et al. (1998) also showed that riders of scooters have a greater risk of head injuries (24%) compared to PTW riders (20%), but the severity was generally lower for scooter riders.

3 Abbreviated Injury Scale (AIS): Scale range 1 - 6.

2.5. Manoeuvres involved

PTWs are over-represented, compared to cars, in crashes involving running off the road in curves and right-of-way violations, a fact highlighted by the Hurt et al. (1981) study. He found that in multiple vehicle crashes, the driver of the other vehicle was at fault in over 60% of situations, usually due to right-of-way violations. Sexton et al. (2004) reported that motorists were at fault in many instances by making turns or u-turns in front of PTW riders. Sporner et al. (2000) identified 5 most typical collision scenarios for collisions between PTWs and passenger cars where traffic drives on the right:

- PTW on prioritised road, passenger car crossing or turning (46%);
- Passenger car turning left hits oncoming motorcycle (26%);
- PTW overtake, passenger car turns left (11%) or turns around (9%);
- PTW hit by oncoming car overtaking another one (7%).

A recent in-depth investigation of fatal crashes in Austria (Stefan et al., in preparation) identified further typical high risk scenarios:

- Test rides: trying out a friend's PTW, mostly without protective clothing;
- A PTW overtaking, and the passenger car turning left;
- A PTW overtaking in a slight right turn. The rider checks oncoming traffic by looking by the right side of the car in front of him. He fails to detect oncoming traffic hidden by this vehicle;
- Trips in groups with less experienced riders trying to follow more experienced members.

2.6. Age and Gender of injured PTW users

Generally speaking, PTW injuries used to be a male phenomenon. However, in most European countries, the proportion of females sustaining injuries as PTW users is increasing. Only the UK and the Netherlands have an almost stable female ratio among PTW users. In the MAIDS study neither gender was over or under represented in the crash population relative to their exposure to risk.

With regards to age, most countries show more or less the same pattern in the period 1991-2001. At the beginning of the 1990s, it was mainly young PTW users who were involved in injury accidents. At the beginning of the new millennium, a trend evolved that led to the increased involvement of older riders. One reason may be due to the introduction of graduated licensing systems and stricter restrictions (and higher insurance) for younger riders. The late 1990s also witnessed a phenomenon whereby motorcycling became a hobby and mode of transport for the 40+ generation. This phenomenon has also been noted in Australia (Haworth, Mulvihill and Symmons, 2002) and the US (US DOT, 2000). Some of these riders may be returning after a break or be new to the activity. For the latter, their experience may be limited – research in the novice driver field has indicated that the first year of driving is the most dangerous in terms of crash risk. Crash liability studies carried out over the last decade (Maycock et al. 1991, Forsyth et al., 1995), show that both age and driving experience are important determinants of crash liability and in this respect, these riders may exhibit similar characteristics to novice drivers.

Not only might the demographics of PTW riders have changed, but also the reasons why they ride. Youths traditionally chose a PTW over a car for economic and accessibility reasons. Today, the reasons may be associated with mobility and image (Jamson et al., 2005). Moss (2000) found that in the UK, sports bikes and riders in the 26-40 years age group accounted for the majority of rural/bend curve crashes. Sexton et al. (2004) reported that many fatal and serious crashes occurred on non-built-up major roads, more usually at weekends and in the summer months. Riders of larger PTWs have also been linked to this risk factor of "riding for pleasure" (Lynam, 2001).

The following sections describe the potential of various PTW safety measures. The measures are categorised as being either those that rely on modifications to the machine (Section 3), those that rely on changes in rider or driver behaviour (Section 4), or that involve amendments to road design (Section 5). Each section concludes with key recommendations, which are summarised in Section 6.

3. Vehicle safety measures

The fields of vehicle safety measures are normally divided into "primary safety" and "secondary safety". Primary safety comprises measures which reduce crash risk while secondary safety describes measures that can be taken to reduce the number and severity of injuries if the collision has not successfully been avoided.

3.1. Primary safety measures

3.1.1. Braking systems

There are a number of considerations to take into account when improving PTW braking systems.

Locking the wheel by braking increases the risk of losing control, particularly when undertaken in emergencies. If, during emergency braking, the rider inadvertently locks the rear wheel, correcting this by reducing braking can have dire consequences. If the wheel is substantially out of line a sudden reactivation of traction can cause the machine to "high side" in the direction of the skid and eject the rider. Only the most experienced riders have the skill to allow a locked rear wheel to "fishtail" knowing that the noise and unfamiliar feel to the machine is not a serious concern. The exact opposite applies in the case of front wheel lock, which – if not corrected immediately by releasing and then reapplying braking as soon as the skid has been corrected – can lead to a crash. Research (Ouellet, 2006) has made clear that in many cases when riders collided with other road users, they just fell down due to locked up wheels, even before actually hitting the "obstacle".

Building up braking pressure gradually allows the rider to adjust the necessary input whilst considering road surface. Even experienced riders may reach the maximum braking capacity only when their PTW almost has come to a halt. The disadvantage here is that valuable braking distance is lost.

Shift in weight of a PTW occurs on deceleration whereby a fraction of its weight shifts from the rear towards the front wheel. This effect depends on the amount of deceleration and is high compared to passenger cars, due to the relatively short wheel base and the high centre of gravity of a PTW. With increasing deceleration, the front wheel is pressed onto the road surface with more power by the shift of weight. With extremely harsh braking, the PTW can tumble over its front wheel.

Rear brake handling also plays an important part in bringing the vehicle to a stop, but the rider has to apply both brakes in such a way that he achieves a maximum deceleration without locking up one of the wheels. In situations of panic, a rider's reflexes may dominate their actions, and hence lock up one or both of their wheels, increasing the risk of losing control. In the case of a locked up front wheel, the rider will probably not be gliding in the direction he originally was riding and will run a considerable risk of hitting obstacles or other vehicles in the vicinity.

Research shows that the average rider can only apply 56% of the available braking in an emergency (Ecker & Wassermann, 2001). Another field experiment has shown that the average rider underestimates the effectiveness of the front brake: asked to perform an emergency stop on a training track, the average rider used the front brakes with only 42% of its potential (Vavryn and Winkelbauer,1998). In contrast, the rear brake was used by 169% of its potential. In total, the average rider decelerated at 6 m/s^2, which is less than a modern 40 tonne truck would achieve. Thus, it is obvious that in a real-life emergency, the rider will often not be able to apply reasonable deceleration. In that case, either he cannot avoid a collision with the obstacle, and/or the collision speed is higher.

Advanced braking systems can help address the typical limitations in human performance, summarised as follows:

- Difficulty in controlling two systems (front and rear brake) at once
- Low deceleration to avoid locked wheels and tumbling over

- The survival reflex, resulting in the locking of one or both wheels
- Poor application of the brakes at the beginning of the braking process
- Not properly re-applying the brakes after locking the wheels and releasing the brake(s) to avoid a crash
- Lack of knowledge about and skills in optimal brake handling

Considering these human failings, there are a number of types of advanced braking systems developed by PTW manufacturers, taking into account the main purpose of the products, their distinctive characteristics, e.g. balance, weight, dynamics, and general capacities, and the cost-effectiveness of the technical solutions, which include:

i. Combined Braking Systems (CBS)
International and EU regulations require PTWs to be fitted with independent controls for the front and rear brakes. Usually this is in the form of a foot pedal and a front brake lever. Most automatic machines (which do not require a clutch control) have the rear brake operated by a lever on the left hand side of the handlebars.. Less skilled riders have a tendency to over-use the rear brake and under-use the front. In a CBS system, the application of one brake control will actuate both front and rear brakes.

ii. Anti-lock Braking Systems (ABS)
Developing ABS to the required level of sensitivity necessary for application to PTWs has been an expensive process and price has been a factor in consumer resistance. Consumer resistance to this technology has also been influenced by a perception that it might reduce the “sporting” character of motorcycling. Experience in Germany (the Better Braking campaign) has shown that this can be overcome. Consumers have also been positively influenced by the ACEA decision regarding car manufacture. As most riders also drive cars regularly they are increasingly asking why this technology cannot be more widely available to them when they ride.

Advantages are self evident as electronic control eliminates the risk of wheel lock. Field experiments (Winkelbauer and Vavyrn, 2004) have shown that a rider demonstrates improved braking manoeuvres on an ABS-bike than on his own machine, even when the ABS-bike is unfamiliar to him. Maybe the greatest benefit derives from the fact that ABS prevents crashes caused by too harsh braking. With ABS it is possible to build up braking pressure extremely quickly, resulting in rapid decreases in speed without the risk of locking up the wheels. Sporner & Kramlich (2000) investigated 910 PTW collisions and found that although in 65% of these cases the rider managed to activate the brakes before the collision, 19% (i.e. 44 riders) fell down. Of these 44 cases, the study concluded that in 93% of these collisions, the consequences would have been mitigated if the PTW had been fitted with ABS. The benefits of ABS (and CBS) are unlikely to transfer into significant improvements in safety without parallel training - so ingrained is the reflex to brake as described above.

iii. Rear wheel Lift-off Protection (RLP)
In order to avoid tumbling over during a braking manoeuvre, RLP detects if the rear wheel lifts. This initiates a momentary reduction of the pressure in the front braking circuit.

iv. Automatic brake force distribution
Due to dynamic shifts in weight, this is strongly dependent on deceleration. Even for an experienced rider it is difficult to accomplish this, particularly in emergency conditions, but it can be achieved electronically.

v. Integral braking systems
Integral braking systems usually cover two or more of the systems explained above. They typically operate on an electronic basis, thus offering many possibilities for additional safety features.

In the long run, all PTWs should be equipped with ABS with mandatory fitment starting as soon as possible. However it is recognized that ABS may not make financial sense on smaller PTWs and we therefore propose a cost/benefit study on braking systems. Practical instructions should be given to purchasers of PTWs with ABS and trainers need to be fully familiar with the varying systems on all machines used by their students.

3.1.2. Conspicuity

Not seeing a PTW has been reported to be a common cause of collisions during both the hours of daylight and at night. MAIDS indicates that among the primary accident contributing factors, over 70% of the OV driver errors were due to the failure to perceive the PTW. Perception failure is the main cause of multi-vehicle accidents involving PTWs. Donne and Fulton (1985), showed that the simplest and most effective aid to day-time and night-time conspicuity is a 55W quartz halogen headlamp. Other studies (PROMISING, 2001) have concluded that riders who use their headlights can reduce their crash rate by 10%.

Since 1970, several European countries have enacted PTW "headlights on" laws – some at their own instance, others following the ratification of provisions under the 1968 Vienna Convention on Road Traffic. The different national laws introduced the use of headlights during the day in the form of a behavioral requirement (asking riders to switch on their low beam headlights). In 2001 the European Motorcycle Manufacturers Association (ACEM) adopted the practice of Automatic Headlamps On (AHO) for all motorcycles, scooters and mopeds. AHO means that the headlight is illuminated automatically whenever the ignition is switched on and, therefore, the normal on-off headlight switch is not even fitted. The self-commitment was adopted in 2001, it progressively entered into force since 2002 and was applied on all models since 2003.

The use of AHO is widely accepted in Europe as being beneficial to the safety of riders even if some PTW associations suggest that when riding in cities in bright sunshine, AHO may have a camouflaging effect, in that they make the PTW and the rider blend with colourful, bright objects in the traffic environment. However, AHO has improved motorcycle and moped conspicuity, particularly in the countries where "headlights on" laws are not enforced, and has addressed rider forgetfulness in the other countries where "headlights on" laws are already enforced.

A meta-analysis of the effects of daytime running lights (DRL) in cars has shown that the measure contributes substantially to reducing the number of pedestrians and cyclists hit by cars, by 15% and 10% respectively (Elvik and Vaa, 2004). Although the effectiveness of DRL use is greater in countries which lie closer to the poles, results from studies indicate that there are still mostly positive effects to be gained in other countries. PTW riders have expressed concerns that DRL use on cars could reduce the visibility of riders. Research (Koornstra et al., 1997) has suggested that such a negative effect would however be offset by the benefits to PTWs of increased car visibility and reduce the number of multiparty daytime collisions involving riders. A TRL study (Knight et al., 2006) reports similar conclusions, although there were some concerns about the size of the effect.

3.1.3. Speed limiters

Intelligent Transport Systems have the potential to significantly improve road safety of all road users. However, some ITS applications will need specific development and adaptation to enable them to be used on PTWs, due to their intrinsic characteristics.

Previous research, whether on technical aspects or on user response on Intelligent Speed Assistance (ISA) has been almost exclusively for cars rather than for motor vehicles in general. There are strong arguments against moving towards an implementation that is limited to one class of vehicle, even a majority class. These arguments relate in part to equity — why should some drivers or riders be free to speed when others are not — but also to the safety and environmental impacts of ISA. In terms of safety, high speed variance is related to risk and leaving one or more groups of vehicle without ISA in a network where most vehicles had ISA would potentially increase speed variance. This is particularly an issue for PTWs, since these would not, in most circumstances, be restrained by slow moving vehicles in front. Any policy move that would make PTWs more attractive as the only general class of vehicle on which speeding was possible would be highly undesirable.

But, if the equipping of PTWs is desirable from a policy perspective, there are also major technical obstacles to be overcome. For reasons of vehicle stability and handling, it is inadvisable to apply deceleration inappropriately to a PTW. Therefore an ISA system for PTWs may be able to restrict acceleration, but will only be able to use deceleration in a way that causes no sudden change in engine power. In addition, there are more severe space and weight issues on PTWs than on cars, so that miniaturisation of the ISA system is a prerequisite. It is recommended that further research in this area is undertaken in order to develop a safe and effective ISA system for PTWs.

Recommendation:	Mandatory fitment of ABS should start as soon as possible, alongside a cost/benefit study on braking systems for smaller PTWs PTW instructors and riders' attitudes and knowledge towards ABS should be improved. Further research should be undertaken to examine the whether ISA for PTWs is technically feasible and beneficial to safety.

3.2. Secondary safety measures

3.2.1. Helmets

The benefits of wearing a helmet with respect to head injury risk have been widely researched. Hurt et al. (1981) concluded that the risk of death is more than halved if a helmet is worn. Given that a number of states in the US still do not have mandatory helmet wearing laws, a number of between-state comparative studies have been conducted and demonstrate reductions in PTW deaths where the laws are mandatory (Sosin et al., 1992; Sass and Zimmerman, 2000; Morris, 2006). More recently, Houston et al. (2007) conducted a cross sectional time-series analysis in the US and examined the effects of universal and partial (which often apply to different age groups) helmet laws. The presence of a universal law was associated with 22% fewer fatalities per 10,000 registered motorcycles than that encountered with no helmet law.

More discussions exist when an open vs. full face helmet is considered. On one hand, some studies (e.g. Otte and Felten, 1991) concluded that the risk of a skull base fracture is increased due to chin impacts, and so, severe head injuries are slightly more likely to occur with a full face than an open-faced helmet. However, Hurt et al. (1981), concluded that a full face helmet offers greater protection without any disadvantage from increased weight.

Hopes and Chinn (1989) reported that helmets are too stiff and resilient, with the maximum energy absorption of the liner occurring at high impact velocities where the probability of death is high. They recommend that 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 wearing a helmet can be more effectively realised.

There is a strong case for more consumer information on the quality of helmets to distinguish those at the bottom end of the quality spectrum designed within the limits of existing standards and those that exceed them. This type of consumer rating would also allow for better promotion of new innovations. Rider education is also an important point here as a helmet can only successfully protect its wearer if the chin strap is properly adjusted and closed – if not, the helmet is likely to be ejected before the wearer's head hits an obstacle.

3.2.2. Protective clothing

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 against lacerations, contusions and fractures, muscle stripping and degloving injuries. In addition protective clothing can improve the conspicuity of the rider and prevent collisions by keeping the rider in good physiological and psychological condition by keeping the rider dry, warm (or cool), comfortable and alert. Of course, some collisions are so serious and involve mechanisms and forces on the body that clothing cannot, so far as is known, significantly mitigate. These include crashes where the leg becomes trapped between the machine and another vehicle or the road, penetration injuries and high energy impacts on the chest or abdomen 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 PTW clothing using current technology. A CEN Standard has been issued that specifies the requirements for body protectors when used inside protective clothing, however there is no standard for protective clothing itself.

3.2.3. Airbags and leg protectors

In head-on impacts, the PTW rider continues to move forward in a seated position and hits the opposing object at close to his pre-impact velocity. These collisions often result in fatal or serious injury to the head and upper body of the rider. The lower body and legs often become entangled with the PTW 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). Two papers describe the development of an airbag system for PTWs. The first (Okello and Chinn, 1996; Chinn et al., 1997) tested an airbag restraint system fitted to a Norton Commander and found that the results of the sled and full impact tests showed a kinetic energy reduction between 79% and 100%, as well as low neck-injury measurements compared with tolerance limits. This airbag system reduced injury costs by over 80%. The second (Iijima et al.,1998) tested an airbag system for a Honda Gold Wing and showed that the injury benefits were very much greater than the injury risks.

The development of airbags for PTWs will be a protracted task, particularly as the trend towards taller cars (people carriers, minivans and SUVs) is having a critical effect on PTW riders – when a rider hits a car with a high, steep front, the rider's flight path is impeded, with the head coming into direct contact with the frame of the car, thus increasing the risk of injury. The wide range of PTW architectures and riding positions complicate matters further. In addition, an increased share of PTWs fitted with ABS will cause more collisions involving PTWs still in an upright position.

Injuries, particularly fractures, to the lower limbs are common and a considerable amount of research has been conducted in this area. Leg protection studies have shown that such devices can protect the legs in collisions but sometimes there are disadvantages for other body regions (i.e. head and neck). There may be merit in combining their development with that of airbags.

3.2.4. PTWs with protective cages

An example of a scooter with a protective cage is BMW's C1. In this vehicle, the passenger is belted with a lap/shoulder belt and uses an additional shoulder belt from the other side. The C1 has a deformable zone at the front and users are allowed to ride without a helmet. The C1 performed quite well in crash tests, in particular, it provided superior leg protection compared to other PTWs and offers some weather protection. As a result of the safety cell concept, the C1 had a high centre of gravity and resulted in an unfamiliar riding experience compared to other PTWs. Although offering some advantages, in particular relating to rider safety, the C1 concept was not successful on the market and BMW ceased its production in 2003. Nevertheless, some ideas within the safety concept of the C1 may be adopted for future improvements in PTW safety.

Recommendations:	Good information about helmets should be given to consumers and the importance of having them properly secured should be stressed. In the long run, the use of protective clothing should be encouraged and, in the long run, minimum standards should be developed and made mandatory. These should be adapted to the different needs of various types of PTWs. Research needs to be intensified in order to provide benefits of airbags and leg protectors to all PTW riders

3.3. Measures involving other road users

3.3.1. Blind spot mirrors

Every year a large number of PTW riders are killed or severely injured due to trucks making a nearside turn, mainly because of poor visibility on the right side of the truck. In 2003, the European

Parliament and Council adopted Directive 2003/97/EC on rear view mirrors and supplementary indirect vision systems for motor vehicles. This Directive has improved vulnerable road users' safety by upgrading the performance of rear view mirrors and by accelerating the introduction of new technologies that increase the field of indirect vision for drivers. In particular, Advanced Driver Assistance Systems which detect PTWs and warn the driver should be researched. The European Commission has also assessed the benefits and costs of retrofitting such systems to existing vehicles and the benefits are approximately four times higher than the costs of retrofitting lateral blind spot mirrors to existing goods vehicles over 3.5 t. In 2006, the European Commission tabled a proposal for a new Directive on "Fitting blind spot mirrors on existing trucks". The Directive has now been adopted by the Council and the European Parliament (Directive 2007/38/EC).

3.3.2. A-Pillar design

In the recent years, A-pillars of cars and light vans have been thickened to prevent the main structure from crumpling in crashes. As a result, drivers need to take a much longer look as a rider can disappear behind the A-pillar for about 0.35 seconds. About 10% of total fatal crashes could be attributed to pillar blind spots. According to the UK Department for Transport, the EU Directive (2003/102/EC) on pillar design contains loopholes that manufacturers are exploiting.

3.3.3. Side protection on trucks

When heavy goods vehicles and PTWs are side by side and the vehicle turns in their direction, the PTW is at risk of being run over. Trucks and trailers have to be equipped with a protection system at the side as defined in the Council Directive 89/297/EEC. Side underrun protection systems are aimed at preventing pedestrians, bicycle and PTW riders from falling under the wheels of the truck when it turns. The protection system fills the open space between the wheels: however, current legislation accepts an "open" frame (e.g. two planks on the side with a maximum distance of 30 cm). Therefore, under some circumstances, PTWs and other vulnerable road users could be caught by such a side underrun protection system. Furthermore, for side collisions with PTWs, the strength of current side underrun protection systems is insufficient.

Recommendations:	The European Union should revise Directive 2003/12/EC in order to address the safety problems A-pillar design can cause to powered two-wheelers. Side underrun protection systems should be of sufficient strength to withstand PTW impacts. Side protection which closes off the open space between the wheels of the heavy goods vehicle should become mandatory for all new heavy goods vehicles.

4. Road user behaviour

4.1. Rider training

Education, information and practical training are essential in acquiring the attitudes, skills and knowledge necessary for safe road user behaviour. This education can realistically commence in the school environment. In some countries, road safety education and training is realised by school teachers in co-operation with the local police, having specific curricula and timetables for traffic safety education in at least the first few years at school. This type of training should take into account the fact that school-age children are permitted to ride mopeds. One of the major weaknesses is that traffic safety education is often not part of vocational teacher training. The development and implementation of best practice guidelines for traffic education and initial and in service training for professionals would be helpful at EU level.

The EU has recently funded a project, Initial Rider Training (IRT). It includes a review and a report on the use of e-learning as a future area worth considering. It also includes a complete syllabus of basic training, designed to meet the needs of all countries within Europe. As this syllabus is currently only in English the challenge is to have it made available in more European languages.

The use and effectiveness of rider training has been the centre of much discussion. Some research (e.g. Haworth et al, 2000) suggests that current rider training programmes focus mainly on the development of machine control skills, due to time constraints and the skill-based nature of the test. The authors suggest improvements in attitudinal and perceptual training to allow riders to change their riding style to avoid high-risk situations. To be able to do this they should have knowledge on why, how and in which situations PTW collisions happen. This also implies improved training of the instructors to be able to impart this knowledge. The ADVANCED report (2002) also highlighted the need to complement skills training with hazard recognition and risk perception training. The GDE-matrix (Table 1) was developed whereby 4 levels of training were identified; only the first two were found to be covered in most existing training schemes.

Table 1 The GDE Matrix

Behavioural level	Knowledge & skills	Risk-increasing factors	Introspection
Norms and values	Lifestyle, controlled behaviour	Risk acceptance	Level of moral development, self-knowledge
Planning of traffic participation	Route choice, mode of transport	Ensuring fitness to drive	Self-estimation
Traffic participation	Diagnosis and prediction	Risk perception	Fitting traffic task to task competence
Vehicle control	Steering, braking, etc.	No automatic task performance	Judgement of one's own vehicle control

Efforts have been made to reproduce the complete riding experience via simulators. The resulting technology proved heavy, expensive and did not deliver anything approximating to a riding experience. There has since been a revision of thinking – the limits are recognised and there is now available on the market a basic Trainer device produced by Honda on a non profit basis. This uses a standard computer with Windows operating system. A basic low cost frame and seating arrangement is utilised which does not seek to replicate the dynamics of riding. Instead, visual simulation is used to teach hazard awareness and this may be a fruitful avenue for further research.

4.2. Rider licensing

Access to PTWs in the EU Member States is regulated by a European Directive on driving licences (Directive 91/439/EC). Mopeds are not covered by the current directive and therefore at the moment their access is regulated at national level. The provisions therefore vary substantially amongst the Members States, concerning minimum access ages, training and testing. Provisions for motorcycles foresee access at the age of 18, with a two-year limitation to maximum 25 kW motorcycles ('A' limited category). Member States have the option to provide earlier access to category A1 light motorcycle and its equivalence with the car licence, as well as the option to provide Direct Access to all motorcycles ('A' category) from the age of 21. The content of the test is also commonly defined, and has recently (Directive 2000/56/EC) been improved with the introduction of additional emergency collision avoidance manoeuvres, currently being implemented by Member States.

A new European Directive (Directive 2006/126/EC) applying from 2013 will extend the coverage to 'AM' mopeds and 'A1' light motorcycles. It will seek to further encourage progressive access by proposing a new 35 kW motorcycle ('A2', replacing the current 'A' limited), introducing testing or training in between the different categories. However, Member States still retain flexibility regarding access ages, 'A1' light motorcycle access with a car licence and Direct Access remaining optional, the latter from the age of 24. This flexibility should seek to encourage riders taking a progressive access to PTWs by recognising the experience gained on lower PTW categories.

4.3. Driver training

Given that a large proportion of PTW crashes involve an "at-fault" driver (see section 2.5) there is plenty of scope to improve driver training with particular reference to PTWs. Mannering and Grodsky (1995) suggest that car drivers have conditioned themselves to look only for other cars as possible collision dangers, and they thus tend to be inattentive with regard to PTW users. Clarke et al. (2007) studied the role of PTW and other driver behaviour in right-of-way and loss of control crashes over a five year period. They found there to be a problem regarding other road users' perception of PTWs, particularly at junctions. Worryingly, these crashes seemed to involve older drivers with relatively high levels of driving experience who had difficulty in detecting approaching motorcycles.

Duncan's (1996) "integrated competition hypothesis" suggests that attention to PTWs in the road scene may be inhibited as drivers concentrate on objects that they think are important. Alternatively, Treisman (1996) postulates that drivers scan road scenes for a single potential hazard (e.g. proximity of a vehicle) and do not notice a distant, but more rapidly approaching, vehicle. Both these theories suggest that drivers are not actively searching for PTWs in their visual scene, and this could be addressed in both the practical and theoretical training that drivers receive, supported with educational campaigns such as the U.K.'s "Think Once, Think Twice, Think Bike" campaign.

4.4. Enforcement

A recent ETSC (2007) report suggests

"If current progress [with enforcement] continues the EU will only reach a 35% reduction [in road deaths] and not 50% by 2010 as planned in its recommendation on enforcement. The European Commission committed itself to proposing a Directive in case this objective was not achieved.".

On the 19th of March 2008 the European Commission finally came forward with a proposal for a Directive which aims to "facilitate cross-border enforcement in the field of road safety". Although this proposal is a step in the right direction, its life saving potential might have been even greater had it included an EU wide reference framework for convergence of enforcement best practices.

For road users in general, there are three key areas where enforcement plays an important role in reducing road deaths: speeding, drink driving and seatbelt and helmet use. Enforcement activities obviously have implications and road safety benefits for all road-users, but for PTWs there are a number of areas where improvements can be made:

- Speed detection and measurement devices are not in all cases optimised for the detection of the speed of PTWs. Enforcement authorities should be encouraged to adapt or replace their equipment-in-use in order to equally treat PTW's in speed enforcement.
- Enforcement activities (routes/times) should be optimised and justifiable using PTW safety data. Venues and timing of speed enforcement in general should be directed by crash figures: on roads or at junctions that show a high volume of collisions with speed as a contributing factor, speed enforcement should be increased.
- The enforcement on the use of helmets (wearing, fastening and required standards) is not prioritised sufficiently by many enforcement authorities.
- The illegal use of bicycle facilities and pavements for riding and parking is often ignored by authorities, but poses a risk of conflicts between vulnerable road users.
- Licence plate visibility and harmonisation across Europe. The effectiveness of enforcement depends strongly on the chance of getting caught violating the rules. To increase this risk, automated detection should be deployed, but this is only reliable when license plates have a certain size, colour and layout. The rules for the configuration of license plates vary across member state and there are many examples of plates that are hard to detect automatically.
- For car drivers, better enforcement against the use of GSM while driving and other sources of distraction can lead to significant safety benefits for PTW users.

A number of countries are linking enforcement with education activities. A PTW rider stopped for speeding may still incur a fine or a citation, but that can be reduced if the option of further training is taken up.

Recommendations:	Existing training schemes should be adapted according to the GDE matrix and rider training should focus on hazard recognition and risk assessment as well as vehicle control. Further development of simulators and virtual rider training should be stimulated.The IRT syllabus should be available in other European languages to encourage wide adoption across Europe. While implementing the Driving Licence Directive, Member States should seek to encourage riders taking a progressive access to PTWs by recognising the experience gained on lower PTW categories. Driver training should specifically make reference to and ensure candidate's understanding of PTW issues and safety concerns, with a particular focus on the risk of perception failure. Enforcement activities should be optimised and justifiable. Attention should be given to appropriate use of helmets, the visibility of licence plates and improving speed detection technologies. For drivers, enforcement against the use of GSM while driving can provide significant benefits. More emphasis should be given to the combining of enforcement with other activities such as education and rehabilitation.

5. Road Design and Traffic Engineering

A significant number of crashes are a result of shortcomings in infrastructure. The MAIDS study results showed that in 8% of cases, an environmental factor was the primary cause of the crash. PTWs differ in their use of the road in a number of ways compared to other vehicles and riders also have different needs. ACEM (2006) has expanded this information in a design and maintenance of infrastructure handbook. The intention of the European Road Assessment Programme (EuroRAP) to include PTW characteristics in risk-assessment and performance-tracking should be welcomed and provide a sound basis for upgrading road networks to be forgiving for all users, especially vulnerable ones, including riders

5.1. Curves

Manoeuvring a PTW in curves is subject to different principles compared to driving a car. In tackling a curve the PTW takes a different line than drivers of other motor vehicles. He traverses the width of the lane for maximal grip through minimal steering. In case of gravel, dirt, oil on the roadway grip may fail. Factors that increase crash risk in a curve are :

- The difference between the approach speed and the speed in the curve
- A reduction of the curve radius
- The predictability of the curve
- The visibility of the curve
- The length of the curve

Road designers should bear the following in mind:

i. Predictable geometry in road building allows safer negotiating of curves: a wide and constant radius is particularly helpful.
ii. Good forward visibility allows for timely detection of hazards and thus appropriate planning. Visibility can be improved by the elimination of excessive vegetation, signs and other objects that impair forward visibility.
iii. A PTW rider can anticipate curves more easily when adequate signs are used. Rationalisation in the use of traffic signs is essential - the need for signs in a curve mainly depends on the difference in approach and negotiation speeds. It should be noted that the positioning of the signs could be a hazard in itself to motorcyclists.
iv. Avoid placing obstacles in the outer curve as they may aggravate the severity of injuries to a motorcyclist in case of a crash. Such obstacles include sign posts, lighting poles or guard rails, and these should be avoided in places with a high crash risk. If their installation is imperative, e.g. guard rails on mountain roads, they should be positioned at a maximum distance from the edge of the road.

A PTW is steered and balanced as a result of a complex interaction of forces as it is leant over. A machine can be steered more effectively, particularly in an emergency, if the rider has received training in the effects of counter steering, and knows how to do this consciously. This forms part of the curriculum of the MSF (Motorcycle Safety Foundation) in the United States, but is not always taught by trainers in Europe.

5.2. Intersections and roundabouts

The MAIDS study showed that half of all PTW crashes occurred at an intersection with poor visibility being an important contributing factor. A PTW has a relatively small frontal area compared to other vehicles and therefore other road users may easily overlook it or cause miscalculation in the estimated time of approach. This is due to the fact that we estimate speed by the difference in expansion rate. At a given distance the expansion rate for small obstacles is lower than for large ones.

The comparatively small size of a PTW requires barriers, vegetation and road signs to be placed in such a manner that they do not hide motorcycles, not even partly, from view. It is a known fact that PTW riders often notice other vehicles before their drivers observe the PTW. The design of intersections should offer a complete view of a PTW in the entire sight zone and enable a PTW rider to have a complete view of the intersection as well, taking into account the higher eye level of a motorcyclist.

Roundabouts generally have a low crash rate for most types of vehicles. However, PTWs score relatively high in crashes on roundabouts. They encounter specific problems whereby too high an entry angle may lead to excessive deceleration on approach and thus result in tail end collisions. A too low entry angle, however, will hide a PTW from the view of drivers of other vehicles. An entry angle between 30° and 40° is recommended and vertical features on a roundabout which may obscure PTWs should be avoided.

5.3. Road safety features

Roadside and roadside safety constructions are mainly designed using the car as design vehicle. A PTW, however, requires another approach. The MAIDS study showed that the fourth most likely obstacle to be struck was 'fixed obstacles' such as barriers, signs and trees. The vulnerability of the motorcyclist often leads to major injuries or even fatal crashes because of the presence of obstacles alongside the road (urban and rural).

Roadside safety barriers are constructed mainly to protect car occupants and to prevent a car from crashing into other vehicles (physical separation of the carriageways). Roadside barriers are not constructed with PTWs in mind, however, and they provide relatively little protection for motorcyclists. Brailly (1998) 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. Different designs of safety barriers, from the PTW angle, should be more thoroughly researched. The following design principles should be kept in mind:

i. It is essential to minimise the number of obstacles especially in high speed bends. The supports should not have jagged or sharp edges, nor have any protrusions that might hurt a fallen motorcyclist. On motorways, the path of the motorcyclist leaning into bends must be considered.
ii. Avoid erecting road safety barriers if alternative measures suffice.
iii. Placing a safety barrier is a matter of careful consideration. A motorcyclist who topples over or falls off his PTW will normally continue in the direction of travel. The PTW seldom ends up far from the edge of the road: therefore it is important to keep the first few meters from the edge free of fixed obstacles.
iv. The use of a PTW-friendly safety barrier system should be considered in places, for example in bends, where motorcyclists will be most at risk. The general principle of a PTW-friendly safety barrier is to protect the fallen motorcyclist from jutting support posts. These PTW friendly safety systems may be newly installed or fitted on existing barriers. Other possibilities are using round posts instead of those with sharp edges or using crash barrier protection.

PTWs have a much greater need for a consistent and high coefficient of friction between the tyre and road surface than four-wheel vehicles. In areas requiring braking and steering, any change in grip between tyres and surface can destabilise the machine. A sudden change in surface level rapidly loads and unloads suspension, thus reducing the grip between front wheel and road surface.

For safety reasons the speed of motorised vehicles in urban areas must be slowed down. Therefore speed inhibitors such as speed bumps or other vertical elements, which are hazardous to a PTW, are often placed on the roadway. If speed bumps are to be installed, it is advisable to install bumps with a predictable impact. Careful consideration should also be given to the location of drainage covers or other items that are placed in the road.

5.4. Road building and maintenance

It is important for PTWs to have a good and constant surface grip. Therefore consideration needs to be given to surface skid resistance of road surfaces, including surfaces of a different colour. This is especially important in bends, since the motorcyclist needs to vary his position across the lane for both maximum safety and forward visibility. Special attention must be given to surface grip and consistency in places where tram rails are imbedded in the roadway.

It is clear that policy changes and innovative design can make a big difference to PTWs safety and their promotion as an alternative mode of travelling. The degree of maintenance, however, is critical to this. Sufficient maintenance should ensure:

- a consistent road surface with proper skid-resistance
- that the roads are kept clear of refuse and rubbish
- that visibility is maintained, especially at curves and junctions
- that the road signs, studs and markings are maintained
- that roadway defects are noticed and repaired quickly.

5.5. Signs and road markings

Where conditions are particularly difficult for PTWs, supplementary signs with PTW symbols could be used to make them more noticeable. Road markings rarely have the same skid resistance properties as the surrounding road surface. Arrows and destination markings in bends or roundabouts are of special concern to motorcyclists as the PTW may be leaning over or may be accelerating or braking. Therefore, the use of road markings needs careful consideration. Used inappropriately they can force motorcyclists away from the safest line, or, if poorly designed or laid they may collect and divert water, adding to the loss of consistent grip. Direction arrows and destination markings are of particular concern. Often they are used in bends whereas - if needed at all - they are better placed in an advanced position on a straight section of the road. A relatively small unevenness of 5 mm can cause stability problems. Consistent and informative advance warning and direction signs should minimise the need for surface signing. Careful thought should be given before using large areas of hatching.

5.6. Road Safety Audit and Inspections

A road safety audit (RSA) is a formalised and independent inspection of road schemes for new road projects or reconstruction projects for existing roads in order to reveal safety deficits and to optimise road design with respect to road safety. It is formalised in that it is an autonomous part of the design process including rules for the road owner, the designer and the auditor. Its independence is assured by using an audit team unconnected with the design team in order to avoid that issues are overlooked.

In the future, focus should be given to road safety needs of PTW within a RSA, which can include aspects of grip, curvature, road side installed equipments and obstacles as well as use of PTW friendly barriers and guard rails. There is some doubt that PTW aspects are fully covered in current RSA schemes in some countries. It would be useful to initiate an international research project or a survey to assess the relevance and consideration of PTWs within the current RSA schemes in Europe.

Road Safety Inspections (RSI) are increasingly used as part of road safety management. A RSI is a systematic assessment of the road standard of an existing road network, in particular with respect to hazards related to traffic signs, environmental risk factors and roadside features. The objective of is to identify traffic hazards and suggest measures to correct these hazards using well-established experience and knowledge of safe road design and traffic operation as well as knowledge about the effect of traffic safety measures.

The same points can be made as for the RSA above. There is no special focus on the different road users' needs within current RSI approaches. The European research project "RIPCORD-ISEREST" is currently developing proposals for a common procedure for RSA and RSI. Checklists exist in some countries but they do not systematically address the specific needs of PTW users. Again, it might be useful to initiate an international research project or a survey to search out the relevance and consideration of PTWs within the current RSI schemes in Europe.

5.7. Use of Bus Lanes by PTWs

Apart from public transport buses, the use of bus lanes is sometimes permitted for use by taxis and bicycles. Although PTWs often use bus lanes, this is not a widely adopted practice in Europe. Notable exceptions include Stockholm and the UK, where a number of pilot projects are being held, with some Local Authorities allowing PTWs in bus lanes. In 2002, Transport for London introduced three pilot schemes whereby PTW riders were permitted to use bus lanes during the times of bus lane operation. The purpose of the trial is to ascertain whether or not permitting PTWs to use bus lanes has a positive impact on PTW safety without causing negative impacts to other users – particularly buses, cyclists and pedestrians. The trial is ongoing, with full results expected in October 2007.

5.8. Advance stop lines for PTWs

The legislation on double stop lines for PTWs is diverse. A double stop line would allow a PTW (and cyclists) to move to the front of the queue at an intersection and thus mean that they are not squeezed between or to the side of vehicles at the head of the queue. In a recent study undertaken in Greater London (Allen et al. 2005), it was found that over 30% of traffic that violated the advanced stop lines were PTWs, most of which used it as if they were a cyclist. However, the overwhelming majority of PTW casualties occur at locations where allowing them into advance stop lines would not be relevant to their safety.

Recommendations:	Curves and intersections should have predictable geometry, good forward visibility, adequate and well positioned signage along with minimum roadside clutter. Excessive roadside features should be avoided to reduce the severity of injuries, whilst those that are essential should not have jagged or sharp edges or protrusions. Essential safety barriers should be positioned correctly and the use of PTW-friendly safety barrier systems encouraged. Road safety measures should be PTW-friendly, particular vertical measures such as speed bumps. This includes their effect on drainage and hence road friction. The materials used in road-building should provide consistent and maximum surface skid resistance, particularly in bends. Roads should be maintained to a high standard and cleared of debris. Consistent and informative advance warning and direction signs should be used where appropriate and care over the use of large areas of hatching should be taken. Both RSA and RSI procedures should address checking roads against the specific needs of PTW users.

6. Recommendations for Improving PTW safety in Europe

General Recommendations

Recommendation 1	*PTWs should be integrated in transport and safety plans with strategies recognising their specificities and needs.*
Recommendation 2	*Crash investigation and databases should be standardised and allow the inclusion of variables specific to PTW safety issues.*

Human Factors Recommendations

Recommendation 3	*Traffic safety education in schools should specifically target moped safety and rider training should focus more on hazard recognition and risk assessment as well as vehicle control skills.*
Recommendation 4	*Driver training should specifically make reference to and ensure candidate's understanding of PTW issues and safety concerns, with a particular focus on the risk of perception failure.*
Recommendation 5	*While implementing the Driving Licence Directive, Member States should seek to encourage riders to undertake progressive access to PTWs by recognising the experience gained on lower PTW categories.*
Recommendation 6	*Provide consumer information regarding helmet safety and educate riders regarding the importance of proper fastening.*
Recommendation 7	*Enforcement activities should focus on helmet use, numberplate visibility and improved accuracy of speed detection, dovetailing with education and rehabilitation.*

Vehicle and Equipment Recommendations

Recommendation 8	*In order to address the major cause of motorcycle accidents, improvement in PTW conspicuity should be further researched.*
Recommendation 9	*All PTWs should be equipped with ABS and riders educated regarding use and benefits. The variety of other advanced braking systems should be evaluated for their safety impact and, if more cost-effective, be considered as an alternative to ABS.*
Recommendation 10	*Further research should be undertaken to examine the whether ISA for PTWs is technically feasible and beneficial to safety.*
Recommendation 11	*Investigate the extent to which airbags and leg protectors are viable PTW safety measures.*
Recommendation 12	*The use of protective clothing should, in the long run, be mandatory using the introduction of minimum standards.*
Recommendation 13	*Revise Directive 2003/102/EC regarding A pillar design and PTW safety and promote legislation to incorporate side under-run protection on HGVs.*

Road Infrastructure Recommendations

Recommendation 14	*Road design, particularly curves and intersections should be optimised for PTW safety, paying attention to forward visibility and signage.*
Recommendation 15	*RSA and RSI procedures should address the needs of PTW riders.*
Recommendation 16	*Excessive roadside objects should be minimised, and where necessary be PTW-friendly. Road surfaces should be well maintained and provided maximum and consistent skid resistance.*

7. References

ACEM (2004) MAIDS project. http://www.acembike.org/html/maids.htm

ACEM (2006). Guidelines for PTW-safer road design in Europe.

ACEM (2007) PTW new Registration in the EU
http://www.acembike.org/html/start.htm

Advanced report, (2002). EU project.

Allen, D., Bygrave, S. and Harper, H. (2005) Behaviour at cycle advanced stop lines. http://www.tfl.gov.uk/assets/downloads/corporate/behavour-at-advanced-stop-lines.pdf

Brailly M C (1998). Studie von Motorradunfallen mit Stahlleitplankenanprall. IFZ No. 8

Chinn, B. P., Okello, J. A., McDonough, P. and Grose, G. (1997) Development and testing of a purpose built motorcycle airbag restraint system. Paper presented to 15th ESV Conference. Crowthorne: TRL Limited.

Clarke, D., Ward, P., Bartle, C. and Truman, W. (2007) The role of motorcyclist and other driver behaviour in two types of serious accident in the UK. Accident Analysis and Prevention , doi:10.1016/j.aap.2007.01.002

Donne, G. L. and Fulton, E. J. (1985) The evaluation of aids to the daytime conspicuity of motorcycles, Crowthorne, Berkshire: Transport and Road Research Laboratory

Duncan, J., (1996) Converging levels of analysis in the cognitive neuroscience of visual attention. In: Humphreys, G.W., Duncan, J., Treisman, A. (Eds.) Attention, Space and Action: Studies in Cognitive Neuroscience. OUP, Oxford, pp. 112–129

Ecker, H. &Wassermann, J. (2001) Brake Reaction Times of Motorcycle Riders. International Motorcycle Safety Conference, March 1-4, 2001, Orlando Florida, USA. http://www.uem-online.org/html2/tourism/rs/ecker_pap01.pdf

EEVC (1994) Review of Motorcycle Safety. EEVC report 1994

Elvik, R., Vaa, T. (2004) Handbook of road safety measures .Amsterdam, Elsevier 2004

ETSC (2006) Road accident data in the enlarged European Union – learning from each other.

ETSC (2007). Traffic Law Enforcement across the EU: Time for a Directive.

Finnis, M. P. (1990) Airbags and motorcycles: are they compatible? In Rider-Passenger protection in motorcycle collisions. (SP-827). Warrendale: PA. Society of Automotive Engineers

Forsyth, E., Maycock, G. & Sexton, B. F. (1995) Cohort study of learner and novice drivers, Part 3: Accidents, offenses and driving experience in the first three years of driving. Department of Transport TRL report PR 111: Transport Research Laboratory, UK

Haworth, N., Symmons, M. & Kowadlo, N. (2000) Hazard perception by inexperienced motorcyclists (Report 179). Melbourne: Monash University Accident Research Centre

Haworth, N., Mulvihill, C. & Symmons, M. (2002) Motorcycling after 30. Accident Research Centre Report No. 192. Monash University

Hopes, P.,D. and Chinn, B. P. (1989) Helmets: a new look at design and possible protection. IRCOBI Conference on Biomechanics of Impacts, Stockholm. pp. 39-54

Houston, D. and Richardson, L. (2007) Motorcyclist fatality rates and mandatory helmet-use laws. Accident Analysis and Prevention: no issue assigned as yet

Hurt, H. H., Ouellet, J. V., Thom, D. R. (1981) Motorcycle Accident Cause Factors and Identification of Countermeasures, Volume 1: Technical Report, Traffic Safety Center, University of Southern California, Los Angeles, California 90007, Contract No. DOT HS-5-01160

Iijima, S., Ozono, S., Ota, A., Yamamotot (1998) Exploration of an airbag concept for a large touringmotorcycle. 16th ESV Canada

Jamson and Chorlton (2005) The Older Motorcyclist. DfT research Report No 55. http://www.dft.gov.uk/pgr/roadsafety/research/rsrr/theme2/theoldermotorcyclistno55

Knight, I., Sexton, B., Bartlett, R., Barlow, T., Latham, S., McCrae, I. (2006) Daytime Running Lights (DRL): A review of the reports from the European Commission, Crowthorne, Berkshire: Transport and Road Research Laboratory

Koornstra, M., Bijleveld, F., Hagenzieker, M. (1997) The safety effects of daytime running lights, Leidschendam, Institute for Road Safety Research, (SWOV Report R-97-36)

Kramlich, Th., Sporner, A., (2000) Zusammenspiel aktiver und passiver Sicherheit bei Motorradkollisionen, GDV, Munich

Lynam, D., Broughton, J., Minton, R., Tunbridge, R., (2001) An Analysis of Police Reports of Fatal Accidents Involving Motorcycles. TRL Report 492, Crowthorne, UK

Mannering, F. L., Grodsky, L. L., (1995) Statistical analysis of motorcyclists' perceived accident risk. Accident Analysis and Prevention 27 (1), 21–31

Maycock, G., Lockwood, C. R. and Lester, J. (1991) The accident liability of car drivers. Department of Transport, TRL Report RR 315. Transport Research Laboratory, UK

Morris, C. C., (2006) Generalised linear regression analysis of association of universal helmet laws with motorcyclist fatality rates. Accident Analysis and Prevention 38, 142–147

Moss,, J., (2000) Rural Leisure Motorcycling—Addressing Accidents. Cheshire County Council Road Safety Section, Unpublished Report; published in 'Street Biker', the magazine of the Motorcycle Action Group (MAG), Feb/Mar 2000 issue

Okello, J. A. and Chinn, B. P. (1996) Frontal restraint for motorcycles: development and testing of a purpose built motorcycle airbag restraint system. Project Report PR/VE/ 209/96. Crowthorne: TRL Limited (Unpublished report available on direct personal application only)

Otte, D. & Felten, G., (1991) Requirements on Chin Protection in Full-Face Helmets for Motorcyclist Impact and Injury Situations. Proceedings of International Motorcycle Conference, Institut fur Zweiradsicherheit, 1991

Otte, D. (1998) COST 327 database

Ouellet, J. and Kasantikul, V. (2006). Rider Training and Collision Avoidance in Thailand and Los Angeles Motorcycle Crashes. Presented at the International Motorcycle Safety Conference 2006. http://www.msf-usa.org/imsc/proceedings/a-Ouellet-RiderTrainingandEvasiveActioninThailandandLA.pdf

PROMISING (2001) Promotion of mobility and safety of vulnerable road users Leidschendam, Institute for Road Safety Research

Ruijs, P. A. J. and Berkhout, M. J. (1997) Motorcycle power 74kW study Phase B Report prepared by TNO for European Commission DG 11, Industry. Report No. 97.OR.VD.056.1//PR

Sass, T. R., Zimmerman, P. R. (2000) Motorcycle helmet laws and motorcyclist fatalities. J. Regul. Econ. 18, 195–215

Sexton B., Fletcher, J., Hamilton K. (2004) Motorcycle Accidents and Casualties in Scotland 1992–2002, Transport Planning Group, Scottish Executive Social Research, http://www.scotland.gov.uk/Resource/Doc/26350/0029551.pdf

Sosin, D. M., Sacks, J. J. (1992) Motorcycle helmet-use laws and head injury prevention. J. Am. Med. Assoc. 267, 1649–1651

Sporner A., Kramlich, T. (2000) Combination of Primary and Secondary Safety Aspects within motorcycle Collisions, 3rd International Motorcycle Conference, IfZ (Institute for Motorcycle Safety), Essen, 2000

Stefan, C., Hoeglinger S., Machata K. (2003) ASTERYX Case Study Motorcycle Accidents. KfV - Kuratorium fuer Verkehrssicherheit, Vienna

Stefan, C. et al. (in preparation). IDAF - In-depth analysis of fatalities in Austria 2004-2005., Kuratorium für Verkehrssicherheit by order of the Austrian Federal Ministry of Transportation, Innovation and Technology, Vienna

Treisman, A., (1996) Feature binding, attention and object perception. In: Humphreys, G. W., Duncan, J., Treisman, A. (Eds.) Attention, Space and Action: Studies in Cognitive Neuroscience. OUP, Oxford, pp. 91– 111

US DOT & Motorcycle Safety Foundation (2000) National agenda for motorcycle safety (DOT HS 809 156). Washington, D.C.: Department of Transportation

Vavryn, K., Winkelbauer, M. (1998) Bremskraftregelverhalten von Motorradfahrern. Kuratorium für Verkehrssicherheit, Vienna

Winkelbauer, M., Vavryn, K. (2004) Braking Performance of Experienced and Novice Motorcycle Riders - Results of a Field Study, ICTTP Conference, Nottingham, 2004

Yannis, G. et al. (2005) Traffic Safety Basic Facts 2004 – Motorcycles and Mopeds, created within SAFETYNET EU co-financed project