International Transport Forum

Improving Safety for Motorcycle, Scooter and Moped Riders

Research Report

OECD

Improving Safety for Motorcycle, Scooter and Moped Riders

Research Report

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Please cite this publication as:
OECD/ITF (2015), *Improving Safety for Motorcycle, Scooter and Moped Riders*, OECD Publishing, Paris.
http://dx.doi.org/10.1787/9789282107942-en

ISBN 978-92-82-10793-5 (print)
ISBN 978-92-82-10794-2 (PDF)

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Background

The powered two-wheeler (PTW) population - which includes motorcycles, scooters and mopeds - has been constantly increasing. In most OECD countries, the motorcycle fleet increased much faster than the passenger car fleet from 2001 to 2010. As such, PTWs are becoming an important component of the transport system. However, they represent an important challenge for road safety.

The International Transport Forum set up a Working Group on the Safety of Powered Two-Wheelers in 2010 to review trends in powered two-wheeler crashes and examine the factors contributing to these crashes and their severity. This report is the result of that effort. It describes a set of countermeasures targeting user behaviours, the use of protective equipment, the vehicles and the infrastructure and discusses motorcycle safety strategies in the context of a Safe System approach.

Main findings

The number of powered two-wheelers on the roads is growing and PTWs play a significant role in mobility in many countries, particularly in many of the world's large cities. Some riders use PTWs as their primary form of transport, others for recreation. For many it is the only affordable or practical means of individual motorised mobility.

Powered two-wheeler riders are at far more risk than car drivers per kilometre ridden in terms of fatalities and severe injuries entailing long-term disability. Moreover, they have not benefited at the same pace as car occupants from safety improvements over the recent decades. In OECD countries, PTW riders represent 17% of total fatalities on average, while PTWs account for about 8% of the motorised vehicle fleet. PTW fatalities often comprise a much higher proportion of total fatalities in low- or middle-income countries. In addition to the human casualties, the economic costs associated with PTW crashes are significant. Investing in PTW safety can therefore bring important societal and economic benefits.

Powered two-wheeler crashes are frequently linked to failures of perception and control. The most frequent PTW fatal crashes are collisions at intersections, commonly involving problems of perception and appraisal by both the driver and the rider and single-vehicle crashes, due to the PTWs' higher sensitivity to external perturbations caused for instance by road surfaces or weather conditions. Speeding and consumption of alcohol or drugs are critical factors in the occurrence and severity of PTW crashes, just as for other road users.

Recommendations

Implement a Safe System approach that caters for the safety needs of powered two-wheelers

Growing PTW traffic makes it imperative to adopt safety interventions targeting this mode of transport, while integrating it into a Safe System approach. The Safe System approach recognises that road users can make mistakes or take inappropriate decisions. The role of the system is both to minimise the production of these errors and to protect road users from death and serious injuries when errors occur.

While a Safe System approach concerns all countries, a tailored approach is required which considers local specificities with regard to the safety of powered two-wheelers.

Involve all stakeholders in sharing responsibility for the safety of powered two-wheelers

Improving the safety of PTWs is a shared responsibility. All relevant stakeholders, including civil society organisations, need to be actively involved in the process of drawing up and implementing a shared road safety strategy which includes safer behaviour of all road users, safer infrastructure and vehicles with enhanced safety features. PTW safety is not only the responsibility of governments, administrations, and manufacturers, but also PTW associations, insurance companies, the media, etc.

Make the needs of powered two-wheelers an explicit part of transport policy

Powered two-wheelers are becoming an important component of the transport system which in many countries has given priority to four-wheel vehicles. In some cities in OECD member countries they represent up to 30% of the motor vehicle fleet. Yet only a few countries have a national transport strategy for PTWs in place. PTWs need to be properly integrated into mobility plans.

Create a toolbox of measures to improve the safety of powered two-wheelers riders

A toolbox of measures is required to improve the safety of PTW riders within the traffic system. These measures must take into account the specific challenges associated with PTW mobility and also consider the variety of PTW users, insofar as some segments may be addressed with specific measures. A strategic approach should consider the most effective combination of measures according to the particular needs of individual jurisdictions.

Promote appropriate behaviour of powered two-wheeler riders and road users generally

Licensing, training and education are essential tools for improving riding safety. Access to PTWs should be gradual, with a comprehensive training and licensing system. Training should be designed to promote safe behaviours and address issues such as hazard perception and defensive riding. Other road users should also be made aware of the specific risks associated with the vulnerability and crash patterns of PTWs. Traffic rules must be enforced among powered two-wheelers as well as among other road users.

Make the use of helmets compulsory for all riders of powered two-wheelers

A helmet is the most important protection against severe injuries and deaths. It dramatically reduces the risk of being killed or severely injured and should be worn by all riders and passengers of motorcycles and mopeds All countries should have and enforce a helmet law that makes wearing a helmet obligatory for riders of all powered two-wheelers. A 100% wearing rate is the only acceptable objective. In addition, the wearing of protective clothing with adequate safety standards – adapted to regional conditions - is essential to reducing the severity of injuries and should be promoted.

Enhance safety features in vehicles

The car and motorcycle industries are continuously developing safety devices to both avoid crashes and mitigate their consequences. The prevention of crashes ("active safety") is crucial for the safety of motorcyclists. Enhanced safety features should be adopted in powered two-wheelers; notably advanced braking systems should be introduced generally. Crash avoidance systems on board other vehicles may also contribute to reducing collisions with PTWs.

Reduce crash risk for powered two-wheelers by introducing self-explaining and forgiving roads

Infrastructure should be improved with the development of self-explaining roads which guide drivers and riders to adopt appropriate speed behaviour along with traffic calming measures and PTW-friendly infrastructure ("forgiving" roads). Engineers, road designers and providers, local authorities, road safety auditors and inspectors should be trained to consider PTWs in the design, construction, maintenance and operation of roads, and be provided with the necessary risk assessment tools to make the right decisions.

Do more research to extend understanding of powered two-wheeler mobility and crash mechanisms

There is a great need to develop and apply relevant methods, tools and indicators to measure PTWs in traffic flows and analyse their mobility and behaviour. In particular, exposure data are needed to better understand the specific crash characteristics of PTWs. Operational research and development is needed to achieve a traffic system which better integrates and protects PTWs in a cost efficient manner. Intelligent Transport Systems (ITS) require more research and development on their capacity to prevent and mitigate PTW crashes. Further investigation is required regarding the content and effectiveness of training, including post-licence training.

Chapter 1. Opportunities and challenges of powered two-wheelers

This chapter provides an overview to the purpose and background of this report. It reviews in brief the diversity of powered two-wheelers (PTWs) and their role within the transport system. It also outlines the risks facing users of PTWs and the various challenges for traffic safety.

Introduction

Gone are the days when powered two-wheelers (PTWs) were a marginal mode of travel reserved for a few fans of speed and adventure. PTW use has grown significantly during the last decades in most parts of the world (Haworth, 2012), resulting in the PTW gradually becoming a true mobility tool, attracting an increasingly vast and varied user population. It has now become an integral part of the traffic system, offering certain benefits over other modes of transport: what would big cities such as Rome or Paris be like now, for example, if all PTW riders were driving a car instead?

It is estimated that there are more than 300 million powered two-wheelers in the world, with a relatively uneven distribution across regions: around three quarters are found in Asia, 16% in North America and Europe, 5% in Latin America, 1% in Africa and 1% in the Middle East (Rogers, 2008). This disparity is also characterised by the uses made of this mode. Primarily recreational in North America and Australia, the two-wheeler has a much more mixed function in Europe, where it is increasingly used to escape the problems of urban traffic congestion. In other regions of the world it may serve a mainly utilitarian function.

The growing use of powered two-wheelers raises a number of road safety issues. The present report focuses on the safe integration of powered two-wheelers in the traffic system, primarily in OECD countries. However, the specific nature of motorisation in developing countries cannot be ignored. This question is raised within the different issues addressed throughout the report, and there is a chapter specifically dedicated to low- and middle-income countries (LMICs).

The issues and challenges related to the integration of PTWs within the traffic system are complex and varied. Safety and mobility issues require a comprehensive analysis to identify the means for effective action. These include taking into consideration the current risk exposures for riders when on the road network, which lead to them, being classed as "vulnerable road users", along with pedestrians and cyclists. But it is also necessary to further analyse this risk through the different facets that characterise it: the various populations involved, the types of travel concerned, the different crash-generating situations, the factors involved, etc., always keeping in mind the aim of improving the system as a whole rather than blaming a particular component. These issues were borne in mind for the establishment of the Working Group, and they constitute the spirit of this report.

The diversity of powered two-wheelers and riders

There is great diversity among PTWs and their riders and the identification of relevant issues and solutions must acknowledge this diversity.

The term PTW encompasses mopeds, scooters and motorcycles. Tricycles are also often included in this category. This report is mainly focused on the most typical PTWs found on the road, i.e.:

- Motorcycles, with an engine displacement above 50 cc;
- Mopeds, with an engine displacement equal to or below 50 cc;
- Scooters (including three-wheeler MP3s) corresponding to a shape classification ("step-through design") and an engine with automatic transmission. They can be either the "motorcycle" or "moped" type, based on engine displacement.

Electric bicycles, quads, trikes, etc., are not addressed in this report insofar as their usage is currently limited and each has its own particular characteristics. In some countries, recreational off-road riding contributes a significant proportion of the crash trauma associated with PTWs. While this report may indirectly assist in the improvement of safety for these riders, the particular issues facing off-road riders have not been addressed separately.

The PTW environment has changed greatly in the last decades, not only in size but also in diversity. Today, the domain of the PTW covers a wide diversity of riders, motorcycles and purposes. For example, mopeds and scooters are more widely used in urban areas at moderate speeds; and motorcycles are more commonly used on roads and highways for longer journeys where higher driving speeds are common. Such diversity of vehicle types, uses and users complicates the problem of integrating PTWs within the traffic and transport system. All of this variety must be considered in order to better understand the different facets of the problem and to put forward targeted solutions.

The role of powered two-wheelers within transport systems

The use of PTWs continues to grow each year with multiple economic and social factors contributing to their expansion worldwide, such as increased traffic congestion and inner-city parking problems, increases in gasoline prices, the development of leisure, changes in lifestyle, etc. (Shinar, 2012). The result is that, in spite of a remarkable improvement in traffic safety for all road users (including motorcyclists) in OECD countries, motorcyclist exposure to road risk has increased to the point that in some countries the number of motorcyclists who died in road crashes actually increased over the past two or three decades (Shinar, 2012), while the mortality of other road users declined significantly.

Moreover, as mentioned above, the types of PTWs and the reasons for their use differ according to geographical areas and economic, social and societal factors. PTWs play a significant role in the transport or leisure of their users in different parts of the world, with diverse consequences for safety and potential countermeasures and solutions. While for some, a PTW is a direct substitute for a car, for others it fulfils quite different roles. Its compactness and manoeuvrability allows for flexible travel in congested traffic: thus, it is increasingly used to gain time. Moreover, the sensory experience linked with riding a PTW makes it an object of pleasure for a certain category of people. In the large cities of developed countries (particularly in Europe) PTWs are primarily used for travel and commuting. In other developed countries, like the United States, Canada, Australia and New Zealand, the PTW is often synonymous with "touring" or "riding for recreation". In emerging and developing economies such as Indonesia, the Philippines and Thailand, the PTW is often a commercial vehicle used for business travel or the transport of goods. Moreover, as pointed out by Haworth (2012), in developed countries PTWs often have a high cylinder capacity and only one passenger, while in the LMICs, engine displacements are smaller and PTWs often have several passengers.

The PTW rider population differs from that of car users in the significant disparity between the use of PTWs by men and by women. However, this disparity varies according to the part of the world, and is currently changing in some countries. This is notably the case in countries with high urbanisation, where a significant increase in the proportion of female PTW riders (from a low base) can be observed. The motivation to ride to avoid traffic congestion is expected to reinforce this trend.

Another change has been noted since the late 1990s: the increasing number of riders (for recreation or transport) in the 40+ generation in certain areas of the world such as Europe, Australia and the United States. This population is partly formed of "returning riders", who are coming back to motorcycling after a relatively long period of car use, mainly for practical reasons (transport of children, etc.), and partly composed of new riders. There is no clear evidence of higher risks for the returning riders than for experienced riders of a similar age, but a trend towards increasing trauma among this age group is observed. For the new riders, research evidence has demonstrated an increased risk in the first year of riding.

PTWs also have a special utility and social relevance. As an example, young workers not yet old enough to hold a driving licence (depending on the OECD countries considered), may find the PTW is the only possible means of transport, particularly in rural areas.

In summary, PTWs play a major role in transport for various reasons in different locations. They represent an opportunity to improve mobility, in conjunction with public transport, in many cities suffering from significant congestion and parking challenges. They constitute an integral part of the traffic system, potentially able to meet important future needs in society. In recent years some countries have experienced a rapid growth in the variety, sales, registrations and activity of powered two-wheelers. It must be considered that this growth is likely to accelerate as the world population increases and more people recognise the potential economic, mobility and environmental benefits of PTWs. However, such a development must not be accompanied by a growth in crashes, injuries and fatalities involving PTWs. The reality is that the potential benefits of PTWs in terms of mobility are currently heavily mixed with an overly high societal cost in terms of safety. It is essential to study these safety issues both in terms of their aetiology and in terms of solutions as part of promoting powered two-wheelers as a viable transport alternative to traffic congestion.

An excessive risk

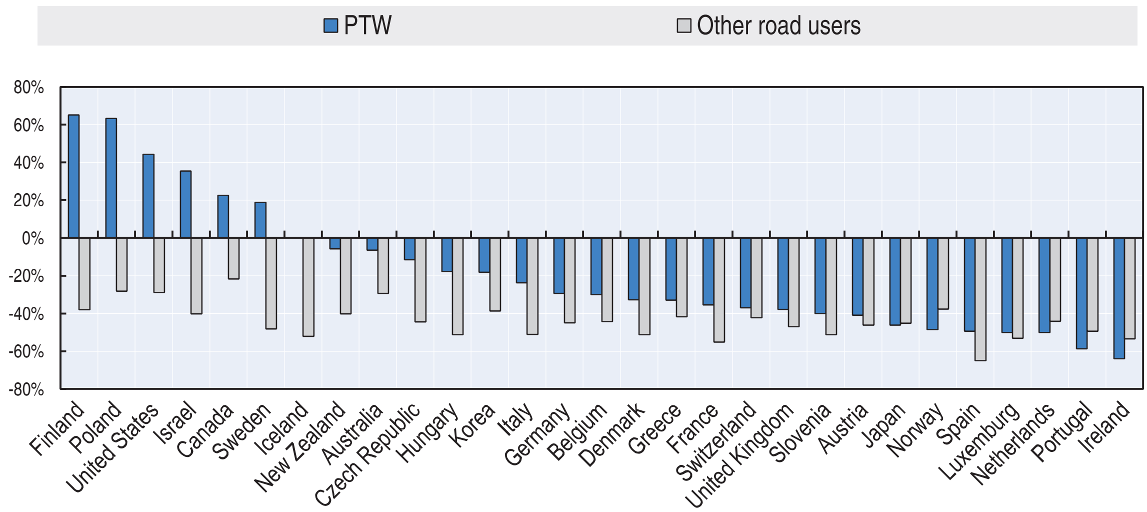
Half of the world's road traffic deaths concern "vulnerable" road users (WHO, 2013), defined as including pedestrians, cyclists and users of PTWs. This proportion is generally higher in low- and middle-income than in high-income countries. On average, PTWs represent 17% of road deaths for only 8% of the vehicle fleet in OECD countries. This proportion can reach higher levels depending on the country, notably as a secondary impact of the progress in safety for other modes.

Regardless of the countries concerned, however, PTW users are confronted with an excessive risk on the road, which has been qualified as "unfair" by Elvik (2009), insofar as for the same number of kilometres driven they have a much higher risk of being killed or severely injured than car occupants. PTW users are clearly overrepresented among road traffic casualty figures, even when they are not overrepresented in crash occurrences. When involved in a crash, PTW riders are significantly more exposed to a higher risk of severe or fatal injury, as are cyclists and pedestrians. Conversely, when involved in a crash with another road user, PTWs are less prone than a car or a truck to provoke severe injuries to others, due to their smaller mass. This is the reason why they can be considered as "vulnerable road users". While the focus is often on the risk of death, the risk of being severely injured, often handicapped for life, is also much higher for PTW users. The number of years of life lost or spent in pain and disability is considerable, with the younger population often being the most affected. This shows the necessity of basing analyses on both fatality and injury data and of integrating the different facets of safety problems.

Whereas there has been substantial progress in most OECD countries in improving road safety and reducing road mortality, PTW riders have not benefited at the same pace as car occupants from safety improvements over the last decade (see Figure 1.1). However, Figure 1.1 does not reflect the increased exposure of PTWs, due to the marked increase of the fleet and its mileage during the past decades.

Figure 1.1. **Changes in fatalities among PTW and other road users**

OECD countries, 2001-2011



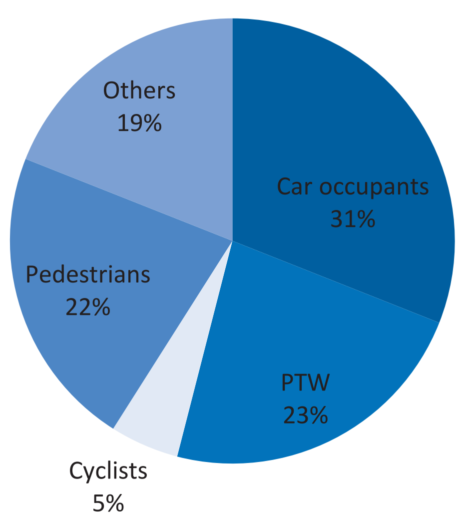
Source: IRTAD (2001-2010 data for Canada).

As we will see in Chapter 3, the risk is unequally shared by different segments of the PTW user population. There are segments of the population with very low risk but, at the opposite, young males are particularly vulnerable.

The situation in developing countries is drastically worse. While they account for only half of the world's registered vehicles, 90% of global traffic deaths occur in low- and middle-income countries. Powered two-wheelers are involved in a very high share of those casualties (see Figure 1.2). For this reason, improving the safety of vulnerable road users, including PTW riders, is among the key priorities identified by the United Nations in the framework of the UN Decade of Action for Road Safety.

Figure 1.2. **World road traffic deaths by road user type**

2010



Source: World Health Organisation (2013).

Why is it riskier to ride a powered two-wheeler?

The level of risk is influenced by many factors. A first, general factor is the intrinsic difficulty of riding a PTW, due to the necessity to balance the vehicle, its lower friction capacity and its greater sensitivity to environmental perturbations (wind, gravel, any change in road surface, etc.) which may destabilise the vehicle. Another influential risk is the domination of cars and larger vehicles in traffic – for which the traffic system has been mainly designed. As a consequence, the traffic system now requires modification to integrate the growing volume of powered two-wheelers.

Elvik (2004) has defined some basic factors which influence the level of risk of road crashes. Among these risk factors, some are considered to affect PTWs more specifically – such as low friction (as mentioned above), but also lack of visibility, failure of road-user "rationality" (such as risk-taking or human error), road-user vulnerability and system forgiveness. All these basic factors will be further discussed within the following chapters.

PTW riders have a higher risk of injury due to their greater vulnerability, resulting from a lack of protection compared to passenger cars, which can lead to very severe consequences in the event of collisions above a certain speed. Safety measures that are already well-recognised, such as helmets, protective clothes, etc., have diminished this vulnerability up to a certain point, but further progress still needs to be made.

Atypical behaviour

By its very nature, driving a PTW may induce a specific behaviour pattern on the road which is different from the drivers of four-wheeled vehicles. Such behaviour is not necessarily "deviant" according to the law, but may surprise other road users.

Even "normal" behaviour (i.e. behaviour common to PTW riders) may be atypical for other vehicle operators. For example, overtaking within a small space, overtaking on the incorrect side, filtering, positioning on one side of the lane, intense acceleration, etc., may be feasible for PTWs but are potentially startling for car drivers, disturbing their normally efficient information-seeking routines. Car drivers and PTW riders need to be aware of and trained concerning the specific driving behaviour and difficulties in perception experienced by both groups.

Atypical behaviour also refers to "deviant" conduct, including stunts, wheelies, etc. Such behaviour is not necessarily frequent, but may contribute to a negative opinion of the PTW community.

A crucial challenge for traffic safety

Road traffic injuries are among the three leading causes of death for people between 5 and 44 years of age. Unless immediate and effective action is taken, road traffic injuries are predicted to become the fifth leading cause of death in the world. May 2011 saw the launch of the worldwide UN Decade of Action for Road Safety, which includes the ambitious target to stabilise and then halve the forecasted level of road fatalities by 2020. To reflect the Decade of Action, several countries have developed strategic plans for the period 2011-2020, including the adoption of safety targets. As an example, the European Union has adopted the target of reducing the number of fatalities by 50% by the year 2020 and a longer term vision to move "close to zero fatalities" by 2050 (European Commission, 2011). The new ISO 39001 standard on road safety management within companies is also an important and ambitious initiative towards this end.

These ambitious targets will only be achievable if serious efforts are made to improve the safety of PTWs. Several countries have developed motorcycling safety strategies and integrated them into their overall safety action plans.

Improving the safety of PTWs must consider all the actors and elements at play. It is not enough to pay attention to PTW riders, one must also monitor their interactions with all other road users, the environment, the vehicles and the social, cultural and political dimensions that shape and supervise their use. Moreover, action should not be restricted to the most obvious parameters but must also take into account the background behind the problems. By acting in a coherent and integrated way on the various axes concerned, safety may be improved through progress on issues as diverse as defensive safety training, development and acceptability of appropriate protective clothing, and raising awareness among road users of the presence of PTWs and the difficulties in their interactions that each may encounter. It is necessary to integrate the specific characteristics of PTWs and their handling difficulties into the design of appropriate and tolerant ("forgiving") infrastructure. Significant progress can now be expected towards the development of devices for active and passive safety, both for PTWs and other vehicles.

But in a longer-term perspective, improving safety also implies improving knowledge of PTWs, by investing in research and in the collection of crash data (not confined to fatalities but also analysing injury crashes and even property damage crashes) and of exposure (traffic) data on which this research work can be based.

A systemic approach to powered two-wheeler safety

Road safety is a complex issue that cannot be solved by focusing only on the behaviour of the operators involved at the sharp end of the process: the road users. As stated in the 2008 OECD report, a focus on enforcement has been the dominant paradigm of traditional road safety policies over the past 30 years. These policies have provided the necessary legislative framework and control with respect to key variables such as speeds, driving under the influence of alcohol, failure to wear a seat-belt or helmet and, more generally, non-compliance with the basic safety rules. Road user compliance with the law and with regulations is a vital element in the delivery of a safe road transport system (Carsten, 2012) and these approaches have contributed to significant improvements in road fatality levels in OECD countries, complementing the improvements made in vehicles and infrastructure, notably in terms of protective devices.

However, even if police enforcement can be considered an inherent part of a sustainable safety approach (Wegman & Aarts, 2006), the focus on the road user is an insufficient paradigm today. To further improve road safety, it is necessary to broaden the spectrum of analysis and intervention. An increasing number of countries tend to think more in terms of the "Safe System approach". This is not opposed to the more classical approach to road safety; it simply provides a wider understanding of the risk factors and the spectrum of interventions which may address them efficiently.

The Safe System approach in traffic

The traffic system was designed and developed by humans but is dangerous to humans, as evidenced by the number of injuries and deaths on the roads. This raises an ethical issue for society, and motivated the Swedish "Vision Zero", directed by the credo that a road safety policy must aim to avoid fatalities and serious casualties.

Beyond ethics, the application of the systemic approach to road safety means considering crashes as anomalies to be suppressed by applying a pattern of measures, which address not only the road users but all the people involved in the traffic system, be it in its conception, equipment, maintenance, legislation, etc. This relies on the notion of shared responsibility, which implies that everyone must act in favour of road safety instead of blaming each other. Action by all stakeholders is needed: public authorities, governments and local authorities, private companies, the car industry, transport companies, road operators and road users. The application of the systemic approach to road safety under the Safe System approach leads us to review the standards that tend to attribute full responsibility for driving difficulties to the road users only. "*This new thinking means a shift and a sharing for overall road safety, requiring a high level of political, social and community commitment, with government, other groups and individuals all having important roles to play in improving road safety* (OECD, 2008)."

A Safe System approach is based on avoiding the most severe traffic crashes by acting on the different components of the road system to 1) promote safe behaviour on the part of the road users; 2) offer the capacity to correct their eventual errors; 3) protect them when these errors cannot be corrected.

A complex problem cannot be solved by a simple intervention without wider consideration of the context. In a system, every action has consequences, and actions that are insufficiently studied from a whole perspective may result in only shifting the problem. The most effective action does not necessarily rely on where the cause (or the guilt) is the most obvious. For example, infrastructure modifications are often the most sustainable way to avoid speeding. Another important point to consider is that several forms of action are often more effective than a single action. This is what is meant by the concept of integrated safety.

The notion of integrated road safety

The notion of integrated road safety implies promoting safety by acting simultaneously on different levers, keeping in mind that each component is an important factor for the potential improvement of safety, even if it is not always identifiable as a direct contributor to crashes. The key is indeed to find, not the element to blame, but the effective and sustainable solutions using the most effective lever.

Road users

Road users directly influence traffic safety in general and therefore PTW safety. All the potential ways to promote safer riding behaviours should be developed in a coherent way with the measures addressed to infrastructure and the vehicles. Firstly, education should aim to influence the attitudes and behaviours toward other road users. Training follows, first for PTW riders, so that they obtain a good understanding of the difficulties they may encounter on the roads and the appropriate behaviours to adopt (including the use of protective equipment); secondly, for other drivers to make them aware of the potential problems in their interactions with PTWs and the right strategies to use (e.g. information-seeking strategies) to prevent these problems. Specific training is also to be promoted for road designers to sensitise them to the particular difficulties induced by riding a PTW and by being confronted with them. More broadly, the use of information campaigns (for PTWs and for other modes) is useful to make a larger audience aware of the potential problems. Finally, as a last step, enforcement is necessary to validate the other measures. No one action is complete in itself, and all have their limitations; which explains the need to integrate safety measures.

Vehicles – rider interaction

Vehicles can be seen as tools to perform the mobility task of the road users efficiently and safely. As tools, they must fit the capacity of each user and the objectives of their task. The vehicle's characteristics have a fairly direct influence on its operator's driving behaviour and they should be carefully considered to avoid potential misuse. A high acceleration capacity and a high maximum speed may influence the drivers' behaviour depending on their objectives and personality. Dealing with PTW safety, much is to be gained from technical improvements at various levels (preventive safety, active safety, passive safety and post-crash safety), not only for the PTW itself but also the other vehicles they may interact with.

Road infrastructure

It is sometimes more effective to act indirectly on the road infrastructure than directly on the road users. Human behaviour is partly the product of the environment in which humans operate. The road layout will thus have a decisive influence on their activity, whether behavioural or cognitive (psychological). For road users, the road environment is both the physical guide to behaviour and the framework of the events that can occur. As a consequence, the design, construction, operation and maintenance of the road environment can influence the mechanisms of safety in diverse ways: first, through maladaptive behaviour (for example, unintentionally encouraging over-high speeds, hasty manoeuvres, etc.) which will make drivers more prone to error; and second, through erroneous analysis of the situation encountered (e.g. inadequate visibility, over-complicated or inconsistent layout, etc.). Finally, gaps in protection may exist that will not allow recovery from these errors (e.g. lack of a stabilised shoulder) or that may aggravate their consequences (e.g. aggressiveness of roadside objects).

Background of the Working Group

This Working Group on motorcycling safety and mobility has built on the work at Lillehammer in June 2008 (OECD/ITF, 2008b), where an international workshop brought together researchers, policymakers, industry and motorcyclists' associations. This workshop established a number of areas for improving the safety of motorcycles, which deserve further investigation. The main recommendations from the Lillehammer Workshop are described below:

Box 1.1. **Main recommendations of the Lillehammer Workshop: June 2008**

The following general principles and priority measures illustrate the key conclusions and recommendations of the Lillehammer Workshop.

General principles

- **Co-operation between the various stakeholders.** Improving safety for motorcyclists requires the establishment of a continuing dialogue and co-operation between the various stakeholders, including the motorcyclists themselves, policymakers, researchers and motorcycle manufacturers.
- **Transport and infrastructure policy.** A fundamental motorcycle safety requirement is that motorcycles should have a place in overall transport policy and infrastructure policy/management.
- **Research and evaluation:** Countermeasures need to be founded on evidence-based scientific research into driver and rider behaviour, and before-and-after evaluations should be conducted.

Priority Measures

Priority measures were classified into the following categories: human factors; social and cultural factors; vehicles; and infrastructure. The priority measures listed below are not exhaustive and the classification should not be seen as a rigid framework.

Human factors

Training programmes for motorcyclists. Countries have different training needs, based on their vehicle fleet and riding environment. Motorcycle training should therefore build on existing standards, focus on risk awareness and risk avoidance, and develop an understanding of rider/motorcycle capacities and limitations.

Box 1.1. **Main recommendations of the Lillehammer Workshop: June 2008** *(cont.)*

- **Improved training for general drivers:** A component on awareness and acceptance of motorcyclists should be included in the general training for all drivers, with a particular emphasis on the need for appropriate traffic scanning strategies.
- **Targeted integrated awareness campaigns.** There should be regular, targeted, campaigns addressing both motorcyclists and other road users, supported where necessary by other actions, e.g. enforcement, focused on mutual respect, protective equipment, speed, alcohol and drug issues.
- **Protective equipment for riders.** Where standards for protective equipment exist, these should be promoted; and where they do not, they should be developed, taking into account their safety performance, rider comfort, the ergonomics of their use, costs and the climates and regions where they will be used.

Social / cultural factors

- **Get safety messages to the riders and portrayal of responsible riding:** Safety messages to riders should be developed in partnership with rider groups, in order to use the effectiveness of peer advice in communicating key issues to riders on issues that will impact their communities.
- **Develop awareness of motorcyclists** and mutual respect between road users, education activities and campaigns should be set up from childhood, to emphasise that "road safety means road sharing".

Road environment and infrastructure

- **Guidelines for the development of road infrastructure and training for road designers.** Each level of government should include in their infrastructure guidelines measures for accommodating motorcycles, developed with input from relevant stakeholders. The guidelines should be relevant to the needs of the jurisdiction concerned and co-ordinated with other jurisdictions and levels of government. The needs of motorcycles should be included in the basic training for road designers and highway and traffic engineers.

Vehicles

- **Braking systems.** Manufacturers should continue to introduce advanced (better) **braking systems**, such as combined brake systems and anti-lock-brake systems.
- **Motorcycles in ITS.** Enhanced awareness of motorcycles should be incorporated into the development of all ITS vehicle projects.
- **Headlamps in daytime.** To improve rider/motorcycle PTW conspicuity, for new motorcycles, headlamps should come on automatically when the engine is started; for other motorcycles, riders should switch on their headlamps before they start their journey.

The objectives of the Working Group have been defined as follows:

- To further document areas that were identified in the Lillehammer Workshop as requiring more research.
- To review and synthesise the most recent knowledge dealing with PTW safety.
- Improve the understanding of PTW crash configurations and mechanisms.
- To progress toward the Safe System approach by going further than blaming weaknesses of a component of the traffic system and thinking more in terms of potential sustainably efficient solutions.
- To provide recommendations to policymakers on measures that can be implemented in the short term to improve the safety of motorcyclists.

Content of the report

This report presents state-of-the-art research conclusions and best practices dealing with the safety of PTWs within the traffic system. It is divided into eleven chapters:

- *Chapter 1*, "Opportunities and challenges of powered two-wheelers", gives an overview of the purpose, background and spirit of the report.
- *Chapter 2*, "Powered two-wheeler fleet and usage", presents the mobility patterns of PTWs as essential elements to be considered in order to thoroughly understand the different aspects of the problems in hand, as well as to assess risk exposure.
- *Chapter 3*, "Powered two-wheeler crash characteristics", introduces PTW crash patterns in a descriptive way with the purpose of defining the basis of the problems.
- *Chapter 4*, "Factors contributing to PTW crash characteristics and their severity", examines the most typical crash scenarios and their contributing factors, both at primary (i.e. crash factors) and secondary (i.e. factors related to injury severity) safety levels.
- *Chapter 5*, "Countermeasures addressing road user behaviour", describes measures targeting the road users through education, training and licensing, enforcement and communication campaigns.
- *Chapter 6*, "Countermeasures promoting the use of personal protective equipment" presents the safety value of protective equipment, including helmets, protective clothing, airbag jackets, high visibility clothing and neck braces.
- *Chapter 7*, "Countermeasures targeting vehicles", presents the current developments in vehicle technologies to improve safety of riders. Intelligent transport systems are also examined in this section.
- *Chapter 8,* "Countermeasures targeting infrastructure and traffic management", addresses the issues related to speed and traffic management, along with the necessity for infrastructure design and maintenance to take PTWs into account.
- *Chapter 9*, "Specific powered two-wheeler issues in emerging countries", presents some particular issues to acknowledge when dealing with the question of PTWs in motorising countries.
- *Chapter 10*, "Developing and implementing an integrated road safety strategy for motorcyclists", outlines the need for a strategic approach to PTW safety to integrate effort and guide the allocation of resources toward initiatives that have proven benefits.
- *Chapter 11*, "Conclusions and Recommendations" provides a summary of the main findings of this report and recommendations for the implementation of a toolbox of countermeasures are provided.

The report does not provide a priority list or best practice list of countermeasures that each country should apply. The PTW culture and safety issues differ in each country; therefore, no countermeasure fits the needs of every country. In addition, it is not always possible to evaluate the impact of different countermeasures in the same way. For some countermeasures (e.g. helmet-wearing and ABS) there is stronger scientific evidence than for others (e.g. education and communication campaigns). Countermeasures presenting less marked scientific evidence of effectiveness are nevertheless presented in this report. In this case, it is the Working Group's expert opinion that a countermeasure can be effective even if strong scientific evidence has not yet been established. It can notably be the case that one measure (e.g. communication) will become fully efficient only when associated with another (e.g. enforcement). No single measure alone will be able to resolve the road safety problems for PTW users. Finally, the countermeasures differ in costs and time span. While some recommendations may be far into the future, others may provide more immediate results.

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Chapter 2. Powered two-wheeler fleet and usage

This chapter analyses the recent evolution in the use of powered two-wheelers (PTWs) and their role in mobility. It highlights the distinction between different types of powered two-wheelers (mopeds, scooters and motorcycles) and describes the main characteristics of riders' journeys in various countries, taking into account geographical differences. It also reviews the policies in place that have a direct or indirect effect on the use of powered two-wheelers.

The fleet of powered two-wheelers

Categories of powered two-wheelers

In this report, the term powered two-wheelers (PTWs) includes all power-driven two- or three-wheeled vehicles but does not include power-assisted or electric bicycles. Classifications of powered two-wheelers were developed by the UNECE in its 1958 Agreement, and by the United Nations in the 1968 Vienna Convention. In this report, for the sake of simplification, we identify two administrative categories of PTWs:

- Mopeds.
- Motorcycles – sometimes with a distinction between light motorcycles and others.

Scooters can belong to either of these categories, depending on their displacement. Electric PTWs are being developed and can belong to either the moped or the motorcycle category.

Mopeds

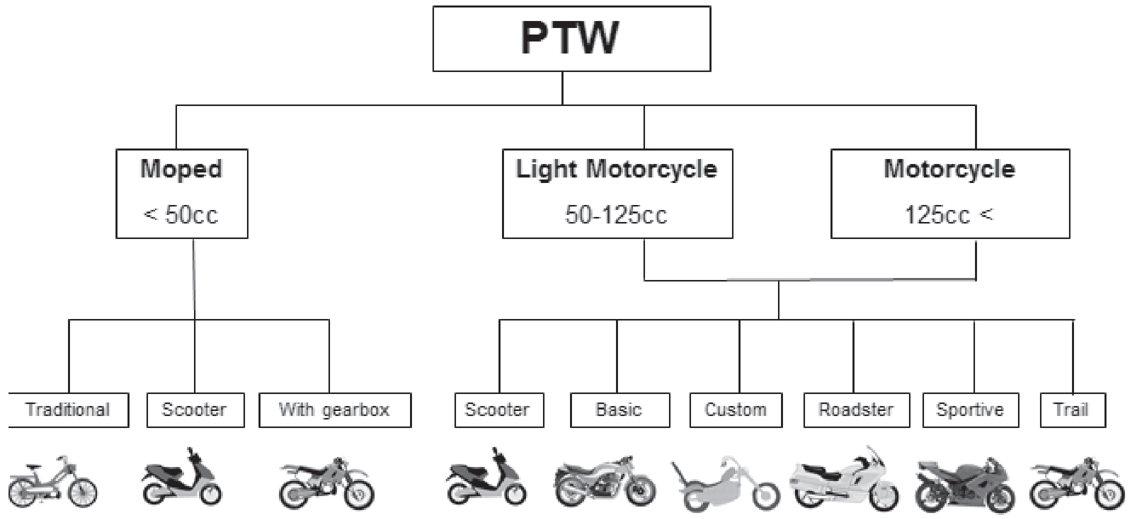
Mopeds are lower-powered, two- or three-wheelers. In most jurisdictions, their engine displacement is less or equal to 50 cm^3. Top speed restrictions often apply and may vary between jurisdictions, but are typically 45 km/h or 50 km/h. Electric mopeds have a power less, or equal to, 4 kW and a maximum speed less or equal to 45 km/h.

Motorcycles

The term "motorcycles" refers to a wide range of vehicles. Some jurisdictions define two categories of motorcycle:

- Light motorcycles, with a displacement less or equal to 125 cm^3;
- Motorcycles, with a displacement above 125 cm^3. This category includes a wide range of motorcycles designed for varying uses. The terms used for particular types of motorcycles differ across the world. Figure 2.1 illustrates a French categorisation developed by Ruscher (2003). In contrast, the US National Agenda for Motorcycle Safety (NAMS, NHTSA/MSF, 2001) categorises motorcycles as traditional, cruiser, sportbike, touring, sport-touring, dual-purpose, scooters, mopeds and nopeds (mopeds without pedals), sidecars and trikes.

Figure 2.1. **Diversity of powered two-wheelers**



Source: Adapted from C. Ruscher, (2003).

Mopeds and motorcycles can be powered by thermal or electric engines. Electric powered two-wheelers are starting to penetrate the market and present a number of advantages in terms of both reduced air pollutant emissions and noise.

Attractiveness of mopeds and motorcycles

The use of PTWs presents a number of advantages for individual users:

- In urban areas, PTWs offer the advantages of individual transport modes with the potential to travel relatively quickly and to have reliable travel times. This is made possible by the capacity to overtake vehicles, allowing riders to get through most traffic jams. In addition, PTW users save time when searching for a parking place, by parking – legally or not – very close to their destination.
- In rural areas, they offer mobility options for users who do not have access to a car and where public transport is sometimes non-existent.
- PTWs are an individual transport mode, offering freedom and flexibility, with almost no constraints on the departure and destination locations.
- Finally, PTWs are a cheaper way to travel than a private car: the purchase cost is lower, maintenance is cheaper, fuel consumption is lower, and tolls and parking are often free or reduced.

At a societal level, PTWs also provide a number of benefits, as they respond to several concerns of governments:

- Providing citizens with efficient transport modes;
- Optimising usage of road space and sharing of limited public space, so the maximum number of people can use it;
- PTWs can bring benefits from an environmental perspective, especially in comparison with passenger cars: less fuel consumption, less CO_2 and NO_X emissions than a private car, but much higher emission levels of HC. The emergence of electric PTWs, which are much cheaper than electric cars, may bring additional environmental benefits (see Table 2.1).

Table 2.1. **Emissions of pollutants by various motorised transport means in cities per km and per passenger**

	Car (1.2 passenger/vehicle)	Urban bus (average occupation)	Motorcycle (urban)	Electric scooter*
CO_2 (g/pax.km)	206	130	129	40.5
SO_2 (g/pax.km)	0.04	0.01	0.04	–
PM (g/pax.km)	0.04	0.05	n.a.	–
HC (g/pax.km)	0.56	0.3	6.82	–
NOx (g/pax.km)	0.65	1.3	0.14	–

* On the basis of an average European electricity mix. With a French mix, CO_2 emissions are: 5.3 g / pax.km

Source: ADEME, France.

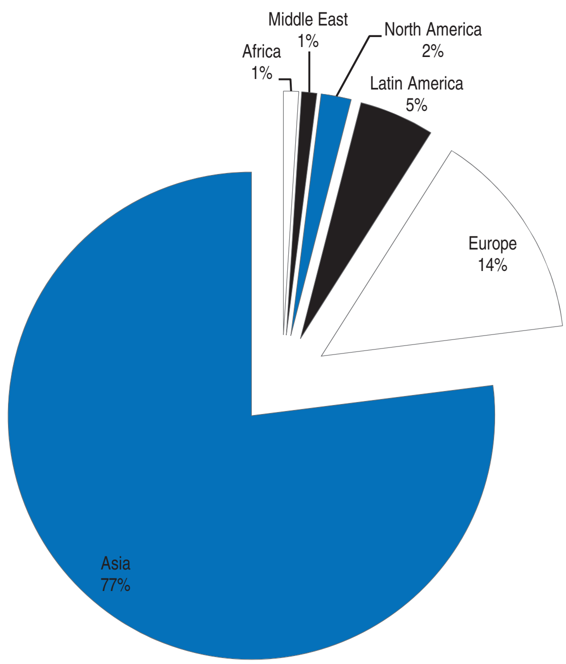
However, PTWs also have a number of drawbacks:

- They are a more risky travel mode (about 20 times riskier than a car).
- They are not emission free. PTWs emit local and global pollutants and are a significant source of noise.
- They do not provide the same level of comfort and service as private cars (e.g., carrying more than one passenger and cargo).

Key figures about the fleet

There is no consolidated data on the global fleet of powered two-wheelers and, in some emerging economies, there is a lack of data. Nevertheless, in 2008, it was estimated that there were 313 million powered two-wheelers in operation in the world, with more than three quarters of the PTW fleet in Asia (see Figure 2.2). Worldwide, the current production of PTWs is around 50 million units per annum, to be compared with around 65 million units for passenger cars.

Figure 2.2. **Geographical distribution of the fleet in 2008**



Source: Society of Indian Automobile Manufacturers (2008)

In most OECD countries, the motorcycle fleet grew much more rapidly than the passenger car fleet in the decade 2001 to 2010 (see Table 2.2).

Table 2.2. **Growth (%) in the PTW and passenger car fleets for a selection of OECD countries**

2001-2010

	Passenger cars	Mopeds	Motorcycles
Australia	25%		88%
Czech Republic	29%	10%	35%
France	11%	-22%	48%
Great Britain	13%	-27%	28%
Greece	52%	-14%	76%
Japan	11%	-20%	14%
Mexico	86%		311%
Spain	22%	27%	82%
Sweden	8%	84%	91%
United States (excl. SUVs)	5%	–	67%

Source: IRTAD; IMT for Mexico.

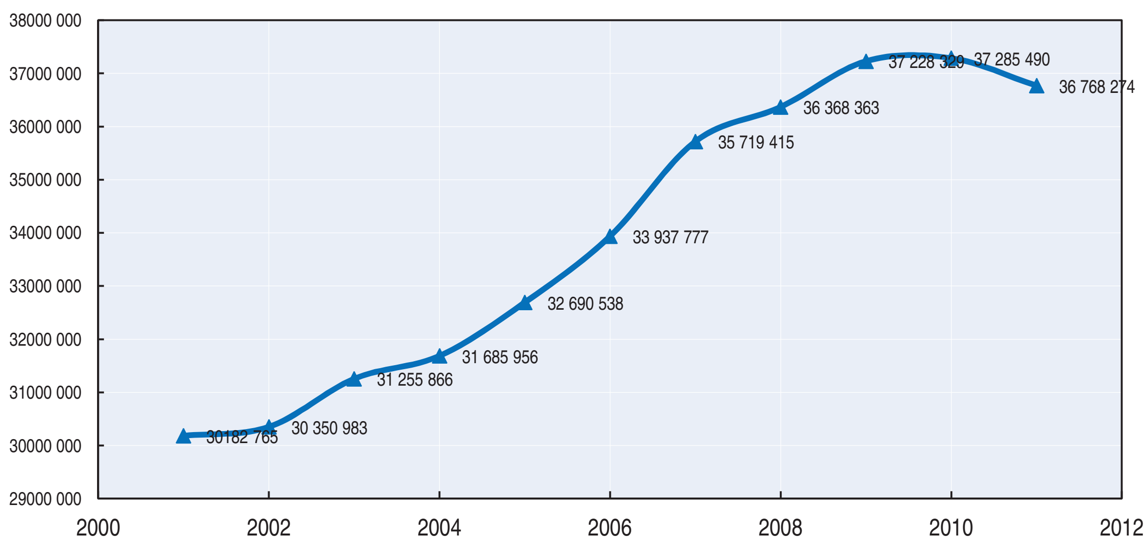
European Union

There were 37 million PTWs in Europe[1] in 2011, of which about 70% were motorcycles and 30% were mopeds (ACEM, 2013). Within the motorcycle fleet, the smallest displacements (between 50 and 125 cm^3) composed more than 60% of the total. The 125 cm^3 class doubled in volume in five years (2003-08). In 2011-12, as a reflection of the overall economic downturn, the growth in sales of new vehicles halted (see Figure 2.3). Mopeds represent between 9% (in the UK) and 60% (in Luxembourg) of the PTW fleet, and their share is declining in most countries.

In large cities, the growing proportion of PTWs in the motorised fleet is marked. In Barcelona for example, PTWs represented 24.7% of the fleet in 2002 (15.3% for motorcycles and 9.4% for mopeds) but rose to 30.2% in 2011 (21.5% for motorcycles and 8.7% for mopeds).

Figure 2.3. **Circulating PTW fleet in Europe***

2001-2011



* European Union + Norway + Switzerland

Source: ACEM.

Russia

In 2011, there were about 2.6 million powered two-wheelers, i.e. 6% of the motor vehicle fleet in the Russian Federation. The large majority (94%) of the fleet is composed of motorcycles; however, the moped fleet is increasing significantly.

United States

In the United States, the number of registered motorcycles rose at the end of the 1970s and early 1980s followed by a sustained decline through the late 1990s. Motorcycle registrations have been on a steady increase since that time. In the United States, a large share of the PTW fleet is made up of powerful motorcycles, with 75% above 749 cm^3 (Motorcycle Industry Council, 2010).

Mopeds are nearly absent from the market, representing less than 4% of the PTW fleet.

Australia

Overall, PTWs compose only a small proportion of the fleet, but their numbers are growing at a faster rate than for other vehicles. PTWs represented 4.1% of the motor vehicle fleet in 2011, an increase from 3.2% in 2006, as PTW numbers grew in this period by 47% (Australian Bureau of Statistics, 2011).

Many motorcycles are larger than 750 cm^3 with a survey of riders in Victoria indicating that approximately 50% had a motorcycle of this size as their main vehicle. In contrast, fewer than 3% of riders reported using a PTW of less than 125 cm^3 as their main vehicle. Scooters represent a small proportion of the PTW fleet, with less than 5% of riders reporting using them as their main choice (VicRoads, 2008).

In Australia, the proportion of mopeds is very low and, in many States, moped data is not separately collected as a full motorcycle licence is required to ride a moped. In the State of Queensland, mopeds may be ridden on a car licence and mopeds constituted 6.9% of registered PTWs in 2003-2008 (Blackman and Haworth, 2013). Given that a car or motorcycle licence is required, access to mopeds is not available to younger riders in Australia (in contrast to Europe), thus reducing demand for these vehicles.

New Zealand

The PTW fleet grew rapidly from 2004 to 2008 and was static in the three following years. The growth categories are concentrated at the extreme of the fleet – the under 60 cm^3, under 250 cm^3 and over 1 000 cm^3 groupings grew the most. The average engine capacity is close to 600 cm^3 and growing (Ministry of Transport, 2013). In 2011, there were 112 000 PTWs, comprising 3% of the motorised fleet.

Asia

PTWs are the principal mode of motorised transport in many Asian countries. PTWs account for up to 85% of the motorised vehicle fleet and the PTW fleet is continually increasing. In many countries, mopeds constitute the biggest market share (see also Chapter 9).

Japan

In Japan, the moped fleet reached a peak in the late 1980s and was at that time twice the size of the motorcycle fleet. It has fallen considerably since, but still represented more than 60% of the PTW fleet in 2010. The relatively high proportion of mopeds in Japan can be explained by the ease in obtaining a licence (car licence holders do not need to take a test), relatively low costs and the fact that automobile insurance covers mopeds for free.

Korea

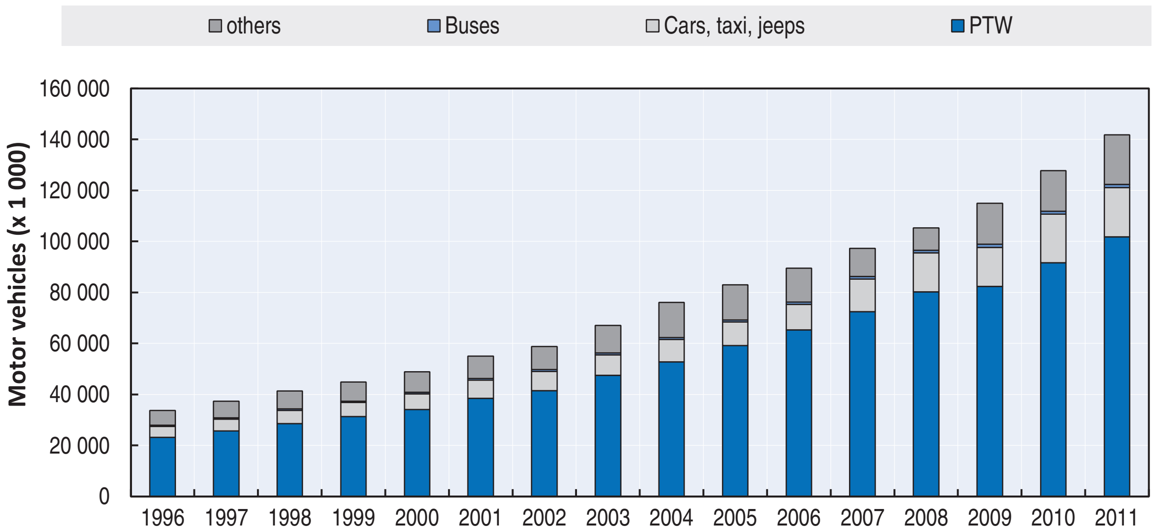
The number of motorcycles is steadily increasing in Korea and reached 1.8 million units in 2011 (with 13.6 million passenger cars). Official statistics are not yet available for mopeds, as registration only became compulsory in 2012 (to increase safety, and also to fight against theft).

India

In 2011, there were 100 million motorised two-wheelers in India, representing 70% of the motorised vehicle fleet. Between 1997 and 2011, the size of the PTW fleet multiplied by four. The significant increase in the PTW fleet across the country is due to the increasing necessity for travel, easy availability, increasing purchasing power, poor public transport and inability to afford personal cars (see Figure 2.4). Mopeds represent 65% of the registered PTW fleet.

Figure 2.4. **Growth in the motor vehicle fleet in India**

1996-2011



Source: Ministry of Roads, Transports and Highways.

China

Based on data from the Traffic Management Bureau of the Ministry of Public Security, the number of motorcycles in China increased by more than 70% between 2003 and 2011 – from 60 million to 103 million units.

Central and Latin America

In many Latin American countries, the mass sales and use of PTWs has been rather recent, and has considerably increased in the past 10 years. The PTW fleet is growing every year by about 10%, slightly faster than the fleet of passenger vehicles. In those Latin American countries for which data are available (see Table 2.3), PTWs make up between 3% (Chile) and 52% (Uruguay) of the motorised vehicle fleet. In Mexico, PTWs represented only 4% of the fleet in 2011, but the fleet is growing rapidly and has almost doubled in 5 years.

Table 2.3. **PTW fleet in Latin America in 2011**

	Estimation of the PTW fleet	% of the motor vehicle fleet
Argentina	3 823 000	21%
Brazil	15 688,000	22%
Chile	113,000	3%
Colombia	3 794 800	50%
Costa Rica	130 500	14%
Equator	329 000	22%
El Salvador	75 000	10%
Guatemala	657 000	30%
Mexico	1 310 000	4%
Nicaragua	134 000	30%
Paraguay	271 900	27%
Peru	1 568 366	44%
Dominic Republic	1 481 200	51%
Uruguay	824 000	52%
Venezuela	985 000	19%

Source: Ibero American Road Safety Observatory (OISEVI).

Africa

There are no consolidated data on the PTW fleet for the African continent. Information gathered from a few countries shows that the use of PTWs as commercial vehicles has substantially increased over the past decade in the big African cities. In particular, the number of moto-taxis has exploded in these cities, as a consequence of the lack of public transport services (Kumar, 2011).

Characteristics of and changes in users of powered two-wheelers

PTW usage and users

It is difficult to analyse the role of PTWs in traffic because there is sparse data on PTW mileage. In most countries, mileage is estimated based on the numbers of registered vehicles; but there is a large difference between owning a vehicle and using it. The most reliable information on PTW usage comes from household surveys. These surveys show that PTW usage has been growing significantly from past levels. Haworth (2012) studied the main reasons for the growth in the use of powered two-wheelers and summarised these as follows:

- Ease of use.
- Efficiency and economy of this mode of transport.
- Their use in businesses.
- Growth in individual leisure.

Mopeds are used mainly in Europe by young people, as there are few access restrictions for this type of motorised vehicle (see next section). Most motorcycle use is for everyday travel, but in mature markets (e.g., Europe, United States) larger motorcycles are used for leisure riding. In Europe, PTWs are commonly used for commuting, but this is much rarer in the United States, Canada or Australia, where PTWs are largely used for recreational riding.

In many OECD countries, there is an increasing number of "returning" riders – typically males in the 40-50 year age group who stopped riding a PTW for a period of more than 5 years, and usually return to riding on powerful motorcycles.

The PTW rider population is composed mostly of males; but the trend is evolving, with increasing numbers of females now riding.

Box 2.1. **Mobility patterns in Greece**

Results of Greek study, based on national transport survey
(Yannis, 2007)

- Mopeds are mainly ridden by the 16-17 age-group.
- 8-20 years-olds use PTWs as much as private cars.
- Most PTWs riders are male.
- There are more females riding mopeds than motorcycles.
- Average yearly distance travelled increases with the power of PTW: 4 172 km / year for a moped; 11 993 km / year for a PTW > 730 cm3.

Other results from this study show that, contrary to what is often assumed, PTWs are not primarily used for leisure. The average distance travelled (on a yearly basis) by moped or motorcycle on a week day is twice as much as during the weekend. This is not the case for cars, for which the average distance during a week day is only 10% higher than during the weekend. In Greece, PTWs are therefore used mainly to go to school or work, while cars are the preferred travel mode for leisure during the week end.

Mopeds are used in predominantly urban areas (87% of their use, compared to 47% for private cars). This is because young people use them to go to school or to visit their friends, which correspond to trips inside urban areas.

Motorcycles are also used mainly in urban areas (83.5% of the distance travelled) but, given their higher performance, they are more suited than mopeds to drive outside urban areas.

Box 2.2. **Mobility patterns in the United Kingdom**

Results of a British study

A TRL study (Christmas et al., 2009) developed a categorisation of riders on the basis of about 1 000 rider interviews. The classification clearly shows that there are groups among riders who have a focus either on leisure and fun riding, or riding for transport. However, none of the groups does exclusively one or the other.

The typical use of PTW in the United Kingdom:

- 53% of riders ride less than 4 000 miles (6 400 km) per annum (47% ride more);
- 34% only ride in summer;
- 14% ride only for commuting;
- 12% ride as part of the job;
- 72% do all year round leisure riding;
- 71% do all year round fun riding;
- 21% ride only on rural roads, 15% only urban and 64% do both;
- 82% of the riders hold a car licence, 72% use a car on a regular basis at an average of 10 000 miles (16 000 km) per annum., which is at least not much less than an average car user.

Box 2.3. **Mobility patterns in France**

Results of a French survey of national households
(CERTU, 2010)

On average, French people undertake 1.5% of their trips by PTW, using their mopeds or motorcycles for two-thirds of their travel. They rarely travel by car or by foot.

Mopeds are used mainly for commuting or going to school/university, with the second travel purpose being to visit friends or for study-related trips. Motorcycles trips are mainly work-related.

Mopeds users: include many children and young people – below 25 years, and rarely more than 34 years old. They include an important proportion of the labour force, but mainly workers or employees, and few people with high educational backgrounds. Both non-motorised households (for whom the moped replaces the car) and over-motorised households (well-off households, who can purchase one or more mopeds for their children) are over-represented among moped users.

Motorcycles users: often include mature people (35-49 year age group) as well as 25-34 and 50-64 year olds. A high proportion is at the higher educational level, with most working – usually as senior staff or professionals. Their households are less likely to be over-motorised (i.e. the motorcycle usually replaces one car).

Box 2.4. **Mobility patterns in New Zealand**

Results based on New Zealand Household Travel Survey 2003-2009
(Study from the Ministry of Transport)

Highlights:

- Motorcycling makes up approximately 0.5% of total travel time and 0.5% of trips.
- About 120 000 people each year ride more than 100 km (82% male, 18% female).
- 30-44 year olds as well as 45+ years made up the greatest proportion of these riders (at 38% each); while those aged 15-29 made up 25%.
- 65% of motorcycling trips are for commuting: to work or to study. (For car trips, it is 30%.)
- 32% of the distance ridden every year is on urban roads, and 68% on open roads.

Access and training

The training and access policies related to this travel mode influence the choice and use of PTWs.

This is typically the case for mopeds which represent, in many countries, the only motorised individual travel mode accessible for 14-18 year olds. This is less the case in the United States, where it is legal to drive a car from age 16 in many states, and does not apply in most states of Australia where moped riders require a car or motorcycle licence.

Box 2.5. **Influence of PTW access policy on the use and choice of PTW in France**

In France, from 1996 to 2007, anyone who had held a car licence for more than two years was authorised to ride a PTW up to 125 cm3 without an additional test or training. There was an increase in the number of 125cm3 PTWs in the fleet after 1996.

Since 2011, those holding a car-driving licence for longer than two years must now also undertake seven hours of training to be authorised to ride a 125cm3 PTW (this training did not apply to people who could demonstrate having held PTW insurance for more than two years). This measure was immediately followed by a decrease in the sales of 125cm3 and a light increase in the sales of 50cm3 PTWs.

There are different categories of licences for motorcycles, usually based on the power of the engine, aiming to ensure an adequate degree of maturity, experience and education to ride a powered two-wheeler. Licence categories might also be put in place to encourage or ensure a graduated access to PTWs (this is further discussed in Chapter 5). For mopeds, access in most countries is very simple; the age of the rider is often the only criterion, although some countries now also require a test on traffic rules.

European Union

Member states of the European Union have a harmonised licensing system, which still offers various options to the Member states. The 3rd Driving Licence Directive (2006/126/EC) came into force in January 2013. Within this Directive, mopeds were included in the licensing system for the first time and a strict graduated approach was mandated for access to heavier machines.

However, the subsidiarity principle applies and countries can adapt the Directive. As an example, the minimum age to ride an A-class motorcycle in most countries is about 20 or 22 years – not 24 years – as prescribed in the Directive (see Tables 2.4 and 2.5). France and Italy are the only EU countries allowing teenagers to ride a moped from 14 years. In France, there is only seven hours of compulsory training, while in Italy children must pass a practical test to ride a moped. In France, the underlying reason is twofold: first, to give young apprentices living in rural areas access to individual motorised transport. Second, to offer a means of individual motorised transport that is not subject to a licence.

Table 2.4. **Riding licence in Europe**

Age and engine power restrictions within the 3rd Driving Licence Directive (effective as of January 2013)

Item	**3rd directive (2006/126 EC)**
Vehicle restrictions	
Category AM (moped)	
Maximum speed (km/h)	45
Minimum age	16 (subsidiary 14 to 18)
Category A1	
Maximum engine power (kW)	11
Maximum power weight (kW/kg)	0,1 max
Maximum. capacity (cm³)	125
Minimum age	16 to 18 (subsidiary)
Category A2	
Maximum engine power (kW)	35
Maximum. power weight (kW/kg)	0,20
Minimum age	18, but A1 min age + 2 years
Category A	
Minimum age for direct access	24

Great Britain

In Great Britain, a system of Compulsory Basic Training (CBT) for new riders was introduced in 1991. Reform of the CBT system is currently being considered. Riders of PTWs of all types must first undertake CBT before being allowed to ride on the road on a provisional licence. The CBT course includes classroom-based theory elements, off-road practice and a road ride, accompanied by a trainer, of at least two hours. Riders must show they are competent before they are issued a certificate.

Riders who have completed CBT are authorised to ride a moped or a motorcycle up to 125 cm^3 unaccompanied, provided they display “L” plates, do not carry pillion passengers, and do not ride on motorways. The CBT certificate is valid for two years, by which time the riders must have passed a test or retake CBT if they wish to continue riding. Riders of larger motorcycles, once they have completed CBT, can only ride on the roads, using L-plates, if they are accompanied by an instructor, in radio contact, for the purpose of training for the test.

Those who passed their car driving test prior to 1 February 2001 have full moped entitlement and are not required to take a CBT course to ride a moped. Those who passed their car driving test after this date need to complete a CBT course to validate their moped entitlement. On completion of CBT they are entitled to ride a moped without L-plates and carry pillion passengers.

United States

In the United States, the licensing rules vary from state-to-stat; ranging from highly regulated systems to no specific licences for PTWs.

Canada

In Canada, the licensing system is defined by each province. Some Provinces have a mandatory rider training requirement while others use a licensing incentive for rider training.

In Ontario, the applicants must be at least 16 years of age and parental consent is not required, while in most other jurisdictions parental consent of age is required until 18 years of age. New drivers applying for a first licence to ride a motorcycle need to enter Ontario's graduated licensing system, described below.

- *Class M1*: After candidates pass a motorcycle knowledge test, they receive a Class M1 licence and an information package for new riders. New motorcycle riders with an M1 licence learn to ride under the following four conditions:
    - blood alcohol level must be zero;
    - ride only during daylight hours (1/2 hour before sunrise to 1/2 hour after sunset);
    - no riding on highways with speed limits of more than 80 km/h (with some exceptions);
    - no passengers.
- *Class M2*: Riders must pass an M1 road test or complete an approved motorcycle safety course before receiving a Class M2 licence. They must hold a Class M1 licence for a minimum of 22 months. If they complete an approved motorcycle safety course, they may reduce this time requirement by four months. With an M2 licence, they gain more privileges – they may ride at night and on any road. However, at this level:
    - their blood alcohol level must be zero;
    - they will be eligible to take a Class M road test after they have completed the required time with an M2 licence;
    - they must pass the on-road test to obtain a full Class M licence.
- *Class M*: Full licence, with no restriction.

Mexico

In Mexico, a car or motorcycle licence is required to ride a PTW. The licensing system is defined by each state; but the main requirements (in terms of medical condition, theoretical and practical tests) are similar throughout the country (see Table 2.5). In most states, the applicants for the restricted licence must be at least 16 years of age (15 in Mexico City) and parental consent and responsibility until 18 years of age is required. For this category, training is usually not compulsory and vehicle insurance is in most cases not required. Applicants for the full licence must be at least 18 years of age and have passed a theoretical and practical test. Training is compulsory only in a few states.

Australia

The licensing system for PTWs is defined by each State. Some States require a motorcycle licence to ride a moped; others allow a moped to be ridden on a car licence. Western Australia has a specific moped licence. In all States, a motorcycle licence is required to ride a scooter that has an engine capacity exceeding 50 cm^3. The minimum age for operating a PTW ranges between 16 and 18 years, and in several States there is a requirement to hold a car licence before learning to ride a PTW. The underlying principle is to avoid a system that would encourage younger people – who are the most at risk – from using a riskier means of transport. Each State has learner, provisional or restricted, and open licence phases, but riders who have completed the graduated licensing scheme for car licences may skip the provisional or restricted phases in some jurisdictions. Novice riders are subject to restrictions on carrying passengers and blood alcohol concentration. Each jurisdiction has a Learner Approved Motorcycle (LAM) Scheme which restricts novice riders to motorcycles with a power-to-weight ratio that does not exceed 150 kW/ton, and an engine capacity that does not exceed 660 cm^3. In Queensland, additional testing is required to remove this requirement after at least one year.

New Zealand

A car or motorcycle licence is required to ride a moped. All other PTWs require a motorcycle licence. There are three stages:

- *Stage 1:* learner licence: candidates must be at least 16 years old and have passed a road rules theory test. While on a learner licence, riders are not allowed to ride a motorcycle of more than 250 cm^3, carry passengers, or ride between 10 pm and 5 am. The motorcycle must display a learner (L) rear-plate.
- *Stage 2:* restricted licence: candidates must be at least 16½ years old, have held their learner licence for at least six months and have passed a practical test of their driving skills. While on a restricted licence, riders are not allowed to ride a motorcycle of more than 250 cm^3, carry passengers, or ride between 10 pm and 5 am.
- *Stage 3*: full licence: candidates must be at least 18 years of age, or 17½, if they have completed an approved advanced driving skills course. Candidates under 25 years of age can apply after having held a restricted licence for at least 18 months (or at least 12 months for those having completed an approved advanced driving skills course). Candidates above 25 can apply after having held a restricted licence for at least six months (or at least three months for those having completed an approved advanced driving skill course).

Table 2.5 summarises the licensing schemes in OECD countries, based on the European categorisation of powered two-wheelers (see Table 2.4)

Table 2.5. **PTW Licence Categories**

Country	AM (moped) Min age	Terms	A1 (engine power ≤ 11kw) Min age	Terms	A2 (engine power ≤ 35 kw) Min age	Terms	A (no restriction) Min age	Terms
Australia	15.5 (WA)	Only W. Australia has moped licence. Theory test. Sth Australia and Queensland allow moped riding on car licence. Other states require PTW licence.		No distinction A1, A2, A – all require same PTW licence		No distinction A1, A2, A – all require same PTW licence	16-18 depends on state	Learner, provisional/ restricted, and full licences. Some states minimum durations, or mandatory training. Learner Approved Motorcycles are <660 cm3 and <150 kW/tonne
Austria	15		16		18		20	
Belgium	16	*Training:* min. 4 lessons, including specific safety for mopeds and 50% on-road. *Exams:* theory test + private ground	18	Direct access: *Training:* 9 stages (evaluate on 9 hours; min 50% on road) in driving school + choice: 1° Temporary Drive Licence and/or 2° 3 stages in driving school *Exams*: theory test + private ground + public road (in principle of GDE)	20	*Direct access:* (see A1) or *Progressive access*: 2yrs experience of A1 + progressive training (specific and individual training of 4 stages) *Exams:* Private ground + Public way	22	Progressive access: see A2 Direct access: see A1
Canada	14	Alberta and Quebec allow 14-year olds to operate mopeds and e-bikes. Most jurisdictions require 16 years of age for any driver licence types.	16	Mandatory rider training may be required in certain jurisdictions.	16	Progressive engine size applies in some jurisdictions. Licensing test is taken on small engine size motorcycles, scooters or moped.	16	Progressive engine size applies in some jurisdiction. Licensing test is taken on small engine size motorcycles, scooters or moped.
France	14	Theoretical test at school (ASSR) compulsory for all children + 7 hours practical training (BSR)	16	*Training:* 15 hours minimum *Exams:* theory test + private ground + public way (identical to A2 and A licence) *Or*: car licence (from 18 yrs) + 7 hours training	18	*From*: 18 to 24 years *Training*: 20 hours minimum (or A1 +15 hours) *Exams*: theory test + Private ground + Public way	24	*Training:* minimum : 20 hours *Or*: hold A2 during 2 years and training 7 hours (accessible from 20 years old)

Table 2.5. **PTW Licence Categories** *(cont.)*

Country	AM (moped) Min age	Terms	A1 (engine power ≤ 11kw) Min age	Terms	A2 (engine power ≤ 35 kw) Min age	Terms	A (no restriction) Min age	Terms
Greece	16	Exams: theory test + closed area practical test	18	Minimum: 10 motorcycle theory lessons of 45 min, 14 riding lessons of 45 min Theory and driving tests	20	Since 19/01/2013 *Minimum:* 10 motorcycle theory lessons of 45 min, 14 riding lessons of 45 min theory and driving tests *or* holding at least for 2 years the A1 licence + new riding tests	24	*Minimum:* 10 motorcycle theory lessons of 4 mn, 14 riding lessons of 45 min, theory and driving tests. *or* holding at least for 2 years the A2 licence
Israel	No such vehicles		16	Min. 15 lessons. No Pillion allowed until 18	18	Min. 15 lessons. Min. 8 lessons for A1 holders.	21	Must hold A2 for 1 year. Min. 8 lessons.
Italy	14	Since 2005 people that don't have a licence need to obtain a certificate (so-called "mini- licence")	16		18	Passing from A1 to A2 is not automatic. There is always a need for a practical exam	21	Those already having the A2, after 2 years automatically obtain the A without limitations
Japan	16	3 hours of training Theory and aptitude test Car licence holders can ride a moped.			16	PTW =< 400 cm^3: Theoretical, aptitude and skill test. 3 hours of riding lessons. 3 hours of theoretical session.	18	PTW > 400 cm^3. Theoretical, aptitude and skill test. 3 hours of theoretical sessions and 3 hours of riding lessons.
Mexico	No Categories. Minimum age to ride any PTW: 16; Conditional permit and parent consent until the age of 18							
Netherlands	16	Theory test + practical (on road) test	18	Theory test + practical test (closed area) + practical test (on the road)	20	*With A1:* Practical test (on the road) *Without A1:* Theory test + practical test (closed area) + practical test (on the road)	22 24	With A2: Practical test (on the road) *Without A2:* Theory test + practical test (closed area) + practical test (on the road)
Norway	16	14 lessons obligatory training	16	9 lessons obligatory training	18	13 lessons obligatory training	20	7 lessons obligatory training. Minimum 2 year with A2 licence

Table 2.5. **PTW Licence Categories** *(cont.)*

Country	AM (moped) Min age	Terms	A1 (engine power ≤ 11kw) Min age	Terms	A2 (engine power ≤ 35 kw) Min age	Terms	A (no restriction) Min age	Terms
Portugal	14	17 hours of training mandatory	16	If under 18 years old, parents' consent required (also applies to AM category)	18	Min. 16+4 lessons	21	21 years old, or must hold A2 for 2 years.
Spain	15*	Theory + closed area practical tests (for non-holders of another licence)	16	Theory + closed area practical+ "real" driving in traffic	18	Theory + closed area practical + "real" driving in traffic. Staged access (for those drivers holding A1 for over 2 years): the theory test does not apply	20	Minimum 2 year with A2 licence. 9 hours training (4 closed area + 2 "real" driving in traffic + 3 theory and awareness)
Sweden	15	Learners permit including a health declaration. Compulsory education; theoretical and practical exercises including driving in traffic (Minimum time:12 hours included 4 hours of practical training). Theory test (no driving test)	16	Learners permit including a health declaration. Mandatory risk education for motorcyclists. At least 3 hours theoretical risk education and at least 4 hours practical risk education. Theory test + practical test (closed area) + practical test (on the road)	18	Learners permit including a health declaration. Mandatory risk education for motorcyclists if such education is not completed for category A1. Theory test + practical test (closed area) + practical test (on the road) No theory test, only if the candidate already has category A1	24 (20)	Learners permit including a health declaration. Mandatory risk education for motorcyclists if such education is not completed for a lower category. Theory test + practical test (closed area) + practical test (on the road) 24 years for direct access to category A, but 20 years if two years of experience of A2. No theoretical test if the candidate already has category A1 or A2.
United Kingdom	16	Theory test + practical test (on the road). Successful completion of category B test (minimum age 17) will also give AM entitlement, which must be validated by completing a CBT course.	17	Theory test + practical test (closed area) + practical test (on the road)	19	If held A1 licence for 2 years, practical test (closed area) + practical test (on the road). *Direct access:* Theory test + practical test (closed area) + practical test (on the road).	24 (21)	If held A2 licence for 2 years, access at age 21 practical test (closed area) + practical test (on the road). Direct access: age 24, theory test + practical test (closed area) + practical test (on the road)
United States	No federal licensing requirements. Each State in the US develops and enforces independent licensing laws for ages and types of PTWs.							

* Spain: 18 to carry passengers.

Transport and mobility policies for powered two-wheelers

National transport policy which has an impact on PTW mobility

European Union: Green paper "Towards a new culture for urban mobility"

The Green Paper of the European Commission integrates the benefits of PTWs in urban traffic. It states that:

> *"Rethinking urban mobility involves optimising the use of all the various modes of transport and organising "co-modality" between the different modes of collective transport (train, tram, metro, bus, taxi) and the different modes of individual transport (car, motorcycle, cycle, walking).*
>
> *... Experiences from stakeholders show that there is no single solution to reduce congestion. However, alternatives to private car use, such as walking, cycling, collective transport or the use of the motorbike and scooter, should be made attractive and safe."*

Nevertheless, in 2011, few European cities (e.g. Rome, Paris, London, and Barcelona) had a dedicated policy to integrate PTWs in their travel plans (European Commission, 2011).

Often, the development of PTW usage is not managed and in some cases comes as a response to strategies restricting car use (parking policy for example), associated with a certain tolerance for PTWs without any formal position regarding PTWs (PTW parking or filtering may be tolerated).

Sweden

The overall objective of the Swedish transport policy is to ensure the provision of transport for people and businesses throughout the country in a manner that is economically efficient and sustainable in the long term. The overall objective is supported by two main objectives: a functional objective that concerns the accessibility of the journey or transport, and an impact objective that concerns safety, the environment and health. The objectives comprise all modes of traffic, which means that they also concern transport and journeys made by motorcycle and moped.

The moped or motorcycle is needed by many for running necessary daily errands or for improved quality of life during leisure hours.

To respond to the doubling of PTW travel in the past ten years, a full strategy to improve the safety of PTWs was developed and a revised version was released in 2012. The strategy is an integrated part of the work to achieve the interim goals for road safety in the year 2020. The goals were decided by the Swedish Parliament in May 2009.

Australia

Most of the responsibility for transport and transport policy in Australia rests with state governments. The Federal Government seeks to coordinate transport policy through the Transport Infrastructure Council (which includes representatives of all states and the federal government) and the National Transport Commission (www.ntc.gov.au) is charged with "developing national regulatory and operational reform and implementations strategies for road, rail and intermodal transport". A National Transport Plan was agreed to in 2008, but the document does not mention motorcycles – although they are mentioned in some of the underpinning documents, including the National Road Safety Strategy. Various state governments have their own transport strategies (not all of which mention PTWs) and some states have PTW strategies or PTW road safety strategies.

United States

The U.S. Department of Transportation has a policy initiative regarding transportation and liveable communities. Former DOT Secretary Ray LaHood stated:

> *"Liveability means being able to take your kids to school, go to work, see a doctor, drop by the grocery or Post Office, go out to dinner and a movie, and play with your kids at the park – all without having to get in your car."*

This effort involves planning and development of communities with transportation as an important consideration. More compact, connected communities could impact the use and infrastructure considerations for PTWs.

Examples of local strategies influencing PTW usage

Policies encouraging the use of PTWs

- Stringent parking policy for cars and tolerance and free parking for PTWs

The cities of Paris, Stockholm, Copenhagen and Amsterdam have stringent parking policies for cars (e.g. diminution of available space, paid parking), while at the same time no parking restriction for PTWs. The result has been a sharp increase in the number of motorised two-wheelers in operation, seen initially as a better alternative to private car use.

- Use of bus lanes by PTWs

In London, PTWs are allowed to drive in most bus lanes. Vienna has launched a pilot test (see description below).

- High Occupancy Vehicle (HOV) Lanes

High occupancy vehicle (HOV) lanes, or carpool lanes, are reserved for vehicles with a specified minimum number of occupants (usually two or three). U.S. Federal law requires that HOV lanes "must allow motorcycles and bicycles to use the HOV facility, unless either or both create a safety hazard." In some states, certain single-occupant vehicles such as hybrid vehicles or those using alternative fuels may be driven on HOV facilities as well.

- Advanced stop lines

Advanced stop lines provide space for PTWs to stop in front of other vehicles at traffic signals (see more in Chapter 8).

- Filtering

In Belgium, filtering has been authorised since July 2011. PTW riders are allowed to move between two lanes at a maximum speed of 50 km/h and with a speed difference of less than 20 km/h compared to the traffic in the adjacent lanes. On motorways/highways, this manoeuvre is only allowed between the two left lanes. There has not yet been assessment in terms of traffic or crashes.

In the ACT – Australian Capital Territory[2] a lane filtering trial will be conducted for a period of two years commencing 1 February 2015

In France, this issue is on the political agenda and experimentation on filtering could start in 2015.

Policies restricting the use of PTWs

In China, mainly for environmental reasons, gasoline motorcycles are banned from downtown Guangzhou, Dongguan, Shenzhen, Zhuhai and Hangzhou; and restricted in Beijing and Shanghai. Electric two-wheelers – ranging from electric bicycles to electric motorcycles – are however, promoted. Electric bike sales began modestly in the 1990s and started to take off in 2004, when 40 000 were sold. Since then over 100 million have been purchased, with more than 20 million sold each year.

Box 2.6. **City of London - Impact of traffic policy on the use of PTWs**

London has recently adopted a number of urban and traffic measures to reduce the place of cars in the city centre. These measures also affected the use of PTWs.

London Parking charges: Parking charges are the responsibility of the 33 London boroughs and each has its own approach. It is only the City of Westminster (which covers much of central London) which has introduced parking charges for motorcycles, alongside the longstanding parking charges for cars. PTW parking remains free in other parts of central, inner and outer London, though often only in designated parking bays. Short-term car parking is allowed for either two, or four hours, depending on the area. Parking for cars is paid by the minute (20 pence per minute, four pounds per hour). PTW parking is much cheaper, i.e. one pound per day in public areas; there are discounts if longer periods are paid in one go (up to GBP 100 per year).

The ***London congestion charge*** is a fee charged for some categories of motor vehicle to travel at certain times within the Congestion Charge Zone (CCZ), a traffic area in central London. It is run by Transport for London (TfL), the regional authority, not by the boroughs. The charge aims to reduce congestion, and raise investment funds for London's transport system. Though not the first scheme of its kind in the United Kingdom, it was the largest when introduced, and it remains one of the largest in the world. The western extension of the charging zone, introduced by the previous mayor, is being removed by the current mayor. PTWs are exempt from the central London congestion charge, recognising that they do not contribute to the congestion problem in central London. There has been an increase in PTW use in London since the charge was introduced.

Use of bus lanes by PTW

Since January 2012, PTWs are allowed to use most bus lanes in London, with the main objective to smooth traffic, cut CO_2 across London and improve journey time reliability for motorcyclists on the network.

Source: Transport for London.

Box 2.7. **PTWs within traffic policy in Barcelona**

Barcelona has a fleet of 300 000 motorcycles (30% of the vehicle fleet), which is the second largest in Europe behind Rome. From the end of 2004 a new law was passed that allowed car drivers who had held a licence for 3 or more years to drive light motorcycles without any other special requirement. This contributed to a sharp increase in PTW crashes in the period 2005-2010. Despite frequent enforcement, problems of noise and air pollution remained. The practice of uncontrolled parking is to the detriment of pedestrian space. The city of Barcelona has seen the increase in PTW use as an opportunity to address traffic congestion and has implemented a number of measures to better regulate the use of these vehicles.

Advanced zones at traffic lights

The advanced zones at traffic lights allow the users of PTWs to position themselves in front of the car traffic on the traffic intersection. ***Parking policy***

PTWs may be parked on footpaths with a width of more than 5 metres.

The municipality of Barcelona has implemented a taxation system for parking to reduce commuting traffic and to facilitate, prioritise and encourage bicycle traffic. The city is distributed into different areas with varying parking charges. There are parking areas, for parking of the resident's cars and others. Residential car owners receive parking privileges in terms of fees and reserved parking areas. Parking fees are 100% invested into improvement of infrastructure, which means both traffic calming measures such as rebuilding 30 km zones, pedestrian areas and other comparable measures and extending the public bicycle-sharing programme. Parking space for these bikes, other bikes and motorcycles is built up using these funds.

Electric powered two-wheelers

The city of Barcelona is now undertaking an ambitious programme focusing on promoting electric PTWs.

Box 2.8. **Traffic policy and PTW in Vienna (Austria)**

Parking policy, parking fees, bus lane use, sidewalk parking, filtering

Mopeds may be parked on footpaths with a width of more than 2.5 metres.

An area around the city centre of Vienna for short term parking was recently extended. The restrictions are valid Monday to Friday from 9:00 to 22:00, with some exceptions in particular on shopping roads. Cars are charged EUR 2 per hour. Parking is limited to a maximum of two hours. Neither the maximum parking duration nor the charges apply to PTWs.

Filtering and advanced stop lines

PTW are allowed to filter between queues of cars, which have come to a complete stop. However, they must not impede drivers wanting to change direction. This does not apply to motorways and PTWs must not travel on the hard shoulder or within the emergency corridor.

There is an increasing number of “advanced stop lines”. Primarily introduced for the sake of bicyclist safety, PTW riders are in favour of these as well.

Bus lanes

In 2005, a pilot has been launched to allow PTW riders to use bus lanes. PTWs are not allowed on bicycle paths.

Conclusions

The powered two-wheeler fleet (which includes motorcycles, scooters and mopeds) has been constantly increasing and plays a significant role in mobility in many countries, particularly in many of the world's large cities. Some riders use PTWs as their only form of transportation (for example in many emerging countries) for commuting (mainly in European cities), for recreation (for example, in North America, the United States, Canada), or for both commuting and recreational riding.

Access to PTW riding usually depends on their engine displacement and the age of the riders. It requires obtaining a specific licence, subject to minimum training, and a practical test at least for engine capacities above 50 cm^3. There is an effort towards regional harmonisation (e.g. in Europe) of the licensing systems for PTWs, but there is still diversity within Federal environments among their jurisdictions, in particular regarding the minimum age to ride a PTW.

PTWs are becoming an important component of the transport system and in some cities represent up to 30% of the motor vehicle fleet. They present both assets for mobility, and also challenges in terms of traffic management and safety. However, only a few countries have in place a national transport strategy for PTWs; though several measures have been taken at local level.

There would be many benefits – in terms of mobility and traffic management as well as traffic safety – in a better integration of PTWs into mobility plans and in the development of national and local transport strategies.

Notes

1. EU + Norway +Switzerland

2. http://www.justice.act.gov.au/page/view/3733/title/act-lane-filtering-trial

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Chapter 3. Powered two-wheeler crash characteristics

This chapter reviews the safety issues of powered two-wheelers (PTWs). It highlights the relative crash risk for motorcyclists and describes PTW crash characteristics in terms of recent crash trends, typical injuries, and crash scenarios.

Introduction

The rapid growth in the variety, sales, registrations, and activity of powered two-wheelers (PTWs) - motorcycles, scooters, mopeds - observed in recent years in most countries has been accompanied by growth in crashes, injuries, and fatalities involving them. Such growth is likely to accelerate as world populations grow and more people recognise the potential economic, mobility, and environmental sustainability benefits of powered two-wheelers. This chapter analyses the safety issues associated with powered two-wheelers.

Data issues

Crash data

Crash data presented in this chapter are mainly based on fatality data from the following sources:

- The IRTAD database, which presents aggregated data for 32 countries;
- The CARE database, which gathers disaggregated data for most EU countries;
- National databases, such as FARS for the United States.

Analysing *serious injuries* is also essential to understand safety issues of motorcyclists, because motorcyclists are more exposed to very serious injuries with long-term handicap, due to their lower mass and occupant protection, which are significantly different from injuries of other road users. In addition, recent work (ITF/OECD, 2011) has shown that reducing the number of seriously injured may require a different approach than reducing the number of fatal crashes.

However, one must be aware of the challenge of analysing injury data because:

- There is no universal definition of serious injuries among countries, despite the recent recommendations from IRTAD and the European Commission to define serious injuries on the basis of the Maximum Abbreviated Injury Scale.
- Data on injuries are largely underreported and biased in the source of information described above. Only a very limited number of countries have systematic exchange of information between police and health data to allow a more complete picture of the situation.[1]

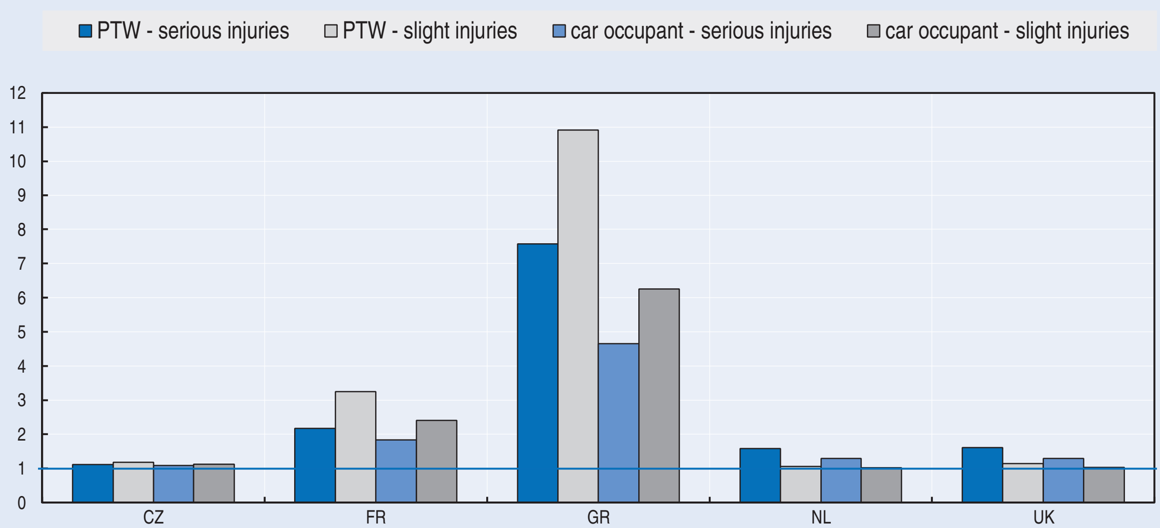
Box 3.1. **The issue of underreporting**

Results of a pilot European study

Within the SafetyNet Integrated European project, a pilot study was carried out in eight European countries, aiming to estimate road accident injury under-reporting coefficients on the basis of linking Police and Hospital data for different road user types, and to propose a common definition of injury severity in Europe (Broughton et al., 2010).

In this study, underreporting coefficients were defined as the ratio of the estimated actual number of injuries of a given severity, to the number of related injuries recorded by the Police.

Figure 3.1. **Underreporting coefficients for PTW riders and car occupants per injury severity in five European countries**



Source: Broughton et al., 2010.

Underreporting coefficients for PTW riders (namely motorcyclists) and car occupants were estimated in five European countries (see Figure 3.1). The extent of the injury underreporting problem for motorcyclists is equal (CZ), slightly higher (FR, NL, UK) or significantly higher (GR) than for car occupants. Serious motorcyclist injuries appear to be less underreported by the Police than slight ones in Greece, France and the Czech Republic, while the opposite is the case for the Netherlands and the UK. The underreporting of motorcyclists' injury is strikingly high in Greece, and the difference compared to car occupants is also more pronounced in that country, a country where motorcyclists' casualties are over-represented in the total road accident casualties.

Despite some limitations of the above European pilot study (e.g. few countries, different sample study area sizes), the results can be considered to be indicative of the overall extent of the injury underreporting problem in the examined countries and in Europe as a whole. The findings from this study confirm that motorcyclists' injuries are more often underreported (Amoros and Laumon, 2006).

Exposure data

To understand PTW crashes, crash data must be analysed and compared with exposure data. Without detailed PTW exposure information, it is difficult to determine risk trends from the available fatality and injury data.

There are various indicators to measure exposure to assess the risks of transport modes:

- Vehicle –kilometres
- Passenger-kilometres
- The number of circulating motorised vehicles
- Total travel time

Using the number of vehicle kilometres travelled by PTWs gives a good proxy of their actual exposure to assess the level of risk. However, very few countries collect this type of data on a regular basis.

More complex information is ideally required such as quantitative and qualitative variations in the activity of particular registered vehicles and drivers, activity of unregistered drivers, changes in the prevalence of driving or riding, types of travel and relevant vehicle characteristics (such as power to weight ratio) in a given population or subpopulation, etc.

Relative crash risk for motorcyclists

As already mentioned in Chapter 1, there is a worldwide pattern that PTW riders experience a greater risk of being severely injured, but contribute less risk for other road users due to the lesser "aggressivity" of PTW vehicles as compared to cars and trucks.

In 2011, there were more than 12 000 PTW fatalities in OECD countries (excluding Chile, Estonia, Slovak Republic, Mexico, Turkey), representing between 8% and 30% of total fatalities. This percentage has to be compared with the percentage of travel by PTWs or the proportion of motorised vehicles that are PTWs. For example, in 2011, in France, PTWs represented 2% of the traffic, 6% of the motor vehicle fleet but 25% of total fatalities.

Table 3.1. **Percentages of PTWs in the motorised fleet and in total fatalities**

2001 and 2011

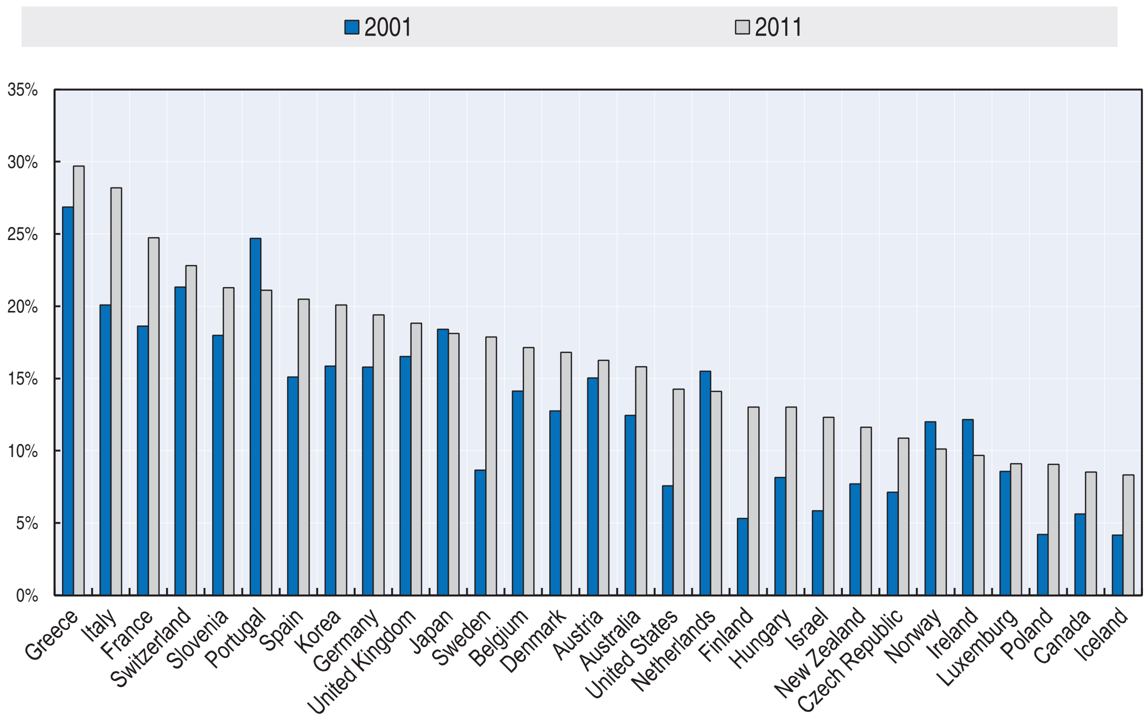
Country	Fatalities PTW	Fatalities-all	% PTW in fatalities	% PTW fleet	Fatalities PTW	Fatalities-all	% PTW in fatalities	% PTW fleet
	2001				2011			
Australia	216	1 737	12%	3%	202	1 277	16%	4%
Austria	144	958	15%	11%	85	523	16%	12%
Belgium	210	1 486	14%	5%	147	858	17%	6%
Canada	155	2 756	6%	2%	190	2 227	9%	
Czech Republic	95	1 334	7%	16%	84	773	11%	15%
Denmark	55	431	13%	3%	37	220	17%	5%
Finland	23	433	5%	7%	38	292	13%	13%
France	1 519	8 160	19%	7%	980	3 963	25%	6%
Germany	1 102	6 977	16%	9%	778	4 009	19%	11%
Greece	505	1 880	27%	35%	339	1 141	30%	31%
Hungary	101	1 239	8%	3%	83	638	13%	4%
Iceland	1	24	4%	1%	1	12	8%	4%
Ireland	50	411	12%	2%	18	186	10%	2%
Israel	31	531	6%	-	42	341	12%	4%
Italy	1 426	7 096	20%	18%	1 088	3 860	28%	17%
Japan	1 854	10 071	18%	16%	997	5 507	18%	14%
Korea	1 284	8 097	16%	12%	1 050	5 229	20%	9%
Luxemburg	6	70	9%	3%	3	33	9%	4%
Netherlands	154	993	16%	11%	77	546	14%	12%
New Zealand	35	455	8%	2%	33	284	12%	3%
Norway	33	275	12%	3%	17	168	10%	4%
Poland	232	5 534	4%	5%	379	4 189	9%	
Portugal	456	1 847	25%	13%	188	891	21%	
Slovenia	50	278	18%	1%	30	141	21%	3%
Spain	833	5 517	15%	13%	422	2 060	20%	
Sweden	48	554	9%	5%	57	319	18%	8%
Switzerland	116	544	21%	15%	73	320	23%	15%
United Kingdom	594	3598	17%	3%	369	1 960	19%	4%
United States	3 197	42 196	8%	2%	4 612	32 367	14%	3%

Source: IRTAD.

Table 3.1 and Figure 3.2 show the trends in the percentages of total fatalities that were PTW riders for the period 2001-2011. For all countries for which data are available, with the exception of Portugal, the Netherlands, Norway and Ireland, the percentages increased. This may reflect increases in PTW fatalities, decreases in other motor vehicle fatalities, or both.

Figure 3.2. **Share of PTW fatalities in total fatalities**

2001 and 2011



Source: IRTAD

There are several different ways of expressing the risk of travelling by a particular mode (e.g. car or motorcycle) and the relative level of risk of different modes depends on which way of expressing risk is chosen. While the number of people killed or injured is generally known to a reasonable level of certainty, the distance travelled value is commonly less precise. Very often, countries do not have good data on the occupancy of vehicles, and so can only use the distance travelled by that type of vehicle. Thus, they are unable to compare the risk of one person travelling a given distance by motorcycle versus the risk of one person travelling the same distance by car. Their data can show fatality (or injury risk) per vehicle-kilometre, but not per person-kilometre.

When related to the number of kilometres travelled, a motorcyclist is, depending on the country, between 9 to 30 times more likely to be killed in a traffic crash than a car driver (see Table 3.2). The relative risk for a PTW rider of being seriously injured is even higher (Martin et al., 2011). Given that a car commonly has more occupants than a motorcycle, the difference in risk per passenger-kilometre between PTW riders and car occupants is probably even greater.

Table 3.2. **Deaths per billion vehicle-kilometres in 2011**

Motorcyclists and car occupants

	Car Occupant	Motorcyclists	Mopeds (when distinction is made in statistics)	Relative risk of motorcyclists vs. car occupants
Australia	5.2	71.8		14
Austria (2010)	4.7	59.7	56.1	13 for motorcyclists 12 for mopeds
Belgium (2010)	5.9	76.9		13
Canada (2010)	4.9	62.9		13
Czech Republic (2010)	10.5	252.6		24
Denmark	4.2	49.5		12
France	4.9	72.4	64.7	15 for motorcyclists 13 for mopeds
Germany	3.3	59.5	14.6	18 for motorcyclists 4 for moped
Ireland	2.5	60.8		24
Israel (2010)	5.1	45.7	26.8	9 for motorcyclists 5 for mopeds
Netherlands (2004-08)	3.0	64	63	21
Slovenia	4.3	112.5		26
Sweden (2010)	2.2	43.9		20
Switzerland	2.3	39.2	29.6	17 for motorcyclists 12 for mopeds
United Kingdom (Great Britain) (2012)	2.1	72		34
United States	5.0	155.0		31

Source: IRTAD.

Characteristics of PTW fatal crashes

Recent trends in fatal crashes

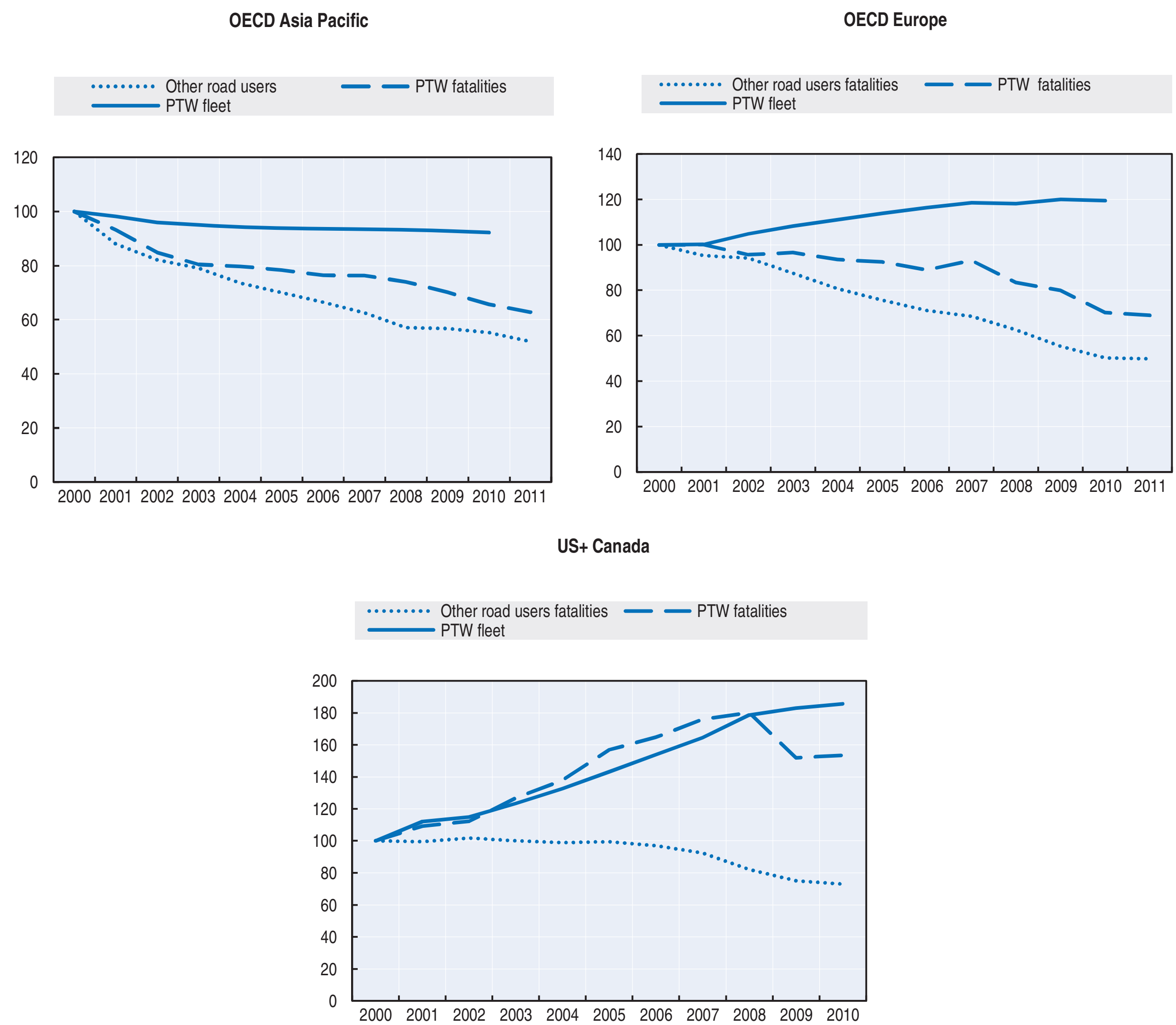
The following sections are based on fatality data; which are the most reliable information for the purpose of comparisons. Descriptive information on PTW injuries is also provided.

Figure 3.3 compares the recent trends in the number of motorcyclists killed and other road users killed in the three main regions of the OECD. A sharp increase in the number of motorcyclists killed is observed in North America and a moderate decrease in the other regions. While on average, OECD countries have seen a reduction of about 36% in the number of persons killed in traffic crashes in 2000-2010, the number of motorcyclists killed decreased only by 13% in total. The discrepancy is particularly obvious in North America.

In the United States, the number of motorcyclists killed increased by 83% between 2000 and 2008, while the number of passenger car occupants decreased by 29% (NHTSA, 2009). The relative deterioration of motorcyclist’s safety in North America has to be seen in the context of a significant increase in the PTW fleet during the same period, which has almost doubled (Paulozzi, 2005) and the repeal of the helmet laws in some states. In 2009, motorcycle fatalities dropped sharply (16% decrease), but only for that one year. Fatalities resumed the increase from that point on; however, the rate of increase is smaller. From 2009 to 2011, motorcycle fatalities increased by 3%.

Figure 3.3. **Trends in PTW fatalities, other road user fatalities and PTW fleet in the three main OECD regions**

2000-2011, Index 100 = 2000



Note: OECD Asia Pacific includes: Australia, Japan, Korea and New Zealand

Source: IRTAD

Trends in PTW crashes compared to other modes

In order to better understand PTW road crashes, it is necessary to analyse crash data for motorcycles and mopeds separately in the context of their exposure. As seen in Chapter 2, mopeds are becoming less popular in many countries, while the number of motorcycles and scooters (125cm3 and more) is increasing very quickly. We will see in Chapter 9 that the situation is however quite different in low- or middle-income countries.

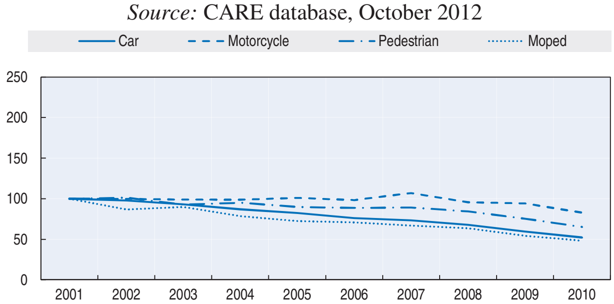
Motorcycle and moped fatalities, together referred to as powered two-wheelers (PTWs), accounted for 16.5% of the total number of road crash fatalities in 2010 in the 29 OECD countries for which data are available, but only 8 % of the fleet.

Figure 3.4 shows the increasing trend for motorcycle user fatalities compared to trends for other modes of transport, such as mopeds, passenger cars and pedestrians, in 14 European countries,[2] in the United States, in Australia, in Canada, in Japan and in New Zealand. The increase is sharper in Europe, the United States, Australia and Canada, and less pronounced – yet still visible – in Japan and New Zealand.

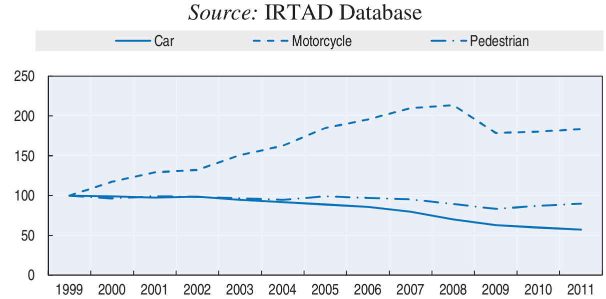
In the United States, there were increasing trends in motorcyclist fatalities and injuries from 2000 to 2009. The vast majority of PTW fatalities (97.2%) involved motorcycles above 50 cc. Moped fatalities, and to some extent estimated injuries, increased disproportionately in 2008 and 2009, perhaps due to increased moped activity in response to increased fuel prices and severe economic conditions during this period (NHTSA, 2012).

Figure 3.4. **Index of motorcycle and moped fatalities compared with pedestrians and car passengers**

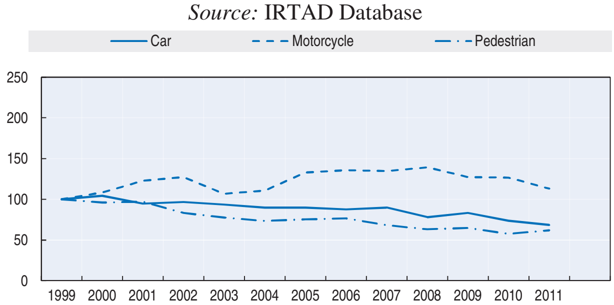
Europe (EU-20), 2001-2010 (Index 2001=100)
Source: CARE database, October 2012



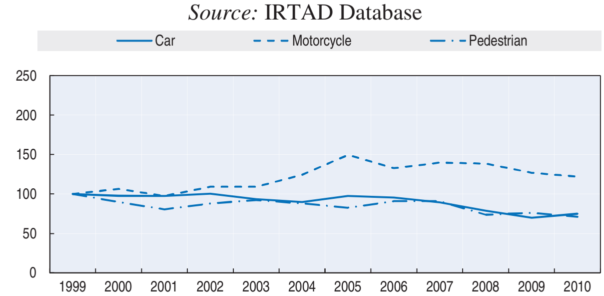
United States, 1999-2011 (Index 1999=100)
Source: IRTAD Database



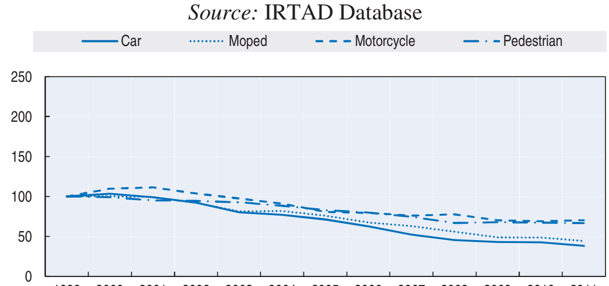
Australia, 1999-2011 (Index 1999=100)
Source: IRTAD Database



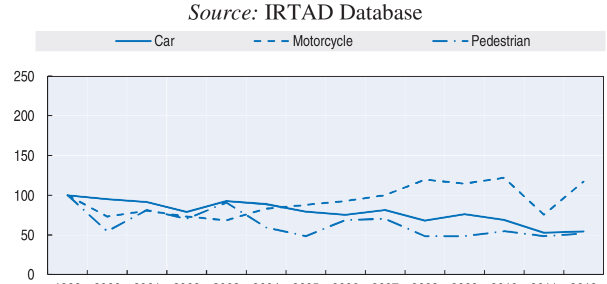
Canada, 1999-2011 (Index 1999=100)
Source: IRTAD Database



Japan, 1999-2011 (Index 1999=100)
Source: IRTAD Database



New Zealand, 1999-2012 (Index 1999=100)
Source: IRTAD Database



PTW-Rider crash characteristics by gender

In most countries, the proportions of males and females among the riders killed follow the proportions of males and females in the motorcyclist population. As PTWs become more popular among females, one can also observe an increasing trend in the percentage of females killed and injured in PTW crashes.

Results of epidemiologic studies do not reach consistent conclusions. Some studies have reported a higher crash risk for men than for women (Lardelli-Claret et al., 2005; Lin et al., 2003b) while one study found the opposite (Chang et al., 2007). Two studies, where the design adjusted for distance travelled, did not observe any valid statistical relationship between gender and crash risk (Harrison et al., 2005; Mullin et al., 2000).

Given the heterogeneity of the male and female populations among the riders, it is difficult to draw firm conclusions on their respective level of risk. As a matter of fact, several factors may explain risk variation between men and women: type of travel, risk taking, natural fragility, choice of vehicle, travel purposes, etc.

Effect of rider age on crash characteristics

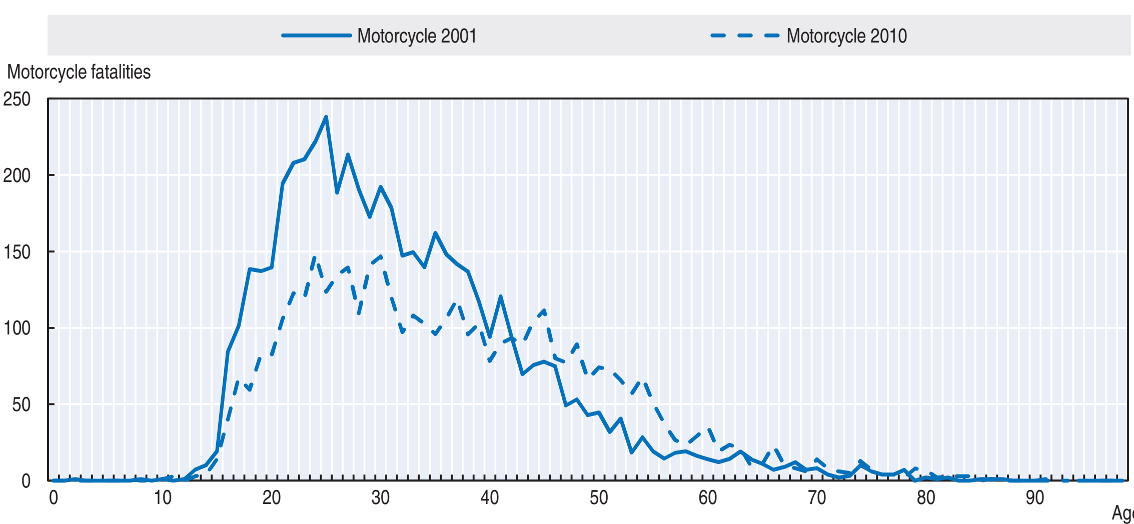
In most countries, the number of fatalities among the 40-60 year old riders increased significantly during the last decade. There has been a shift in fatalities from the youngest age groups to middle-aged riders. This is linked to the increasing popularity of PTWs among this age group.

In Europe, 30% of motorcyclists killed are less than 25 years old. However, the average age of motorcyclists killed has increased, from 30 years in 1995 to 38 in 2007. The number of rider fatalities decreased between 2001 and 2010 only for those under the age of 40 (Figure 3.5). During the decade, the number of fatalities among the 40-60 year old riders doubled.

The same patterns are observed in the United States, Canada and Australia. Data from the United States (NHTSA, 2012) shows a 78% increase in fatality of motorcyclists (including 3-wheelers) in the 40+ age group over a ten-year period.

Figure 3.5. **Motorcycles rider fatalities by age in 2001 and 2010**

Both EU-20



Date of query: October 2012

Source: CARE Database / EC

Most epidemiological studies show a higher crash risk for the youngest age groups (Chang et al. 2006; Evans 2004; Harrison et al., 2005; Lardelli-Claret et al., 2005; Lin et al., 2003; Mullin et al., 2000; Reeder, 1995 and Yannis et al., 2005).

Monthly, weekday, and hourly periodic characteristics

PTW rider crashes, injuries and fatalities are strongly correlated with periodic factors such as seasons, months, day of week, and time of day. These periodicities reflect both environmental and socio-cultural factors.

PTW crashes reflect the motorcycling activity associated with season and weather. In most countries, there are relatively few fatalities in the winter, and relatively many in the summer, reflecting the seasonal pattern of use of mopeds and motorcycles. The impact of season is however less marked for mopeds.

As with other crashes, the number of PTW crashes increases during the weekend. While there are many crashes every day of the week, these numbers increase on weekends. However, in an Australian study, Blackman and Haworth (2013) found that this trend occurred for motorcycle crashes, but not moped and scooter crashes, presumably reflecting the greater use of mopeds and scooters for commuting.

Road type

In most OECD countries, the majority of PTW fatalities occur outside urban areas, and particularly on the non-motorway rural roads. The existence of medians, separating opposite traffic flows, the quality of the road surface and the absence of sharp bends explain the lower fatality rate on motorways. However, in several Southern European countries (Greece, Italy, Portugal, Slovenia and Romania), more than 50% of PTW fatalities occur inside urban areas, most probably due to increased PTW mobility inside urban areas compared to the other countries.

Almost one third of all PTW rider fatalities occur at a junction, whereas for car occupant fatalities, only 14% occur at junctions. Nearly 50% of the total number of PTW rider fatalities recorded at a junction occurred at crossroads.

Impact of engine displacement and type of vehicle

Engine displacement, expressed in cubic centimetres (cm^3), is an indicator of the power of a vehicle.[3] Several epidemiological studies focused on the relation between engine displacement and crash occurrence and severity. Some studies suggest that users of PTW with higher displacement have a higher risk of crash (Nairn et al., 1993) and a higher risk of being seriously injured (Pang et al., 2000; Quddus et al., 2002). Other studies have not found any association (Chang et al., 2006; Langley et al., 2000; Zambon et al., 2006).

According to the MAIDS project (which analysed both fatal and non-fatal crashes), there was no significant difference between the crash data and the exposure data except for the over 1001 cm^3 category, which was found to be under-represented (i.e. had less risk) (see Table 3.3) (ACEM, 2006).

Table 3.3. **Distribution of crashes in the MAIDS project by engine displacement**

Engine displacement (cm^3)	Crash data		Exposure data	
	Frequency	Percent	Frequency	Percent
Up to 50	394	42.7	367	39.8
51 to 125	89	9.7	86	9.3
126 to 250	37	4.0	32	3.5
251 to 500	56	6.1	50	5.4
501 to 750	206	22.4	193	20.9
751 to 1000	80	8.7	107	11.6
1001 or more	58	6.3	88	9.5
Unknown	1	0.1	0	0.0
Total	**921**	**100.0**	**923**	**100.0**

Source: MAIDS (ACEM, 2006).

A recent study in Greece showed the highest severity is observed for motorcyclists aged less than 21 years riding mopeds (Yannis et al., 2005). This result may be attributed to more risk-taking behaviour and inexperience of young drivers, together with the poor driving performance of mopeds in demanding conditions.

In the United States, a study (Teoh, 2010) found large variations in driver death rates (per 10 000 registered vehicles) when examined by motorcycle type, and the biggest risk was found for the super sport category (see Table 3.4). However, its results cannot be generalised, as the study was undertaken in the United States, where the motorcycle fleet composition may not be representative of those of other countries, and neither the distance travelled nor the age or experience of the rider were taken into account.

Table 3.4. **Motorcycle driver deaths per 10 000 registered vehicles by motorcycle type**

2000-2008, United States

Motorcycle type	Drivers Deaths (2000 -2008)	Relative risk compared to cruiser/ standard motorcycle
Cruiser / Standard	5.1	1.0
Touring	6.0	1.17
Sport Touring	4.3	0.85
Sport / unclad sport	11.6	2.28
Supersport	22.3	4.36

Source: Teoh (2010).

Studies of the influence of engine displacement on safety should take into account that riders of high displacement PTWs ride further every year than those riding small PTWs (Broughton, 1988; Carre et al., 1994; ONISR 2005; Yannis et al., 2007). One study estimated that riders of PTWs with an engine capacity of greater than 500 cm^3 on average travel four times as far as those driving PTWs of 50 cm^3 (Broughton 1988). The choice to replace a low displacement PTW with a more powerful bike is often due to the desire to travel more (Broughton 1988; Yannis et al., 2007). Therefore, statistically, riders of the most powerful motorcycles may be over-represented but, in terms of km-ridden, their fatality rate may not be significantly higher.

To summarise, power may not constitute by itself a direct cause of crashes; but it can be associated with purchase motivation by different age groups of riders and their usage of their PTWs.

Serious injuries among motorcyclists

The challenge of serious injuries

As seen earlier in this chapter, most of the information above is based on fatal crash data, because they are easily available in most countries. However, understanding the nature and extent of serious injuries among motorcyclists is essential in the perspective of a Safe System approach. It is also very important from an economic and health perspective, given the high costs associated with the most severe injuries.

Compared to other road users, motorcyclists sustain much more severe injuries and the risk of sustaining a major handicap is higher than the risk of dying. As an example, in France in 2006, motorcyclists represented 24% of fatalities and 30% of injured road users with a long-term handicap (Amoros et al., 2008; ONISR 2007). In 2004, there were as many motorcyclists severely injured as car occupants. In 2012, in Great Britain, motorcyclists were 35 times more likely to be killed in a road crash than a car occupant and 50 times more likely to be seriously injured (Department for Transport, 2013).

Motorcyclists are more likely, not only to be killed, but also very seriously injured in a road crash than other motorised road users. As the large majority of motorcyclists is younger than other motorised road users, this translates into many years lost or with reduced capacities.

Characteristics of motorcyclist injuries

Motorcyclist injuries most commonly occur to the extremities – lower limbs in particular – and then head injuries. Spinal injuries are less frequent, but can have severe long-term consequences. Spine, head and limb injuries are the main causes of long-term handicap (Moskal et al., 2008).

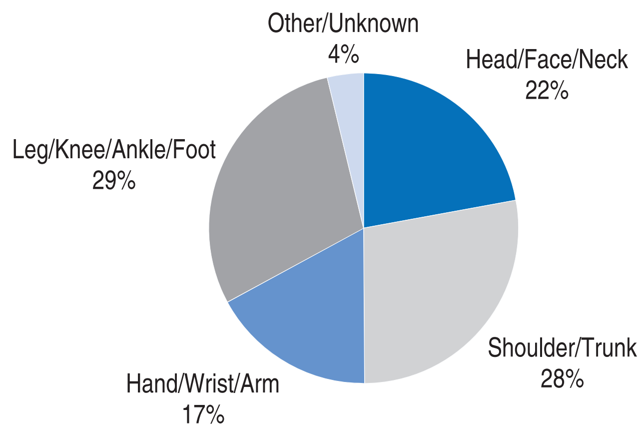
The percentage of severe head injuries remains high, despite the use of helmets. Head and trunk injuries are the main causes of death (Dischinger et al., 2006).

In France, in 1996-2004, 24% of head injuries, 44% of spine injuries and 38% of leg injuries leading to severe handicap were sustained by motorcyclists (Amoros et al., 2008).

Figure 3.6 presents the distribution of injuries among motorcyclists in the United States in 2009. It shows that half of all injuries were to the head/face/neck or shoulder/trunk regions, while almost three in ten were to the leg/knee/ankle/foot region.

Figure 3.6. **Distribution of injuries among injured motorcyclists**

United States, 2009

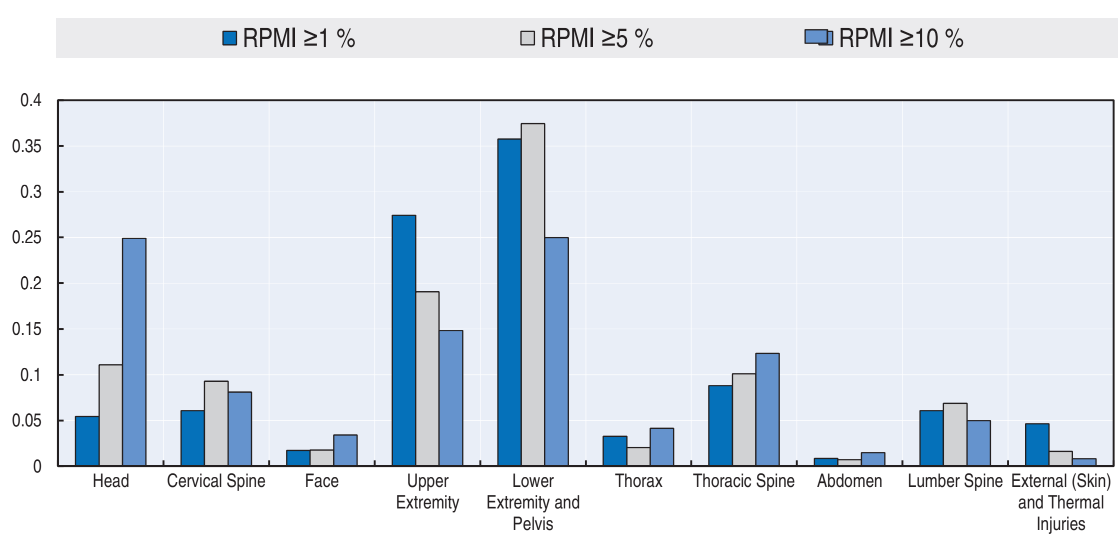


Source: NHTSA.

Figure 3.7 illustrates some Swedish findings and how the severity of motorcyclist injuries compares across parts of the body. For the broadest spectrum of injury, where the risk of permanent medical impairment is 1% or greater, lower extremity and pelvis, and upper extremity injuries predominate, together accounting for more than 60% of injuries. Head and lower extremity and pelvis each comprise a quarter of the most severe injuries, where the risk of permanent medical impairment is 10% or greater. Thoracic spine injuries are also more strongly represented among the most severe injuries.

The very severe injuries with long term impairment suffered by motorcyclists translate into very high social and medical costs. Reducing not only the number of deaths but also the number of serious injuries among motorcyclists is a top priority in the context of a Safe System.

Figure 3.7. **Motorcycle injury distribution and risk of permanent medical impairment**



* RPMI: Risk of Permanent Medical Impairment.

Source: Swedish Transport Administration.

Crash scenarios

Table 3.5 summarises the various types of crashes which are detailed in the sections below. The exact prevalence varies greatly among the different countries, depending in particular on the characteristics of their road network and traffic. Sometimes loss-of control crashes are classified in the police reports as multi-vehicle crashes, although the crash with the other vehicle is only the result of the loss of control. On the other hand, a single vehicle crash may originate from a problem of interaction with another road user.

Table 3.5. **Types of crashes involving PTWs**

Single vehicle crashes (20 to 45% of fatal crashes)	Loss of control Other
Multi vehicle crashes (30-50% of fatal crashes)	At junction Not At junction with vehicle in the same direction Not at junction with vehicle in the opposite direction Other
Crash with a pedestrian (less than 10 % of fatal crashes)	

Single vehicle crashes

Single-vehicle crashes are estimated to comprise between 20% and 45% of PTW crashes, depending on the jurisdiction. The Department for Transport reports 24% of motorcycle fatalities and 28% of casualties are attributable to single vehicle crashes in Great Britain (Department for Transport, 2013). In France (ONISR, 2010) in 2009, 36% of motorcycle fatalities and 34% of moped fatalities were due to single-vehicle crashes, these crashes comprising 19% of motorcycle injury crashes and 18% of moped injury crashes. Results from the 2BESAFE project suggest that single-vehicle crashes make up 25% of all PTW crashes in Italy, 38% in Greece and 44% in Finland and Sweden (2BESAFE, 2010). In 2011, 46% of motorcyclists killed in the United States were involved in single-vehicle crashes (NHTSA, 2013). Single-vehicle crashes are often underreported in official statistics, particularly those of relatively low severity. Thus, official statistics may underestimate the true number of single-vehicle PTW crashes and over-estimate their severity compared to multi-vehicle crashes.

Loss of control

A loss-of-control crash is considered as such – for research purposes – when only one vehicle is at the origin of the crash situation, independently of the number of vehicles finally hit. A difficulty with police reports in some countries is that they are based on the number of vehicles hit, while the concept of “loss of control” is sometimes absent from police reports.

Loss of control is due mainly to the following causes:

- poor road design in curves (lack of visibility, changes in the curve radius, etc.) and/or an excessive speed (exceeding speed limits or inappropriate speed);
- lack of riding technique and competence in analysing the situation of the rider;
- the influence of alcohol;
- poor control of the trajectory (e.g. over-braking);
- mechanical problems;
- bad road conditions.

Other "single vehicle" crashes

This second category of single-vehicle crashes does not, strictly speaking, refer to a loss of control initiating the problem but a sudden encounter with an unexpected obstacle (which is not a road user) on the carriageway. In practice, these situations only account for a small proportion of PTW crashes. The following configurations can be distinguished:

- PTW is confronted by an animal suddenly crossing the carriageway.
- PTW hits an obstacle on the carriageway (stone fallen down from a hill, or any object fallen from a truck, etc.).
- Other.

Multi-vehicle crashes (excl. pedestrians)

At junction

Crashes at junctions cover a large proportion of crashes involving a PTW and another vehicle (principally a passenger car). According to the MAIDS project (ACEM, 2006), 50% of PTW crashes occur at junctions; however, this proportion varies largely between countries or settings. The SafetyNet project (SafetyNet, 2009)) identified four typical scenarios:

- Turning left (or right)[4] by the other vehicle, with the PTW arriving in the opposite direction;
- Turning left or Turning right or U-turn by the other vehicle, with the PTW in the same direction;
- Other vehicle crossing the path of the PTW, which has the right of way;
- PTW crossing the path of the other vehicle which has the right of way.

Not at junction with vehicles in the same way and same direction

Typical crash scenarios include:

- Other vehicle changing lane or overtaking,
- PTW changing lane or overtaking,
- Rear-end collision (by a PTW / by the other vehicle).

Not at junction with vehicles on the same road at opposite direction

Typical crash scenarios:

- PTW is overtaking or has crossed the centreline onto the opposite carriageway;
- Other vehicle is overtaking or has crossed the centreline onto the opposite carriageway.

Other types of multi-vehicle crashes

Typical crash scenarios include:

- Aberrant manoeuvre by the PTW (wheelies, going the wrong way along a street, going the wrong way in a roundabout, sudden acceleration, etc.
- Aberrant manoeuvre by the other vehicle (U-turn, door opening, etc.).

Crashes with pedestrians

Crashes between PTWs and pedestrians represent a growing issue as part of overall pedestrian crashes (Martin et al., 2011), notably due to the increasing proportions of PTWs in cities (Kopp, 2011). Paulozzi (2005) showed that the risk of PTW drivers fatally injuring a pedestrian was twice that than for automobile drivers. A recent study (Clabaux et al., 2014) shows that two-wheeler drivers run a risk of hitting and injuring a pedestrian in towns that is nearly three times higher than for four-wheeled vehicle drivers, notably linked with filtering manoeuvres.

Conclusions

Crash characteristics and scenarios

On average, in OECD countries, PTWs riders and passengers comprise 17% of all road fatalities, while only representing 8% of the fleet. PTWs are clearly overrepresented in road traffic casualties. Depending on the country, they are between 9 and 30 times more at risk in traffic than a car occupant. This is largely due to their greater vulnerability and lack of protection in the event of collision. When involved in a crash, PTW riders are exposed to a significantly higher risk of severe injuries, entailing long-term disabilities.

The safety situation of motorcyclists has deteriorated in the past decade compared with the significant progress for other road users. PTW trends are not following the overall decrease in fatalities in the OECD countries; this may be explained by the large increase in PTW numbers and respective mobility, as PTWs have been steadily gaining in popularity in recent years. PTW is the only mode of transport for which the number of fatalities has increased over the last decade – significantly in some countries – which stresses the importance of taking immediate appropriate countermeasures.

Many countries face similar patterns. In Europe, the number of motorcyclists killed in the 40-60 year age group has doubled in 10 years. The fatality rates for moped riders aged 15-19 and motorcycle riders aged 20-30 are notably high. It appears that being young, male and lacking experience is associated with increased PTW fatality risk.

A significant proportion of crashes are single-vehicles crashes occurring on rural roads. Almost one third of all PTW fatalities occur at junctions – a proportion notably higher than for other road users. This stresses the importance of taking specific measures to improve junction safety for PTWs.

Most of the data presented in this chapter and in other research publications are based on fatality data because these data are easily available and usually reliable. It is, however, essential to gain more information on serious injuries, because they represent a major challenge in improving road safety and, perhaps more for motorcyclists, measures and equipment can help to reduce the severity of serious injuries.

Figures dealing with non-fatal crashes generally tend to be more or less underestimated, notably due to under-reporting to police and subsequent under-reporting in police crash databases. However, some countries now have experience in linking police and health database in order to have a more complete picture of the consequences of crashes.

Notes

1. In Sweden, the STRADA (Swedish Traffic Accident Data Acquisition) information system gathers crash information from the police (when, how and where the crash took place) which is linked with information from health care on the nature of the injuries.

2. These include: Belgium, Denmark, Greece, Spain, France, Ireland, Italy, Luxembourg, Netherlands, Austria, Portugal, Finland, Sweden and United Kingdom

3. Power-to-weight ratio more directly indicates acceleration and top speed performance capacity. Weight can vary markedly for the same power

4. Turning left in countries where one drives on the right; Turning right in countries where one drives on the left.

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Chapter 4. Factors contributing to powered two-wheeler crashes and their severity

This chapter discusses the most frequent factors contributing to powered two-wheeler (PTW) crashes. They are described following the traditional interaction between the three basic components of the traffic system: PTW riders and other road users, road environment and vehicle factors.

PTW rider-related crash factors

Some factors involve the riders themselves and notably relate to the various parameters characterising the states and conditions of the powered two-wheeler (PTW) riders: their motivations, physical states, experience and awareness, etc. Research literature has shown that factors such as speeding, impaired riding, non-respect of traffic rules and lack of experience, notably the experience of the vehicle driven, are the main human-related contributing factors in PTW crashes.

The increased flexibility and performance (engine power/vehicle mass) of motorcycles may influence their riders and facilitate inappropriate or dangerous manoeuvres, especially in regard to overtaking, negotiating bends, crossing intersections and filtering. These manoeuvres may be the most characteristic types of motorcyclist violations.

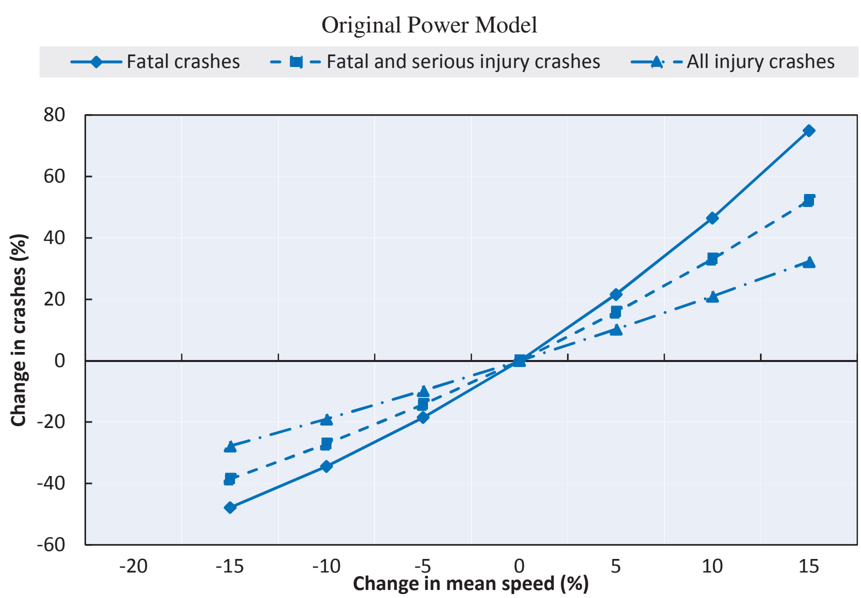
The likelihood that motorcyclists will respect traffic rules is strongly correlated with other characteristics such as age, experience, engine power and social influence. A recent study (Wu et al., 2012) shows that the probability of a rider running through a red light is higher for young and middle-aged riders, when the rider is alone, when there are fewer riders waiting, and when there are other riders already ignoring the red light.

Excessive and inappropriate speed

It is well known that excessive and inappropriate speed features in a large number of crashes. As shown by the Nilsson model (Nilsson, 1994), the risk of being killed in a crash varies exponentially with change in speed. While there is discussion on the exact value of the exponent when taking account in particular the initial speed (Elvik, 2013), the overall shape of the curve is not debated among researchers (see Figures 4.1 and 4.2).

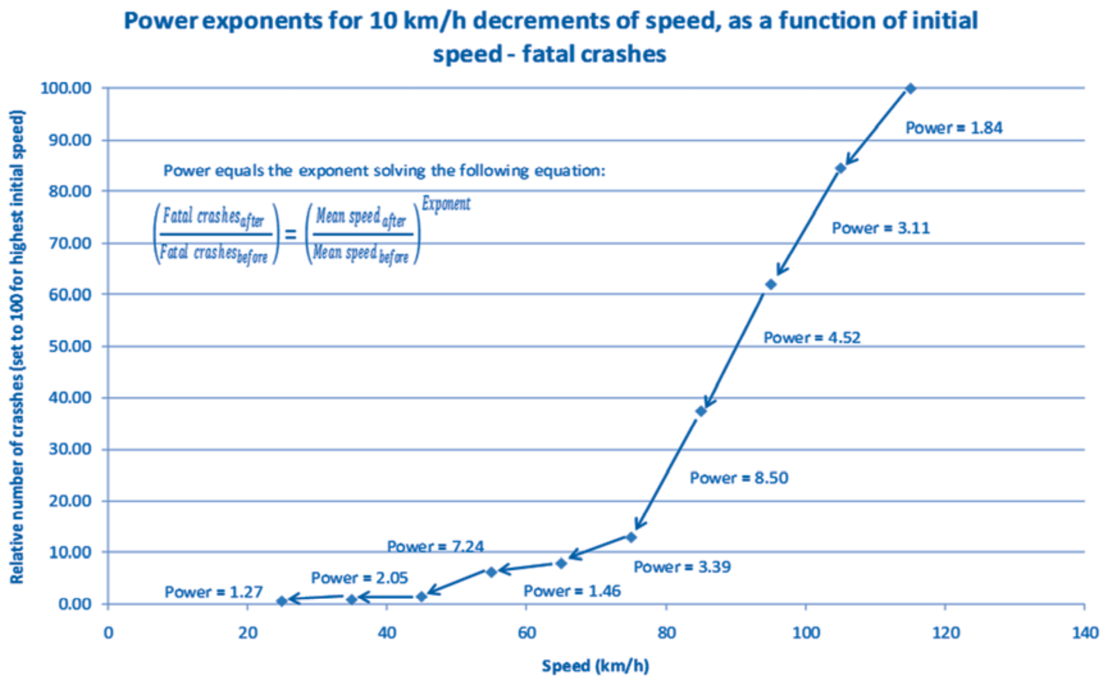
While there is no modelling specific to PTWs, as the average speed of PTWs is generally higher than for passenger cars, there is no doubt that the model at least applies.

Figure 4.1. **Power model representing the relationship between change in mean speed and changes in crashes**



Source: Nilsson.

Figure 4.2. **Reparameterisation of the Power**



Source: Elvik.

Speed is a complex factor which can influence the crash process at the different stages of its production:

- At the driving phase, an excessive speed can put the driver of a vehicle in a non-optimal driving condition by limiting the time available for information processing and/or by limiting the dynamic capacity for adequate regulation. Thus, by favouring the production of some errors and mistakes, speed can act as a crash-producing factor.
- At the emergency phase, an inappropriate speed can prevent the driver from efficiently regulating the vehicle direction and deceleration in such a way as to compensate for a delicate situation. Thus speed can also act as a factor that impedes vehicle control.
- At the collision phase, speed will systematically constitute an aggravating factor, drastically increasing the crash severity due to the kinetic energy dissipated during the crash.

Speeding mainly concerns riders of motorcycles and is less common among moped riders (Blackman, 2012; Langley et al., 2000). Excessive (i.e. over the speed limit) and inappropriate (e.g. not adapted to the circumstances, even if within the legal limits) speed is responsible for about 2/3 of single vehicle fatal crashes (Lardelli-Claret et al., 2005; Shankar et al., 1992). The speed risk is more important for young riders (Lardelli-Claret et al., 2005; Mullin et al., 2000; Wells et al., 2004).

Riding a PTW with an excessive or inappropriate speed is a common type of unsafe riding behaviour. Because of their small size and their acceleration capacity, PTWs allow overtaking others and approaching bends at high speed and quickly inserting into traffic compared to four-wheel motorised vehicles.

Speeding is a bigger problem for PTW crashes, compared to other modes. On average, motorcyclists ride at higher speeds than cars and PTW crashes usually occur at higher speeds than car crashes (Horswill et al., 2005). Speed differences between motorcyclists and car drivers are higher on rural roads, as are speed violations (Guyot, 2008). Walton et al., 2012) report that motorcycles and scooters travel through T-junctions about 10% faster than other traffic and are 3.4 times more likely to be exceeding the speed limit than cars.

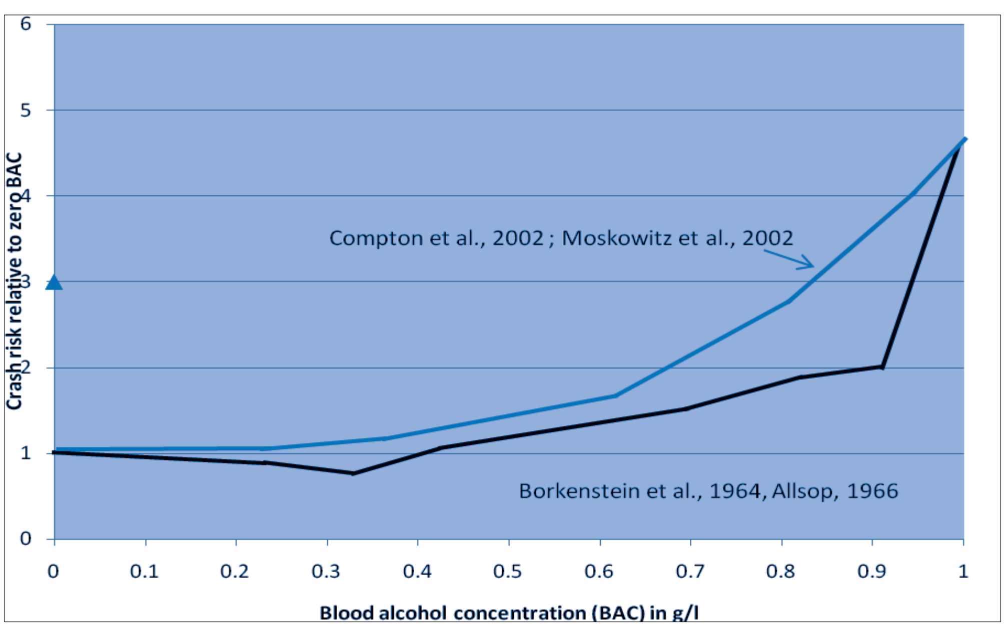
In 2004 in France, nearly half of the PTW casualties occurred while the riders were driving above the legal limit (ONISR 2006a). In the United States, in 2011, 35% of all motorcycle riders involved in a fatal crash were speeding, compared to 22% for passenger car drivers (NHTSA 2013). However, there are regions in the world where efforts have led to less speed differences between PTW and other motorised vehicles.

Impaired riding: alcohol, drugs and fatigue

Alcohol

The impact of alcohol consumption on driving performance is well demonstrated (Borkenstein et al., 1974; Compton et al., 2002; Moskowitz et al., 2002) as illustrated in Figure 4.3 for car drivers. Similarly, the consumption of alcohol is associated with increased risk of fatal crashes among PTWs (Evans 2004; Kasantikul et al., 2005; Luna et al., 1984; Shibata et al., 1994, Rag et al., 2012). Given the complexity of riding a powered two-wheeler, the risk for PTW riders is expected to be larger, although few studies have clearly examined this (Creaser et al., 2009). There is some evidence that ability to safely ride a motorcycle is impaired at lower alcohol concentrations than is the ability to safely drive a car. In an early Texas study, the BACs of motorcycle riders and car/truck drivers who were arrested for driving while under the influence were compared (Watson and Garriott, 1992). While both groups were clearly impaired, this was evident at lower BACs for the motorcycle riders than the car/truck drivers.

Figure 4.3. **Drivers' blood alcohol concentrations and the relative risk of police-reported crash involvement**



Source: Borkenstein et al. (1974), Compton et al. (2002), Moskowitz et al. (2002), Allsop (1966), in WHO (2004).

In addition, several international studies show that riders with a BAC above the limit have a higher probability of speeding and not wearing a helmet than a rider who has not been drinking (SARTRE4, 2012. Peek-Asa et al., 1996; Soderstrom et al., 1993).

Except for Sweden and Australia, data regarding the prevalence of alcohol in fatal crashes among different road users show a higher share of alcohol-related crashes among killed riders compared to car drivers (Table 4.1). In addition, alcohol-related crashes are usually more severe (i.e. lead to a fatality) for PTW, which implies that for the same BAC, the severity of the crashes is higher for the PTW than for the other road users (McLellan et al., 1993; Soderstrom et al., 1993; Soderstrom et al., 1995; Williams et al., 1985).

- In Sweden, on the other hand, the percentage of alcohol-related crashes is the same for PTW and car drivers, i.e. about 24%.
- In France, the percentage or riders having drunk alcohol is higher among moped than motorcyclist for both injury and fatal crashes (Guyot, 2008). In France, in 2012, 8.4% of moped riders and 5.2 % of motorcycle riders involved in an injury crashes had a BAC above the limit (6.6% for car drivers). For fatal crashes, these percentages are 36% for moped riders, 21% for motorcyclists and 21% for car drivers (ONISR 2013).
- In the United States, in 2011, a higher percentage of motorcycle riders had a BAC above the legal limit of 0.8 g/l than any other type of motor vehicle operator. The percentages of alcohol impaired drivers involved in a fatal crash were 29% for motorcycles, 24% for passenger cars, 21% for light trucks and 1% for heavy trucks. 30% of all fatally injured motorcycle riders had a BAC above the legal limit of 0.8 g/l and 42% of motorcycle riders who died in single vehicles crashes had a BAC above the limit (NHTSA, 2013) (see Table 4.1).

Table 4.1. **Share (%) of alcohol-related crashes for PTW and car drivers**

(i.e. BAC above the limit)

Country	Fatal crashes		Injury crashes	
	PTW	**Car drivers**	**PTW**	**Car drivers**
Sweden (2005-08)	24%	23%	n-a	n-a
United States (2011)	29%	24%		
France (2012)	21% for motorcycle 36% for mopeds	21%	5.2% for motorcycle 8.4% for mopeds	6.6%
Australia (1999-2003)	26%*	26%	n-a	n-a

Source: survey of the Working Group.

* Includes alcohol and other drugs.

Studies have shown that alcohol was present in 29 to 75% of PTW rider fatalities (Drummer *et al*. 2003; Holubowycz et al., 1994; Hurt et al., 1981; Larsen et al., 1987; Preusser et al., 1995) and between 13% and 60% of PTW riders injured (Holubowycz et al., 1994; Kasantikul et al., 2005; Luna et al., 1984; McLellan et al., 1993; Sun et al., 1998). On average, PTW riders involved in fatal crashes have a higher BAC than those involved in injury crashes (Holubowycz et al., 1994).

Similarly for car drivers, PTW alcohol-related crashes may involve more often young men (Holubowycz et al., 1994; McLellan et al., 1993; Williams 1979). Studies also show an overrepresentation of alcohol related crashes at night time (Kasantikul et al., 2005; Peek-Asa et al., 1996;

Williams et al., 1985), during the week-end (Holubowycz et al., 1994; Kasantikul et al., 2005), and at high speed (Colburn et al., 1993; Peek-Asa et al., 1996; Soderstrom et al., 1993).

Drugs

As for alcohol, the effect of drugs can be amplified for PTWs as riding a PTW requires more balance, co-ordination and accuracy than driving a car (Van Elslande et al., 2003). The consumption of drugs, in addition to the consumption of alcohol, mainly by young people, during the weekend nights should not be ignored (Assailly et al., 2002).

Very few studies focus on the relationship between drug consumption and crash risk for PTWs; most focus on the prevalence of different types of drugs among injured riders (Drummer et al., 2003; Longo 2000; Soderstrom et al., 1993; Soderstrom et al., 1995; Mclellan et al., 1993; Sun et al., 1998; Williams et al., 1985). In these studies, the proportion of vehicle controllers consuming drugs is higher among PTW riders compared to car drivers (Drummer et al., 2003; Longo et al., 2000; Soderstrom et al., 1995; Sun et al., 1998; Williams et al., 1985) and the proportion of drivers or riders positive both to alcohol and drugs cannot be neglected (Drummer et al., 2003; Williams et al., 1985).

Results from the French case study[1] in the European DRUID project, suggest that among drivers involved in fatal crashes, drivers of motorised two-wheel vehicles, especially moped drivers, have a higher prevalence of alcohol and cannabis than other road users.

Table 4.2. **Prevalence of drug consumption among different road users**

Road user type	n	Alcohol	Cannabis	Amphet.	Cocaine	Opiates
Bicyclist	131	22.1%	3.8%	0.0%	0.0%	0.0%
Moped driver	217	55.8%	14.3%	1.4%	1.4%	0.9%
Motorcycle driver	1 018	32.9%	9.0%	0.4%	0.4%	0.9%
Car driver	7 455	28.5%	7.5%	0.8%	0.5%	1.0%
Van driver	340	13.2%	5.0%	0.9%	0.3%	0.3%
Truck driver	1 092	3.8%	1.9%	0.2%	0.5%	0.3%
Other	266	9.8%	0.4%	0.0%	0.0%	0.4%

Positivity (blood dosage):
Alcohol ≥ 0.1 g/l, THC ≥ 1 mg/ml, Amphet ≥ 20 mg/ml, Cocaine ≥ 10 mg/ml, Opiates ≥ 10 mg/ml.

Source: DRUID, French Case study.

A US study (NHTSA, 2007) based on roadside surveys of alcohol and drug use by drivers showed that compared to other road users, motorcyclists had the greatest percentage of drug positive results, mainly at night-time. In addition, the study showed that drug prevalence was higher for riders who were not using a helmet.

Age and experience

Age

The relationship between age and risk is complex. While younger riders may exhibit riskier behaviours leading to an increased crash risk, older riders may have a higher risk of severe injuries in a crash due to their greater physical fragility.

Young people, in general, have a higher crash risk. As for the other modes, the higher risk of young motorcyclists can be explained by the combination of a lack of experience and a propensity to adopt risky behaviours (speeding; consumption of alcohol or drugs; riding for fun, etc.) (Chesham et al., 1993; Ryan et al., 1998).

Several studies show that crash risk decreases with age, which is mainly explained by a decrease in the distance ridden every year (Chang et al., 2006; Harrison et al., 2005; Lin et al., 2003; Mullin et al., 2000). On the other hand, studies also show an increased risk for riders over 60 years of age (Lardelli-Claret et al., 2005). This can be explained by a decrease in their ability and riding performance and difficulty in managing complex riding situations (Ryan et al., 1998).

The population aged 40-60 is increasingly represented in motorcycle crashes, mainly due to a significant increase in the number of PTW riders of this age group (SafetyNet, 2010).

Lack of experience

Studies show the importance of experience in traffic – not only as a PTW rider, but also as a car driver. Experience with riding a PTW also decreases the crash risk: the more distance travelled on a motorcycle, the lower the risk per kilometre (Mullin et al., 2000). The experience of driving a car contributes to a decrease in crash risk as a PTW rider among young people: those with more practice as a car driver have a lower crash risk when riding a motorcycle (Reeder et al., 1995), reflecting a positive transfer of experience.

A recent study (Bellet et al., 2012) investigates four populations of motorcyclists in terms of experience: professional riders (e.g. policemen), experienced riders, young and novice riders. The results show that cognitive abilities in both hazard detection and situational criticality assessment depend on riding experience: professional and experienced riders obtained better results than novice and young riders for hazard perception (i.e. shortest reaction time), and the latter also underestimate the situational risk and seem overconfident in their abilities to manage the situational risk.

More than for passenger cars, the experience of the vehicle ridden itself seems to be important. In the motorcycle fleet, there is a higher diversity of vehicle types, which may require a period of adaptation to a new vehicle. As an indicator of this, the number of kilometres driven with the same vehicle (familiarity with the PTW) has been proved to be strongly associated with a decrease in fatal or severe crashes, even more so than with other aspects of rider experience (Mullin et al., 2000). For example, people who borrow a motorcycle have a higher crash risk than people who own their motorcycles (Haworth et al., 1994; Mullin et al., 2000; Reeder et al., 1995).

Finally, increased crash risk is often found among those not holding a valid licence (Haworth et al., 1994; Hurt et al., 1981; Lardelli-Claret et al., 2005; Lin et al., 2003; Magazzu et al., 2006; Reeder et al., 1999; Rutter et al., 1996; Wells et al., 2004).

Perception and awareness

As seen in Chapter 3, the three most common crash scenarios for motorised two-wheeled vehicles (motorcycles and mopeds) are as follows:

- The motorcyclist/moped rider has a single vehicle crash while riding along a road and losing control (e.g. at a curve).

- The motorcyclist/moped rider approaches a junction and hits, or is hit by, a car driver who fails to see the two-wheeler in time.
- A car driver turns left (or right in countries where driving is on the left) and fails to yield the right-of-way to a motorcyclist/moped rider coming in the opposite direction.

Except for single vehicle crashes, these scenarios show that an important element of crashes involving motorcyclists is car drivers failing to give right-of-way to motorcyclists. According to a large body of research, this is mainly because the car driver fails to see the motorcyclist. For example, the MAIDS project (ACEM, 2009) examined over 900 crashes in five countries (France, Germany, Italy, Spain and the Netherlands) involving a motorised two-wheeled vehicle (motorcycle/moped). The study concluded that in over 36% of the cases, the driver of the other vehicle did not see the two-wheeler; while in 12% of the cases, the rider of the two-wheeler failed to see the other vehicle.

Perception issues vis-à-vis PTW

In situations where a car driver fails to give way to a PTW rider, the car driver often admits having looked in the direction of the motorcyclist prior to manoeuvring, but not having seen the rider who was theoretically visible (Wulf et al., 1989). These crashes are called “looked-but-failed-to-see” crashes (Clarke et al., 2007; Koustanaï et al., 2008) or “motorcycle conspicuity-related crashes“ (Radin-Umar et al., 1996; Wulf et al., 1989); and are often characterised by a high level of severity (Pai, 2009).

“Fail to look” and “look but fail to see” are the two main categories of perceptual errors that contribute to crashes (Staughton and Storie, 1977). The first one can be explained by inadequate visual screening: failing to look at the correct location at the correct moment (e.g. the blind spot). The second is due more to the weakness of our perceptual system, which under certain conditions (time constraints, too many sources of information) can fail to see what is however in our visual field. This is one of the reasons explaining why car drivers have difficulties in detecting PTWs.

Perception and awareness of PTWs by other road users have been recognised as part of the critical points characterising the problems of interaction of these vehicles within the traffic system. It notably deals with the intrinsic difficulty of a motorcyclist to be seen by other road users – concept referred in the literature as its low *detectability* or *conspicuity* (e.g.(Hurt et al., 1981; Preusser et al., 1995; Yuan, 2000).

Weaknesses of the human visual perceptual system

The traffic environment is very demanding on human perceptual capacities, due to high speed and complex situations sometimes pushing these capacities to their limits. This can lead to failing to perceive unexpected, unusual pieces of information, as is sometimes the case with PTWs because they present a different shape, a different behaviour, and they are more difficult to detect due to their smaller frontal size.

Detection is not the only challenge for the perceptual system: detection alone does not ensure the correct processing of visual information. It is common for PTWs to be detected on the road, but their distance and approach speed are not assessed properly by the observer (Pai, 2011). Poor PTW perception can have an impact on each stage of the information-processing chain, from detection to decision making.

The complex causes of perceptual problems

Numerous parameters may contribute to detection and evaluation challenges for car drivers in the presence of a PTW. These parameters can relate to the human visual system's capabilities, characteristics of the environment, and characteristics of the PTW as a perceptual object.

- Small size of PTW: The smaller frontal dimensions of PTWs on the road are the most commonly mentioned explanatory element of the specific difficulty to perceive them (e.g. (Hurt et al., 1981; Wulf et al., 1989). Physical characteristics of PTWs often push the capacity of the human sensory system to its limits, explaining the difficulty to detect it and evaluate its approach.
- Obstructed visibility: By its size, a PTW is more easily hidden by an object or vegetation than a larger vehicle.
- PTW rider behaviour: PTW riders' behaviour can also indirectly contribute to the fact that they are not easily perceivable. PTWs can surprise other road users by deviating from behavioural standards with their manoeuvres, for example by their positioning (e.g. riding in the blind spots of cars), speeds and acceleration capacity and confound the perceptual strategies of car drivers (Ragot et al., 2012; van Elslande, 2009).
- The low familiarity of PTW for most car drivers due to their relative rarity in traffic poses cognitive challenges for car drivers: The low level of expectation that automobile drivers have concerning motorcyclists is the main reason why they do not perceive them (Rogé et al., 2012; Gershon et al., 2012).

The road environment

Road environment factors can have an important influence on the crash severity, even if they are rarely the primary cause of crashes. For example, according to the MAIDS study, the road and its environment were a primary cause in 8% of all PTW crashes. Nevertheless, powered two-wheeler riders are more sensitive to road design and maintenance than car drivers. An environmental perturbation can be easily managed by car driver but be a challenge for a PTW rider.

Road design, condition and maintenance

The design of roadway elements influences how a road user interacts with the roadway. These elements include bends, junctions, the road surface and the roadside.

Curves

The radius of a horizontal curve has a strong impact on the ability to control the trajectory of the vehicle and is a factor for higher crash risk. About 30% of all PTW crashes occur in or after a curve, compared to 21% of crashes of other vehicles. Curves with small radii are more difficult to handle and poor road conditions in a curve significantly increase the crash risk for motorcyclists (ACEM, 2006).

Junctions

About one third of fatal PTW crashes occur at a junction (intersection or roundabout), compared to only 14% for cars. The severity of a PTW crash at an intersection is higher than for other road users (CERTU 2010). Road signs or other objects installed near intersections can significantly reduce visibility and make it more difficult to detect road users coming from other directions.

A series of Belgian studies (Daniels et al., 2010; De Brabander and Vereeck, 2007) supported the common finding that roundabouts reduce injury crashes overall, but identified that roundabouts are not as beneficial for vulnerable road users (pedestrians, cyclists and PTW users). Daniels et al. (2010) demonstrated that mopeds, bicycles and motorcycles were involved in more single-vehicle crashes than was expected given the mode share of each vehicle. There were fewer moped crashes at more recently constructed roundabouts (roundabouts that are more likely to be "turbo roundabouts"), and crashes involving mopeds were more likely to occur on three-legged roundabouts. While the overall safety benefits of roundabouts result from their geometry forcing conflicting traffic to slow down, the greater manoeuvrability of PTWs may mean that PTWs do not slow down and so are more liable to single-vehicle crashes. Improving sufficient skid resistance on roundabouts is therefore crucial for PTWs. Roundabouts that are not sufficiently visible (particularly at night) can present obstacles themselves.

Road surface quality

PTWs are more sensitive to roadway surface conditions than other motorised vehicles. Several factors can cause unsafe conditions for motorcyclists by reducing the amount of friction (skid resistance) or creating an uneven travel surface, including: surface rutting, corrugation, potholes, pavement swelling, etc. (IBSR, 2005; MOW, 2008). Longitudinal joints between lanes present a small zone with different skid resistance or a small irregularity in the road surface. Steel expansion joints, sometimes used on bridges, can destabilise a PTW (SETRA, 2002; CROW, 2003).

Elements of the road surface (gully tops, drainage grates, manhole covers, tram rails, etc.) can also be a risk factor for PTWs (IHIE, 2010; MOW, 2008; ERF, 2009; CROW, 2003), because of their different surface characteristics (skid resistance) than the surrounding pavement. Additionally, these elements can induce irregularities in the road surface level (see Figure 4.4).The difference in skid resistance between a road marking and the surrounding road surface can be problematic leading to loss of stability (ACEM, 2006; ERF, 2009; IHIE, 2010). When poorly designed or executed, there is a risk of water pooling on the surface of the road marking. Wear caused by traffic deteriorates the characteristics of the road markings rapidly. Renewal of a marking without removal of the old layer can negatively lead to an "elevated" layer and may cause loss of stability. (ACEM, 2006; CROW, 2003).

Traffic calming devices used to reduce vehicle speeds can induce a loss of grip to the road surface and destabilise the PTW (ACEM, 2006; ERF, 2009; MOW, 2008). In some countries, kerbs and delineation posts are sometimes used to separate lanes or to delineate the side of the road. However, when crossed by a PTW, even at moderate speed, there is a high risk for loss of stability (IBSR, 2005).

Debris, pollution and fallen loads on the road surface

Debris, pollution and fallen loads on the road can create unsafe conditions for motorcyclists. Overhanging trees and other vegetation can create unsafe conditions on the road surface: falling leaves (from overhanging trees and other vegetation), gravel, earth, mud and liquids can cause local slippery spots or hide local road surface defects (IBSR, 2005). Gravel, earth, mud and liquids influence the skid resistance of the surface. Discharged fuel can be slippery, difficult to detect by the motorcyclist, and difficult to remove (IBSR, 2005). This is more dangerous in curves and on roundabouts where a sufficient grip is particularly important for PTWs.

Aquaplaning/Hydroplaning

Water on the road surface can have different origins (e.g. insufficient or blocked drainage, extreme weather, road surface evenness problems, etc.) and reduces the skid resistance, which is even more of a problem for PTWs than other road users.

Roadside

Obstacles (vegetation, construction, road equipment, etc.) in the inner curve or at intersections can compromise visibility by either obscuring or limiting sight distance. Road users travelling from different directions will have more difficulties detecting each other (MOW, 2008). Although they contribute only to a minor portion of PTW crashes, obstacles are responsible for a relatively high number of fatalities (IBSR, 2005). Obstacles considered as 'safe' or not aggressive for car users can be very aggressive for PTWs, resulting in fatalities or severe injuries (CROW, 2003).

Road restraint systems / barriers

Road restraint systems are beneficial for passenger cars, but can be very aggressive for PTW riders in the event of a collision with them. Crashes with road-restraint systems or barriers contribute to between 2% and 4% of all PTW fatalities. Impacts to non-protected posts – particularly the exposed sharp parts – of guard rails can be critical (CIDAUT, 2006 and 2-BE-SAFE, 2009).

Generally speaking, any unprotected post is a real danger for motorcyclists. According to the European Smart Road Restraint System (SMARTRSS), wire rope safety barriers are considered as among the most aggressive forms of road restraint systems for PTW riders (Universita degli Studi di Firenze, 2013). However, according to Rizzi et al. (2012) no significant differences are found between wire-rope and other types of discontinuous guard rails. Nevertheless they found that the position of the motorcyclist when impacting the guard rail is the most important influence on the overall outcome of the collision.

Road maintenance works

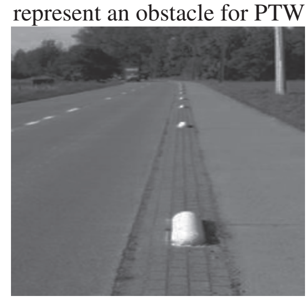
Local spot repairs or surface treatments (surface dressing) that are not properly executed create a risk so that these repaired sections are a (temporary) hazard for PTWs. Insufficient adherence, too much loose chippings or an insufficient amount of gravel or antiskid aggregates (e.g. for local repairs with cold asphalt) can locally reduce the skid resistance (CROW, 2003; IHIE, 2010). During resurfacing, the exposed scarified pavement that is left open to traffic before the new surface is laid can represent an additional hazard for motorcyclists (CROW, 2003).

Figure 4.4. **Infrastructure hazards related to road design and maintenance**

Natural stone paving elements and cast iron gully tops; slippery when wet

Intersection - road sign hides traffic coming from the left

Road delineation elements represent an obstacle for PTW

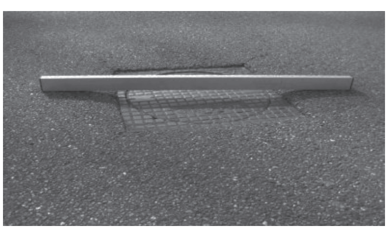


Different paving material in the inner border creates a zone with different skid resistance

Joints

Traffic calming – speed humps

Level difference between gully top and road surface



Road markings can reduce the skid resistance

Tram rails

Rutting

Collapsed side

Source: AWV, BRRC, http://www.motorcyclenews.com/.

Weather conditions

Weather is rarely a primary factor in PTW crashes. Studies in Europe, Australia and the United States based on in-depth crash investigations, suggest that adverse weather conditions are a contributory factor in less than 10% of PTW road crashes (Hurt et al., 1981; ACEM 2003; Johnston et al., 2008). These results are partly explained by the fact that weather conditions have an important impact on PTW mobility: as daily users are more likely to shift to other modes of transport, and occasional users (e.g. recreation users) may postpone their trip.

Adverse weather conditions for PTWs may also refer to high temperatures, which may equally affect riding comfort and safety; however, further research is needed to understand their impact on riding behaviour.

The vehicle

The contribution of technical defects to PTW crashes ranges according to studies from 5.1% (MAIDS, 2009) to 8% (European Commission, 2012). A study from Victoria, Australia found that vehicle defects were relatively common in crashed motorcycles and contributed to about 12% of motorcycle crashes, compared with 3% of car crashes (Rechnitzer, Haworth & Kowadlo, 2001. Tyre and brake defects are the most frequent problems. Tyre failure may create a risk of serious personal injury or death. To reduce the risk of tyre failure, it is strongly recommended to follow all safety information regarding tyre inflation, tyre loading, tyre damage, tyre size selection, etc.

While both crash involvement and the prevalence of defects increased with vehicle age for cars, this was not the case for motorcycles because motorcycle crashes often involved inexperienced riders with newer motorcycles (with fewer defects) than more experienced riders.

Some vehicle defects clearly contribute to the occurrence of crashes. However, challenges exist in identifying systems that can adequately identify and reduce the occurrence of such defects. Even when periodic inspection programs exist, a significant percentage of vehicles still have defects, rendering the vehicles 'unroadworthy'. Yet only some of these defects appear to contribute to crashes. This would suggest that only in certain circumstance are defects contributing factors in crashes. This conclusion is not at all surprising as crashes can result from a large number of factors and a chain of events, with vehicle defects being just one of these factors.

Vehicle characteristics (or their absence) can contribute to PTW crashes and their severity in several ways: they can make the vehicle more difficult to control, they can encourage or facilitate dangerous behaviours by the rider, they can be defective or malfunction and thus contribute to crash causation or they can fail to provide protection in a crash.

As mentioned in Chapter 3, the existing studies are inconclusive regarding the effect of engine displacement on motorcycle crash risk. Two literature reviews were conducted (Mayhew et al., 1989; van Honk et al., 1997) and highlight the lack of evidence linking engine displacement and the occurrence or gravity or a crash. An analysis combining the results of 13 studies found that the association between the vehicle displacement and the occurrence of a crash is lower when adjusted with age, gender and kilometres driven, than when the results do not adjust with these factors (Elvik et al., 2009).

The power of the PTW engine does not by itself explain a higher crash rate. There are a number of associated factors such as the type of vehicles (sport, tourism, trail), exposure conditions (day or night driving, length of the trip), age of the riders which influence riding behaviours. For example, Bjornskau et al. (2012) reported that sport bikes (i.e. racing replica bikes) showed significantly increased crash risk in Norway. As seen in Chapter 3, in the United States, a study (Teoh, 2010) showed an increased crash risk for certain types of motorcycles. It also shows that this increase in risk is often associated with risky behaviours such as speeding and drink driving (see Table 4.3). There is need for further research to establish the association between the PTW displacement and the occurrence or severity of a crash.

Table 4.3. **Relative prevalence of driver and crash characteristics**
United States, data for 2000 and 2003 to 2008

	Speeding	Driver error	BAC 0.08+ g/dL	Helmeted	No motorcycle license	Single-vehicle crash	9 p.m. to 6 a.m. crash
Touring vs. cruiser/standard	0.90*	0.95*	0.82*	0.96*	0.65*	1.08*	0.90*
Sport touring vs. cruiser/standard	1.45*	1.05	0.30*	1.67*	0.47*	0.94	0.49*
Sport/unclad sport vs. cruiser/standard	1.70*	1.22*	0.53*	1.49*	1.24*	0.95*	0.77*
Supersport vs. cruiser/standard	1.86*	1.28*	0.44*	1.56*	1.25*	0.98	0.80*
10 year increase in driver age	0.88*	0.95*	0.88*	1.07*	0.75*	1.01	0.80*
Female vs. male	0.67*	0.97	0.51*	1.20*	0.66*	1.00	0.57*
Calendar year (1 year increase)	1.00	0.98*	1.01	1.01*	1.02*	1.00	1.00

* Statistically different than 1.00 at the 0.05 level.

Source: Teoh (2010).

Association of risk factors

Risk factors are often correlated and sometimes interdependent. Risky behaviour, such as riding a PTW at a high speed, under the influence of alcohol, without a helmet, without a valid licence, or without daytime running light, has been identified as a possible explanation of the higher risk for young men in addition to their lack of experience (Lin et al., 2003; McLellan et al., 1993; Rutter et al., 1996; Chesham et al., 1993).

Research has shown the following association of risks:

- Compared to a driver with a valid licence, those without a valid licence have a higher probability to not wear a helmet, to drive above the speed limit, to drive under the influence of alcohol and without daytime running lights (Peek-Asa et al., 1996; Reeder et al., 1996).
- Riders not wearing a helmet are more likely to ride above the speed limit (Shankar et al., 1992). Moreover, individuals who are impaired are more likely not to wear protective equipment (NHTSA, 2007).
- Riding under the influence of alcohol is associated with riding above the speed limit, not wearing a helmet and not having a valid licence (Hundley et al., 2004; Luna et al., 1984; Nelson et al., 1992; Peek-Asa et al., 1996; Soderstrom et al., 1993).

Conclusions

Most crashes are the result of a combination of factors intervening differently at different steps of the crash process (pre-crash, crash, post-crash). Some of these factors (e.g. alcohol, speed, etc.) act more directly and preventing them appears to be an obvious way to reduce road trauma. Driver and rider-related behaviour factors are often considered more prevalent in PTW crashes, compared to vehicle and road environment factors. However, while acting more indirectly, other factors and elements (i.e. lack of experience, road infrastructure, etc.) should not be forgotten as a potential complementary and efficient ways to promote traffic safety.

As found for other road users, speeding and consumption of alcohol and/or drugs are critical in the occurrence and severity of crashes. Operating a PTW requires more co-ordination and balance than operating a car, which explains why impaired riding is even more problematic for PTW riders.

A large number of crashes involve problems of perception or appraisal by the other vehicle operator. The over-representation of inappropriate perception in PTW crashes suggests a specific problem of detectability (conspicuity) of PTWs. The problem of perception is complex and cannot be reduced to the simple fact that PTWs are physically less visible than other vehicles. There are many causes behind the poor detectability of PTWs and these are often connected to each other and with the general parameters of the driving context. Indeed, this problem can be explained by the visual characteristics of PTWs, by the sensory capabilities of the human perceptual system, by the atypical behaviour of PTWs and by the expectations that road users develop.

Road environment factors have an important influence on crash severity (e.g. roadside obstacles and barriers, speed reduction installations) rather than on crash occurrence. A more frequent combination of road crash contributory factors is found in PTW crashes, compared to other road users crashes, which results in the multiplication of the relative risk. In addition, road design and maintenance can also be an essential means to promote the "right" behaviour in terms of speeds and manoeuvres undertaken, and in terms of understanding and expectancy of traffic situations. This is true for all road users, but it applies specifically to PTWs who are, by their nature, more sensitive than other road users to any roadway irregularities (road surface, weather conditions, etc.).

While it has been shown that vehicle technical failures are only minor contributors to PTW road crashes, vehicle improvements have potential to affect rider behaviour and improve rider safety (see Chapter 7).

Even if human behaviour and characteristics are often considered the most frequently represented contributing factors in crashes; this does not mean that a solution to improve safety conditions for PTWs must only focus on behaviours. A Safe System approach is required to change behaviour by acting on a range of levers, including the infrastructure, the vehicle and the system as a whole.

Note

1. The DRUID deliverables distinguished age, gender, time of day and substance type; but only the French case study distinguished different road users.

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Chapter 5. Countermeasures addressing road user behaviour

Road user behaviours are an essential lever to improve road safety. This chapter reviews education, training and licensing; enforcement and communication measures that can influence both riders' and other drivers' behaviours.

Introduction

Road safety research has indicated that human behaviour contributes to the majority of road crashes and powered two-wheeler (PTW) crashes in particular (see Chapter 4). This chapter presents some countermeasures addressing (rider and driver) behaviour, including training, education and licensing; enforcement and communication campaigns.

Licensing, training and education

Licensing systems

A licensing system is a national (or provincial/state) system consisting of different requirements such as age, medical status, theoretical knowledge and practical skills that must be fulfilled to obtain a driving licence. The requirements differ between various jurisdictions and also depending on the kind of vehicle to which the licence applies. The systems also consist of specific rules for withdrawal and renewing of licences. Systems also include having a register of all licences and licence holders in the jurisdiction.

In the European Union, the driving licence requirements are regulated by a Driving Licence directive (2006/126/EF) which sets minimum standards for the member states. In the EU there is an on-going push for harmonisation. Since January 2013, the licence categories are the same for all countries in the EU. In this way, a driving licence from one country can easily be recognised in another. Theoretical and practical tests will be progressively harmonised in all EU countries and planned EU legislation will also introduce minimum standards for the training of examiners.

In other regions, there has been less effort in harmonising the licensing systems. In the United States and Australia, for example, the licensing system is regulated by each individual state.

PTW power and engine size restrictions for novice riders have been a cornerstone of licensing systems in many countries for many years. In many countries, the licensing system based on power and engine size has been extended to also include criteria such as the age and experience of the riders, which is known as the "Graduated Licensing System".

In some countries, it is possible to ride a moped without a licence, or a light motorcycle with a car driving licence. A study conducted in Spain (Perez et al., 2009) assessed the crash risk for motorcyclists when the law changed in 2004 to allow car driving licence holders to ride a light motorcycle (< 125 cm^3) without a specific PTW licence. The results of this study suggested that the number of road traffic injuries increases as a result of greater exposure to motorcycles when no special licensing requirement for motorcycle drivers is in place.

Graduated driver licensing systems

Graduated driver licensing systems are designed to provide new drivers with driving experience and skills that can be developed gradually over time in low-risk environments. The driver passes through a number of stages: restricted, provisional or probationary, and full licence. By testing the driver`s knowledge and ability during the process, the restrictions are gradually removed and the process ends with the driver gaining a full licence. Graduated licensing systems (GDLS) for motorcyclists can be found in several OECD countries. Licence restrictions normally consist of different conditions that must be fulfilled if the rider wants to obtain the licence. The restrictions typically consists of age, engine size, passenger riding, night riding, limitations on the kind of roads the rider can use and Blood Alcohol Concentration (BAC) limits for novice and young riders below a certain age.

The research on GDLS for car drivers shows that countries that have implemented graduated driver licensing systems report significant drops in fatal crashes but there are only few evaluations of GDLS for motorcyclists. The system introduced in 1987 in New Zealand was evaluated in terms of the general effect on motorcycle traffic (Reeder et al., 1999). Injury crash data were obtained from the New Zealand Health Information Service's national public hospital inpatient data for the years 1978-1994. The introduction of the graduated licensing system was found to be closely followed by a significant reduction (22%) in motorcycle crash hospitalisations for the 15-19 year age group. An examination of vehicle registration and driver licensing data suggests that the reduction in injury crashes may be largely attributable to an overall reduction in exposure to motorcycle riding.

It is important to note that some countries, for example the United Kingdom, do not make the prior assumption that graduated licensing is beneficial. The aim in the United Kingdom is to reform the training and testing system so that all riders are equipped to ride on the road under all circumstances by the time they pass their test and gain a full licence. A major problem, according to the United Kingdom, is that graduated licence restrictions can be difficult to enforce, encourage people to ride outside the law, and place restrictions on all young riders that may only be needed to address the problems of a minority.

Implementation issues and recommendations

Graduated licensing is an approach which has now been adopted in several jurisdictions, and has proven to be effective for car drivers. There is less research on the effects of graduated licensing systems for motorcyclists than for car drivers. The experiences from and research done on graduated licensing systems for car drivers indicates, however, that it might be a type of licensing system that can be more successful for motorcyclists than licensing systems based upon power and engine size. Research on the latter type of system indicates that it is hard to find any scientific evidence for a relationship between engine size and crash risk, when controlled for personal differences.

Graduated licensing systems help in better managing the impulsive behaviour of younger people by only allowing progressive access to the more powerful motorcycles as they gain more experience and maturity.

The main objectives of licensing systems are to evaluate riders' competence, to ensure a minimum qualification to ride safely and to ensure that riders are capable of assuming their own responsibility. In this respect, the main recommendations are the following:

- National (provincial/state) authorities should consider that riding a PTW requires a certain level of personal maturity, as for all road users.
- Access to PTWs should be gradual, with a licensing system aiming at managing young and novice riders' risk as they are gaining more experience.
- The purpose of the licensing system should be that riders, irrespective of age, possess the skills, knowledge and correct attitude to ride as safely as possible without unduly restricting mobility.

Ultimately, implementation of training and licensing of PTW riders will need support from riders, the public and politicians. PTW riders in many countries represent a small proportion of the motoring public. A tendency by policy makers to introduce similar licensing requirements for PTWs and cars often leads to inadequate solutions (Haworth and Rowden, 2012). It is, however, worth noticing that a very restrictive and complicated motorcycle licensing system might result in delinquency by some riders while unnecessarily complicating the process.

Pre-licensing training and education

Pre-licensing training and education are important parts of a licensing system. The training and the education can be divided into three different types: Voluntary initial training, mandatory initial training, and a mixture of voluntary and mandatory elements in the curriculum.

Examples of pre-licensing and training from OECD countries

Canada

In Canada, rider training is still mostly voluntary with a few exceptions. The strategy is to enhance PTW rider awareness and education regarding the inherent risk of motorcycling. Novice on-street rider training has developed in Canada, where province-wide government insurance programmes are in place. On-street training for more experienced riders using their own personal motorcycles and insurance has developed in response to demand by riders and rider groups, or as approved by government for an unrestricted licence or as a final licensing test.

While the majority of the time is spent on a motorcycle, part of the course is delivered in a classroom environment. Students learn defensive riding strategies and risk awareness skills they can use in conjunction with their on-bike skills. At the end of the course participants are tested to determine how well they have learned. More importantly, though, the final test gives participants an idea of where their weaknesses are and how to improve on them. In many jurisdictions such rider training will move the riders into the next step along the graduated licensing process but not the final licence.

United States

In the United States rider training is still mostly voluntary with a few exceptions. Historically, the US Motorcycle Safety Foundation has provided a national standardised curriculum for novice rider training. The US DOT developed model national standards for entry-level rider training which were released in 2011. It is anticipated that in many States PTW rider training programmes will be based on these standards.

A second level of traffic rider training – on-street training – has been difficult to develop. The cost of a proper fleet of motorcycles for on-street training including maintenance, insurance and proper plates or tags has often been prohibitive. The likelihood of public liabilities resulting from an on-street collision due to a multitude of uncontrollable variables has led insurers to withdraw from such projects.

Europe

In most European countries, pre-licensing training includes both theoretical and practical training courses. Many European countries have to a large extent based their approaches to driver education on the GDE-matrix. The matrix is the result of an EU project, GADGET, (Hatakka et al., 1999). GADGET is an acronym for **G**uarding **A**utomobile **D**rivers through **G**uidance, **E**ducation and **T**echnology. The GDE-matrix is widely recognised within the European traffic research as a fruitful theoretical basis for the development of driver training (Peräaho et al., 2003). The model separates what the driver must learn into the following four hierarchical levels listed from the lowest to the highest level:

- Operational level (manoeuvring the vehicle)
- Tactical level (acting in accordance with traffic conditions)
- Strategic level (selecting journeys/trips and factors related to journeys/trips)
- General level (personal characteristics, ambitions and competencies)

Driver and rider training traditionally cover the two first levels, "manoeuvring and tactical level", rather well. The "strategic" and "highest" levels are often not emphasised in curricula for driver and rider training. The GDE project concluded that including the two highest levels in driver and rider training was very important to improve traffic safety.

Another ambitious project on pre-licensing training is the Initial Rider Training programme (IRT), that was developed in 2007 by the Federation of European Motorcyclists' Associations (FEMA), the Fédération Internationale de Motocyclisme (FIM), the Motorcycle Industry in Europe (ACEM) and the Swedish Road Administration, with the support of the European commission. The focus of the programme was to consider and deliver conclusions and recommendations on:

- The essential elements of a model European initial rider training programme.
- How a model European initial rider training programme could be utilised in different social and economic circumstances.
- The potential of e-Coaching (e-Learning) to support initial rider training and how virtual training approaches could be developed.
- The development of the essential elements into a comprehensive, cohesive and cost-effective European initial rider training initiative.

The programme includes a modular approach to initial rider training, the essential elements and aspects for initial rider training, a method and approach to support initial rider training, and a comprehensive manual for use in a range of situations. The manual is now available to a wider audience in Europe and around the world, with a translation in 11 languages provided by the European Commission (European Commission, 2011).

It is essential to raise the awareness of all road users about interacting with vulnerable road users. Several European countries have implemented this in their curricula, requiring knowledge of different road user groups and special needs. Interaction with motorcyclists is an integral part of this tutorial.

Competencies for safe driving, such as attitudes and motivations, are not easy to evaluate by a theoretical or a practical test. With these limitations in mind, some European countries have introduced mandatory driver training modules on safe driving. There are variations between the countries on the content and scope of these specific modules.

Instructor education

The instructor's competence and attitude towards road safety are critical. There should be minimum competence requirements for instructors according to the training they provide. The requirements could be on the instructors' own riding competence, and their pedagogical competence, e.g. competence in coaching. It is important that the driving instructors' education is developed so that they can fulfil the intention of the curriculum. In education, the curriculum is of vital significance, but without a high level of instructor competence even a good curriculum might lose its effect. Norway and Sweden are examples of addressing both driver training and instructor education.

Implementation issues and recommendations

Even more than for driving a car, riding a PTW requires technical skills. Good pre-licence rider training is an important element in striving for improved road safety for motorcyclists. Results of metaanalyses show that compulsory training and testing before obtaining a licence contribute to reductions in crash risks (Ulleberg, 2003).

The implementation of pre-licence rider training systems depends on political support and an understanding from society that good rider training is an important element in working towards better traffic safety. It is essential to create good foundational documents to be used in communicating with politicians, stakeholders etc. Training content should be developed taking into account that crash risk is influenced by many factors, including ability to master the motorcycle, but also attitude and motivation regarding riding and safety.

The recommendations of the Working Group concerning pre-licence training are that:

- Training should not only focus on basic manoeuvring skills and mastering traffic situations, but also address attitudes towards general issues of mobility as well as safety;
- Training should put a special emphasis on defensive riding. Defensive riding is both an attitude and ability. As an attitude, defensive riding enables the rider to systematically foresee what the riskiest scenario may be at any given moment. As ability, defensive riding makes the motorcyclist ready to cope with that riskiest situation, should it occur.
- The curricula for training and education of drivers in all other vehicle categories should also focus on risk awareness when dealing with PTWs, their vulnerability, and crash patterns.

Testing and assessment

A licensing system is a national (or provincial/state) system consisting of different requirements such as age, medical status, theoretical knowledge and practical skills to obtain a driving licence. To ensure that the requirements for theoretical knowledge and practical skills are met, it is necessary to assess the applicants. A driving test is a procedure designed to assess a person's ability to drive a motor vehicle. It exists in various forms worldwide, and is a requirement to pass in order to obtain a driver's licence. A driving test generally consists of one or two parts: the practical test, called an on-road test, used to assess a person’s driving ability under normal operating conditions, and/or a written or oral test (theoretical test) to confirm a person's knowledge of relevant rules and laws.

Types of assessment

Different types of assessment can identify various aspects of a learner rider’s competence (i.e. knowledge, skills and attitudes). Before selecting the type of assessment, it is necessary to clarify its purpose.

There are roughly two types of individual assessment; formative and summative assessment.

Formative assessment, also called process evaluation, takes place during the training process and is often of an informal character. The focus is on the learner rider’s learning process. The result is often used as a guide for adjusting the training content.

Summative assessment, also called product evaluation, takes place at the end of the training process. This assessment step is more formal. It is the product of the student’s learning that is made subject to assessment, and the purpose is to assess the learner rider’s level after completed the training.

During rider training and testing it is desirable that all learner riders are treated equally. This means that assessment should be as objective as possible. In the evaluation of theoretical knowledge this is to a large extent achieved through standardized theory tests. The assessment of driving skills takes place under such varied conditions that a certain subjective judgment cannot be avoided, even though nationwide assessment criteria are used combined with coordination of the examiners. This should not result in the discrimination of certain groups of users (e.g. smaller women).

Special competencies for motorcycle riders

Motorcycle characteristics require specific competencies compared to other vehicles. Mastery of technical skills is all the more important when driving vehicles with only two wheels. Technical riding skills should be seen as a "tool" to carry out wise tactical and operational choices when riding in traffic. Testing these skills on a closed track is not sufficient to assess the ability to safely ride in traffic.

Testing should also aim to assess whether riders have acquired the necessary on-road skills, including hazard perception and the understanding of riders' inherent vulnerability. Due to the size of the motorcycle, an important competence is the ability to gain best visibility by positioning, speed and predictable (non-surprising) riding behaviours. The inherent vulnerability also requires knowledge about helmets and appropriate protective clothing. To evaluate these special competencies, the examiner must have both good knowledge and experience as a motorcyclist.

Examples of testing and assessment

United States

Rider licensing is typically obtained after an off-road test. Many jurisdictions in the United States have adopted the test developed by the Motorcycle Safety Foundation (MSF) for the US Government, known as MOST II. It is believed to be both credible and highly objective, eliminating complaints of subjectivity by licensing examiners. This well-documented and objective skill test has allowed governments to entrust the written examination portion of licence testing to approved motorcycle training agencies in many jurisdictions.

European Union

Most European countries are subject to the EU Driving Licence Directive, and will follow the requirements for licensing and testing according to Directive 2006/126/EC, which was implemented in 2013. The Directive has detailed requirements relating to the theoretical test, special manoeuvres test and the on-road testing.

Recommendations

- Defining the objectives of the training and licensing process is a prerequisite of an effective system. The content of the training should reflect these objectives and be validated by relevant competence and performance testing.
- There should be minimum requirements for the examiners' competence. To make a good test/assessment, the examiner must have both good assessment and rider competencies.
- The practical test should be divided into an assessment of the technical driving skills off-road, and an assessment of traffic skills on-road (in-traffic test).
- The motorcycle used for testing should be in accordance with the motorcycle that applicants will be authorised to ride.

Post-licence education and training

Post-licence education and training seeks to further develop the basic competencies that the initial rider training has provided the rider. It can also aim to refresh riding skills, for example, after not having ridden a motorcycle over a long period (e.g. the winter) or when purchasing a new model. These courses are not compulsory. Returning riders are a target group for post-licence education and training. Their numbers have been growing rapidly in several western countries in recent years. It is therefore very important to adapt the content of post-licence training to the targeted group.

Examples

United Kingdom

In the United Kingdom, the Driving Standards Agency has devised a post-test rider training scheme called the Enhanced Rider Scheme, which is based on evidence of what makes an effective training scheme which delivers safer riders. This is one of a number of post-test training and development schemes that are available, including Bikesafe, IAM and ROSPA advanced training, and various local schemes.

Norway and Sweden

Following winter, efforts are made to motivate PTW riders to take post-licence courses, both on-track and on-road training. In Sweden, for example, the Swedish Motorcyclist Association (SMC) organises post-licence courses during the summer. The courses are designed for various types of riders and bikes, for example, women, new riders, and riders of sports bikes. In Norway, the users' organisation Norwegian Motorcycle Union (NMCU) promotes a schedule of courses, and ensures that these are designed for developing good competence in terms of traffic safety, and are not turned into racecourses.

The Netherlands

Recently, the 'Risk' advanced training course of the Royal Dutch Motor cyclists Association (KNMV) was evaluated (Boele and de Craen, 2014). This one-day course teaches motorcyclists to recognise, analyse, and anticipate potential traffic hazards. Results from the two-year evaluation indicate that 'Risk' training has a positive effect on the safe riding behaviour and hazard perception of motorcyclists in the short term (the first few months after training). Even in the long term (one year to eighteen months after training) 'Risk' trained motorcyclists showed safer traffic behaviour than a control group without this training.

Evidence of effectiveness

While many motorcycling organisations promote post-licence training, it is difficult to assess the effectiveness of these programmes in reducing the risk or severity of crashes. Participation in the courses is voluntary, meaning that evaluation studies are faced with relatively few participants who may not be representative of the rider population (and for which no natural control group exists). The research on post-licence training courses indicates that these types of courses might lead to an increased risk for crashes if not clearly directed to road safety. A literature review and meta-analysis conducted by Ulleberg (2003) showed that riders could feel more competent and overconfident after completing the course, without actually having significantly improved their skills or having improved riding skills that are not focused on crash prevention.

While there is little scientific evidence, it is likely that well-designed post-licence training courses, focused on refreshing basic manoeuvring skills and risk awareness, can be useful to some riders (for example the “returning” riders). For example, the Dutch advanced training showed positive effects on riding behaviour, with no indication that the training caused overconfidence in skills.

It is therefore essential, when planning and implementing post-licence training, to ensure that the main focus is safe-riding knowledge and that the courses are not orientated towards the promotion of specific skills resulting in over-confident riders taking risks that they cannot handle in real traffic conditions. More research is needed on the safety impact of post license training and the underlying conditions for an optimised effectiveness, including ways of maximising voluntary participation in effective courses.

Monitoring and feedback

Monitoring and feedback are potential contributors to driver education and licensing which have received relatively little attention. In some graduated licensing systems, learner drivers are required to keep logbooks that record their trips in terms of time, distance and location. The logbooks provide documentation for requirements of a minimum number of hours of supervised driving before the restricted licence can be obtained. However, more detailed logbooks could also be used to ensure that sufficient driving experience under different conditions (time of day, traffic density, high speed roads, etc.) is obtained. A challenge, though, is to ensure the reliability of information filled in by the learner driver. Recent research has examined the safety benefits of electronic driver monitoring systems for young drivers. Simons-Morton et al. (2013) found that feedback to teen drivers *and* their parents on the teens’ risky driving events led to a reduction in these events, but that feedback to the teen drivers *only* did not result in a reduction. Therefore it appears that monitoring systems can be beneficial, but that feedback to “authorities” may be needed for this effect to occur.

Another way of facilitating learning is by rider coaching. These programmes provide feedback to riders on their on-road riding skills and techniques. This approach has been incorporated in the BikeSafe UK programme and an evaluation is being undertaken of an assisted ride programme in Victoria, Australia. The Victorian study focused on riders who had obtained their licence within the last year and ridden at least 500 kilometres (Sakashita et al., 2013). While no evaluation of the safety effects of the programme is currently available, one of the important learnings was the general lack of interest in participation among the newly-licensed riders. This presents a real challenge to any voluntary post-licence educational programme.

Effectiveness of training and expectations vis-à-vis riding safety

The effectiveness of training activities within the area of road safety remains a controversial subject. Training is seen as an important road safety measure by some safety stakeholders, while others consider it a measure which does not yield any demonstrable positive road safety effects.

In his policy recommendations for educational work in the road safety area, McKenna (2010) stated that education interventions should be evidenced-based, with an underlying formal body of knowledge and be evaluable through well-defined and objective criteria.

Ideally, the effectiveness of training should be assessed based on the reduction in the number of killed and injured. In practice, it is very difficult to establish a direct link between training and safety performance. The Cochrane Collaboration (Kardamanidis et al., 2010) reported that due to the poor methodological quality of the existing studies, it was difficult to draw any conclusions about the effectiveness of rider training and therefore to recommend best practices in rider training. In addition, some poorly planned and executed training programmes may have had a negative impact on road safety, therefore biasing the overall assessment of training on road safety. Alternatively, if the assessment is based on criteria focused on effects like improved knowledge, changed attitudes etc. the outcome might be positive.

Implementation issues and recommendations

Driver training is a long-term measure to improve road safety. It might have positive short term effects, no effect or even negative effects if the driver/rider training is unorganised and on a low level. The latter is probably one of several explanations as to why it has been so difficult to find a direct correlation with crashes.

The value of the training as a road safety measure requires careful analyses, based on facts about the conditions under which training is conducted, before its road safety value can be assessed. More or less uninformed analyses may impact assessments which can be overly positive or overly negative. The points below and the policy recommendations should be seen as an attempt to, in an overall way, sum up what is important to consider when training is evaluated as a road safety measure.

- The internal and external framework for the training activities is crucial for what effect a training activity in the road safety area can be expected to provide.
- It is important to have realistic goals for the training activities and to evaluate against the goals and assessment criteria that have been set.
- Rider training must be seen as only one of several measures that together affect the overall road safety level.
- Training can only be regarded as an indirect measure that creates opportunities which, in turn, can influence the riders' individual requirements (practical and theoretical knowledge, attitudes, norms, behaviour) for being in the road system.

Enforcement

General principles

The necessity and effectiveness of police enforcement to improve the compliance of all road users with traffic rules and increase safety levels have been studied and are well-established (Elvik & Vaa, 2004). A mix of traditional, visible, enforcement (with on-the-spot roadside checks by police) and automated enforcement for offences such as speeding or red light has the biggest deterrence effect. Randomness of enforcement also increases the deterrent effect. Moreover, enforcement has to be well conducted in order to be efficient (Jou & Wang, 2011).

PTW operators, as other operators of motorised vehicles, must comply with traffic rules, and typical enforcement activities to control speeding, drink-driving and non-respect of traffic rules apply equally to all motorised vehicle operators.

Both traditional and automated enforcement are more complex for PTWs. Their manoeuvrability and speed means that they are difficult to catch and stop when an offence is detected by traditional enforcement. In addition, they are less easily detectable by photographic enforcement because they do not have front registration plates and the identity of the rider is hard to establish in jurisdictions where this is required. Enforcement activities are more effective if police officers are well trained to detect dangerous manoeuvres and equipped to intercept the riders quickly and safely. This often means that the traffic police should be riding a PTW.

While most of the focus in this section is on enforcement directed at PTW riders, it must be acknowledged that enforcement of traffic rules for other drivers is an important measure to improve PTW safety. To the extent to which this enforcement is able to reduce speeds at intersections, reduce drink-driving and prevent other dangerous behaviours, then motorcycles are less likely to be the counterpart in these collisions or the severity of their injuries will be reduced.

For motorcyclists, as for other road users, enforcement alone has a limited effect. Communication campaigns and publicity are important complementary measures to ensure the long term impact of enforcement. Motorcyclist associations also have a key role to play in informing riders about the rules and promoting respect for them. A study conducted in France (Eyssartier, 2011) showed that, while most riders do recognise the danger of extreme behaviours, they consider it the norm to drive 10 km/h above the limit. This section focuses on specific challenges of PTW enforcement and specific enforcement activities towards all motorised vehicle operators to increase safety of PTWs, including:

- Speeding
- Helmet wearing
- Extreme behaviours of PTW riders
- Vehicle maintenance and inspection

Speeding

As seen in Chapter 4, inappropriate and excessive speed is a major contributor in PTW crashes. In addition, PTW riders are over-represented in speeding offences in most countries. Reducing the speed of PTW riders is a priority in all countries, on urban as well as non-urban roads.

In addition to traditional enforcement activities targeting all road users as well as traffic management measures, education and campaigns, two main enforcement measures can contribute in reducing speeding offences of PTW operators:

- Greater use of automated speed cameras with rear cameras, as PTW registration plates are fixed on the rear of the vehicle. This supposes that sanctions can be based on the "owner liability" principle. In many countries, it is legally necessary to have a picture of the operator of the vehicle in order to proceed with the sanction. This also supposes that registration plates are visible and can be read by automated speed cameras and that misplacement of the plates can be punished. In 2012, in France, 100% of speeding PTWs were not caught by automatic devices with front cameras, and it is estimated that only 15% of PTW speeding were caught by devices with rear cameras, because their plates could not be read (CNSR, 2013). Technical inspection is one option to contribute to ensuring the conformity of the registration plate. Australian research has examined the feasibility of several alternative approaches to motorcycle frontal identification, including front number plates, adhesive stickers and radio frequency identification tags. None of these systems has yet been implemented.
- Progressive implementation of point-to-point enforcement, also known as section control, which measures the average speed of vehicles on a section of road, thus contributing to a "fairer" enforcement and greater acceptability. It also avoids the "sudden braking" of road users when approaching a speed camera.

A study by Christie et al., (2003), demonstrated a 63% decrease in injury crashes involving motorcyclists after setting up a network of 101 mobile speed cameras (mostly on roads where the speed limit is 30 mph) in the South Wales region of the United Kingdom.

Other specific speeding issues which can occur with PTWs concern moped riders on cycle lanes, where there are usually no cameras.

Drink driving

As seen in Chapter 4, drink-driving is not necessarily more prevalent among motorcyclists, but this group is over-represented in comparison to other drivers in fatal and non-fatal crashes because of their greater vulnerability, and particularly after having consumed alcohol.

There are usually no specific programmes to target drink-driving among PTW riders. The most effective measures to combat drink-driving is the enforcement of legal limits of blood alcohol content (BAC) and should target all operators of motor vehicles. In some countries, a lower maximum blood alcohol content may be in force for young drivers and riders. In some countries (such as Austria) moped riders (who usually are teenagers) are subject to lower BAC.

Widespread and unpredictable random breath testing (RBT) is very effective in reducing the prevalence of drink-driving by car drivers. PTW riders can be breath tested in the same way as car drivers. However, most RBT tests are conducted at the times of day when the prevalence of drink-driving in car crashes is highest: at night, particularly on weekends. Given that most PTW use occurs in daytime hours (more so than for car use), then PTW riders are less likely to be tested for alcohol and so may be less deterred from its use.

As for passenger cars or buses, an alcohol ignition interlock can be installed on PTWs. This is a device, like a breath-analyser, installed on the dashboard of a motor vehicle. Before the motor can be started, the driver must first exhale into the device. If the resultant breath-alcohol concentration analysis is greater than the programmed blood alcohol concentration, the device prevents the engine from being started. In the state of Victoria, Australia, work is in progress to extend current interlock programmes to require any driver or rider who is convicted of drink- driving to fit an alcohol interlock for a period of time as a condition of their licence reinstatement (VicRoads, undated). Regardless of whether the offence was committed while driving a car or riding a PTW, the PTW must be fitted with an interlock if the rider wishes to be allowed legally to ride it during this period. A similar programme exists in Sweden. In both programmes, the number of interlocks fitted to PTWs has been very small and no PTW-specific evaluations have been possible to determine how effective this has been in preventing initial drink-riding, or subsequent re-offending.

Helmet wearing

The proper use of a quality helmet is certainly the most effective protection to prevent head injuries and reduce the consequences of motorcycles injuries (Rutledge and Stutts, 1993; Lin et al., 2001).

Government administrations and motorcycling stakeholders should recommend and strongly promote the correct fitment and wearing of certified helmets. All countries should aim at a 100% wearing rate of helmets, which implies strict enforcement.

The enforcement of helmet wearing first requires the existence of a helmet law. This is not the case in all OECD countries, however: in the United States, for example, only 19 out of 50 States have a universal helmet law. In the other States wearing a helmet is either not compulsory or compulsory for specific segments of the population only. According to NHTSA (2012), 65% of motorcyclists killed in 2010 were not wearing helmets in States without universal helmet laws, as compared to 9% in States with universal helmet laws (these figures include riders on 3-wheeled motorcycles). It is estimated that 703 lives (37% out of the 4 502 killed) could have been saved, with a 100% wearing rate.

In Italy, the mandatory helmet law for riders of all ages entered into force in 2000. The "Casco 2000 study" (Giustini et al., 2000) dealt with emergency room access in many cities in Italy. A sample of 1 548 cases was analysed, 659 of them after the law was passed. The incidence of head injury diminished notably after the helmet law entered into force: 37% of cases before the law versus 17% of cases after the law.

The helmet law must be enforced on a continuous basis by roadside checking. Enforcement needs to be conducted in a continuous and random basis and target all riders and their passengers. The Box below illustrates the situation in Vietnam, which could inspire other countries.

Box 5.1. **The development and implementation of mandatory motorcycle helmet legislation in Vietnam**

Motorcycles represent 95% of Vietnam's 27 million registered vehicles. On 29 June 2007, Vietnam introduced the first universal mandatory helmet law. Taking effect on 15 December 2007, this legislation covered all riders and passengers on all roads. Penalties were increased tenfold and cohorts of the police were mobilised for enforcement. Despite past barriers to enforcement, prioritisation within traffic police resulted in 680 000 infringements being issued, in 2008, for non-wearing of a helmet. In selected provinces, helmet wearing increased significantly in the first 6 months of the helmet law. In Danang, for example, helmet use increased from 27% to 99%. Through political leadership, advance public education and stringent enforcement from the day the legislation took effect, reductions in head injuries and deaths are evident.

Source: Passmore J and N. Nguyen Phuong (2010), World Health Organization.

While the use of helmets is relatively easy to enforce, the *proper* use of *standard* helmets is more complex. Police officers should be trained to notice inappropriate wearing of helmets, and non-standard helmets. In developing countries in particular, the sale of fake helmets should be actively discouraged and punished.

As for other enforcement activities, it is important to complement these with targeted communication campaigns, adapted to local conditions, highlighting the benefits of using proper helmets.

Extreme (or deviant) behaviours

Some riders exhibit extreme and dangerous behaviours, deliberately taking risks which are a threat both to themselves and other road users. These include high acceleration, very high speeds, zig-zagging, competing, and aggressive behaviour.

It is not easy to enforce these behaviours, because the offences are not well defined, concern only a small portion of the riders, and it is difficult for police officers to catch the offenders. Nevertheless, their actions must be stringently sanctioned as they are a threat to road safety and present a negative image of the overall motorcyclist population.

In Sweden, reducing extreme behaviours of motorcyclists is a priority in the new strategy for PTW safety. Extreme behaviours are defined in a very large sense, as they encompass riders who clearly violate speed limits, ride without a driving licence, drive aggressively, or with alcohol or other drugs in their system. It is intended to disseminate information to police and prosecutors regarding the possibility of confiscating motorcycles (Swedish Transport Administration, 2012).

In Norway, the most important step in dealing with extreme behaviour in traffic is to work in close connection with the police, as they will be the first to detect that kind of behaviour in other areas – such as drug abuse, robbery etc. In an investigation in Norway, results showed that about 80% of traffic offenders (based upon extreme behaviour in traffic) were already registered by the police for other illegal behaviours (Norwegian Public Roads Administration, 2010).

Finally, extreme behaviours from all road users should be strictly identified and enforced, as the safety of motorcyclists are also put at risk.

Communication campaigns

Although there is little research evidence on the effectiveness of communication campaigns, the media can certainly positively influence attitudes and behaviours, provide information and increase the acceptability of enforcement. Regarding the safety of PTWs, periodic and thematic campaigns targeting both motorcyclists and other road users typically focus on:

- Vulnerability of PTWs and the most common crash scenarios and risks factors.
- PTW risky behaviours.

These communication campaigns aim to promote harmonious car-PTW co-existence and safe behaviours by all road users.

Development of a communication campaign

There are various media avenues for such campaigns, including TV, radio, press (general-interest newspapers or specialised press), Internet (online-press, blogs, social media...), variable message signs, etc. It is possible to communicate effectively with even a modest budget, as long as the messages and target groups are well defined.

Successful communications campaigns are developed in consultation with relevant stakeholders depending on the topic of the campaign (e.g. PTW associations, manufacturers, professional riders, etc.). The role of PTW associations in disseminating the communication is particularly important. During specific events where motorcyclist exposure is increased (motorcycling races, motorcycling rallies), it is essential to deploy more resources to ensure their safety (see box below).

Where the strategy focuses on specific risky behaviours, best results will be achieved when these are combined with enforcement campaigns (Henkens & Hijkoop, 2008).

Box 5.2. **UK, "Think!"**

THINK! provides road safety information for road users.

The **specific focus for PTWs** can be summarised in the following communication campaign: "Motorcycling: Motorcyclists fatalities are out of proportion to their presence on our roads. 'Think bike, think biker'".

The campaign is divided in three main points:

- ***Facts:*** motorcyclists are just under 1% of total road traffic, but account for 19% of all road user deaths; they are 50 times more likely to be killed or seriously injured in crashes than car drivers. In 2012, 328 motorcyclists died and 5 000 were seriously injured in road collisions in Great Britain. In 2012, around two thirds of motorcycle fatalities occurred on rural roads.

- **Advice for Riders**: choosing the right helmet could help save your life, wear the right gear, riding defensively makes you less vulnerable, consider further skills-training to improve your performance and safety on the road, etc.

- ***Advice for Drivers:*** keep your distance, check for bikes when changing lanes, check for bikes when turning, motorcyclists might pass you on either side, check for motorcycles at junctions and park safely.

Source: UK Government.

Box 5.3. **Safety and enforcement during motorcycling event**

Jerez, Spain, 2011

In Spain, during one of the most important sport events ("FIM MotoGP 2011 World Championship", in Jerez) the traffic agency carried out specific measures to avoid incidents as much as possible:

Deployment of resources (eighteen helicopters) and police forces (600 people) belonging to Traffic Police Departments (at National and Local level). These resources were located especially at locations where intensive surveillance was thought to be needed (based on previous events). More than 150 speed cameras were installed in the surroundings of the circuit. More than 20 police units were equipped with "alcohol detection systems" and carried out alcohol testing during the race weekend.

Campaigns (especially on radio) were carried out three days before the event, and targeted messages were displayed on electronic information boards on roads (e.g. "*Driver, think about the motorcycles* or *Road is not a circuit").*

Awareness communication campaigns

Awareness communication campaigns typically aim at combating risky practices or achieving harmonious coexistence between PTW and other road users.

Risky practices of PTW riders addressed by awareness campaigns include common traffic violations, such as speeding, drink driving or impaired driving in general, not wearing a helmet use or wearing it poorly fastened, and disobeying traffic lights in urban areas. Countries now have considerable experience with campaigns specifically targeting these risky behaviours.

The road is a common space that must be shared by different users (car, PTW, truck drivers, etc.) to fulfil the mobility needs of everybody. Messages should be sent to two and four wheel users to obtain a common goal.

Car drivers need to be aware of systematically using turning lights and make an effort to look for PTW drivers through their mirrors. While riders can do much to reduce the risks, there are also simple actions that drivers can take, including: indicating their intention to turn or change lanes well in advance; using mirrors and doing a head check to make sure blind spots are clear; making eye contact or acknowledging riders, etc.

Box 5.4. **VAL OP, LET OP**

(Netherlands, 2007)

"Motor platform" is a working group of PTW groups supported by the Dutch Government. In 2007, they launched a campaign aimed at motorcyclists and drivers, encouraging greater awareness and the understanding between "parties".

The campaign has two strands: VAL OP provides advice and survival strategies for motorcyclists, stressing the need to be visible to other road users; LET OP gives guidance to car and truck drivers on watching blind-spots and keeping a permanent eye looking out for PTWs.

The project provided leaflets and posters, which were available as downloads from the Motor platform website.

These messages are thought to be given to PTW users as well as to the other road users (passenger cars, vans...).

Source: Motorplatform Netherlands.

Conclusions

Road user behaviours are an essential lever to improve road safety. To improve the safety of motorcyclists, it is possible to influence both riders' and other drivers' behaviours through education, training and licensing; enforcement and communication.

Licensing, training and education are essential tools for improving riding safety. Access to PTWs should be gradual, with a licensing system aiming at managing novice rider risks while riders are gaining experience and maturity. Novice riders of every kind of PTW should be trained. Training should not only focus on basic manoeuvring skills and mastering traffic situations, but also address attitudes towards safety, placing special emphasis on hazard perception and defensive riding. Other road users should also be made aware of the specific risks associated with PTWs vulnerability and crash patterns.

Traffic rules apply equally to operators of two- and four-wheeled vehicles and thus should be equally enforced. As for other motorised vehicle users, enforcement is needed to improve compliance with key safety rules such as speed, drinking and driving, helmet use, proper licences and vehicle safety standards. High-visibility enforcement accompanied by other measures, such as communication and publicity, has proven to have a strong deterrent effect. Speed enforcement is essential in reducing speeding and associated crash risk. Automated speed enforcement has proven its effectiveness for cars, but further adjustments are needed to make it as effective for PTWs.

Communication campaigns are potentially a good means to promote safety in general, in association with other measures. They are most effective when targeted at key groups of drivers and riders. The combination of enforcement-communication campaigns (on speeding, riding without a helmet and other risky behaviour) has proven its effectiveness in many countries.

The success of an enforcement and communication strategy depends on the involvement of motorcyclists themselves, and motorcyclists associations have an important role to play in disseminating communication messages, informing riders about the rules and making enforcement acceptable.

All these measures directly address drivers and riders behaviours. However it must be kept in mind that is also efficient to act indirectly on the behaviour by measures concerning infrastructure and vehicles (see Chapters 7 and 8).

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Chapter 6. Countermeasures promoting the use of personal protective equipment

Head injuries are the most critical injuries affecting powered two-wheeler (PTW) riders. This chapter presents the safety value of the helmet which is the primary equipment to protect the rider. It also describes other protective equipment, including protective clothing, airbag jackets, high visibility clothing and neck braces.

Introduction

The proper use of helmets has strongly proved its efficiency to reduce injuries. A helmet is therefore the primary equipment to protect the rider. Other recommended protective equipment includes protective clothing (such as protective gloves, boots jackets and pants, often equipped with limb protectors), airbag jackets and neck braces.

Helmets

A helmet prevents or reduces head injury. The SWOV factsheet on helmets (SWOV, 2010) describes the four basic components of a helmet: outer shell, inner shell, protective padding, and chin strap. Furthermore, most types of helmet also have a visor. The task of the hard outer shell, usually made of fibre reinforced composites or thermoplastic, is to prevent objects from penetrating, and to spread energy. The task of the soft inner shell, usually made of polystyrene foam in various densities, is to absorb the collision energy slowly and to spread it over a large area of the head. The protective padding, often made of polyurethane, ensures comfort of wear. The chin strap ensures that the helmet remains on the head no matter what happens. The helmet wearer's vision is guaranteed by the hinged visor. The shape of the helmet reduces wind noise to acceptable proportions, although turbulence can still raise the sound level.

There is a wide diversity of standard helmets, including Open-Faced, Full-face and modular helmets. These offer differing levels of protection, albeit there is no requirement for a specific type of helmet for specific use.

Helmet standards

Motorcycle helmets sold in the United States are required to meet the federal standards set forth by the Department of Transportation (FMVSS 218). In addition to these federal required standards, the Snell Memorial Foundation has set up a series of voluntary standards for motorcycle helmets as well. The tests in the two sets of standards are different in both design and specifications for the results of the testing. Riders should choose a helmet that is DOT certified and many riders also choose to wear a helmet that has the additional Snell certification. A helmet that meets multiple safety standards provides more safety benefit to the rider. The Economic Community of Europe (ECE) is currently the most commonly used motorcycle helmet safety standard internationally, as compliance with ECE 22.05 is required by over 50 countries worldwide. One of the advantages is the requirement for mandatory batch testing of helmets before they are released to the public. This means that the quality of the helmet in meeting the ECE 22.05 standard is assured by the compulsory sample testing of every production of helmets before they leave the factory.

The Safety Helmet Assessment and Rating Programme (SHARP) was established by the UK Department for Transport in 2007, as part of the Government's commitment to reduce motorcycling casualties. SHARP's objectives are twofold:

- To provide clear advice on how to select a helmet that fits correctly and is comfortable.
- To provide consumers with clear, impartial and objective information about the relative safety of motorcycle helmets through a 1 to 5 star safety rating.

Each model of helmet rated is subjected to 32 impact tests and, to date, 304 helmet ratings have been published.

Certainly, the protective effects of the helmet can still be improved. Perhaps this requires adapting the test procedure requirements so that advanced materials and constructions can contribute optimally. Of course it is important to aim for the highest quality and protective effect of helmets. In any case, users should be aware of the technical performance of their helmets and quality should be assured.

Affordability is sometimes claimed as an excuse not to wear a helmet, however this cannot be an acceptable argument, at least in high-income countries, where the cost of a standard helmet is only a very small proportion of the purchase price of a motorcycle, and tiny in comparison with the health expenses and the consequences of a head injury. In lower income countries, the situation might be different, and a solution must be found to offer well protecting helmets at a reasonable price (see also Chapter 9).

Helmets standards should be developed taking into account the various climates in the world: it might be challenging to wear the same helmet in tropical conditions and during the winter in a country with very cold temperatures.

Evidence of effectiveness

Wearing a helmet considerably reduces the risk of head injury in a crash. An international review of 61 studies on the use of a helmet shows that the risk of severe head injury decreases by about 69% when wearing one (Liu et al., 2007). The risk of being killed in a motorcycle crash decreases by about 42%.

Studies have compared the effectiveness of the various helmet types, particularly the integral helmet and the jet helmet. It is clear that an integral helmet with a fixed jaw guard considerably reduces the risk of chin and facial injury. Studies carried out in Taiwan and Australia found no difference between the integral and the jet helmet in causing spinal cord injuries (Lin et al., 2004; O'Connor, 2005).

In a recent study in 70 countries, factors such as helmet non-usage percentage and motorcycle per person ratio were positively associated with motorcycle-related death rates. A simple linear regression model between helmet usage and road traffic death rate has shown that for each 10% increase in helmet usage, one life per million inhabitants can be saved per year (Abbas et al., 2012).

Measures to increase wearing rates

Given the proven effectiveness of a helmet, motorcycle safety could benefit considerably from a nearly 100% wearing rate. This first requires that helmet wearing is mandatory. As mentioned previously, not all OECD countries have a helmet law. Only after such a law is installed can helmet wearing be enforced (see also section on enforcement). In order to increase the acceptability of the helmet law, the enforcement strategies should be complemented with communication campaigns and publicity.

In aiming to increase wearing rates there are a couple of issues to consider. First, not only should wearing be enforced, also *proper* wearing of a helmet should be enforced. When a helmet is worn without a fastened chin strap, the effectiveness of protection in a crash is considerably limited. Therefore it is important to keep the chin strap well fastened, allowing no slack. Especially among moped riders there is a tendency not to wear the helmet correctly.

Protective clothing

The term "protective clothing" refers to garments (i.e. boots, gloves, pants and jackets) that aim to prevent, or reduce, the severity of injuries when a crash occurs. Protective clothing essentially reduces the risk of abrasion in case of friction with the road surface. It also prevents some piercing injuries and increases the threshold for fractures.

Research has indicated significant benefits from wearing protective equipment. A study undertaken by de Rome et al. (2011) showed significant reductions in injury risk if riders were wearing a range of protective clothing. Riders were significantly less likely (20% to 60%) to be hospitalised if they were wearing jackets, pants or gloves and less likely to incur injury if garments included fitted body armour with greatest reductions for injuries to extremities. Even non-motorcycle boots showed a halving of risk compared with shoes.

The study also showed that 25% to 30% of gloves, jackets and pants designed for motorcyclists failed due to material damage in the crash. While this may indicate the need for improved standards, it may also indicate that the practical limit of the protection available from clothing can frequently be exceeded in a crash. Consistent results were obtained from ACEM (2009) (see Table 6.1).

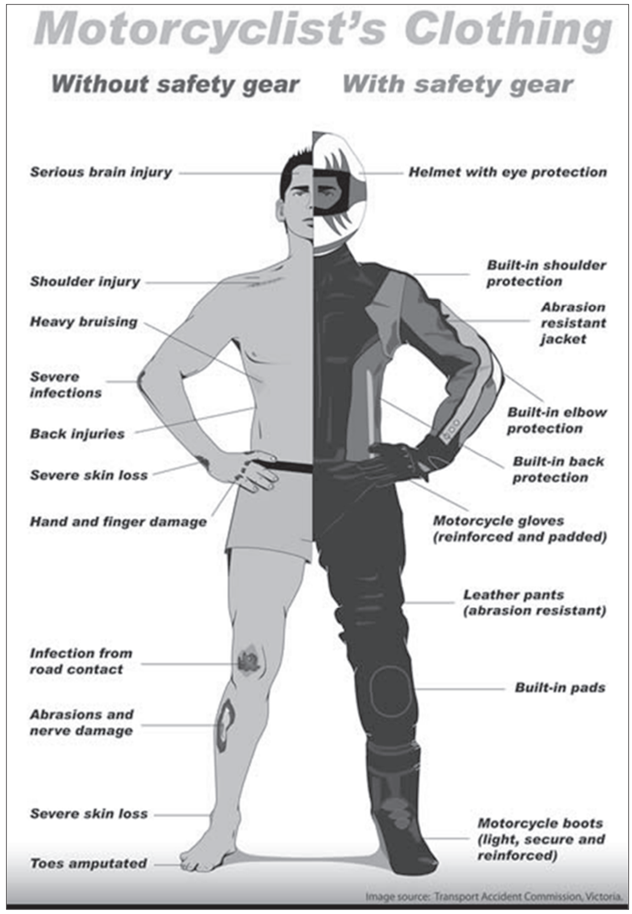
Table 6.1. **Percentage of crashes in which protective equipment contributed to reduced, or prevented, injury**

Protective clothing worn	**Percentage (%) of crashes in which coverage was present and contributed to reduced or prevented injury**	
	Rider	Passenger
Upper torso	65	49
Lower torso	61	46
Footwear	49	29
Gloves	44	25

Source: ACEM (2009).

There are benefits from the introduction of harmonised standards to support the global product production and distribution. On the other hand, there is a trade-off, if a minimum standard is imposed that results in a price on equipment that exceeds the riders' willingness, or ability, to pay. In particular, the need to increase equipment wearing rates in developing countries may not be supported by a global standard based on the needs of more affluent riders in OECD member states. The European Committee for Standardisation (CEN) has published standards for protective equipment for motorcyclists' protective clothing against mechanical impact.

Figure 6.1. **Protective clothing zones**



Source: Transport Accident Commission, Victoria.

While the introduction of mandatory requirements imposes a cost on riders, and may therefore be subject to significant community opposition, any increase in the use of protective clothing through promotion to increase rider awareness has the potential to provide significant benefits. Elvik and Vaa (2004) have analysed several studies of the impact of protective clothing. Respective injuries are expected to decline between 33% and 50% by use of protective equipment. The benefit-cost ratio was estimated to be 5.3, which makes protective equipment a highly efficient way of reducing the number and severity of injuries.

The publication and distribution of brochures on protective clothing promotion by licensing agencies or at point of sale, supplemented by mass media advertising, form an important part of motorcycle safety strategies.

While research into the benefits of protective clothing is unequivocal, there remain a number of impediments to increased or, eventually, universal use. The first is inconvenience. The most effective protection involves a significant amount of bulky clothing and the time and effort required to use this every time may be a deterrent for riders, particularly in short trips perceived to be of low risk. For example, research by the Victorian Transport Accident Commission (TAC, 2011) indicated that while boots were almost universally worn by recreational riders, they were only worn by 60% of commuters.

This bulk and weight leads to two other factors acting against universal use: heat and comfort. Finally, costs may also be an issue.

Another impediment to promotion and increased use of protective clothing is lack of good consumer information provided to riders about the protective value of the particular item that is being sold. While standards for motorcycle protective clothing were issued in Europe in the late 1990s, few European manufacturers submit their products for testing, circumventing the need for compliance by avoiding any reference to safety or protection in product descriptions.

Further research and development into clothing and equipment with lower weight and improved ventilation should be encouraged. Promotion of the benefits of protective clothing and resulting consumer awareness and demand is likely to be one of the key drivers of this.

Airbag "jackets"

Airbags built into a rider's jacket, or suit, are a recent development in motorcycle safety. These systems involve the same principles as vehicle-mounted airbags where, upon detection of a crash situation, the airbag is automatically deployed to minimise injury to the rider.

Two different mechanisms of airbag jackets exist. The first mechanism of airbags jackets come into effect once the motorcyclist has been thrown from the vehicle. The jacket is connected to the vehicle through a cable, and when this connection is severed (the force of the rider being thrown from the motorcycle uncouples a pin or key in the jacket) the airbag inflates. The second one is based on radio communication between the front wheel and the jacket. When sensors placed in the motorcycle (accelerometers fixed in the front wheel for example) detect a crash (because it reaches a high level of acceleration for example) a signal is sent to the jacket which inflates immediately. The first one will only inflate in the case of a separation between the rider and its engine, thus preventing undesired (and potentially dangerous) inflation; but it will not inflate in case of a crash when the rider and the vehicle are split late in the crash process. The electronic one will prevent the latter case, but must rely on complex (and expensive) technological devices.

The riders will still hit the obstacle with the same force, but they will be protected with a cushion of air surrounding their upper body. Airbag jackets are inflated by a carbon dioxide cylinder built into the jacket, which is less flammable than the gases used to inflate vehicle-mounted airbags.

Airbags jackets, like vehicle-mounted airbags, are passive systems which serve to reduce injury severity. In addition to front-impact crashes, airbag jackets could be effective in a range of loss of control or multiple vehicle crashes where the rider is thrown from the vehicle.

In order to evaluate the rider protection performances of various airbag jacket models, the Japan Automobile Research Institute (2011) has conducted an impact test and an inflation time test. Analysis of the measurements of shear and tension force in the neck have showed that the probability of a crash impact generating a serious injury to the neck is low if the rider wears an airbag jacket. The results of the chest impact test indicated that the probability of a crash impact generating an Abbreviated Injury Score of 3 (serious injury) to the chest region can be reduced by as much as 14% if the rider wears both a protector and an airbag jacket, as compared to wearing no protective gear . The time required to fully inflate an airbag jacket measured 90 ms for the fastest model and 180 ms for the slowest one.

There are a number of commercially available airbag jackets. However, there is no existing independent evaluation of their effectiveness. The European Technical Committee CEN/TC 162 "Protective clothing including hand and arm protection and lifejackets" has been working on a European

Standard which covers requirements and test methods for mechanically activated inflatable protectors for motorcycle riders. As of January 2014, this standard was not yet published.

High visibility clothing

As mentioned in Chapter 4, conspicuity is a crucial issue in the crash production and high visibility clothing has the potential – in addition to the PTW equipment (projectors, indicators) – to mitigate the problem of perception met by other road users as regards to PTWs. There are many types of motorcycle clothing available aimed to improve conspicuity. Some motorcycle protective clothing incorporates fluorescent and/or reflective sections. There are also many variants of a separate vest that can be worn over standard clothing. In addition there are fluorescent or reflective helmets, top panniers, backpacks, gloves etc. available. In general, all high visible clothing can be separated in two categories:

- fluorescent or bright clothing, vest, helmet, etc. to improve conspicuity during daytime;
- reflective parts incorporated in the jacket or vest to improve conspicuity during night time.

More recent developments in high visibility clothing are LED lighting in jackets or on backpacks. Still under development is a "glow in the dark" helmet, which charges light during daytime and then lights up when it is dark.

There are several studies on high visibility clothing of motorcyclists. However, the literature shows different results, depending on time and location, concerning their effects on safety.

Wells et al. (2004), conducted a large-scale case-control study on the effect of conspicuity on crash risk for New Zealand motorcycle riders. Fluorescent or reflective clothing, wearing a white or light helmet were associated with a reduced risk of motorcycle crashes. Olson et al. (1981) conducted a gap-acceptance experiment in which they varied, among others, the clothing of the motorcyclists. They found that during daytime car drivers accept smaller gaps when the motorcyclist is not wearing fluorescent clothing. While driving in the dark, the same applied to reflective clothing. Acceptance of a small gap was interpreted as the driver being unaware of a dangerous situation.

In contrast, studies based on reaction time or detection rate measures do not show a general trend towards a better or quicker detection of motorcyclists when the motorcyclist was wearing bright clothing. These studies concluded that it is the contrast with the environment that is important (Hole et al., 1996; Rogé et al., 2010; Gershon et al., 2012). For instance, Hole and colleagues found that in urban environments observers responded quicker to motorcyclists with bright coloured or fluorescent clothing than to motorcyclists with dark clothing. This effect was reversed in rural settings, the observers responded quicker to motorcyclists wearing dark clothing. They concluded that this was due to the brightness of the environment: the environment in the rural setting was clear blue sky. As summarised by de Craen et al. (2011), the most important aspect of PTW conspicuity is contrast with the environment.

Some conspicuity-related crashes can be prevented with high visibility clothing, but certainly not all. Schematically, when riding through highly dense traffic, a rider should wear bright clothing. When riding mostly in open-space (cruising) a rider is better off wearing darker clothing. At night, reflective clothing could be more effective. This implies that it is not always that simple to let motorcycles 'stand out' more in traffic, and makes it difficult to give a single message to motorcyclists that applies in all traffic situations.

Neck braces

Neck braces are designed to bring the head to a gentle stop in the event of a crash which will minimise the possibilities of the injuries caused by extreme (forward/ rearward/ sideways) movements of the head. Neck braces are most commonly used by off-road motorcycle riders.

As of today, for road riders, neck braces may have more drawbacks than benefits, as the reduction in head mobility (in particular the ability to look over the shoulder and clear blind spots) creates a greater risk of crash, than the possible benefit the product could bring in the unlikely risk of a neck fracture.

Conclusions

The use of helmets with adequate safety standards should be promoted and regulated. The helmet is the most important source of protection against severe injuries and death for both motorcyclists and moped riders. A helmet reduces dramatically the risk of being killed or severely injured. Helmet can prevent damages to the brain, which may entail very severe physical and psychological handicaps.

All countries should have and enforce a helmet law. A 100% wearing rate is the only acceptable objective. Still, not all OECD countries have a national helmet law. Enforcement should not only focus on wearing but also on *proper* wearing of a helmet (i.e. with fastened chin strap).

Airbag jackets appear to be a promising technology to minimise injury to the rider in case of a crash. Further research is needed to evaluate their effectiveness.

Research shows different results regarding the effectiveness of high visibility clothing in reducing conspicuity related crashes, depending on time and location, concerning their effects on safety. In short, when riding through highly dense traffic, a rider should wear bright clothing. When riding mostly in open-space (cruising) a rider is better off wearing darker clothing. At night reflective clothing could be more effective.

While research into the benefits of protective clothing is unequivocal, there are some issues with mandatory requirements for protective clothing. Clearly there are benefits from the introduction of harmonised standards to support the global product production and distribution. On the other hand, there is a trade-off, if a minimum standard is imposed that results in a price on equipment that exceeds the rider's willingness, or ability, to pay. While the introduction of mandatory requirements imposes a cost on riders, and may therefore be subject to significant community opposition, any increase in the use of protective clothing through promotion to increase rider awareness has the potential to provide significant benefits.

Further research and development into clothing and equipment with lower weight and improved ventilation should be encouraged. Promotion of the benefits of protective clothing and consequently consumer awareness is likely to be one of the key levers of this.

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Chapter 7. Countermeasures targeting vehicles

The vehicle is an essential component of traffic safety and its quality of functioning is part of the basic measures to promote. This chapter highlights the importance of adequate maintenance. It then describes the current developments in vehicle technologies to improve the safety of riders. It focuses in particular on the potential of advanced braking systems, measures to enhance the conspicuity of powered two-wheelers (PTWs) and the visibility of the riders, measures to support rider behaviours and discusses the challenges regarding the development of intelligent transport systems.

Introduction

The vehicle is an essential component of traffic safety and its quality of functioning is part of the basic measures to promote. Two aspects are developed in this chapter, the first dealing with maintenance, the second dealing with vehicle technologies.

Developments in safety systems have led to significant improvements in survivability for car occupants; these improvements have however been more limited for motorcyclists, due notably to the lack of structure around the rider to protect from impact and to attenuate the forces. There has been limited demand in the past for motorcycles with enhanced safety features; however, this trend is changing nowadays with the introduction of safety equipment that can contribute to reducing the risk of crashes and their consequences. The sections below discuss vehicle safety systems, which are either already in the market or future concepts.

The terms "active" and "passive" safety are important terms in the world of automotive safety. "Active safety" is used here to refer to technology assisting in the prevention of a crash and "passive safety" to components of the vehicle that help to protect occupants during a crash. Systems such as Anti-lock Braking System and Traction Control are categorised as active safety features as they are acting when the vehicle is moving and step in whenever necessary to prevent a crash. A frontal airbag fitted on the motorcycle is considered a passive safety feature, as well as wearable inflatable devices, limb protectors, helmets and protective clothing.

The Vienna Convention on Road Traffic of 1968, establishing standard safety and traffic rules, includes a number of technical requirements regarding all motor vehicles, including powered two-wheelers (PTWs). For details on vehicle technical requirements, the Vienna Convention makes reference to UN Instruments for harmonisation of Vehicle regulations, in particular the 1958 and 1998 Agreements, managed by WP.29, the World Forum for Vehicle Harmonisation.

Vehicle maintenance and inspection

Adequate vehicle maintenance undoubtedly contributes to safety and manufacturers recommend service intervals for the optimal performance of the vehicle which are linked to the vehicle warranty. This is an incentive for the vehicle owner to follow the recommended maintenance intervals. Periodical technical inspection is a tool to make sure that vehicles on the road are in good technical condition and are safe for road use. But of course, countries developing an inspection regime should adapt regulations to meet national characteristics and needs. For example, the very highest standards of Periodic Technical Inspection (PTI) regimes may not be appropriate in territories where incomes and economies are a challenge.

Periodic inspection of PTWs has the potential to reduce the incidence of defects in the basic safety-related items, such as tyres, brakes, lights, etc. Even if some riders take care of the maintenance, others (e.g. urban commuters) may be less concerned with technical features. Periodic inspection is also an opportunity to check the conformity of rear-light indicators and registration plates, which is a prerequisite to enforce speeding and deviant behaviours; moreover it is likely to discourage tampering of PTWs (notably mopeds). In many countries, technical inspection of cars is compulsory to sell a second-hand vehicle. There could be interest in widening this measure to PTWs.

The current EU rules, which only set minimum standards for vehicle checks, date back to 1977, with only minor updates. The new proposals, published on 13th July 2012, aim to widen its scope and include powered two-wheelers in particular. The Commission proposes mandatory tests for PTWs four years after the date of registration, followed by a second roadworthiness assessment after two years, after which the test must be carried out every year. As of January 2014, this measure was not yet implemented and a decision has been postponed to 2022.

In 2012, in the European Union, about 10 countries had in place a compulsory technical inspection for motorised two-wheelers. Annual inspection is required in some Australian states, but not all. There is not a federal requirement for safety inspections of PTWs in the United States; a limited number of States require safety inspection of motor vehicles and PTWs.

Moped anti-tampering measures

Tampering consists of unauthorised modifications of the vehicle (air filter, carburettor, intake pipe, etc.) which may prejudice safety, in particular by increasing the maximum design speed and the engine power of the vehicle. Motivation includes: by-passing driver licensing restrictions; saving on road tax; saving on insurance premium; interest in customising and modification (Dittmar et al., 2003). Tampering may also have consequences on the environment (noise and increased emissions of air pollutants). In addition, in the case of a crash, the insurance may refuse to cover the damages. Parents should be made well aware of this fact and prevent their children from tampering with their mopeds.

This problem mainly concerns mopeds, and young people are particularly involved in these risky modifications to their vehicles. In OECD countries, significant amounts of PTW tampering offences are systematically reported. Tampering in order to increase performance was observed by visual inspection in 17.8% of all moped cases in the MAIDS study (ACEM, 2009). On the other hand, the exposure study showed tampering in 12.3% of controls.

No research is known about the effectiveness of anti-tampering efforts. However, tampering allows riding at higher speeds, without the rider having followed the proper training to do it and without the vehicle having the required technical specifications (e.g. brake system, suspension units).

In Europe, light motorcycles (<125cc) and mopeds have to comply with the requirements of Directive 97/24/EC relating to anti-tampering. Specific anti-tampering provisions have also been added in the UNECE regulation, some of the amendments are very recent and are still to enter into force. There are currently no measures in place for larger motorcycles, tricycles or quadricycles. In Australia, a moped that has been tampered with is then defined as a motorcycle, not a moped. In Australian states where moped use is allowed on a car licence, then the rider of a tampered moped who does not have a motorcycle licence would be legally an unlicensed rider and subject to sanctions.

Classification of vehicle technologies

There are several ways to classify the vehicle technologies aimed at improving the safety of motorcyclists. This chapter describes the safety technologies based on their functions (Table 7.1). It does not make a specific distinction between traditional technologies and intelligent transport systems as the frontier between both is sometimes vague. There is a specific discussion on the development of ITS later in this chapter.

Vehicle safety technologies can act on:

- Longitudinal and lateral dynamic control.
- Visibility of the riders and other road users.
- Warning of riders and other road users.

- Protection of the riders.
- Rider behaviour improvement.
- Localisation and communication of hazards.

Some of these technologies are already available, have been assessed and proposed as an option when purchasing the bike, while others are still at the development stage.

Table 7.1. **Classification of functions based on vehicle technologies**

Function	Technologies / Equipment	Development stage
Longitudinal and lateral dynamic control of the powered two wheeler	Advanced braking system, including: *Antilock braking system (ABS)* *Combined braking system (CBS)* *Amplified braking system* *Rear wheel lift off protection*	 Introduced in many models Introduced in many models Introduced in few models Introduced in few models
	Electronic Traction control	Introduced in some models
	Motorcycle stability control	New
	Anti Hop clutch system	Introduced in many models
Conspicuity	Automatic Headlamp(s) On (AHO)	Introduced in many models
	Daytime Running Lamps or Lights (DRLs)	Introduced in few models
	Alternative Front Light Patterns	Introduced in few models
	Amber Position Lights	Introduced in few models
Visibility	Adaptive front lights	Introduced in few models
	Advanced light source technologies	Introduced in few models
Hazard Warning	Speed alert	R&D phase
	Curve warning	R&D phase
	Frontal collision warning	R&D phase
	Lane changing information	R&D phase
	Blind spot monitoring	R&D phase
	Tyre pressure monitoring	Introduced in few models
Rider Protection	Airbags	Introduced in limited models
Supporting rider behaviour	Intersection safety assistance	R&D phase
Real time information hazard localisation and prevention	e-Call	R&D phase
	Weather, traffic and black spot information	Introduced in few models

Enhancing the longitudinal and lateral stability of PTWs

Advanced Braking Systems

Stability when braking is as important for motorcyclists as short stopping distance.

Advanced Braking Systems encompass several braking technologies including anti-lock braking system, combined braking system and amplified braking systems which are described below. This variety of “advanced braking systems” can make a positive contribution to motorcycle road safety. In the event of emergency stops the primary objective is to ensure that the vehicle remains stable or, in the case of combined braking system, to increase braking power in case of inadequate braking operation.

Antilock Braking System (ABS)

Description

ABS allows safer, mainly straight-line, braking by optimising braking distance and helping riders keep stability when braking hard (especially in wet conditions). It has therefore the potential to reduce the occurrence of PTW crashes and to attenuate their consequences. The system prevents the wheels from locking up by automatically modulating the brake pressure when the rider brakes hard. By preventing the wheels from locking, the system aids riders to maintain steering control which may reduce stopping distances in certain emergency conditions. ABS is technically suitable for most types of motorised two-wheelers, but in practice it is currently mainly available on the more powerful motorcycles. Analysing the top 10 motorcycles sold in Spain in 2011, only one model was equipped with ABS, while another one offered it as extra equipment. According to the Fédération Internationale de l'Automobile and Bosch (2011), the penetration of ABS has accelerated recently for PTWs above 250 cm3 (see Table 7.2).

ABS cannot prevent or mitigate all crashes, and neither can one expect the same level of benefits from ABS on crash risk for PTWs and passenger cars, especially when braking in a curve.

Table 7.2. **Recent evolution in the penetration rate of ABS on PTWs in Europe**

2007 and 2010

Engine displacement / Year	2007	2010
Less than 250 cm^3	Less than 1%	3%
Above 250 cm^3	26%	36%
Total	9%	16%

Source: Fédération Internationale de l´Automobile and Bosch, 2011.

Anti-lock braking systems have been evaluated in many experimental studies by the industry, research organisations and automobile associations. Some studies report a huge potential in reducing crash occurrence and crash severity. If all the fleet was equipped with antilock braking systems, one study estimated that about 25% of PTW fatalities could be avoided every year (see box 7.1).

It should be noted that all the studies on ABS were undertaken in industrialised countries, with mature traffic systems (in terms of traffic rules and regulations, infrastructure standards, licensing system, etc.) and involving mostly large displacement motorcycles. ABS, as other advanced technologies, may not be a priority measure to get obvious and immediate safety benefits in less developed countries.

Box 7.1. **Results of recent research on anti-lock braking systems**

Sweden: Compilation of ABS studies (Trafikverket, 2010)

- By fitting motorcycles with ABS brakes, the risk of fatality or serious injury in a crash is reduced by about 50%. At intersections alone, the risk is reduced by about 70%.
- The effect of anti-lock brake systems (ABS) is estimated to be a 40% reduction in all types of crashes that result in injuries.
- The overall effectiveness of ABS in Sweden was 38% on all casualty crashes and 48% on severe and fatal crashes. The minimum effectiveness ranged from 11% to 17%, respectively.
- The effectiveness on severe and fatal crashes in intersections was estimated to be at least 42%.
- Injury severity in crashes with ABS-equipped motorcycles is markedly lower than in similar one with non ABS-equipped motorcycles.
- Head-on motorcycle collisions are not, or only slightly, affected by ABS.

Germany, ADAC German Automobile Association

- Tests conducted by ADAC showed that the average brake distance was reduced by 25% when driving at 100 km/h (ADAC, 2000).

United States, NHTSA (2006)

- A research paper by NHTSA (Green, 2006 and NHTSA, 2006), studied the comparison of stopping distance performance for motorcycles equipped with ABS, CBS and conventional hydraulic brake system. It showed that motorcycles equipped with ABS provided all riders with the advantage of a high level of braking performance at the time of need. On the wet surface, the overall average stopping performance with ABS improved on the best non-ABS stopping distance by 5.0%. The stopping distance reduction with ABS was more significant when both brakes were applied, with an overall improvement averaging 10.8% over the best stops without ABS. The greatest stopping distance reduction with the use of ABS was observed when the motorcycle was loaded and both brakes were applied, averaging a 15.5% improvement over the best stops without ABS.

United States, Teoh (2013)

- Based on FARS data, Teoh (2013) found that the rate of fatal motorcycle crashes per 10 000 registered vehicle years was 31% lower for ABS models than for their non-ABS versions. Results of this analysis are similar to those of Teoh (2011) and indicate that ABS is proving to be effective as ABS begins to be offered on an increasing number of make/models. However, it should be mentioned that ABS was studied as optional equipment, so the cohort of motorcyclists who choose ABS may differ in some substantive way from those who decline to purchase it. In particular, motorcyclists who choose ABS may be more concerned about safety than those who decline, thus leading to lower fatal crash rates through other safer riding practices.

International study on the effectiveness of ABS on motorcycles in reducing crashes (Rizzi et al., 2013)

- While most previous research focused on the impact of ABS on the largest motorcycles, this study used police crash data from Spain, Italy and Sweden in an attempt to analyse a wide range of motorcycles and compare countries with different motorcycling habits (leisure and commuting).
- The effectiveness of motorcycle ABS in reducing injury crashes ranged from 24% in Italy to 34% in Sweden. The reduction of severe and fatal crashes was even greater.
- ABS on scooters with at least a 250 cm3 engine was found to reduce the involvement in severe and fatal crashes by 31%.
- The study recommends that manufacturers work toward a broad fitment of ABS on light scooters as well before 2016 in Europe (when ABS will become mandatory for all PTW above 125 cm3) and other regions.

Implementation issues

Costs

An antilock braking system represents a significant cost for the user (about EUR 500 according to the European Association of Motorcycle Manufacturers, ACEM), especially for the smaller motorcycles (see Table 7.3). Currently it is proposed as an option on vehicles in the medium- to higher-engine displacement category (usually above 300 cm^3). The industry has a role to play in anticipating a large penetration of this technology, in order to reduce the costs. In this respect, it is worth noting the commitment of ACEM, following a voluntary agreement in 2005, to introduce, at least as an option, advanced braking systems on more than 50% of street motorcycle models offered on the European market. This commitment was renewed in 2010, to extend the coverage to 75% by 2015. Preliminary results indicate that the manufacturers will be in a position to meet the commitment.

Table 7.3. **Share of ABS costs on end-users price in Europe**

Vehicle category	**<= 125 cm^3 (L3-A1)**	**> 125 cm^3 (L3-A2/3)**
Average price of the vehicle (EUR)	2837	8994
Cost of ABS (EUR 500) as % of average price	17.6%	5.6%

Source: London Economics, based on ACEM data in European Parliament (2012).

Light motorcycles and mopeds

ABS can also have a positive impact in the crash risk of the less powerful bikes. However, it will be challenging, in the short term, for this technology to quickly penetrate this market, unless it becomes mandatory. For light motorcycles (< 125 cm^3), CBS could be a useful alternative for a much lower cost (see below).

Need for training

Anti-lock braking systems need adequate training of the riders and complete information for optimal use of its wheel-lock prevention potential. ABS in itself is no guarantee of successful braking in an emergency. Braking in a curve produces forces on the steering system which must be corrected by the rider. For this reason ABS cannot be used whilst steering. Riders therefore have to learn the conditions under which ABS is effective, i.e. mainly when riding in a straight line.

Mandatory vs. optional

There is an open discussion on regulatory vs. non regulatory introduction of ABS in PTW vehicles. It seems clear that ABS improves braking potential but its regulation raises questions:

- Should ABS implementation be accompanied by mandatory training programmes?
- What would be the real ABS price, should it be mass-produced as per regulatory requirements?

Regulation

In the European Union, new type-approval rules that will make mopeds and motorcycles safer and greener by 2016 were approved by members of the European Parliament in November 2012. Under the new legislation, anti-lock braking systems (ABS) are required to be fitted to all motorcycles (over 125 cm^3), while motorcycles $\leq$125 cm^3 will have to be fitted with combined brake systems (CBS) (see description below). The legislation will take effect on 1st January 2016 for new type approval vehicles and on 1st January 2017 for all new vehicles. By the end of 2019, the Commission should present a cost-effectiveness analysis with recommendations as to whether the rules should be revised to make ABS mandatory for smaller motorcycles. A cost-benefit study commissioned by the European Commission and released in early 2012 (European Parliament, 2012) estimated that several thousand lives could be saved within 10 years by this regulation.

Creating demand

Demand and road user acceptance are central to the development of advanced braking systems on PTWs, and largely depend on the appropriateness of the solutions offered, technically and in terms of cost, to the specific PTW market segments and models. It is also important to educate customers on the benefits and limitations of ABS and to recommend this safety equipment (via association, riding school, media, etc.) in order to accelerate its quick adoption even before it becomes mandatory. Incentives to purchase ABS-equipped motorcycles, such as insurance discounts or scrapping programmes are also efficient to influence the choice of the motorcyclists.

Combined Braking System (CBS)

International and EU regulations require PTWs to be fitted with independent controls for the front and rear brakes. For motorcycle, this is usually in the form of a foot pedal for the rear brake and a front brake lever both on the right-hand side. Most automatic PTWs (which do not require a clutch control) have the rear brake operated by a lever on the left-hand side of the handlebars. In a CBS system, the application of one brake control actuates both front and rear brakes.

CBS could be promoted as a less expensive braking technology (compared to ABS) for smaller powered two-wheelers. It will become compulsory in the European Union in 2016 (for new type approval vehicles) and 2017 (for all new vehicles) on motorcycles below 125 cm^3.

The cost-benefit analysis undertaken in the European Parliament's impact assessment (European Parliament, 2012) concluded that CBS is appropriate for lower powered vehicles. CBS helps riders to brake more effectively and reduce their stopping distance by automatically braking on both wheels. It automatically applies braking force to both the front and rear wheels, enabling the rider to stop up to 40% quicker.

Other advanced braking systems

Other advanced braking systems are being researched and developed and include:

- ***Amplified braking system***: This system amplifies the activation input made by the rider, resulting in a more rapid deceleration. It enables a stronger braking pressure from the start of the braking procedure. This can be compared to the emergency brake assistance system in cars.
- ***Rear wheel Lift-off Protection (RLP)***. Certain PTW architectures can benefit from RLP, which detects if the rear wheel lifts during braking operation. This initiates a momentary reduction of the pressure in the front braking circuit.
- ***Brake by wire***. The system consists of an electronically controlled combined brake by wire system with an innovative stroke simulator. Direct motor control ensures precise operation of the ABS, resulting in reduced pitching and smooth modulated ABS intervention.

The advanced braking systems listed above offer a multitude of possible combinations, enabling manufacturers to develop the offer of a wide variety of solutions 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.

The benefits and limitations of the various Advanced Braking Systems vary significantly per type of vehicle. The weight, weight distribution, the centre of gravity and the rider braking behaviour have an influence on the braking capacity of the system.

The World Forum for harmonisation of vehicle regulations (WP29) has made significant advancements in the creation and updating of global braking requirements, now defined in GTR No. 3 and UN Regulation 78. While the UN Regulation No. 78 and GTR No. 3 have been adopted by many Contracting Parties (European Union, Russia, Japan, Australia, the United States; Canada, India, Russia, and South Korea), there remain many countries that have yet to consider adopting these regulations as well as harmonising their braking system to the latest standards.

Electronic Traction Control System

Electronic Traction Control is a technology now largely adopted for the passenger car market. A Traction Control System (TCS) has the potential to prevent the rear wheel from spinning uncontrolled when accelerating all-out and thus avoids any loss of side forces and stability which otherwise would make the rear wheel swerve out of control. Lift-off detection and intervention serves furthermore to prevent the front wheel from moving up when accelerating under full power (Anti Wheelie Control).

In reality, the principles of the systems cannot be the same for 2-wheeled and 4-wheeled vehicles: on a PTW, it acts more as an anti-skidding system; therefore one cannot expect the same benefits as from Electronic Stability Control (ESC) installed on cars which uses the same technology but which has the possibility to stabilise the vehicle by acting differentially on the left/right wheels on the same axle. Nevertheless TCS provides useful assistance, particularly on powerful motorcycles and when riding under conditions with slippery surfaces. TCS is a logical complement to ABS insofar as these two functions together enhance riding stability and control.

Electronic traction control system TCS can potentially reduce motorcycle crashes, notably single PTW ones (Seiniger et al., 2012).

Box 7.2. **Integral ABS, combining ABS and Electronic Traction Control System**

BMW has developed a new system, “BMW Motorrad Integral ABS”, which not only acts on the brakes but also intervenes on the dynamic control of the bike. The Integral ABS provides additional dynamic riding control systems with a reduction in technical requirements and features. The technology also opens up the option in the future for further rider assistance functions.

Motorcycle stability control

In 2014, a new advanced technology was introduced on high-performance motorcycles named motorcycle stability control. This highly advanced system is designed to allow a braking manoeuvre while cornering. It works on the basis of a combination of ABS, electronic CBS, a lean angle dependent traction control and lean angle dependent brake control. Motorcycle Stability Control detects critical situations, and instantly computes the best possible values for acceleration and braking.

Anti-hop (slipper) clutch system

This system is designed to partially disengage or "slip" when the rear wheel tries to drive the engine faster than it would run under its own power. The engine braking forces in conventional clutches will normally be transmitted back along the drive chain causing the rear wheel to hop, chatter or lose traction. This is especially noted on larger displacement four-stroke engines, which have greater engine braking than their two-stroke or smaller displacement counterparts. Slipper clutches eliminate this extra loading on the rear suspension giving riders a more predictable ride and minimise the risk of over-revving the engine during downshifts. Slipper clutches can also prevent a rear wheel lockup in case of engine seizure.

Vehicle technologies to enhance conspicuity of PTWs

Headlamp on

The lack of conspicuity of PTWs is a major factor in crashes involving PTWs. Driving with headlamp-on, including during daytime, has proven to be an effective measure to improve the conspicuity of PTWs and improve PTW safety (see summary by Wells et al., 2004, Umar et al., 1996; Yuan, 2000 and Elvik et Vaa, 2004). The 1968 Vienna Convention recommends the 80 signatory countries to implement the obligation for PTW riders to drive with the headlamp on during daytime.

Automatic Headlamp On for PTW (AHO)

To support riders to ensure that the headlamp is on, most PTWs are now equipped with Automatic Headlamp On (AHO). This is a switch that ensures the (main or dipped beam) headlight (or the Daytime Running Lamp if the vehicle is equipped with such lights) is always on when the engine is running.

AHO can be considered as a general practice in many parts of the world, though it is not applied everywhere. The general practice mainly results from mandatory application e.g. in the United States, and Japan, a voluntary introduction for all vehicles by ACEM, the European Manufacturers in 2003, and inclusion of headlamp-on provisions in 2005 in Regulation 53 for motorcycles and in 2009 in Regulation 74 for mopeds under the 1958 Agreement of UNECE WP.29. More recently in Europe, in November 2012 the European Parliament welcomed the same measure to improve the visibility of PTWs and riders introducing automatic switching on of the lighting when the engine starts, to be applicable from 2014.

A review of daytime running lights and headlamp on practice on motorcycles in 16 countries by Elvik et al. in 2003 concluded that laws and campaigns advocating their use had led to an average reduction of 7% in multi-vehicle PTW collisions. However hardwiring of motorcycle headlights (headlamp on) requirement for motorcycles in Australia introduced in 1992 was revoked in 1997 due to a lack of evidence of their effectiveness (which may have been an outcome of relatively small numbers of crashes making any effects difficult to detect).

The use of driving with Headlamps On during daytime by motorised two-wheelers has been shown to reduce visibility-related crashes in several countries by between 10% and 15%. In a study of 14 states in the United States with motorcycle headlight-use laws, a 13% reduction in fatal daytime crashes was observed (Zador, 1985). In Singapore, a study conducted 14 months after the introduction of legislation requiring motorcyclists to switch on their headlamps found that fatal daytime crashes had reduced by 15 % (Yuan, 2000).

Daytime Running Lights or Daytime Running Lamps (DRL)

Daytime running lights (DRL) are proposed as an option by some manufacturers. DRLs for motorcycles are bright white forward-facing lights designed to optimise the conspicuity of PTWs during daytime, while reducing the energy consumption in comparison to the use of regular headlamps.

There is, today, little research on the relative effectiveness – in terms of safety or energy savings – of daytime running lights for motorcycle compared to riding with the dipped beam headlight on during daytime.

There is an open debate on whether DRLs for all vehicles negatively affect PTW road safety. In many countries, some PTW advocacy groups are concerned over the potential for reduced PTW conspicuity with the introduction of headlamp-based DRLs on cars and other dual-track vehicles, since it means PTWs are no longer the only vehicles displaying headlamps during the day. Some studies claim that lights on passenger cars, with variant shapes, create a competing light pattern to the detriment of PTW identification within the traffic (Cavallo and Pinto, 2012). The question is still subject to debate. In any case, motorcyclists are better seen with headlamps on than without.

Alternative Front Light Patterns

Alternative front light patterns aim to provide a unique visual signature (signal pattern) that clearly differentiates them from other vehicles and may facilitate their perception by other road users. Such visual configurations as distinctive features can be implemented by varying the colour of the headlights (e.g. yellow) or by dedicated positioning and lay-out of PTWs' frontal headlights (e.g. T-light configuration, Long-Light-system by Honda, triangular configuration). The T-configuration uses vertical linear lights at the fork and horizontal ones at the rear of the mirrors. The headlight is positioned at the intersection of the two. Development and evaluation took place as part of the European 2BESAFE project. The T-design (consisting of five dedicated daytime running lights) was found to be the easiest to recognise because the design reflects the silhouette as well as the size of the motorcycle. A study from Pinto et al. (2014) suggests a better motorcycle-detection performance for such a configuration with a yellow headlight and the addition of a light on the helmet.

Advanced lighting technologies to enhance the visibility of the riders

Another recent technology is the adaptive front headlights which improve the illumination of the motorcycles path on curves. They ensure that the illumination from the headlight is projected on the intended path of the motorcycle when cornering by adjusting it in accordance with the speed and position of the PTW. Improving the illumination of the path of motorcycles improves the sight of motorcyclists and can therefore lead to a reduction of PTW crashes.

Warning devices

Speed alert

A speed alert system refers to an informative Intelligent Speed Adaptation (ISA) system that uses information on the position of the vehicle in a network in relation to the speed limit in force at that particular location to warn the rider (visibly and/or audibly) that the speed limit is being exceeded. The rider then decides whether or not to slow down.

There is also research on active ISA that would automatically increase the required pressure on the accelerator when the speed limit is exceeded (the 'active accelerator'). Apart from the technical challenges, the introduction of active ISA may not be well accepted by riders because intervention on brakes/throttle during cornering or other manoeuvres can perturb the rider's control.

Curve Warning

The Curve Warning function provides the rider with a warning signal when the motorcycle speed is too high in relation to a curve ahead. The safe speed is estimated in real time by comparing the PTW speed and acceleration to the road profile and map based information, such as the presence of critical locations (e.g. intersections, pedestrian crossings, etc.).

The Curve Warning function provides continuous feedback about possible acceleration, i.e. the system intervenes when the rider accelerates in a way that makes it impossible to hold the optimal and safest riding line. In order to work efficiently the system requires the rider's acceptance and immediate reaction that would lead to safe deceleration and curve negotiation.

Frontal Collision Warning

The Frontal Collision function aims to warn the rider when an obstacle has been detected in the headway of the PTW and a collision is likely to occur. The Frontal Collision Warning function will not only detect obstacles, but also evaluate the severity of the encounter.

This function is made of two functions: the Safe Distance and the Safe Relative Speed/Path. The former warns the rider if the distance is too close compared to the calculated reaction time, while the latter alerts when a prompt correction is suddenly needed but the rider seems not to react to an imminent collision. By producing the alert, the riders' attention is refocused on the headway and they have time to react adequately by braking or an evasive manoeuvre.

Lane Change Support and blind spot monitoring

Lane Change Support (LCS) aims to alert the rider in case of an imminent lane change that may cause a collision with another vehicle. PTWs have large blind spots due to their small mirrors and small gap. Thus, dangerous situations are quite likely to occur when motorcyclists miss another vehicle while changing the lane. In blind spot monitoring systems, the rear/lateral surroundings of the motorcycle is monitored by a radar sensor that provides information about the speed and position of oncoming vehicles. This information is used to assess how critical could be the lane change. In the event that the rider activates the indicator to perform a lane change, if another vehicle is approaching and it is in the blind spot, the rider is informed about the potential risks by an appropriate HMI (usually by different colour lights on the top of the left mirror).

Tyre Pressure Monitoring Systems

Riding is a task which requires appropriate maintenance of the vehicle; poor maintenance of tyre pressures may impair the vehicle's safety and therefore lead to unexpected vehicle dynamics. Many PTWs are often unused for weeks and tyre pressure is likely to significantly decrease during this period. While vehicle failure is rarely cited as a causal factor of motorcycle crashes, mechanisms that detect and alert the rider of potential problems will contribute to motorcycle safety. These systems will be especially relevant to infrequent riders who may not regularly maintain their vehicle.

Tyre Pressure Monitors give indication and assurance to the driver that tyres will perform according to manufacturer's standards. There are a number of tyre pressure monitors on the market which provide either a visual or an acoustic warning of falling tyre pressures. The least expensive ones (though less accurate and durable) are Flag Indicating Tyre Pressure Monitors, which are fitted on the tyre valve externally by removing the existing valve dust-cap and screwing the indicator in place. Also available are Digital Tyre Pressure Monitor Systems, which use internal wheel mounted pressure sensors.

Improving rider protection

PTW airbags

Airbags absorb the kinetic energy of the vehicle occupant during a crash, reducing injury severity. Airbags inflate when triggered by impact sensors in the front wheel/s, and are relevant to all frontal impact crashes. Airbags for motorcycles requires special design as they need to take into account that the position of the rider is not always upright such that there may be smaller distances between the rider's face and the airbag than that typical for car drivers, and that the presence of pillion passengers will affect the forward force of the rider.

Computer modelling and simulated crashes conducted as part of the ROSA project suggest that these systems can help reduce consequences of the impacts of the rider in a majority of collision configurations. Nevertheless, no data from real crashes have been monitored.

The resulting injuries will depend on "the speed of the PTW, the type of PTW, the seating position of the rider, the angle and point of collision against the car and the type of car". Only a limited number of these variables have been included in such tests. For this reason, it is difficult to decide how effective devices such as airbags are in practice. It seems that a combination of such devices will be needed to prevent injuries in a number of types of collision but could also have adverse effects in others.

Apart from the Honda Gold Wing, airbag systems have not been adopted by any other manufacturers, so its fleet penetration is very limited.

Supporting rider behaviour

Intersection Safety

Intersection safety (INS) assists the driver in avoiding common mistakes which may lead to typical intersection crashes. It covers the following functions:

- Traffic light assistance: preventing red light ignoring. The system emits an urgent acoustic warning if the situation becomes critical.
- Right-of-way assistance: The right-of way assistance pays special attention to lateral traffic. The system warns the driver if violating a right-of-way, but also if somebody else is expected not to give the right-of-way to the case vehicle.
- Left-turn (right-turn) assistance: The left-turn (right-turn in left-hand-side countries) assistance warns the drivers about potential collision with other vehicles with crossing path.

Real time information, hazard localisation and prevention

Warning system in case of a crash (e-Call)

When a road crash occurs, the rapidity with which rescue services are mobilised is of utmost importance for saving lives or reducing the effects of injuries. In the event of an emergency situation, such as a crash, a warning system can considerably reduce the response time of the emergency services.

The warning can either be generated manually by vehicle occupants or automatically via activation of in-vehicle sensors when a crash occurs. The in-vehicle system directly establishes a connection with emergency services and sends crucial information, such as time and location of the crash, as well as information about the vehicles involved.

Within the European Union, a system by the name of e-Call is currently under development. This system should become compulsory on all new cars sold in 2015. A Finnish study (Virtanen et al., 2006) assessed the impacts of e-Call on crash occurrence and found that the system could prevent up to 10% of road deaths. It showed that e-Call is expected to have the biggest effect in rural roads, at night-time in off-peak traffic. A version of e-Call could be proposed by the European Union for PTWs, but this would most likely happen in a second stage.

Adapting e-Call to PTWs requires specific research and development in order to develop an "on-vehicle" system that is weatherproof, resistant to increasing vibration and with a triggering system that judges the dynamic of the vehicle so as to avoid false alarms.

Weather traffic & Black Spot information

The Weather, Traffic & Black Spot Warning module integrated in the Navigation System can provide useful information to PTW riders about weather and traffic conditions. Navigation indications provide a familiar and reliable reference for the rider as riding-related information. It is employed with a double objective: it provides a tool to support the rider in planning the route as well as finding the best alternative in case of change based on traffic or weather conditions.

Black Spot Warning can alert the rider and provide information about specific spots on the planned route where crashes are more likely to occur: relying on accurate understanding of crashes scenarios, the system could effectively inform the rider about a potential danger, i.e. if the rider approaches a junction with high crash risk associated to it, a warning could appear.

Safety devices on other vehicles impacting PTW safety

Other vehicles are involved in about half of PTW serious casualty crashes (ACEM, 2009). Many of the high risk traffic situations between other vehicles and PTWs could be prevented if the drivers anticipated the presence of a PTW (when entering or crossing a road, when turning left and when changing lanes). There are a number of new technologies, such as forward collision warning, blind spot information and vulnerable road user protection systems, which can prevent collisions, in general including those with PTW riders, pedestrians and cyclists.

Blind Spot Information Systems (especially for heavy goods vehicles)

The BLIS detect vehicles and possible-colliding objects in the blind-spot area, on both right and left side, by computer vision techniques. Once possible-collision objects enter the blind-spot area, the system raises a pre-collision alert, which consists of an LED light and buzzer. The system has been adopted by both car manufacturers and heavy vehicle industry.

Lane departure warning

Certain lane-changing crashes could be prevented if drivers are warned of vehicles in their blind spots. As a number of crashes involving a car and a PTW involve a wrong decision by the driver on lane changing manoeuvre, it is anticipated that this technology will also contribute to reducing PTW crashes.

VRU Detection Systems

The sensor systems (often a combination of several sensor types) monitor the area in front of the vehicle, detect vulnerable road users and distinguish them from other obstacles. The systems use different actuators which help avoid collisions or significantly mitigate their impact by reducing the speed of the vehicle before the collision. The systems can combine visual and acoustic alerts and even actively take actions by means of autonomous braking systems. They commonly use forward-looking sensors to predict emergency situations. If this is a case, they inform the driver of the potential danger (if there is enough time for the required evasive action) and in case of limited time or no driver response, the systems activate the brakes of the vehicle shortly before the predicted impact. In the case where the crash cannot be avoided, the reduction in the impact speed will mitigate the VRU injury severity.

Such a warning device was designed in the WATCH-OVER project, which is based on the cooperation of communication and sensor technologies. It provides users with an in-vehicle module to warn drivers of approaching vulnerable road users (VRUs) on the one hand and wearable modules that call the attention of VRUs to critical traffic situations on the other hand.

Another example of VRU detection is the Night Vision Warning (NVW) system. Its aim is to extend the visible range for a driver in darkness, including obstacle detection and warning. This is achieved by using an infra-red camera, looking forward, and displaying its view on a screen in the vehicle. The display shows the area in front of the vehicle with a longer range of visibility than with the normal headlights beam. It detects and warns for obstacles and vulnerable road users if a critical driving situation is identified.

Post-impact safety systems

If a collision cannot be avoided, protective structural actuators can be triggered which reduce the chance of serious injuries or even save the lives of vulnerable road users. The pop-up bonnet was designed for pedestrians but this innovation in vehicle design could protect all VRUs who are hit by the front of the vehicle. Pop-up bonnets are designed to rise in a crash involving VRUs to soften the crush, absorb the head impact energy, and reduce the severity of the injury. Several manufacturers are developing these systems, which are often combined with external airbags.

Considering ITS technologies as motorcycle safety countermeasures

Some of the measures described above are considered as "Intelligent Transport Systems" (ITS). ITS technologies have the potential to improve the safety, security and efficiency of surface transport systems, in particular at high risk locations for PTWs such as intersections. To benefit from opportunities offered by ITS, much care is needed in a number of interoperability issues to ensure that the various systems are co-ordinated, as well as in managing the quantity of information that the road user operating a vehicle can safely handle.

Safety research addressing the development and application of ITS technologies has focused primarily on passenger vehicles and has not been vigorously developed or applied to motorcycles. Nevertheless, existing and emerging ITS research results have the potential to be adapted to motorcycles. The two research areas below have the potential to significantly contribute to such applications.

There are two main categories of ITS:

- *Vehicle to Vehicle (V2V) communication system* consists in the dynamic wireless exchange of data between nearby vehicles that offers the opportunity for significant safety improvements.

The vision for V2V is that eventually, each motor vehicle on the roadway (inclusive of automobiles, trucks, buses, motor coaches, and motorcycles) will be able to communicate with other vehicles and that this rich set of data and communications will support a new generation of safety applications that will enable crashes on the roadway to be prevented.

- *Vehicle-to-infrastructure (V2I) communications system* is the wireless exchange of data between vehicles and highway infrastructure, intended primarily to avoid or mitigate motor vehicle crashes but also to enable a wide range of other mobility, and environmental benefits. V2I communications apply to all vehicle types and all roads, and transform infrastructure equipment into "smart infrastructure". One particularly important advance is the ability for traffic signal systems to communicate the signal phase and timing information to the vehicle in support of delivering active safety advisories and warnings to drivers.

During the last decades, ADAS (Advanced Driver Assistance Systems) and IVIS (In-Vehicle Information Systems) development have been some of the main research areas of the automotive industry in order to increase safety and comfort of cars. As a consequence, these technologies have already been explored for passenger cars, whereas the application of such devices on PTWs (so-called ARAS – Advanced Rider Assistance Systems, and OBIS – On-Bike Information Systems) in order to increase the safety and comfort of riders, is still at the early stages of development.

In Europe two major projects, funded by the European Commission, have focused on enhanced vehicle equipment. The SAFERIDER project aimed at studying the potential of ADAS/IVIS integration on motorcycles and at developing rider-friendly interfaces. The ROSA project developed a Handbook on Good Practices in Safety for Motorcycles, with one volume dedicated to "Vehicles". The information contained in the sections below is partly based on deliverables from these two projects.

A number of specific challenges face the development of ITS for motorcycles:

- The human-machine interface (HMI) requirements of the motorcycle are hugely different from passenger cars. The driving task requires more instantaneous attention and the possibilities to provide visual or audio information in a safe manner are limited due to the position of the dashboard, the helmet and the background noise experienced by the motorcyclist. Compared to car technologies, the specifications of the hardware need to be more resistant to vibration, have lower levels of electric consumption and be water resistant. In addition, the system must adapt to much-reduced fitment space.
- A system that removes or interferes with the longitudinal or lateral control of the vehicle, such as automatic braking, could destabilise the rider and his machine, potentially causing, rather than preventing, a crash.
- The impact of systems that intervene in the riding task is quite different from passenger cars and requires specific R&D. Stability is critical on a motorcycle and imposes very different constraints compared to four-wheeled vehicles. The process of deployment of Advanced or Automatic Driver Assistance Systems (ADAS) is extremely complicated, notably due to the leaning behaviour of motorcycles.

Some motorcyclist groups have expressed concern about the potential for ITS technologies to automate aspects of the riding task or to compromise rider safety. It is essential that the view and needs of the motorcyclists be properly understood and researched and this knowledge be used to develop the design of ITS devices, which are acceptable to them (Bayli et al., 2006).

Regional conditions are an important element to be considered in assessing the potential and successful fitment of advanced technologies. For example, the traffic composition, the road environment, the quality of the infrastructure, and the regional economy are important factors to be analysed.

It should be understood, before fitting vehicles with advanced technologies in regions where the basic road safety provisions for PTWs are not widely applied (such as adequate infrastructure quality, helmet wearing, headlight and rider training and policies), that the benefits of such systems are likely to be limited.

Creating demand for vehicle safety equipment

The penetration of safety technologies on passenger vehicles has benefited from such projects as new car assessment programmes in various countries which rate vehicles based on their passive road safety performance. Recently, active safety functions have also been included in these programmes.

A similar approach could be usefully applied to new motorcycles with a dedicated assessment programme to provide information to consumers, although it should be remembered that improving the passive safety of PTWs is extremely complex, as the rider becomes separated from the vehicle in many crashes. Consumer assessment programmes of the safety performance of motorcycles on the market could be a way to raise consumer awareness of the safety features of motorcycles and influence their choice when purchasing a new vehicle.

However, more research is needed on the development of appropriate and feasible crash test and safety assessment of motorcycles, taking into consideration the existing standards, such as ISO 13232, whilst being aware of the challenges in selecting crash tests which are truly representative of the reality and diversity of crashes.

Conclusion

Adequate vehicle maintenance undoubtedly contributes to safety, and manufacturers recommend service intervals for the optimal performance of the vehicle which are linked to the vehicle warranty. Periodic inspection of PTWs has the potential to reduce the incidence of safety-related defects of the tyres, the brakes and the lights.

There are a number of developments within the motorcycle industry for technologies to assist in the prevention of a crash (active safety) and to contribute to protecting occupants and riders during a crash (passive safety). Some are already available and proposed as an option when purchasing the bike, while others are still at the development stage.

Advanced Braking Systems, which include Anti-lock Braking System (ABS) and Combined Braking Systems (CBS), are a well-proven technology which can contribute to reducing crash risk in certain situations when other, basic, road safety policies are in place. While ABS is currently offered as an option on new high-end bikes of major PTW manufacturers (with a slow penetration rate in most OECD countries) the Working Group considers that it can certainly benefit all PTWs and should become a standard. Cost is, however, an issue, and industry and government should work together to facilitate a quicker penetration of these technologies, which will become mandatory in some regions in the coming years (expected in EU for the year 2016). While this technology is mature for OECD countries market, there might be other priorities in low- and middle-income countries especially for the light motorcycles, such as basic braking regulation, or in other fields the generalised use of helmet, training of riders and development of adequate road infrastructure.

Other advanced braking systems, such as Brake by Wire, Combined Braking System, or Rear Wheel Lift-off Protection, may also contribute to reducing injury risk, but the priority today is to continue ensuring the penetration of ABS in the fleet.

There is a consensus that there has been little advancement of intelligent transportation systems (ITS) research dedicated to motorcycle safety. ITS, developed for motorcycle, offer opportunities to improve the safety of the rider as well. There is, however, a number of obstacles specific to PTW that need to be carefully addressed, including the challenges posed by the Human Machine Interface requirements, costs, and the required support from the motorcyclists community. In spite of these obstacles, ITS definitely has a role to play in increasing motorcycle safety in the future. e-Call, blind spot detection, curve and collision warning systems are suitable applications for the motorcycle – once sufficiently developed for them. Successful implementation and wide deployment of ITS depends on close cooperation between various key stakeholders.

Whatever the potential of vehicle technologies to improve safety, it remains critical that drivers and riders do not become over-reliant on safety technologies for warnings of potential dangers. Training and education, and the continued enforcement of traffic rules are also important factors for safer road use.

Promoting safety equipment of vehicles is also necessary. The development of an assessment system for new motorcycles could be interesting to explore as a way to raise awareness of motorcyclists of the safety performance of vehicles and creating demand for safety devices.

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Chapter 8. Countermeasures targeting infrastructure and traffic management

The quality of the road layout and adequate traffic management play an important role in powered two-wheeler (PTW) safety. This chapter reviews the general principles for a safe infrastructure which takes into account specific needs of PTWs. It describes good practices for road infrastructure design and management. It highlights the potential of traffic calming and other traffic management measures.

Introduction

As shown in Chapter 4, powered two-wheelers (PTWs) are by their nature very sensitive to environmental influences including weather and infrastructure conditions. The same element of perturbation which is easily mastered by a car driver can quickly become problematic for a PTW operator.

The road environment has a significant influence on the risk of crashes involving PTWs. Contributing factors include: road surface defects (such as unevenness, potholes or debris on the road); presence of slippery material (water, oil) on the road; road markings with insufficient skid resistance or use of raised pavement markers; poor road alignment; presence of obstacles, roadside hazards and safety barriers, and interaction with other road users (including heavy vehicles, cars, cyclists, pedestrians and other PTWs).

As a consequence, the quality of the road layout and adequate traffic management play an important role in helping riders in mastering their vehicles, preventing loss of control, and influencing interactions with the other road users. Infrastructure determines and organises the way road users interact. The road layout has an important impact on the harmony and efficiency of the interactions between road users, specifically between cars and PTWs drivers. More particularly, it can condition the capacity of car drivers to detect the PTW, and favour a driving speed conducive to safety, both elements recognised as critical in crashes involving PTWs.

General principles for safe infrastructure

PTW-friendly road design, maintenance and infrastructure generally benefit all road users. The aim is to ensure that the safety of PTW riders is considered in the design and maintenance of roads and the implementation of traffic management plans.

When constructing new infrastructure, many elements can contribute to safer roads for motorcyclists. Special consideration also is required during periods of construction when temporary construction materials are used. The road surface properties during the works can be hazardous for motorcyclists. The following sections describe general principles for the construction of new infrastructure or the maintenance of existing ones. Several infrastructural measures are easy to implement at a relatively low cost (e.g. removal of dangerous and unnecessary obstacles, installation of motorcyclists protection systems on existing guard rails, road markings with increased skid resistance, etc.). These measures also have an immediate effect.

Self-explaining / Readable roads

A consistent road and road environment invite road users to adopt the appropriate behaviour. A self-explaining road allows road users to anticipate changes in the local road context.

A road should be readable; road users should be able to identify the trajectory of the road and any hazards eventually present. To allow appropriate anticipation and to avoid sudden manoeuvres, potentially dangerous situations should be easy to identify. Signing should be sufficiently visible and not contradictory with other signs or with the road context (CERTU, 2011).

Visibility

Due to their smaller frontal size, PTW are more vulnerable than other motor vehicle to any kind of visibility obstructions, whether linked to the presence of vehicles, vegetation or traffic signs, etc.

To allow road users to adapt their behaviour to others, sufficient visibility is crucial. Obstacles that potentially obstruct the visibility should be avoided or removed. In particular in the vicinity of intersections or in curves, it is important that road users are able to detect others, including PTWs (CERTU, 2011).

Forgiving roads and roadsides

All road users make errors. A Safe System should compensate for human errors. This involves first the possibility for road users to correct their errors without further consequences and secondly to mitigate their consequences when the crash cannot be avoided (see following section for more detail).

Road infrastructure design and management

Product and testing standards, which are referenced in the technical specifications for road works, should also be relevant for PTWs. Commonly used standards in the domain of road construction usually contain characteristics that are relevant for this group of road users (visibility, skid resistance, evenness, ...). Guidelines used by road engineers should correctly reference these standards and include recommendations on correct use of these, while taking into consideration the local conditions.

In several countries, road administrations and other stakeholders have developed road design and maintenance management guidelines to improve the safety of PTWs (e.g. ACEM 2006, MOW 2008, IHIE 2010, CERTU 2011).These guidelines have many principles in common, which are described below.

Road infrastructure and PTW interaction

The stability of a PTW is particularly influenced by the road geometry and road surface characteristics. For example, curves with a small or variable radius (especially decreasing radii) require more skills from the rider. When such situations are combined with insufficient grip (due to road surface defects, road markings without appropriate skid resistance, debris on the road surface, pollution, etc.), hazardous situations can arise. On straight sections also, PTW stability requires sufficient and consistent grip to the road surface. A number of measures can be implemented to prevent hazardous situations connected to the infrastructure such as good paving material, appropriate road markings, regular road maintenance, etc. (see examples in Box 8.1).

Box 8.1. **Infrastructure related issues and possible solutions**

- **Skid resistance**

Some paving materials offer better and more durable skid resistance then others. Specifically in wet conditions, natural stone, wood or steel (for bridges) should be avoided when possible or clearly indicated (e.g. tramway rail).

Large surface road markings (including markings at pedestrian crossings) with insufficient skid resistance can be a problem. Road authorities are encouraged to develop guidelines for the required skid resistance; monitor this characteristic and take action when skid resistance drops below the acceptance level. Solutions that allow a rider to avoid the marked area (without dangerous manoeuvres) are also good.

The use of objective test methods to monitor the grip/skid resistance and the implementation of acceptance criteria for sections where this characteristic plays an important role (bends), should be encouraged.

- **Road surface defects and hazards**

Road surface defects (rutting, potholes…) have a negative influence on grip. Regular maintenance is essential to prevent these defects. Immediate repair is desirable, otherwise warning signs should be posted.

Box 8.1. **Infrastructure related issues and possible solutions** *(cont.)*

Elements of the road surface (such as gully tops, rails, etc.) can confront riders with a sudden grip change because of their nature or because of inappropriate installation (level difference). Remedial actions or appropriate warning are desirable.

Sudden changes in road surface characteristics are always a hazard but especially in zones with regular braking and accelerating, and should be avoided.

Contamination of the road surface (oil spills, gravel, mud caused by road works, lost charges, etc.) reduces local skid resistance and may lead to hazardous avoidance manoeuvres.

- **Road geometry**

Bad road design can contribute to a loss of control (change in the curve radius, lack of visibility) and/or excessive speed.

The entry angle of a roundabout should not be too low (to ensure that the PTW is visible) nor too high (to avoid excessive speed).

Safe intersection design

As noted in an earlier chapter, PTW crashes are more likely than car crashes to occur at a junction (intersection or roundabout) and the severity of these crashes is higher than for other road users (CERTU 2010). Given that many of these crashes result from drivers failing to give way to PTWs, designs should minimise the likelihood that PTWs are obscured by signs, vegetation or other objects. In addition, vehicle detectors at traffic signals should be calibrated to allow reliable detection of PTWs (or specialised equipment installed).

Roundabouts are not as beneficial for vulnerable road users as car occupants, particularly due to a high proportion of single vehicle crashes (Daniels et al., 2010; De Brabander and Vereeck, 2007). Nevertheless recent injury data from Sweden revealed that the risk for PTW riders to sustain a severe injury is reduced by half in roundabout when compared to conventional intersections in urban areas. To maximise the performance of round-abouts in location where there are high numbers of PTWs, attention should be paid to removing any obstacle on the roundabout, improving skid resistance and moderating PTW entry speeds by ensuring that roundabouts are sufficiently visible (particularly at night).

Obstacles and clear zone

An impact with a roadside obstacle increases the severity of the crash. Different measures are possible to reduce this impact severity, the best of which is to avoid potentially dangerous obstacles.

As already mentioned, all road users make errors. For different reasons a vehicle can leave the road. A small recovery zone next to the outer lanes and without any obstacles, allows riders to correct minor errors without further consequences. In case the road user is not able to correct his or her error he or she will end up in the verge next to the road. The zone that needs treatment is often identified as the “clear zone”.

To avoid fatalities or severe injuries, aggressive obstacles (trees, posts, ditches, etc.) within a short distance of the roadside should be avoided. Such obstacles can be treated, removed or moved further away from the road border in order to reduce the risk of an impact. For some types of road equipment (lighting, sign posts), the market offers alternatives that are less aggressive when impacted. Unfortunately these alternatives have only been evaluated for car impacts. However, crash absorbing devices, designed to attenuate collision impact, remain an obstacle, which can be a threat to PTW riders above a certain impact speed.

Countries are encouraged to develop guidelines for the recovery zone and the clear zone which also take the safety of more vulnerable PTWs into account and to promote the implementation of these principles.

Vehicle restraint systems

When potentially aggressive obstacles in the clear zone cannot be avoided, the last option is to isolate road users from these obstacles by the installation of a vehicle restraint system. Today these systems are tested according to standards such as the European Standard (EN 1317) and are usually very effective in containing cars without too severe injuries for the occupants.

However, some of these installations can be extremely aggressive for PTW riders. Guard rails with unprotected posts are a real danger for motorcyclists. Recent research, however, did not reveal significant differences between wire-rope and other type of discontinuous guard rails (Rizzi et al., 2012). In general, the position of the motorcyclist when impacting the guard rail influences more the overall outcome of the incident.

The European research project 2BESAFE (2010) recommends using crash barriers that allow a falling motorcyclist to slide along the surface of the barrier without hitting objects that concentrate the collision energy. For guard rails several solutions exist to protect sliding motorcyclists from impacting the exposed posts (or other obstacles behind the guard rail). Today, CEN/TS 1317-8 offers an objective evaluation method for the sliding impact scenario. Future developments should also include other crash scenarios. 2BESAFE further recommends that priority is given to improve barriers/guard rails that are located in sharp curves or on motorcycle crash black spots.

For road restraint systems to perform correctly it is important that they are properly installed. The installation instructions from the manufacturer of the system need to be respected. Incorrect installation or damaged systems that are not properly repaired will not function as expected and can be an additional hazard.

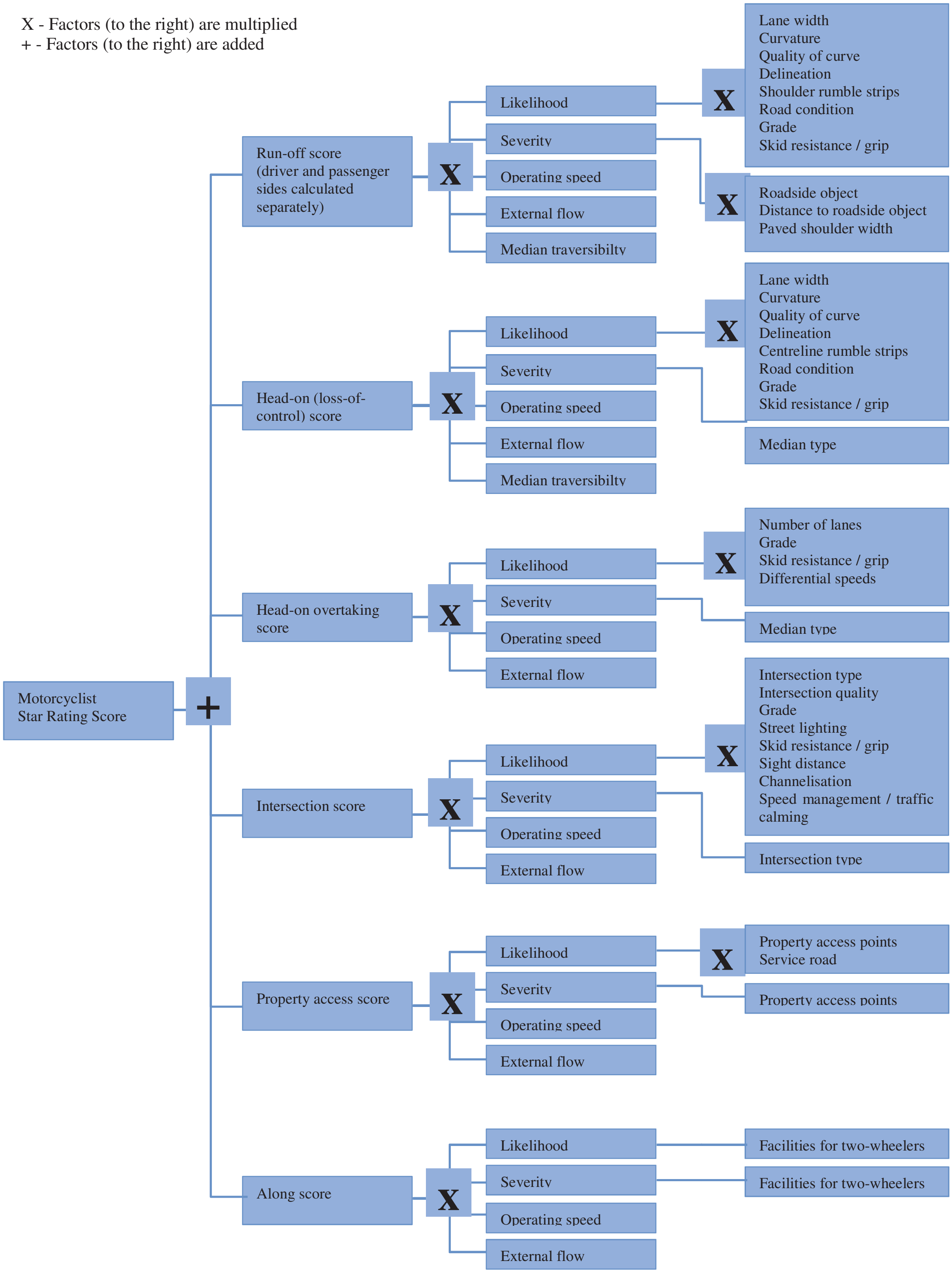
Road safety audits and inspections

Regular audits are useful and are conducted in most countries. Although essential, a focus on PTWs is not always included in these audits. More attention could, for instance, be given to the anti-skid properties of the road (European Road Federation, 2009).

iRAP offers tools to assess road risk. iRAP Star Ratings are based on road inspection data and provide a simple and objective measure of the level of safety which is ‘built-in’ to the road for vehicle occupants, motorcyclists, bicyclists and pedestrians. Five-star roads are the safest while one-star roads are the least safe.

The motorcyclist Star Rating is generated from the Star Rating Score (SRS), which in turn is based on an assessment of the road infrastructure elements that influence the main types of crashes of motorcyclists (run-off the road, head-on collision, intersection and sideswipes). The motorcyclist Star Rating Score is the sum of the score for the different crash types, which are in turn of function of likelihood, severity, operating speed and external flow influence functions (see Figure 8.1).

Figure 8.1. **Motorcycle SRS equations**



Source: IRAP

Traffic calming measures.

Excessive or inappropriate speed is one of the main risk factors for PTW crashes. Speed is both a contributing factor and an aggravating factor in crashes. Traffic calming measures are very effective in reducing the number of crashes. They aim at lowering the speed of all motorised vehicles by intervention on the road design or actions to influence traffic. These measures have proven their effectiveness to improve safety, including the safety of PTWs (OECD, 2006); but require careful design to benefit PTWs.

Road design and equipment

Road design and equipment dedicated to moderating speeds are useful in reducing the speed of all vehicles including PTWs. All traffic calming measures benefit all road users as long as they are properly designed.

Special attention is required in the choice of location and materials and in the lighting and maintenance of these devices. The consequences of poor design and maintenance can be harmful for riders, defeating the purpose for which traffic calming is intended (IHIE, 2005). For example, measures such as speed humps and small vertical obstacles used to moderate speed in urban areas can negatively influence the grip of a motorcycle to the road surface and can also cause the destabilisation of the motorcycle; they should therefore be preceded by a non-vertical speed reduction feature (e.g. horizontal marking) and placed at a reasonable distance from junctions to allow riders to pass them perpendicularly.

One alternative is to introduce perceptual countermeasures to create cues, usually visual, to encourage riders to slow down by increasing the perception of speed or by increasing the apparent curvature of bends. However further research may be warranted, particularly targeted at isolated locations where there are risks due to overestimation of appropriate speeds, such as curves with tightening radii.

30 km/h zones

30 km/h zones are widely implemented in urban areas and have largely proven their effectiveness in reducing speed and the number of crashes and improving the quality of life for residents. There is less research on their specific impact on PTW speeds and crashes. Webster and Mackie (1996) observed that implementing 72 traffic-calming schemes (20-mph zones) in Great Britain led to a reduction of approximately 60% in the average annual crash frequency in these zones. This reduction was 73% for crashes involving PTW users.

Vehicle –infrastructure interaction

More targeted interventions can include electronic signage to detect motorcycle approach speeds and provide a visual warning to those travelling at higher speeds that they are approaching a hazard, such as an intersection. Victoria, Australia is currently trialling a number of locations with such treatments. However, evaluations have not yet been completed.

Other traffic management measures

Segregation of PTW traffic

Specific lanes for PTWs

Provision of separate lanes where there are large numbers of PTWs can reduce the potential for conflicts with larger vehicles. Motorcycle lanes can be ‘inclusive’ or ‘exclusive’. Inclusive lanes are installed on an existing road and are separated from the main road by painted lines or physical barriers. Exclusive lanes are completely separated roads and minimise crash risk at intersections.

The world's first exclusive motorcycle lane was constructed in the 1970s in Malaysia where the concept has progressively expanded. In this country, PTWs make up more than 50% of the motorised vehicle fleet and 60% of road fatalities. According to Radin Umar et al. (2012), the introduction of such exclusive motorcycle lanes led to a reduction of 39% in PTW crashes. Depending on local circumstances, and in particular the proportion of vehicles that are PTWs, it can be considered a highly successful and cost-effective measure, because it eliminates conflicts with heavier vehicles and notably reduces speed differentials (where they previously occurred). However, further research is needed to assess the economic and technical feasibility of such exclusive lanes under different social and economic environments.

Use of bus lanes by PTWs

Allowing PTWs to travel in bus lanes is not necessarily a measure to improve safety, but rather to improve traffic flow. It has safety implications, however. Several cities have allowed PTWs to use bus lanes, including London, Oslo, Norway and Madrid. Other cities are opposed to such a measure.

The layout and operation of bus lanes varies markedly depending on road space, traffic volumes, layouts of junctions, etc. Some bus lanes may be more suitable for use by PTWs than others. Indeed, several cities have allowed PTWs to use some identified bus lanes, which are indicated by specific signage. Presently there is no general consensus on the safety impact of this measure and the debate is still open. Few impact studies have been conducted and there is no real convergence in the results of these studies.

Research conducted in Paris (Maestracci, 2012) has demonstrated that driving in a bus lane offers some advantages for PTW riders, including better peripheral vision of surrounding traffic and a feeling of being better protected, but it can lead to higher PTWs speed, which can endanger safety at intersections in particular. On the other hand, a recent epidemiological study conducted in the city of Marseille in France concluded that the risk for powered two-wheeler riders driving in bus lanes of being involved in an injury crash is more than 3 times higher than the risk run by riders driving in general traffic lanes (Clabaux et al., 2014). This higher risk is partly due to the risk of collisions between car (or truck) drivers turning right and powered two-wheelers driving in the bus lane who continue straight ahead. Box 8.2 presents the results of a few experiences and research in London, Barcelona and Vienna, which show some diverging results, with a negative safety impact in Barcelona and no safety impact in London or Vienna.

As the safety impact of this measure seems to depend on PTW traffic volume, it is recommended that pilot tests are run and the results carefully analysed before its deployment. Each specific case must be carefully assessed. If this measure is to be adopted, careful attention needs to be paid at the junctions between the bus lane and the regular lane in order to avoid unexpected conflicts by both car drivers and PTW riders.

Road safety gains can only be obtained if PTW users strictly respect speed limits in the bus lanes and if all road users are well aware of the possibility to meet a PTW at a junction when crossing the bus lanes.

Box 8.2. **Use of bus lanes by PTW – safety impact: Results from experiences and research**

London

Following the completion of two trials, in January 2012 motorcycles were given permanent access to bus lanes on the majority of the Capital's red routes. The two trials have shown reduced journey times and environmental benefits with no significant safety issues ensuing for motorcyclists and other vulnerable road users As part of the second trial, Transport for London (TfL) increased enforcement specifically at locations with a high collision history involving motorcycles. In line with this increased enforcement, the average speed for motorcyclists in bus lanes reduced by 6.5 per cent during the trial, with the proportion of motorcyclists exceeding the speed limit decreasing by one fifth (51% in September 2010 down to 41% in September 2011).

The scheme run by TfL covers with-flow bus lanes on the strategic road network, but not those on most borough roads. A few boroughs have also allowed PTWs in their bus lanes, but one, Ealing, has already ended motorcycle access to bus lanes. Several other cities in England have also introduced motorcycle access to bus lanes.

Source: Transport for London, York et al. (2011)

Barcelona (RACC, 2010)

RACC (Automobile Association in Cataluña) presented Barcelona City Council its report about PTW users´ utilisation of bus lanes. The most representative conclusions were :

– PTWs are a key factor for mobility in the city of Barcelona.
– Allowing PTWs in bus lanes would lead to an increase in PTWs' average speed; an increase in the occurrence and severity of PTW crashes, a potential weak point in right turns between bus lanes and the second general traffic lane.

To summarise, the probability of collision with buses, cars or other PTW vehicles would raise significantly.

As of 2013, PTWs were not allowed to use bus lanes;

Vienna (Austria)

In 2005, a pilot was launched to allow PTW riders to use bus lanes. There are three test sites. The administration carefully selected places where there are no pedestrian crossings, no oncoming left turn traffic and no induction loops under the road surfaces for prioritising public buses at traffic lights. On these test sites, there were no severe (injury) crashes before starting the pilot and, as of June 2013, there has been no crash since implementation. It is however not planned to extend the experiment.

Advanced Stop Line

Advanced stop lines permit PTWs to stop in front of other vehicles at traffic signals, allowing motorcycles and mopeds to manoeuvre more safely without conflicting with other road users when the light turns green.

This is clearly comfortable for PTW users; however very careful consideration should be given to traffic signalling calibration to avoid conflicts with pedestrians, as PTWs can accelerate very quickly, which may surprise pedestrians. In addition, when the advanced stop line is shared with cyclists, careful consideration should be given as both users have very different acceleration capacities.

Trials were conducted in Spain and the United Kingdom to assess the safety impact of this measure (see Box 8.3). Legal coverage of Advanced Stop Trials is being incorporated in the Spanish Traffic Code. A study by Haque and Chin (2010) gives some more pessimistic results, showing that advanced stop lines can increase right-angle collisions involving PTWs. According to these authors, advance stop lines should be seen more as a measure to facilitate PTW traffic and mobility.

Box 8.3. **Trials with advanced stop line for PTWs**

United Kingdom

In the UK, the Traffic Signs Regulations and General Directions do not permit PTWs to use Advanced Stop Lines (ASLs). The Transport Research Laboratory conducted an experimental study on behalf of the Department for Transport on the effects of allowing motorcycles the use of ASLs; at present only bicycles are permitted to use them. During the test track trial, motorcyclists were also permitted to use ASLs at signal-controlled junctions. No actual conflicts were recorded during the trial, but the combination of cyclists going straight on with motorcyclists turning left was identified as a potential source of conflict (Ball et al., 2011). There are no plans to change the Regulations to allow PTWs into ASLs.

Barcelona (Spain)

In Barcelona a similar measure was initially assessed at 3 main junctions in the city. The ‘bike box’ is available to all two-wheelers and is indicated with yellow hatched boxes. Barcelona city undertook the evaluation of this measure and concluded that it benefited PTW safety. As of 2011, 56 advanced stop lines for motorcycles had been implemented. A time-series study with comparison groups is carried out to evaluate the road safety effectiveness.

Madrid (Spain)

Trials are being carried out in Madrid to allow PTWs to enter the area ahead of the main traffic stop line at traffic signal controlled junctions. Motorcycles can enter this ‘box’ via a bus/motorcycle/taxi/cycle lane to reduce the risk of PTWs weaving through traffic to reach the head of the queue. The box is formed by positioning a second stop line for PTWs about 4 metres ahead of the main stop line for other vehicles. The box is marked with motorcycle pictograms (see figure 8.2).

Figure 8.2. **Advanced stop line in Madrid**

Allowing PTWs to use shoulders in congested traffic

Some countries are considering allowing PTWs to use shoulders or emergency lanes in traffic jams. While this could certainly be considered attractive from a mobility perspective, the impact on safety is not yet documented. Concern has been expressed about its foreseeable negative impact on road safety. No impact assessment has been made on the effect of this measure.

Traffic filtering and lane splitting

Filtering and lane splitting are used by bicyclists and motorcyclists to overtake vehicles on a stopped or slow-moving lane by travelling between the lanes. In broad terms, filtering by motorcyclists is defined as moving between traffic when other surrounding traffic is stationary. Lane splitting is defined as moving through traffic in motion. These practices are progressively becoming more common, even if not legal in most countries, due to the increasing congestion in many cities. Both lane splitting and filtering by PTWs are currently illegal in most OECD countries. However, both practices are tolerated in most of the countries, to the extent that they are done with prudent manner.

There is little research and few experiments so far on the safety impact of lane splitting and filtering. Preliminary results from a study in the United Kingdom, conducted by the University of Nottingham for the Department for Transport (Clarke et al., 2004) show that filtering is responsible for about 5% of motorcycle Killed or Seriously Injured (KSI) crashes. A US study (Ouellet, 2012) conducted in California concluded that lane splitting occurred in less than 1% of motorcycle crashes and 7% of freeway crashes and that lane splitting may reduce crash risk for motorcyclists.

Consideration should be given not on the principle alone of authorising or not filtering but on the conditions in which it could apply and the road types that may be concerned. For example, on a 3-lane road, what is the safest place to filter (between the second and the third lanes, on the emergency lane, etc.)? Should filtering be authorised when the traffic speed is above a certain level (e.g. 80 km/h)? What should be the maximum speed of the PTW when filtering? Practices are diverse, and so are the resulting risks. Finally, how filtering behaviour can be trained, controlled and enforced?

The debate is still open. Nevertheless, this practice exists. Research is needed to better understand the safety impact of legalising it.

Conclusions

PTW are very sensitive to the road and traffic environment, including infrastructure design (e.g. alignment, curves, etc.), maintenance (holes, gravel, etc.) and interaction with other road users. Due to this sensitivity, defects in the road layout are likely to create more difficulties for PTW riders than for operators of other motorised vehicles.

Road and traffic management have traditionally been designed for four-wheeled vehicles. In some cases, these are not properly adapted for PTWs. Much could be done to facilitate the mobility and safety of PTWs, without compromising the mobility of other motorised vehicles.

Self-explaining roads and traffic calming measures are ways to guide drivers and riders to adopt appropriate traffic behaviours and speeds. Designing “forgiving” roads, using PTW friendly equipment, conducting regular audits and inspections contribute to a safer environment for PTWs. Traffic calming measures aim to lower the speed of all motorised vehicles by interventions on the road design or actions to influence traffic. These measures have proven their effectiveness to improve safety, including the safety of PTWs but require careful design to benefit PTWs.

Engineers, road designers and providers, road safety auditors and inspectors should be trained to consider PTWs in the design, maintenance and operation of roads, and be provided with the necessary risk assessment tools to make the right decisions based on an overall impact assessment. Local authorities’ staff should be trained and informed on the infrastructure requirements for PTWs.

Traffic management measures can have a dual purpose: facilitating PTW traffic and increasing safety. Further research is needed on the safety impact of measures such as advanced stop lines and traffic filtering. When implementing any new measure in favour of PTW mobility, caution must be paid that no new risk is induced for themselves or for any other road users.

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Chapter 9. Specific powered two-wheeler issues in low- and middle-income countries

This chapter is dedicated to the specific issues of powered two-wheeler (PTW) safety in low- and middle-income countries, which account for 90% of traffic casualties and where PTWs play a very important role in the transport system. There are a number of challenges in most of these countries, including the lack of institutions responsible for road safety; the lack of knowledge of traffic rules, the lack of enforcement; the lack of proper infrastructure, the sale of low cost PTWs; and the lack of data to properly assess the safety issues of PTW in particular.

Introduction

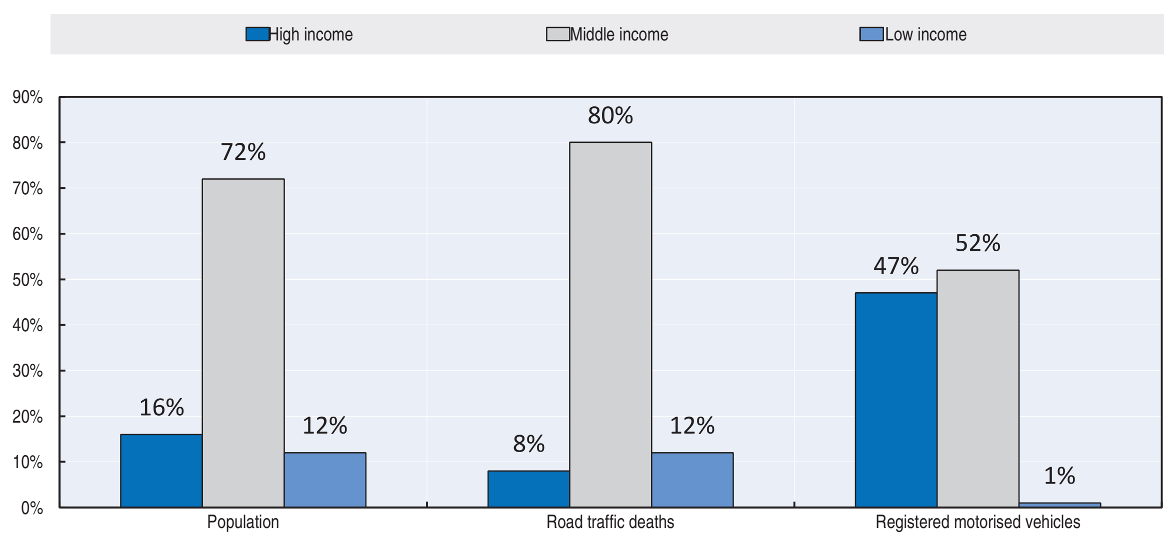
The previous chapters have mainly focused on high-income countries. This chapter is dedicated to the specific issues of powered two-wheelers (PTWs) in low- and middle-income countries (LMICs). It is acknowledged that the situations in low- and middle-income countries cannot be summarised easily and there is a wide diversity in the role and conditions of PTWs in the transport system and in the characteristics of PTW crashes.

This chapter gives some indications of common trends in LMICs and where the experience of industrialised countries can be transferred.

Road safety in low- and middle-income countries: general trends

Globally, about 1.24 million people die every year on the roads, and more than 10 million are severely injured. Low- and middle- income countries account for 90% of the victims (see Figure 9.1) and a very large proportion are vulnerable road users, including children, bicyclists and PTW users (WHO, 2013). Unless immediate and effective action is taken, road traffic injuries are predicted to become the fifth leading cause of death in the world, resulting in an estimated 1.9 million deaths each year by 2020. This is, in part, a result of rapid increases in motorisation without sufficient improvement in road safety strategies and land use planning.

Figure 9.1. **Population, road traffic deaths and registered motorised vehicles in high-, middle- and low-income countries**



Source: WHO (2013).

In all countries, road crashes result in tragic human consequences. In low- and middle-income countries, the considerable economic and social consequences of road crashes constitute a serious brake to economic development. Road traffic crashes are one of the three leading causes of death worldwide for persons aged 15-45 years. The death of a working-age man in low- or middle- income countries significantly reduces the income of his household and leads to direct and indirect economic losses to the country. Road traffic injuries and fatalities typically consume between 1-3% of LMICs GDP (WHO, 2013).

Low- and middle-income countries are disproportionally affected by traffic-related injuries and fatalities. This is largely because they do not have the national structures in place to promote and enforce quality road safety laws and regulations. Examples of regulations include mandatory helmet laws and helmet production standards, police enforcement, road maintenance, etc. In addition, populations generally lack education and awareness about road safety. Vulnerable road users represent the most significant group of victims of road crashes because of the greater variety and intensity of traffic mix and the lack of separation from other road users. Of particular concern is the mix between the slow-moving and vulnerable non-motorised road users, as well as motorcycles, and fast-moving, motorised vehicles.

The UN Decade of Action for Road Safety 2011-2020

In 2011, the United Nations called for a global decade of action for road safety with a goal of stabilising and then reducing the forecasted level of global road fatalities by increasing activities conducted at national, regional and global levels. It released the Global Plan for the Decade of Action for Road Safety to serve as a tool to support the development of national and local plans of action, while simultaneously providing a framework to allow coordinated activities at regional and global levels. The Plan is based on 5 pillars: Road safety management; Safer roads and mobility; Safer vehicles; Safer road users; and Post-crash response. The Plan is very much focused on the specific issues of vulnerable road users and addressing the issue of PTW safety is a main challenge of the decade.

Role of PTWs in mobility in low- and middle-income countries

Powered two-wheelers play a very important role in the mobility and transport system of low- and middle-income countries.

While in many industrialised countries PTWs can be seen as an alternative to the car, in many low- and middle-income countries, the PTW is the only affordable personal motorised mean of transport. In Southeast Asia, PTWs are often the family vehicle. Families use PTWs to get to work, take their kids to school, go to the market, and manoeuvre in every day urban and rural life. In many countries, the increase in urbanisation and motorisation has led to an increase in PTW use in conjunction with new needs in mobility and because of their easier accessibility, lower cost of use and smaller dimensions as compared to cars (Haworth, 2012). In addition, PTWs are also used for the transport of goods (see Figure 9.2).

Figure 9.2. **PTW use in Vietnam**

Source: Graeme_Newcomb on Flickr.

Rogers (2008) observed that in developed economies, most PTWs have a large engine displacement and are commonly used for leisure, while in developing and emerging economies PTWs have a smaller engine displacement, are more often mopeds and scooters and are often the sole motorised vehicle for the family.

In Latin America, the development of the PTW fleet has led to the creation of a large number of new jobs, such as messengers, couriers or moto taxis, which are a source of income for many young males. With congestion becoming a major issue in large cities, PTWs are considered as an efficient means of transport. Based on indicators from 25 cities in Latin America, the Observatory for Urban Mobility concluded that travelling by PTW could halve the travel time when compared to mass transit, and was in some cities much cheaper as well. Figure 9.3 illustrates, for a selection of Latin American cities, the relative marginal cost of a 9 km journey by public transport, PTW and car and confirms the cheaper price of travelling by PTW, which contributes to the success of this transport mode.

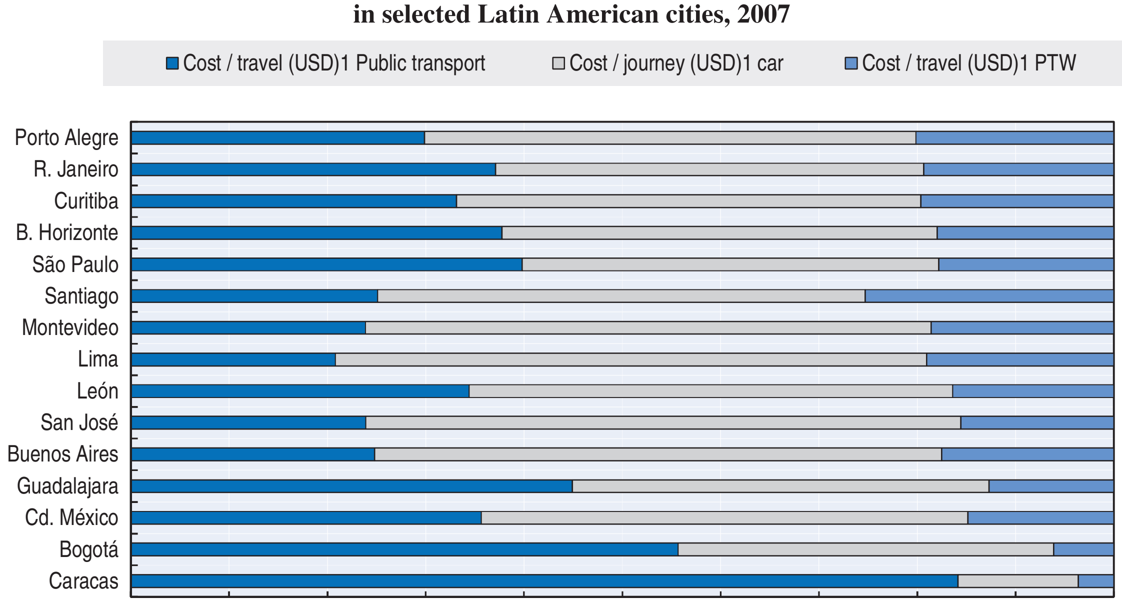
Box 9.1. **The use of Bodas Bodas in Uganda**

In Uganda towards the end of British rule in East Africa, citizens needed a quick and cheap means of crossing the border into Kenya, and thus a thriving motorcycle taxi industry was established. The motorcycle taxis are referred to as "boda bodas," meaning "border-to-border." Now, boda bodas mostly operate within Kampala and citizens use them commercially to get around the city. There are an estimated 200 000 boda boda operators throughout Kampala, predominately young adult males (KCCA, 2013).

In a congested city, the boda bodas, while convenient, have become a hazard on the road. According to a study from Mulago Hospital, the largest public hospital in Uganda, boda boda-related injuries consume more than 65% of the annual budget for the hospital's surgical unit, and boda bodas are responsible for approximately 75% of all road traffic-related trauma cases (Kigera, 2010). AIP Foundation runs a "Wear a helmet!" public awareness campaign in Kampala and conducts road safety workshops for boda boda operators in coordination with the Uganda Police Force and other agencies.

Source: AIP Foundation.

Figure 9.3. **Relative marginal costs* of a 9 km journey by different transport means in selected Latin American cities, 2007**



* Costs include gasoline costs for car and PTW travel, and ticket for public transport. Costs do not include insurance and vehicle depreciation.

Source: OMU.

The fleet of PTWs in low- and middle-income countries

In low- and middle-income countries, PTWs account for up to 85% of the motorised vehicle fleet and the PTW fleet is continually increasing. Two thirds of the total registered PTWs worldwide are concentrated in Asian Countries, The large majority of the PTW fleet is found in Asia with China largely dominating the market. In India, the PTW fleet, composed in majority of mopeds, represents 72% of the motorised vehicle fleet and has more than doubled between 2001 and 2011. In Cambodia, since 1990, the number of PTWs has continually increased with an average annual increase of 20%[1]. In Vietnam, between 2007 and 2011, 9.5 million registered two-or-three wheelers were added to the roads, bringing the number to 31.5 million units. (2009 and 2013 Global Status Reports on Road Safety, WHO).In South America and Africa, the PTW fleet is much smaller but is gradually increasing. In China, according to data from the Traffic Management Bureau of the Ministry of Public Security, the number of PTW units reached 103 million in 2012 and nearly doubled in the last decade.

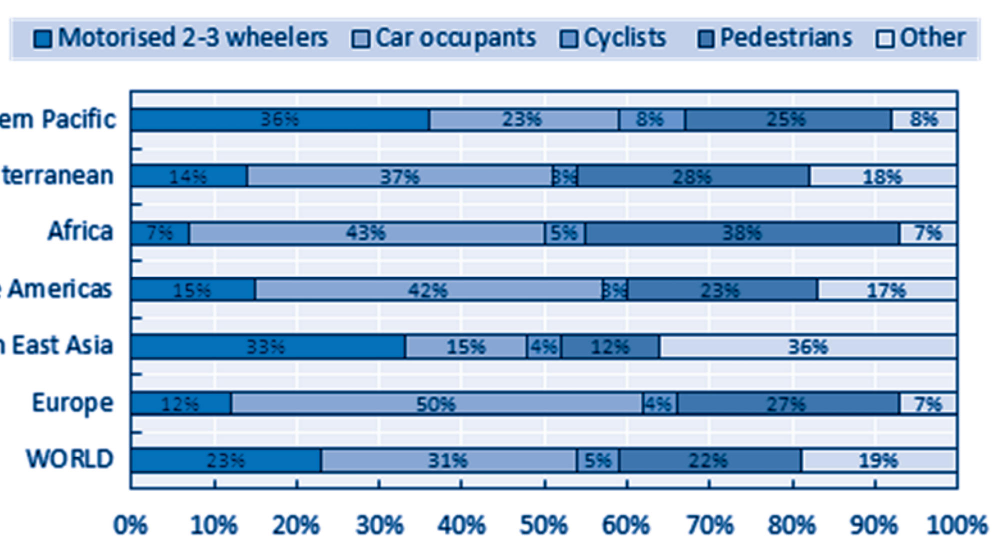
Although the registration system does not always allow a distinction between different types of PTW, in many countries, based on general observation in the streets, the large majority of the fleet is composed of small PTW below 125 cm^3.

In most LMICs, car ownership is still at an infant level with rate about 20 cars per 1 000 inhabitants (e.g. 8 in India, 41 in Indonesia, 17 in Benin). The first lesson to learn from OECD countries is that approaching a car ownership of 800+ cars per 1 000 inhabitants will not solve the mobility issues and is certainly not a sustainable path to follow. While it is anticipated that public mass transport systems should and will play a central role in mobility, there is no doubt that individual motorised transport will heavily rely on PTWs.

Safety of PTWs

Among the 1.24 million people killed every year on the road, 90% of casualties live in a low- and middle- income country, and depending on the country, up to 74% of casualties are PTW riders. Looking at the situation of road traffic deaths per geographical area (Figure 9.4), significant differences appear between regions. The countries most impacted by PTWs traffic deaths are in Asia.

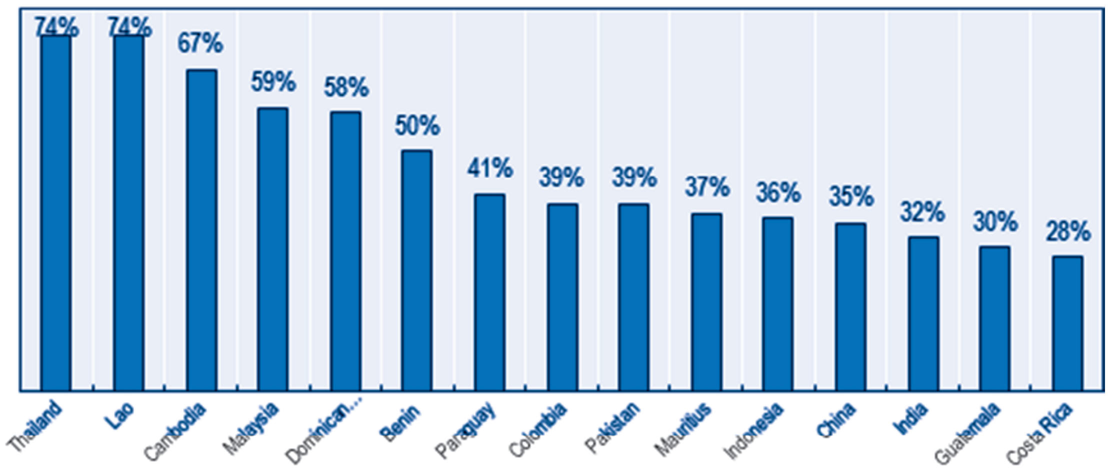
Figure 9.4. **Road traffic deaths by user type**



Source: WHO (2013).

Figure 9.5 is based on the statistical annex of the WHO Global Status Report on Road Safety and identifies the fifteen countries with the highest share of PTW users killed among low- and middle-income countries of more than 1 million inhabitants and for which data are available.

Figure 9.5. **LMICs with highest percentage of PTW users killed in 2010**



Source: WHO (2013), countries with more than 1 million inhabitants.

Specific challenges of PTW safety in LMICs

As in other countries, crash contributing factors include human behaviours, infrastructure and vehicle factors. There are a number of specific challenges, though, to overcome to tackle the issue of safety in general, including PTW safety:

- Lack of institutions responsible for road safety and lack of laws.
- Lack of knowledge of traffic rules and lack of enforcement.
- Lack of proper infrastructure, including poor, or low, maintenance.
- Sale of low-cost PTWs.
- Lack of data to properly assess the safety issues in general and of PTW in particular.

Countermeasures

This section aims to complete the chapters of this report dedicated to countermeasures, by highlighting areas deserving specific attention or higher priority in LMICs. It focuses on the following issues:

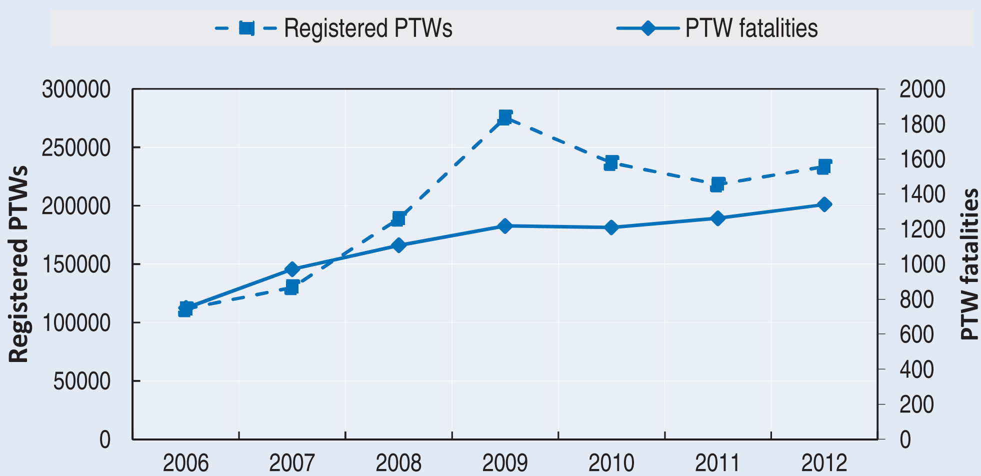
- Legislation and capacity building, including work related legislation and enforcement.
- Measures to improve user behaviour.
- Measures to increase the use and quality of helmets and other protective equipment.
- Measures to improve the safety of vehicles.
- Measures to improve the road infrastructure.

Box 9.2. **PTW Crash trends in Cambodia**

According to the Road Crash and Victim Information System (RCVIS), in 2012 there were about 16000 road crash casualties, including 1 966 persons killed. About 70% of those casualties were PTW riders (drivers or passengers).

Over the last 5 years, the number of PTW fatalities has increased by 21%. However, there was a slight decrease in the PTW fatality rate (expressed in terms of fatalities per PTW registered). This decrease can be attributed to the huge increase in motorisation.

Figure 9.6**. Trends in registered PTWs and fatalities**
2006 – 2010



Source: RCVIS.

Speeding was the leading cause of PTW casualties and fatalities, followed by drunk driving and dangerous overtaking. In 2012, 63% of PTW fatalities were between 15-29 years old. Higher percentages of PTW fatalities were observed during weekends. Phnom Penh, Kampong Cham and Kandal shared about 35% of PTW fatalities. Almost half of the PTW fatalities occurred between 4pm and 10pm.

In 2012 66% of PTW fatalities suffered head injuries (compared to 76% in 2009). Among them, only 22% wore a helmet.

The wearing rate was higher among driver casualties (28%) than among passenger casualties (7%). This can be due to the fact that helmets are compulsory only for PTW drivers and that since January 2009 there has been enhanced enforcement by traffic police, especially in Phnom Penh.

Legislation and capacity building

Many countries suffer from the lack of a legal framework for road safety in general. According to the World Health Organisation, only 28 countries, representing 7% of the world's population and mainly OECD countries, have a comprehensive legislative framework addressing all main risk factors (speed, drink-driving, helmet and seatbelt wearing) (WHO, 2013).

Despite road trauma being recognised as a sizeable and growing health problem in LMICs, it is generally neglected in those countries. Indeed, it is often given a relatively low priority from central government. There are usually no government departments or agencies dedicated specifically to road safety, and, where they are given responsibility, they are often inadequately funded.

The process of road safety improvement needs to be multidisciplinary and dynamic:

- This requires the involvement of people competent in road safety to manage this process. Thus, improvement of road safety should begin by capacity building to have skilled professionals in road safety.
- There will often be a need to strengthen the institutions responsible for various aspects of road safety, and to increase their capability for multi-sectorial action.
- Co-ordination between the various bodies involved in road safety activities, such as the engineers, police, and the health sector is essential.

Solid crash data system

Estimating the risk in different countries is not a simple task because of the need to control the 'exposure' (taking account of the size of the population, the number of registered vehicles or kilometres driven), and to define fatal road crashes (the specified interval between the traffic crash and time of death which vary between countries). However the most important problem is how crashes are recorded. Under-reporting of crashes is known to be a particular problem in the developing countries. Aeron-Thomas (2000) reported that between 25 and 60% of crashes can go unrecorded.

Box 9.3. **Challenges of PTW safety in Brazil**

The current state of PTWs in Brazil

As in many Latin American countries, the mass sales and use of PTWs has been rather recent. The expansion of PTW use in Brazil followed the process of economic liberalisation of the 1990s. Between 1992 and 2011, the number of PTWs multiplied by four. As of 2000, the production and export of PTWs increased by almost 10% per year with the highest sales in 2011 surpassing the two million units.[2] In November 2012 the total number of PTWs in Brazil was above 16 million, representing 26% of all motorised vehicles in the country. It is likely that annual motorcycle sales figures will surpass those of automobiles during the next few years.

The surprising increase in sales and production of PTWs in the last two years is related to the additional incentives provided to stimulate the manufacturing of PTWs in 2009.

Brazilian PTW rider profile

A significant number of consumers have moved from using public transportation to motorcycles, due to lower costs and the poor quality of public transportation in their cities. Recently, middle class people have been purchasing motorcycles to avoid congested traffic in large towns. The most common reasons for buying a PTW are as a substitute for public transport (60%); for pleasure/leisure (19%), as working mode of transport (16%), for several reasons (15%), and the remaining 10% as a substitute for their automobile (Vasconcellos, 2010).

Many of the new motorcycles are used in delivery services, mainly in the cities with large levels of congestion, like Sao Paulo (the 'motoboys'). Motorcycles are also used as taxis, legally and illegally, to transport passengers.

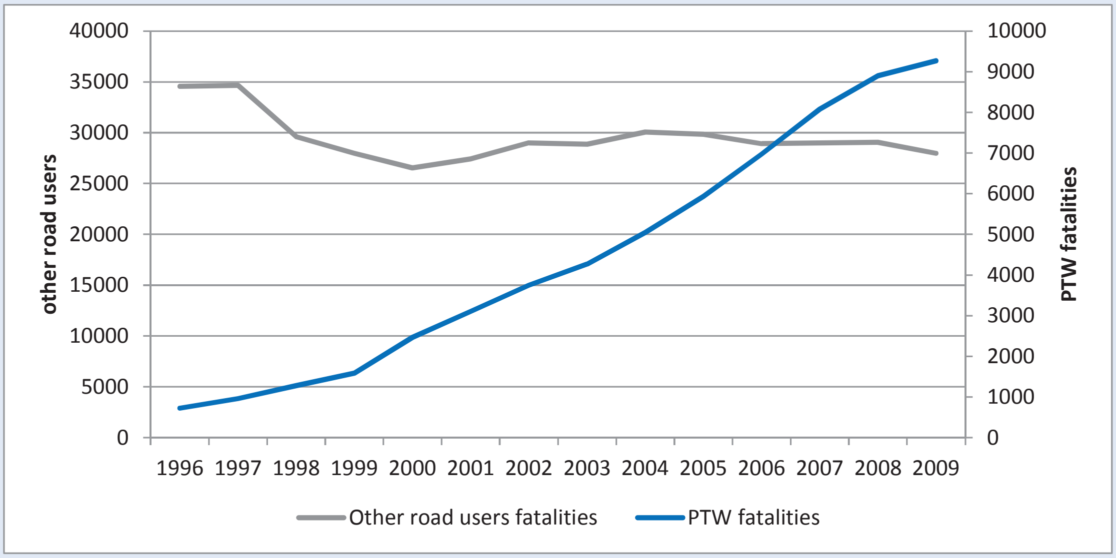
PTW safety

Between 2000 and 2009, the number of motorcyclists killed was multiplied by four; they represented one quarter of all fatalities in 2009 (see Figure 9.7).

Box 9.3. **Challenges of PTW safety in Brazil** *(cont.)*

Figure 9.7. **Trends in the numbers of PTW and other road users killed in Brazil**

1996–2009



Source: Ministério da Saude. (2011).

The problems and actions

One of the biggest current problems with PTWs is their "illegal" use as a mode of public transport (moto-taxis). Moto-taxis are a common problem in intermediate cities; however, in big cities these are not as common due to heavy traffic and the danger that this mode poses to potential passengers. A moto-taxi ride costs about 1 Real (USD 0.5) in the favelas. Moreover, the use of motorcycles as a means of public transport is supported and is considered "appropriate" by the authorities in poor areas.

The Federal Law No 12.009 strengthened the requirements for drivers who use PTWs as a way of living. This law states that the "profession" can only be exercised by those who are over 21 years-old. They require a minimum of 2 years to be qualified as a professional motorcycle rider as well as specialised courses.

One of the most common responses to adapt city conditions for motorcycles is the use of special lanes for these types of vehicles.

Source: Fundacion Ciudad Humana.

Improving behaviours of riders and other road users

Helmet wearing

This is by far the highest priority and the area where most attention should be given in the short term. The wearing by all PTW drivers and passengers of a helmet meeting international standards has the potential to reduce the number of death and serious injuries most effectively and rapidly. As seen in Chapter 7, the proper wear of quality helmet reduces the likelihood of injury in a crash by 69% and the likelihood of death by 42%. (Liu et al., 2007).

Little data is available on the rate of helmet wearing in LMICs. In general, the rate of helmet wearing in LMICs is lower than in HIC. In addition, the helmet wearing rate of passengers and children tends to be significantly lower than the helmet-wearing rate of drivers. The helmet wearing rate is estimated between 60% and 70% in most of the LMICs, while the rate registered in HIC is about 86%. A significant difference appears for the LMICs belonging to Middle East and North Africa, where the wearing rate is about 50%. Lack of awareness and affordability contribute to low helmet-use rates. A study of the affordability of helmets in 18 countries demonstrates that in low income countries, helmets are unaffordable for the majority of the population.

Some countries do not have a compulsory national motorcycle helmet law requiring all passengers to wear a helmet on all PTWs, although the situation has improved in the last decade. The majority of these countries are concentrated in Asia and in Africa . In some countries, helmets may be compulsory, but the safety standards of the helmet may be very poor or non-existent. As an example, in Vietnam, despite a mandatory helmet production standard, a survey conducted in 2008 by the Vietnam Consumer Safety Association found that 80% of all helmets sold did meet the standard requirements. While there are several internationally recognised standards, it is important that a particular government's helmet standard is suitable for the weather conditions of the country and is both affordable and available to users (WHO, 2013; WHO, 2006). Simply adopting the European ECE standards may be not the optimal situation. The availability of an affordable and effective motorcycle helmet in low- and middle-income countries would certainly improve the current road safety situation in these countries. AIP Foundation introduced the "tropical" helmet, which is a low-cost, light-weight and high-quality helmet design, to increase the presence of quality helmets in Vietnam. The tropical helmet design fully meets the requirements of the mandatory helmet standard, which AIP Foundation helped the Vietnamese government develop in 2007. The production standard adopted reflects the reality of road crashes in Vietnam, and considers the economic and environmental factors that affect consumption.

Box 9.4. **The Global Helmet Vaccine Initiative**

The Global Helmet Vaccine Initiative (GHVI) – elaborated by the Asia Injury Prevention Foundation (AIP) and supported by the World Bank and the FIA Foundation – aims to promote motorcycle helmet wearing across the developing world, working in partnership with governments, the private sector and non-governmental organisations, with the objective to "put a helmet on every head" in the Decade of Action for Road Safety (2011-2020). The Programme was first launched in 2007 in Vietnam and has since been extended to other countries.

GHVI's interventions combine five pillars, each valuable independently, but most effective when implemented together:

- Helmet production: Establishing helmet assembly and testing facilities to make affordable and climatically appropriate helmets accessible to the market and reinvest the profits into other pillars.
- Targeted programmes: Providing quality helmets and road safety education to promote safe behaviour among vulnerable road users.
- Public awareness education: Coordinating national mass media campaigns to elicit social change regarding road safety and correct helmet use.
- Global and legislative advocacy: Supporting the development of comprehensive, enforced traffic standards, laws, and curricula on the national and local level.
- Research, monitoring, and evaluation: Collecting data to identify high-risk road users, tracking progress toward targets, adapting to changing circumstances and disseminating best practices.

Target countries are Vietnam, Cambodia, Thailand, China, Uganda, and Tanzania.

Some accomplishments:

- In the six years following the Vietnam helmet campaign and law in 2007, it is estimated that 20 600 lives have been saved, 412 200 road injuries have been avoided and approximately 2.6 billion USD have been saved.
- In Cambodia, average helmet use across nine target schools increased from 0% to 87% by the end of each the 2011-12 and 2012-13 school-years.

In Uganda, between 2011 and 2013, over the course of GHVI's campaign targeting motorcycle taxis (boda bodas), helmet use increased from 31% to 49% among boda boda drivers in Kampala.

Box 9.5. **Helmet wearing in Nigeria**

In Nigeria, PTWs have become increasingly popular as a means of commercial transport. It is often the only form of transport available and useful for navigating poor road networks or congested work.

In Nigeria, four reasons sustain the increasing use of motorcycles:

1. The low cost when brand new (about USD 500) compared to second hand cars (about USD 3 000);
2. It is the only means of transport to many streets, connecting roads or villages;
3. It is fast and efficient in traffic jams in urban roads;
4. It holds a commercial opportunity to earn quick money (in fact, many are quitting menial jobs and becoming commercial riders overnight, without undergoing the necessary pre-licence tests).

In Nigeria, the mandatory helmet law was repealed in 1979 in some States in the northern part of Nigeria and was re-enacted in 2009.

Box 9.5. **Helmet wearing in Nigeria** *(cont.)*

A study of helmet wearing conducted in by University of Ilorin Teaching Hospital observed that none of the PTW patients wore a helmet at the time of injury, even after the law was re-enacted. This is the result of non-compliance by motorcyclists and weak enforcement by the authority in some parts of the country. Enforcement of the law was initially ineffective in some parts of the country as riders gave excuses regarding cost of helmets and the tropical heat. Others cited health and religious concerns.

Source: Solagberu et al. (2006).

In 2006, the World Health Organisation published a road safety manual on helmet wearing for decision makers and practitioners, focusing specifically on the needs of low-and middle-income countries. This document provides practical recommendations on the various steps required to improve the rates of helmets use among PTW users, nationally or at local level. The manual in particular recommends:

- The adoption of appropriate legislation.
- The development and adoption of helmet standards to ensure access to quality safety equipment.
- The implementation of both voluntary and compulsory measures to increase the compliance with a helmet law.
- A well-designed marking campaign to promote the benefits of helmets.
- An adequate school education and peer education among young people.

Education and licensing

All the steps and measures described in Chapter 5 are appropriate for all countries. Regarding LMIC, specific attention could focus on:

- Adopting a licensing system, based upon age and experience, for all types of drivers and riders.
- Inserting crucial road safety awareness issues, such as helmet wearing in the training for obtaining the licence and in the test.

Communication campaign

While experience from developed countries can certainly be useful, it is very important to adapt the communication campaigns to the specific nature and culture of each country. Communication campaigns should be targeted at the specific safety issues of the country. Of course, one of the focuses of these campaigns should be on the use of helmet for riders and also their passengers. Another focus should be on respecting traffic rules, respecting other road users and pedestrians in particular.

Enforcement

In some countries, the low number of road users checked by police, police corruption and the lack of knowledge among road users of the risk of sanctions, severely limits the effectiveness of enforcement.

Enforcement requires collaboration from multiple sectors. A designated government agency should collaborate with the police department to increase enforcement of road safety laws, and the police should be well trained in standardised enforcement measures. It also requires the development of a sensible set of rules that are known to all and the systematic implementation of these rules.

Vehicle measures

The lack of legislation and vehicle conditions can be a serious issue in LMIC. Main problems include: poor quality of motorcycles being manufactured or assembled in LMIC, and being modified by user and the import of old vehicles; lack of maintenance; the lack of legislation regarding technological requirements, overloaded vehicles.

Headlamp On and Automatic Headlamp On (AHO)

While Headlamp On is included in the 1968 Vienna Convention and compulsory in many countries, it is not yet an obligation in a number of low- and middle-income countries. In countries with a very high share of PTW in the traffic, it is sometimes claimed that conspicuity is not a significant issue. However, even in countries with a very high proportion of PTWs, this measure has proven to be very effective in reducing the number of crashes involving PTWs and legislation should be adopted when needed.

To facilitate the use of Headlamp On, Automatic Headlamp On should progressively be proposed for the PTW fleet.

Box 9.6. **Headlamp on for PTWS in Malaysia**

Research in Malaysia, where headlamp on was made compulsory for PTWs in 1992, showed that following the legislation and two-month information campaigns, collisions where conspicuity was a contributing factor decreased by 29% (Umar et al.,1996).

The benefit-cost ratio of using running lights during daytime is about 5.4:1 for mopeds and 7.2:1 for motorcycles.

Infrastructure measures

The UN Global Plan for the Decade of Action for Road Safety takes into account improving infrastructure for the sake of the vulnerable road users. One of the main pillars refers to PTW riders and states the following:

Actions should aim at raising "the inherent safety and protective quality of road networks for the benefit of all road users, especially the most vulnerable (e.g. pedestrians, bicyclists and motorcyclists). This will be achieved through the implementation of various road infrastructure agreements under the UN framework, road infrastructure assessment and improved safety-conscious planning, design, construction and operation of roads."(United Nations, 2011)

Most roads in developing countries are multifunctional and used by pedestrians, cyclists, PTWs, cars and trucks and also animal towed vehicles, with substantial differences in speed, mass of vehicle and degree of protection. Ideally, vulnerable road users would be physically separated from the main traffic flow of cars and trucks.

Economic activity, housing and even villages develop along the sides of rural highways, sometimes without being properly planned. Such situations generate conflict between road users travelling at different speeds and directions. In such situations, the use of proper entries and exits and so called 'lay-bys' should be promoted to allow road users a secure exit from and entry into the on-going traffic flow and to allow safe stopping. Public activity areas should be developed only on one side of the road, with speed reduction measures taking place.

Alternatively, if physical separation is not possible, line markings should clearly delimit the space dedicated to vulnerable road users. For many rural single carriageway roads, therefore, other options should be chosen in order to increase the protection of vulnerable road users. These options include improving hazard perception by means of road lighting at junctions and roundabouts, improving vertical alignment, introducing advisory speed limits at sharp bends, introducing regular speed limit signs and introducing deterrents to high speed such as rumble strips.

As seen in Chapter 8, the first world exclusive motorcycle lane was constructed in the 1970s in Malaysia, where the concept has progressively expanded and contributed to a diminution by 39% of PTW crashes (see also box 9.3). This solution presents the greatest benefit for a traffic volume in excess of 15 000 vehicles a day, and where the proportion of PTWs in the traffic is between 20% and 30% (Radin et al., 2000).

The implementation of a road infrastructure assessment programme should be encouraged to allow for a systematic, objective and documented review of the safety characteristics of new and existing infrastructure. Road infrastructure where safety performance was upgraded can serve as a demonstration project and promote knowledge transfer, research and innovation.

Funding for new road infrastructure programmes could take the safety characteristics of PTWs into account.

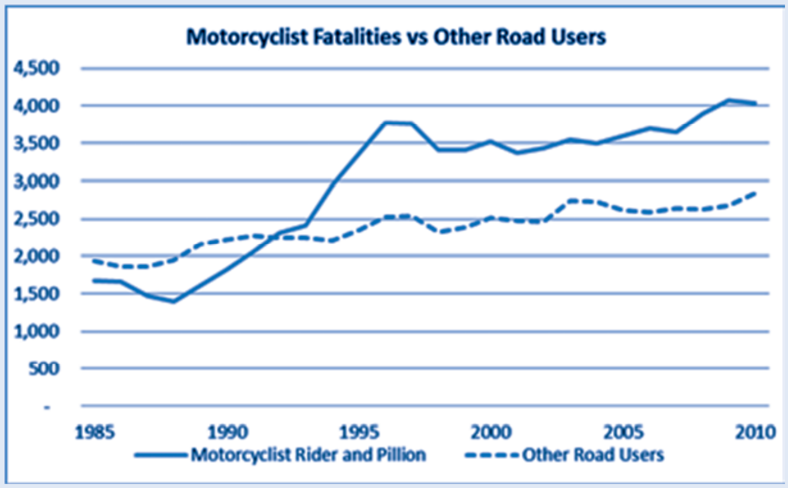
Developing a strategy for powered two-wheelers in low- and middle-income countries

In many ways, the process of developing a PTW safety strategy in low- and middle-income countries should follow the same steps as outlined in the E-SUM Action Pack (see Figure 10.1). The first step should be to gather together all available crash and PTW use data and supplement this with workshops of stakeholders to identify priority issues. The UN Plan for the Decade provides a good framework for considering potential actions on the 5 pillars. The feasibility of particular actions within the national situation should be assessed and short-, long- and medium-term actions identified. Improving data is likely to be an action that is needed, not only to better understand the current issues, but also to monitor the outcomes of the actions.

Box 9.7. **PTW safety in Malaysia**

Motorcycle is the most preferred, convenient and affordable mode of transport in Malaysia. In 2013, there were 10 million PTW units, representing half of the country's total registered vehicles. 90% of the fleet has an engine capacity of 250 cc or less, with the majority of motorcycles between 100 and 250 cc. In Malaysia, the minimum age to possess a valid motorcycle license is 16.

In 2012, powered two-wheelers accounted for 61% of the total road deaths. In the past two decades PTW fatalities have more than doubled. PTW users also sustain very serious injuries, which entail enormous social costs.



Source : MIROS.

Motorcycle lanes

Exclusive motorcycle lane physically segregates motorcycles from other road vehicles. These lanes are usually constructed along expressways. A study of a-14 km exclusive motorcycle lane along Federal Highway F02 found that installation of the lane had led to a 25% reduction of the motorcycle crashes, rising to 34% when confounding factors were taken into account (Radin*,* 1995). A larger subsequent evaluation on the same route found a reduction of 39% in PTW crashes (Radin*,* 2000).

Non-exclusive motorcycle lanes are constructed within the carriageway of an existing road and usually located along the left side of the road. Pavement markings delineate the corridor dedicated for PTWs. These lanes are quite common in Malaysia and constitute a cheaper alternative to exclusive lanes.

As of 2014, the total length of motorcycle lanes (exclusive and non-exclusive) was about 200 km. In 2011, 70% of fatal PTW crashes involved other motor vehicles. Fully segregating the PTW traffic could reduce the risk very effectively.

Box 9.7. **PTW safety in Malaysia** *(cont.)*

Exclusive motorcycle lane

Non-exclusive motorcycle lane

Source: MIROS.

Helmet – Standard and regulation and awareness campaigns

Helmet wearing has been compulsory since the 1970s. The helmet standard MS1:2011 was recently revised and is similar to the UN standard. The overall national helmet-wearing compliance rate is about 70%. The helmet-wearing rates are higher in urban areas compared to rural areas.

There are still a very high number of PTW fatalities caused by head injuries, due to failure to wear a helmet or the improper use of a helmet. In order to increase the (proper) use of helmet, a six months Community Based Programme (CBP) was carried out in 2012 in two districts of the city of Putrajaya. The programme involved social marketing campaigns, education and enforcement activities to encourage higher compliance with proper helmet wearing. In the concerned districts, (proper) helmet wearing rate increased from 70% to 86% among riders and from 64% to 82% among pillions (Ghani, 2013).

Daytime headlamp on

The mandatory use of headlamp on during daytime was introduced in the early 1990s in order to increase PTW conspicuity and subsequently reduce motorcycle crashes involving other vehicles. Radin (2005) showed that daytime conspicuity related crashes dropped by 29 % after the introduction of this measure.

Examples of the development of strategies and other resources that may be useful in LMICs are provided in the APEC Compendium of Best Practices in Motorcycle and Scooter Safety (APEC, 2011).

Box 9.7. **Conclusions of the International Forum on PTW Safety in Latin America, held in Sao Paulo Brazil, in September 2013**

Between 2008 and 2012, the number of registered PTWs almost doubled in Latin America, while the car fleet increased by around 20%. During the same 5-year period, the number of PTW users killed grew by 36%. The typical casualty is a young male with less than two years' experience driving a PTW.

Main recommendations of the Forum:

1. Safety strategies at national or local level must include special plans for PTWs. These should be formulated with all stakeholders, with the active participation of motorcyclist associations.
2. Ideally, countermeasures should be scientifically based; but since the region suffers from a lack of research and reliable data, programmes should be designed and implemented following the stakeholders' requirements and monitored to check the results and generate new knowledge.
3. Priority measures should focus on novice riders and include better education programmes, as well as riding skill tests. A graduated licensing system, with restrictions in the first year, should be adopted.

Box 9.8. **Conclusions of the International Forum on PTW Safety in Latin America, held in Sao Paulo Brazil, in September 2013** *(cont.)*

4. Awareness campaigns, backed up by education and enforcement, are necessary.
5. The PTW industry can play a very important role in funding research, contributing to PTW training and in the rehabilitation of injured people.
6. Safe infrastructure for motorcyclists must be promoted, and roadside hazards and road elements that generate risks should be eliminated.
7. There is a need for regulation of work-related PTW usage (deliveries, moto taxis…). Companies should be responsible for providing adequate training and protection for their staff.

Source: CAF, the Development Bank for Latin America.

Conclusions

PTWs often play a more important role in the transport system of low- and middle-income countries than in high-income countries. While public mass transport should and will play a central role in mobility, there is no doubt that individual motorised transport will rely heavily on motorised two-wheelers. Public authorities and the other stakeholders are faced with the difficult challenge to manage the expected increase in PTW traffic volumes, and to provide conditions that will prevent an explosion of the number of casualties.

Addressing this challenge is urgent and cannot wait for the collection and analysis of detailed data. Some areas can benefit from the in depth knowledge acquired in OECD countries and priorities measures should be implemented quickly.

The number one priority in all countries should focus on the proper wearing of good quality helmets by all PTW passengers. This requires the adoption of a national helmet law, the development – when needed – of appropriate helmet safety standards, as well as intense communication campaigns backed up by enforcement. All stakeholders have a role to play in this endeavour. One of the most important challenges is to facilitate the purchase of standardised helmets at reasonable prices adapted to the size of the head. Strong communication on the relative low cost of helmets when compared to hospitalisation costs and the risk of disability and death and school education is needed. Particular attention should be paid to the proliferation of fake helmets.

Rider and driver education and a licensing system to test the capacity of the riders are also priorities. Regarding the vehicles, priority actions should focus on the mandatory use of headlamp on to improve the conspicuity of PTWs, and the progressive implementation of automatic headlamp on (AHO) should be considered. Other priorities include the need to upgrade and maintain the infrastructure, or ideally to construct dedicated equipment for PTWs, especially in countries with the highest share of PTWs in traffic.

Measures taken in isolation are not likely to be effective. As for most advanced countries, the adoption of a Safe System approach should be the way to follow. This requires in particular the existence of adequate institutions and qualified staff to organise road safety activities and integrate them into transport and development plans.

Notes

1. Source*:* Ministry of Public Works and Transport – Vehicle registration statistics, 2010.

2. ABRACICLO Associação Brasileira dos fabricantes de motocicletas, ciclomotores, motonetas e similares URL: www.abracilo.com.br

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Chapter 10. Developing and implementing an integrated road safety strategy for powered two-wheelers

This chapter outlines the need for a strategic approach to powered two-wheeler (PTW) safety to integrate effort and guide the allocation of resources toward initiatives that have proven benefits. It discusses motorcycle safety strategies in the context of a Safe System approach.

Introduction

This chapter outlines the need for a strategic approach to powered two-wheeler (PTW) safety to integrate effort and guide the allocation of resources toward initiatives that have proven benefits.

The structure of this chapter follows the recommended approach of the OECD's Towards Zero – Ambitious Road Safety Targets and the Safe System Approach (OECD/ITF 2008):

- Adopt a highly ambitious vision for road safety.
- Set interim targets to move systematically towards the vision.
- Develop a Safe System approach, essential for achieving ambitious targets.
- Exploit proven interventions for early gains.
- Conduct sufficient data collection and analysis to understand crash risks and current performance.
- Strengthen the road safety management system.
- Accelerate knowledge transfer.
- Invest in road safety.
- Foster commitment at the highest levels of government.

These principles will provide a test to determine the completeness of any final strategy but effort needs to be paid to the process of planning and developing a strategy to ensure that these principles are met. While drawing on these principles, the need for adaptation to the specific needs of motorcyclists is also discussed.

These principles can be re-ordered into a strategic planning process:

Situational analysis

- Conduct sufficient data collection and analysis to understand crash risks and current performance

Define strategic objectives

- Adopt a highly ambitious vision for road safety.
- Set interim targets to move systematically towards the vision.
- Develop a Safe System approach, essential for achieving ambitious targets.

Determine strategies and actions

- Exploit proven interventions for early gains.
- Invest in road safety.

Establish supporting arrangements

- Strengthen the road safety management system
- Accelerate knowledge transfer.

- Invest in road safety.
- Foster commitment at the highest levels of government.

Each of these sections is covered in this Chapter.

However, before the work to develop a strategy starts, planning the development activity and establishing commitment to undertake the strategy development is essential.

Planning a strategy

Planning the development and implementation of a strategy should take account of the benefits to be accrued from the development process and provide a balance between these benefits and the need for early actions to create quick benefits. Apart from the value of these benefits in themselves, they can also serve as valuable examples to engage stakeholders and garner support for further, perhaps more challenging initiatives.

Strategy development is an iterative process that can achieve commitment to change through a process that spirals in from broad discussion of the situational analysis and future trends, to overarching vision and objectives then to strategies and finally to the specific actions required to achieve the strategic goals. This process should provide the opportunity for stakeholder and broader community input to the key issues of concern and the key areas in which significant change in policy, practices or investment is required.

A key step in the planning process is the identifications of the lead agency, its roles and responsibilities and those of other agencies and non-government stakeholders. Relevant stakeholders will include user groups and commercial organisations, such as the motorcycle industry and equipment suppliers and retailers. One of the challenges in this process is to ensure that all stakeholders are considered and not just those who have the greatest capability or the loudest voice. For example, non-recreational riders are usually not represented to the same extent as recreational riders involved in club activity.

The capacity of lead agencies and other stakeholders needs to be recognised and, if necessary, actions taken to increase capacity and capability. In particular, the inclusive involvement of the motorcycling fraternity in the planning of a strategy will not only assist in the development of shared, agreed objectives, but may also identify areas in which capacity building and the sharing of information is required.

Agreement to the objective of the strategy and its interrelationships with other pre-existing, or planned strategies will provide a sound basis for a development process that achieves agreement and stakeholder buy-in. Demonstrated buy-in can be achieved in a number of ways:

- Agreement that a variety of motives for action are legitimate but all should contribute to any overall target of strategy objective.
- Acknowledgement that evidence-based measures should form the basis of the strategy.
- Commitment to the strategy and, ideally, agreement to incorporate the strategy into their own management systems.

A key issue in the development of a motorcycle safety strategy is the status of strategies covering road safety generally and covering motorcycles' role in the transport system. There needs to be recognition that many actions under the umbrella of a general road safety strategy will have benefits for motorcycle riders. Conversely, there will be little chance of success in implementing measures addressing motorcycle safety if the necessary broader institutional frameworks are not in place.

Ideally, a motorcycle safety strategy would be one of a suite of strategies that, together, address the dominant road safety factors in each jurisdiction. There may also be benefit in developing comprehensive motorcycling strategies that include safety as a desired outcome alongside accessibility, mobility and environmental outcomes. This may provide justification for actions that contribute to a number of outcomes, where justification may otherwise be insufficient if safety alone is considered.

The link between planning a strategy and developing a strategy

Early engagement by all stakeholders in the process of strategy development will increase the opportunity that the strategy will address all key and emerging issues and will be accepted by all parties who will share the responsibility for its implementation and success. The key stakeholders in this process are the road users themselves – both riders and other road users. Their engagement in the process of planning a strategy can represent the start of the strategy development process.

Key outcomes from this stage include:

- Consensus regarding the vision for motorcycling's role in the transport system, and its safety, in particular. How are the sometimes competing demands of safety, mobility and personal freedom to be reconciled?
- Agreement to the scope of the strategy – its timelines, coverage.
- The level at which the strategy is aimed – national, regional or local and the linkages to existing or required strategies at the other levels or for road safety more broadly.
- Strengthening the social processes and individual or organisational capabilities to support their role in road safety management.
- Increasing community and media interest in the issue and the need for evidence-based solutions.

At the local level, an example is provided through the E-SUM Action Pack which is "*...intended to provide an easy-to-use template to help municipalities better understand their own PTW road safety problems, and to develop and implement remedial measures in a practical way.*" The process outlined in the E-SUM Action Pack is summarised below (Figure 10.1).

This statement emphasises the need for the complexity and scope of strategies to reflect their intended audience and the depth to which different strategies tackle the issues outlined in this chapter should depend on this overarching need – fitness for purpose.

Figure 10.1. **Processes in planning and developing a strategy**

The contents of the E-SUM Action Plan also provides a description of the recommended strategy development process – following the standard Plan-Do-Check-Act cycle (see Table 10.1).

Table 10.1. **E-SUM Action Plan recommended strategy development process**

1.	Identification and collection of data required for analysis of PTW casualty problems
2.	Data analysis
3.	Identification of casualty issues
4.	Using the Esum Good Practice Guide and Demonstration Projects to select interventions
5.	Setting up a monitoring framework for interventions
6.	Implementation of interventions
7.	Evaluation of effectiveness and reporting

Developing a strategy

The process of developing a strategy can provide significant benefits not only from the research and analysis necessary to inform the content of the document, but also from the stakeholder engagement required to obtain broad consensus to the actions that the strategy sets out.

A new strategy provides the opportunity for a review and testing of the assumptions underlying current policies and may provide a once in a decade opportunity to set new paradigms in relation to expectations of road user behaviour, resource commitments and legislative frameworks.

The development process will normally follow the strategy content as outlined at the beginning of this Chapter as it describes a process of problem definition, objective setting, agreement to strategies and actions and, finally, implementation mechanisms.

Situational analysis

These issues should inform the strategy development activity. Issues covered may include:

- Current and potential future trends in PTW use.
- The facts about risks and serious casualties by crash types; by location (urban/ rural); by type of PTW user – including scooters, mopeds, low powered motorcycles, higher powered motorcycles; commuter or recreational use; age category of user; speed and alcohol (and non-helmet wearing) involvement in serious casualty crashes, and comparing these to data for the balance of non PTW serious casualties by crash type.
- The role of other road users in PTW safety.
- The licensing requirements and practices in a jurisdiction for: (a) novices obtaining a riders licence for the first time; and (b) those returning to riding after a long absence – and reach an understanding of their implications for safety outcomes.
- Research advice which models the estimated impact of a number of individual interventions upon serious casualty outcomes.
- Areas where further research is needed.
- Current funding levels and funding options in a resource constrained environment.
- The different target segments of the PTW road safety market.

It can also be beneficial to define current coordination arrangements and the involvement of national, regional and local governments, and develop options for strengthening these.

As the role of stakeholders will be critical in the development and implementation of road safety measures, the context of this should be clearly stated, including:

- Understand, and effect, the "shared responsibility" concept – what it means and requires.
- Agreement by stakeholders around most of the issues identified in the planning stage.
- Identification of those issues where differences remain.

Defining strategic objectives

Setting a vision and targets

While a number of jurisdictions have established ambitious visions for road safety supported by aggressive targets, the level of ambition directed towards PTW safety is less common.

Sweden provides:

> "The objective of this strategy is to demonstrate how the number of motorcycle and moped fatalities could be halved and the number of seriously injured riders reduced by 25 per cent by the year 2020, thus contributing its share to the 2020 interim goal.
>
> The strategy is based on the management by objectives model for road safety based on Vision Zero – the Swedish Parliament's long-term road safety plan.
>
> The motorcycle and moped are a natural element in the transport system and thereby also in road safety operations.
>
> Accident prevention measures are the most important element in making motorcycle traffic safe.
>
> The most important element for safe moped traffic is to limit the consequences of accidents."

(Trafikverket, 2010).

Whereas the statement from the Lillehammer conference is less explicit:

> "It is a fundamental motorcycle safety requirement that motorcycles should have a place in overall transport policy and infrastructure policy/management."

(OECD/ITF, 2008).

This seems to imply that the goals for motorcycle safety should be equal to those for other modes but this is not clearly stated.

The European Commission acknowledges the need for ambitious targets:

> "Why set targets?
>
> In the latest evolution of the road safety management system, key institutional management functions provide the foundation for system-wide interventions to achieve a range of results expressed as different types of quantitative targets (Bliss and Breen, 2009). Targets provide the focus for the national road safety strategy and the level of their ambition drive decisions about coordination needs, legislative needs, funding and resource allocation, promotion needs, monitoring and evaluation, as well as research, development and knowledge transfer."

It includes ambitious overall reduction targets within its Strategic Plan to 2020 but the specific goals for motorcycling recognise the challenges in achieving targets:

> "This ever-growing group of users is the one where it is the most difficult to attain a significant reduction in accidents and fatalities. In particular the reduction rate of fatalities amongst motorcycle riders is lower than for other road users.
>
> The problem of motorcyclists' safety should be addressed through a range of actions."

(European Commission, 2010).

The Spanish plan recognises the need for a visionary approach but does not make this vision concrete through ambitious targets:

"It has been wished to base the preparation of the plan on a 'shared vision' among all operators intervening in the phenomenon of the accident rate regarding motorcycles."

Similar to the Lillehammer statement, the Victorian PTW Strategic Action Plan recognises the need for improvement without defining any degree of ambition (Victorian Government, 2008):

> "With such significant increases in the numbers of PTWs on Victorian roads, there is a need for greater consideration of PTWs in road use and transport policy development and planning. Those working in these fields need to become more aware of the needs of PTWs and the role they can play in the transport network.
>
> In an environment where PTWs are an increasing component in Victoria's transport mix, the plan seeks to identify initiatives and actions that will:
>
> - significantly reduce the number of riders and pillion passengers killed or seriously injured
> - ensure that PTWs are given appropriate recognition in transport and road use policy and planning."

The UK followed a similar approach in its 2005 motorcycling strategy (DfT, 2005):

> "The principal aim of our strategy is to 'mainstream' motorcycling.
>
> The theme of this strategy therefore is to facilitate motorcycling as a choice of travel within a safe and sustainable transport framework.
>
> Our aim is to make motorcycling a safe, enjoyable experience for those who choose this mode. This means taking account of the needs of motorcyclists, promoting safety measures and mainstreaming motorcycling, so that its needs are considered as fully as any other transport mode, in the development of transport policy."

The United States document provides the answer to a much more fundamental question:

> "The mission of the National Agenda for Motorcycle Safety is to point the way to the most promising avenues for future motorcycling safety efforts in the United States (U.S.).
>
> The goal of the National Agenda for Motorcycle Safety is to enhance and improve motorcycle safety. The National Agenda simply attempts to answer the question, "What are the most important issues in improving motorcycle safety?"

The key issue to address in this matter is described in The Netherlands' Sustainable Road Safety (SWOV, 2006):

> "Do motorised two-wheelers actually fit into Sustainable Safety? The brief answer to this question is no, because Sustainable Safety speaks of achieving a considerable reduction of risks and of numbers of casualties. We could say that motorised two-wheelers (motorcyclists and moped riders) would fit within Sustainable Safety if the risks for this group were reduced to a similar level to that of car drivers and pedal cyclists. Currently, the risk is still 75 fatalities per billion person kilometres for

motorcyclists, and 91 for moped riders, whereas the risks for car drivers and pedal cyclists are respectively 3 and 12 fatalities per billion person kilometres. Such a sharp decrease in risk is inconceivable without draconian measures. It is difficult even to conceive of Sustainable Safety measures that could lead to a substantial reduction in the number of victims of crashes involving motorised two-wheeled vehicles.

Furthermore, the relatively high risk of motorised two-wheelers calls for a discussion concerning the acceptance of risk in a risk society ('How safe is safe enough?'); what should reasonably and responsibly be done to reduce risks ('As low as is reasonably achievable').

While this document was drafted by road safety practitioners within the Government, the result of this consideration is reflected in the Dutch strategic action plan for motorcycling (Rijksoverheid, 2011), which, as is recommended in this report, was prepared to reflect the consensus views of stakeholders:

> "The aim of this action plan is to reduce the per kilometre risk of accidents faced by motorcyclists with a view to reducing the number of motorcycle casualties. Although the multi-year trend does reflect a reduction in the number of fatalities, the number of motorcyclists killed in road accidents has not decreased in the past three years, providing additional impetus for the introduction of this action plan.
>
> This action plan is part of the Strategic Plan for Road Safety 2008-2010 (Strategisch Plan Verkeersveiligheid 2008-2010). The implementation of additional protective measures for vulnerable road users (including motorcyclists) is one of the cornerstones of this Strategic Plan, the guiding principle of which is that all measures must be proportional, i.e. increasing motorcycle road safety must not come at the expense of the freedom of motorcyclists to use the road in a responsible manner. The Ministry of Infrastructure and the Environment believes that this action plan will facilitate achieving the ambitious aims mentioned above, while adhering to this principle."
>
> (Action plan for improving road safety for motorcyclists – Strategic approach)

Research and modelling

The development of an effective strategy implemented through sound actions depends on a solid research base to ensure that specific interventions are supported by evidence. Research can also inform the mix of strategies necessary to achieve desired outcomes.

These desired outcomes should include ambitious improvements in road safety as measured by fatalities and serious injuries. However, this work should also include the development of agreed safety performance indicators set at a level to allow continual monitoring of the factors it is possible to manage. The determination of strategies and actions should be driven by the desired intermediate and overall outcome targets that have been agreed.

A process to achieve to ensure an evidence-based strategy will include steps to:

- Obtain research advice which models the estimated impact of a number of individual interventions upon serious casualty outcomes and other safety performance indicators.
- Progressively refine the research-based modelling of estimated effects on serious casualties of a mix of initiatives to establish materiality awareness, (to lessen the tendency by senior bureaucrats and Ministers to discard potentially uncomfortable but substantially beneficial interventions) and to underpin target setting for the strategy.

- Set targets for fatality and serious injury reductions for the life of the strategy and key safety performance indicators and measure (and report publicly on) progress.

While this process has been exploited in a number of jurisdictions in the development of general road safety strategies, its application for PTW safety will be faced with greater sensitivity to research and modelling accuracy due to the relatively smaller number involved and the greater the impact of variability on the currently quite broad-brush estimates used in current modelling.

This demand for increased accuracy will remain a challenge to be gradually addressed as research improves the ability to predict the impact of future interventions.

For example, while the impact of infrastructure spending or speed enforcement may be relatively certain, the impact of changes to protective clothing or improvements in rider training or driver awareness are currently less amenable to predictive modelling.

Nevertheless, the Swedish Strategy for 2010-2020 indicates how modelling can inform the development of a suite of measures to meet a specific target (see table 10.2).

Table 10.2. **Potential of safety interventions – Results of modelling in Sweden**

Prioritised operational areas for motorcycles	**Potential** (Number of lives saved per year)	**Present situation**	**Goal level**	**Effect**
Anti-lock braking system (ABS)	31	30%	98%	15
Traction control	5	?	?	?
Speed limit observance	At least 15	?	80%	At least 9
Correctly used helmet + full-body protective equipment	4+3	-	-	?
Visibility of motorcycle / alertness of other road users + alertness of motorcycle rider	6+5	?	?	?
Sobriety	8	?	?	?
Safe intersections in built-up areas + urban areas	4+8	?	50%+?	2+?
Make existing guard rails appropriate to motorcycles	5	0%	?	?
Safe lateral reserves	6	?	?	?
Other operational areas	5	-	-	5
Total (lives saved per year)				31
Target: -50% reduction in motorcyclist fatalities by 2020 (Lives saved per year)				**27**

Source: Trafikverket (2010).

PTWs in the Safe System

The safe system is variously described in a number of jurisdictions but has a single core principle: a recognition that road users will make mistakes, or inappropriate decisions, and that the system, while also minimising errors, should accommodate these errors so that no individual road user is exposed to crash forces likely to result in death or serious injury.

This unacceptability of trauma is central to approaches such as Vision Zero in Sweden and Sustainable Road Safety in the Netherlands.

The Safe System approach assumes that road users will enter the system competent and will take measure to ensure that they remain compliant and alert. The system then ensures their safety by providing vehicles, road and roadside infrastructure and travel speeds that combine to ensure that any crashes that do eventuate result in crash forces that are below the level of human tolerance to physical harm.

Applying the Safe System to reduce general levels of road trauma will result in developments in vehicle occupant protection, protection from roadside hazards and separation from oncoming traffic on high speed roads with limited access and lower speed limits (e.g. 50 km/h) and intersection treatments such as roundabouts where traffic conflicts are inevitable. Where pedestrian and cycling traffic is introduced into the mix, there is a growing use of even lower speed limits (e.g. 30 km/h).

Another characteristic of Safe System approaches is consideration of the interactions between the different elements of the system and between the effects of different interventions. Some aspects of this are well recognised, for example, the influence of road design on chosen travel speeds. The challenge is to optimise the protection by combining the components of the road traffic system.

A potential area of future research would be to investigate such interactions in more detail to determine whether future road safety interventions and their underlying standards may need to be improved. For example, research (Berg et al., 2005) has indicated that the interactions between riders and roadside barriers are evenly split between riders and their vehicles sliding into barriers (separately or together) and others hitting the barrier on the motorcycle while in an upright, riding position. If loss of control due to braking leads to the former scenario, it could be hypothesised that an increasing uptake of ABS would lead to a relative reduction in such crashes. The most effective interventions to improve safety in impacts with roadside objects may therefore need to consider the rider/PTW system and also the potential protection that may be offered by the vehicle, as well as protective clothing or modifications to the roadside environment and furniture.

Inclusion of PTW riders into the Safe System yields two challenges. The first is the technical problem of providing protection from physical harm at the speeds at which collisions with other vehicles or fixed objects are likely. While this could be solved by ensuring travel speeds by, and in the vicinity of, motorcyclists are much lower, this then amplifies the second challenge. This is to ensure that any measures taken to improve PTW safety are supported both by the broader community and by PTW riders in particular.

This leads to consideration of whether the conventional Safe System approach should be modified by recognising that, in the short to medium term, use of PTWs will remain an inherently risky activity and that measures should be taken to reduce risk. This may result in, for example, strategies that focus more on avoiding crashes, rather than mitigating their effects, as outlined above in the Swedish strategy.

The risk mitigation approach then poses another challenge for jurisdictions. While the Safe System approach – for example as exemplified by Vision Zero – reinforces the unacceptability of trauma, a risk reduction approach to some extent confirms that some level of risk is acceptable.

In other words, in considering Reason's model of reducing trauma outcomes (Reason et al., 2006), the "Swiss cheese" model, the later interventions in the model will, for many years, contain large gaps that cannot be easily plugged. This leads to the conclusion that the most significant gains may derive from attention to the early parts – error and crash avoidance, rather than mitigating their effects.

However, as guided by Safe System thinking, strategies should not ignore the opportunities that are available to address the later stages of the causal chain – such as the promotion of improved protective clothing and equipment.

Decisions regarding resource allocation to road safety, the level of regulatory controls imposed on road users and other community costs will depend on agreement regarding the level of risk, or the reduction in trauma that is being sought over the life of a strategy. While the Swedish strategy spells this out, very few others do. This can lead to constant debate between stakeholder groups regarding the acceptability of proposals as there is seldom any objective target that any proposals are supporting.

The contrary view to the Safe System is that continued progress to reduce PTW risks is sufficient even if these reductions do not lead to reductions in overall levels of trauma, as the growth in PTW use outweighs the reduction in risk.

So, in the development of a road safety strategy for PTWs, while many jurisdictions recognise the need for broad stakeholder agreement to the content of the strategy, a shared commitment to a specific target will assist in subsequent determination of actions. Spain, in particular has put a strong emphasis on the need to achieve a shared vision (DGT 2007).

One of the factors in determining the appropriate level of risk, or the rate of risk reduction, is the proportion of traffic represented by recreational riding and the proportion of stakeholder input that is provided by that sector. While this will vary across developed economies, the domination of PTWs in emerging economies may provide different opportunities for interventions that may be unacceptable amongst the more recreationally-focused users in developed countries.

While this discussion has considered strategies for improving PTW safety as separate from general road safety strategies and their overall target, over time these two needs will merge. Growth in PTW use and improvements in safety for other road users are resulting in a general trend, across all countries, for PTWs to represent a growing proportion of road trauma. Achievement of overall Safe System goals will be increasingly difficult without close attention to PTWs.

Determine strategies and actions

Effective strategies will address the problem through a broad and integrated range of interventions that will exploit the synergies from multi-action programmes.

These should cover the full suite of Safe System interventions, subject to evidence of effectiveness and prioritised and targeted according the special needs of motorcyclists and the individual needs of each jurisdiction.

Some key questions can assist in the development of strategies and actions:

- What proven countermeasures can be implemented immediately – to provide immediate benefits and to provide visible evidence of commitment to action. Such commitment can then help garner broader stakeholder and community support for further, perhaps more challenging, actions.
- The development of what longer-term actions should be started now to address known or predicted future issues
- What work needs to be considered to develop greater understanding of motorcycle trauma, future trends and research findings to allow future countermeasures to be planned.

The development of countermeasures should also take into account that evidence about crash cause and driver culpability, although valuable input to the process, may not assist in the development of the most effective actions to reduce trauma that results from these factors. For example, while a proportion of crashes may be caused by other drivers not looking for – or seeing – PTWs, countermeasures that only tackle this root cause may be less effective than approaches that seek to modify car driver behaviour yet also recognise that other measures will be needed to cater for the limitations in any behavioural change programme.

The limitations in focusing on crash causation highlight the need for a combination of measures to be taken in many cases.

Safe System actions

The discussion of the Safe System, above, considered the applicability of the Safe System in relation to the setting of strategic targets that reflected the desire to move to, or towards, a Safe System, or whether a less ambitious, but more pragmatic, goal of risk reduction was more appropriate.

The Safe System also provides a framework to ensure broad consideration of a range of countermeasures that, together, provide a more complete system of protection.

Broadly, the Safe System components of road users, vehicles and infrastructure follow three well-established pillars of road safety, as described by models such as the Haddon Matrix. The Safe System goes further, by recognising that human error is inevitable and that the other components of the system should work together to prevent the outcome of these errors from being death or serious injury. This results in the fourth factor – speed – being introduced as a factor to mitigate harm, based on the known empirical relationships between impact speed and the probability of serious trauma. This approach is illustrated in the growing use of 30-40 km/h speed limits in areas of significant potential interaction between pedestrians and powered vehicles.

Similarly, data for passenger car crashes indicate that the potential for side impacts at speeds greater than 50 km/h and head-on impacts at greater than 70 km/h should be designed out of the system if the risk of serious injury or fatality is to be avoided

Similar empirical data for PTW riders is scant. However, the protection afforded by helmet and protective clothing would not approach that provided by a car's occupant restraint system, including the substantial structure around the occupant. The application of this approach to PTWs could lead to a conclusion that, as rider and driver error is inevitable, speeds should be managed so that impacts with other vehicles or infrastructure are below the level that would contribute to life threatening trauma. This speed would be increased through the use of frangible infrastructure, improved protective equipment and the physical separation from other vehicles. The difficulty in achieving these, in practice, and within the bounds of community acceptance, demonstrates the large gap between current practices and a Safe System.

In applying the Safe System to passenger cars, an assumption is made that drivers are competent and compliant and that the system of vehicles, infrastructure and speed working together has the potential to remove all risk of serious trauma. For PTWs, the speeds necessary to achieve these outcomes with the present performance and extent of use of protective equipment and forgiving infrastructure are likely to be so low that an alternative approach may need to be considered. That is to accept that a significant proportion of the gains to be made will be due to measures taken to improve the compliance, and competence of riders and other road users. So, while jurisdictions should select strategies and actions appropriate to their needs and institutional and social environment, there may need to be a conscious decision not to follow the same balance of strategies that provide optimal outcomes for other road users.

The specific actions included in a strategy should build on the evidence-based countermeasures described in the previous chapters. This Section provides examples of important questions that a strategic process should answer in developing a suite of measures that work together to address the key issues identified during the problem definition process.

Road users

Ensuring safe entry of riders to the road system:

- What measures are necessary to ensure that riders enter the road system with adequate riding skills, hazard perception and responsible attitudes?
- Has the minimum age for riders been set with full consideration of the social and road safety impacts?
- Once on the road system, how do they develop skills through experience and what measures are necessary to manage the elevated risk during this period?
- What measures need to be taken to target specific rider groups, e.g. returning riders or off-road riders?
- What are the appropriate mechanisms to achieve desired capability and behaviours – off- and on-road training, mentoring etc. and how should these differ for different subsets of the rider population?

Ensuring compliant behaviour by riders in the road system:

- What are the key behaviours to be managed?
- How should enforcement, education, marketing and sanction schemes work together to achieve desired behaviour change?
- What innovative communication channels can be used to reach the target audience?
- What measures are necessary to improve the effectiveness of systems that prevent access to the road system by those who have demonstrated an inability or unwillingness to comply?
- What electronic or other systems are in place to reduce unlicensed riding?

Ensuring continuing alert and competent riders:

- Apart from those addressing the general road user population, should there be specific measures targeting PTW riders to reduce the influence of alcohol, drugs, fatigue, drowsiness etc.?
- What interventions are required to respond to the different segments of the PTW road safety market, with the style and tone of communications programmes which seek to encourage safe behaviours selected to gain the greatest traction with the identified sub-group?

Shared responsibility:

- What measures are necessary to reinforce the concept of shared responsibility for road safety and what are the specific behaviours these are seeking to influence?
- Are these opportunities to improve other road users' ability to look for, perceive and react to motorcycles?
- Segmentation.
- How should the above actions be tailored and priorities altered for different PTW groups? These may include:
  - Moped riders
  - Scooter riders
  - Commuters
  - Recreational riders
  - Returning riders
  - Off-road riders
  - Urban versus rural riding

PTW users can also be segmented according to attitudinal and motivational differences, leading to different attitudes to risk, use of protective clothing and riding styles.

Vehicles and equipment

Crash avoidance:

- What current or emerging technologies should be encouraged or required on PTWs to reduce the incidence of crashing due to rider error? These might include improvements to braking and/or stability systems, tyres, etc.
- What current or emerging technologies should be encouraged, or required, on PTWs or other vehicles to reduce the incidence of crashes due to other factors? These might include conspicuity aids, collision detection systems, v2v communications, etc.

Crash protection:

- What current or emerging technologies should be encouraged or required to reduce the risk of serious injury to riders in the event of a crash? These might include airbags, automatic crash notification.

Helmets and protective clothing

- What standards are set to define the required level of protection afforded by helmets and other protective equipment?
- What regulations are necessary to ensure the wearing of this equipment?
- Are these standards and regulations consistent with the physical and social environment?

- What programmes are required to increase compliance with these regulations and to encourage the use of additional protection?
- Are these actions tailored to different PTW groups, e.g. novice riders, off-road riders, scooter riders?

Infrastructure

Provision for motorcyclists in new road infrastructure:

- Has the impact of network developments on PTW trauma been taken into account in the determination of PTW road safety targets?
- What standards should be set to define required infrastructure design and performance?
- What guidelines are necessary to encourage motorcycle-friendly infrastructure?
- What procedures are necessary to define when investment in PTW-compliant infrastructure is required?
- What programmes are required to increase road authorities' and road designers' awareness of the needs of PTWs and their capability to design to these needs?
- Are road safety audits undertaken from the perspective of all road users, including PTW users?

Segregation:

- What measures can be taken to reduce the interaction between incompatible traffic streams, particularly between PTWs and heavier motor vehicles?
- Is it necessary to reduce the sharing of lanes by PTWs and other vehicles?

Specific motorcycle treatments:

- What innovative treatments should be trialled to investigate the potential to improve PTW safety?
- Are programmes in place to collect and analyse crash data to determine the locations of greatest PTW risk?
- Are programmes to address these risks in place and is the rate of investment consistent with the targeted reductions in PTW trauma?
- Do these programmes encompass blackspot/black length (reactive) and infrastructure safety risk reduction (proactive) investment programmes?
- Are effective practices for reporting (of on-road motorcycling hazards) and response arrangements in place by all road authorities including local government?
- Do road operations practitioners share experiences within/with other road authorities about good operating practices?

Speed management

- How much is the community (motorcyclists and the general community) prepared to support speed limits that are set at, or approaching, Safe System limits?

- What limits should be placed on the maximum speed, power or acceleration of all PTWs, or those ridden by certain riders, for example novice riders?
- What programmes are necessary to increase riders awareness of the role of low-level speeding?
- Should differential speed limits be applied for different classes of motorcyclist, e.g. novice riders, moped or scooter riders?
- How should speed limits, roads and roadsides and vehicles interact to optimise progression to a Safe System?
- Are there locations where speed limits should be reduced on winding recreational routes so motorcyclists are not encouraged to engage in legal but unsafe speed behaviours?
- What current or emerging technologies should be introduced to raise riders' awareness of speed limits or restrict vehicles to the speed limit?
- How should enforcement technologies, sanctions and licensing procedures work together to discourage speeding and remove irresponsible and recidivist speeders from the road system?

Establish supporting arrangements

Consideration of the questions above should result in agreed strategic actions that address the PTW safety issues that are the most critical for each jurisdiction. They define WHAT needs to be done to improve PTW safety. The following section of a strategy will define HOW these actions can be implemented and supported.

Resource allocation and prioritisation

Actions taken to address PTW safety need to be balanced against the competing demands for resources from other road safety actions and from unrelated programmes seeking support in a resource-constrained environment. In addition to funding for the delivery of interventions, there is also competition for support in areas such as research, policy development and legislative processes.

The establishment of quantitative outcome targets and the development of an understanding of the outputs required to achieve these targets will help inform the resource allocation process. Without these targets, there is a risk that competition for limited resources will result in resources being directed to other areas of road safety. The monitoring of performance to outcome and output targets should provide an objective process to help support the case for increased overall funding to cover this gap should this allocation to other areas occur.

There are three key decisions to influence the allocation of resources to PTW safety:

- How can existing programmes be shaped to enhance PTW safety?
- How much can be allocated to programmes that are specifically targeted at PTW safety?
- What processes should be used to prioritise effort, once a decision to allocate resources has been made?

While economic tools such as benefit cost analysis will help direct resources at the key problems, they carry the risk that some areas, such as PTW safety, may be less able to attract funding than other modes with greater traffic densities. Blackspot programmes can deliver outcomes with very significant benefit cost ratios, but crash types that are more dispersed in the network will not be able to compete against crashes at, typically, intersections.

PTW safety may therefore be enhanced by the application of road safety resources toward conventional initiatives that benefit the whole road user base, if these are targeted at locations or other demographic sectors that would otherwise not be supported. Indeed, the benefits for PTW riders may be less than for other road users, but they may be considered to be PTW programmes if they would otherwise not be funded under a process driven purely by benefits for the whole road user population.

On the other hand, the provision of infrastructure – or implementation of other measures – specifically for the benefit of PTW riders will be influenced by the benefits for PTW riders alone and the cost of providing these benefits. The lower the marginal cost of making provision for PTW riders, the greater will be the opportunities to make these provisions.

As an example, consider the case of roadside barriers. Policies to provide supplementary protection for PTW riders that increase the overall cost of barriers may result in fewer locations being able to be treated for the benefit of all road users and this could result in a net community cost. A challenge for the future is to minimise the cost differential to render the compromises that need to be made less significant. While this trade-off is particularly important for retrospective programmes that are treating existing locations with higher crash risk, it can be addressed in the provision of new infrastructure by the establishment of standards and policies to require improved performance in PTW crashes. However, in the allocation of scarce and limited resources, such policies will always result in trade-offs being required in other areas and these trade-offs may carry a net community cost.

An alternative approach, such as that adopted in Australia with the Victorian Motorcycle Safety Levy, is to dedicate a specific expenditure programme to PTW safety, without competition from other demands for road safety investment. In the Victorian case, this expenditure programme is funded by a specific levy on PTW owners (see Box 10.1).

Box 10.1. **Australian Case Study: The Victorian Motorcycle Safety Levy**

The Motorcycle Safety Levy (AUD 66 for 2012/13) is an addition to the compulsory personal injury insurance premium on PTWs with a capacity of 126cc and over. The levy is included with registration renewals.

Special purpose vehicles, recreation registered motorcycles, motorcycles used solely for primary production operations and veteran, vintage, or classic motorcycles with club permits are exempt from the levy.

The funds from this levy go directly to projects to improve the safety of riders.

From the start of the levy in October 2002 to the end of June 2012, approximately AUD 45 million was raised from the levy. To date, the funds raised have been allocated to over 148 road improvement projects and 54 other projects involving areas such as research and education.

Application of funds follows a Strategic Guide for Expenditure of the Motorcycle Safety Levy Funding to achieve the greatest benefits for rider safety.

This Strategic Guide defines four priority areas for projects to be considered for funding:

- Engineering, technology and Intelligent transport systems (ITS).
- Enforcement.
- Education.
- Enhanced information for decision making.

Benefit-cost analysis

Analysis of relative benefits and costs can be used in a number of ways to influence resource allocation and project prioritisation. Benefit-cost analysis can be used to help answer the following questions:

- How should resources be allocated between competing programmes; for example between a motorcycle blackspot programme, or a programme in another area of road safety, or a completely different area of government responsibility? In this case, the power of the analysis can be limited by the varying assumptions made about very different types of benefit. As discussed earlier, the most appropriate tool may be a more strategic analysis of overall resource needs to meet agreed performance targets.
- How should programme resources be allocated between competing projects? For example, which blackspot projects should be funded from a fixed resource source? In this case, the benefit-cost analysis should result in the optimal programme being developed with maximum road safety benefit resulting from the resource input. While this analysis should provide more useful results as the nature of inputs and outcomes should be the same, there is still a need to understand the role of uncertainty both in the underlying risk and in the effectiveness of the proposed treatment.
- Is an action worth doing? In other words, is the benefit-cost ratio above one, or above some predetermined level that has been set as a target return?

Role of stakeholders to promote consumer demand, community acceptance and participation

While much of the responsibility for implementing a PTW safety strategy will rest with governments and industry, no significant change will be possible without engagement with the community to ensure that they are aware of the shared responsibility for road safety. This extends beyond responsibility on the road to responsibility at other times.

Programmes such as New Car Assessment Programmes, now in place in many countries, have demonstrated the benefits in achieving improvements in safety performance driven by manufacturers' offers and consumer demand rather than the slower pace of regulatory change. The SHARP programme in the UK applies the same principle to motorcycle helmets to raise consumer awareness that they can provide themselves with a greater level of protection by making informed choices. This should then stimulate the market to provide improved performance in response to this demand.

The extension of this process to PTW protective clothing may provide similar benefits, but it would also benefit from an international approach.

Suppliers, clubs and other organisations have a role to play in promoting safe riding practices, safer clothing and equipment and safer bikes.

Economic incentives should be investigated to determine the extent to which safe choices and safe riding can be influenced by economic factors. These might include incentives for participation in effective training, offence-free riding, tax breaks for safety equipment. The source of these incentives may be government or insurers. The design and scale of these incentives are likely to vary considerably between jurisdictions due to differing economic conditions and financial systems in place.

Alternative mechanisms may include the imposition of insurance penalties; for example if PTW users are involved in a crash while not wearing protective gear.

One of the challenges of many road safety programmes is that the recipient of the benefits and the provider of the resources are often not the same organisation or group of individuals. Opportunities to create this link should be investigated.

Implementing a strategy

The implementation of a strategy starts with its development, and the process outlined in this chapter would lead not only to the creation of a strategy, but also to the engagement of all relevant stakeholders in the process.

Accountability for implementation will be a key factor in determining the success of a strategy. Through the situational analysis and development of strategic response to this, the desired key performance indicators should be developed to ensure that tracking of performance can be done.

There can be a benefit, through demonstration projects being developed, funded and implemented at local and regional level, to enable innovation and change to be progressed. This can not only provide early tangible benefits, but can also promote the strategy and increase awareness and knowledge.

Early achievement of tangible benefits can provide momentum for on-going effort by validating the direction of the strategy and strengthening the shared ownership.

Monitoring and evaluation

No strategies can provide a complete and accurate roadmap of the actions to be taken throughout its life. Limitations in data, uncertainty of effects, the development of new trends and the emergence of new technology all drive the need for flexibility in implementation. A safety performance framework, including responsibilities, monitoring, measuring, reporting and accountabilities will facilitate this process. This could be complemented by performance indicators for each stakeholder, measuring the output of each stakeholder’s actions.

The “Plan-Do-Check-Act” cycle of continuous improvement documented in management systems, such as ISO 39001 will be both a relevant and helpful tool to support the systematic and continuous improvement for each stakeholder, both public and private, by ensuring establishment of effective management systems.

These systems will include input and output measures to determine whether the strategy is being implemented and intermediate and overall outcome measures to assess whether the strategy is producing the desired result. Tracking of these measures and regular reporting to practitioners and the community should prompt review of ways to improve implementation, as well as the need for adjustment of the strategy in the face of changing trends or unexpected variations in the road safety impacts.

In addition to on-going monitoring, the implementation plan should include regular reviews to check and report that implementation of the strategy is proceeding to schedule and whether the strategy itself needs to be adjusted in light of experience gained, emerging trends and technological developments.

The key outcome measure for the community, opinion leaders and policy makers will be trends in serious casualties, particularly fatalities. Owing to the random variation in some of these data, the development of understanding of statistical significance will provide benefits in avoiding knee-jerk reactions to short-term trends that prove to be the result of no more than uncontrollable random variation. For PTWs as a subset of the total road safety situation, the smaller total numbers involved can increase the potential for this.

Conclusions and recommendations

Growing PTW traffic makes it imperative to adopt safety interventions targeting this mode of transport. A strategic plan to achieve the goal of a Safe System should be integrated with road safety strategies across all modes, as well as examining opportunities across society for the cultural and attitudinal changes that are required for significant and sustainable improvement.

As the economic costs associated with PTW crashes are significant, investing in PTW safety can bring important societal and economic benefits. These benefits are likely to amplify as growth in PTW usage increases the total cost the trauma imposes on the community.

Improving the safety of PTWs should be a shared responsibility. All relevant stakeholders need to be actively involved in the process of drawing up and implementing a shared road safety strategy which includes safer behaviour of all road users, safer infrastructure and vehicles with enhanced safety features. A toolbox of measures is required to improve the safety of PTW riders within the traffic system. These measures must take into account the specific challenges of PTWs traffic, and also consider the variety of PTW users, insofar as some segments may be addressed with particular measures. A strategic approach should consider the most effective combination of measures according to the specific needs of individual jurisdictions.

Additional research will provide a better understanding of current challenges related to PTW mobility and safety problems and help achieve a traffic system which better integrates and protects PTWs in a cost efficient manner. However, significant benefits can be achieved by applying current knowledge. A lack of complete understanding should not be an impediment to action being taken immediately. A robust strategic management process should ensure that on-going monitoring and evaluation are in place to adjust and improve strategies as new knowledge emerges.

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Chapter 11. Conclusions and recommendations

This chapter provides a summary of the main findings of this report, indicating the steps that should be taken to ensure increased safety for all users of powered two-wheelers (PTWs). The need for a systematic approach to powered two-wheeler safety is highlighted and recommendations for the implementation of a toolbox of countermeasures are provided.

The role of powered two-wheelers in mobility

The powered two-wheeler population is increasing and plays a significant role in mobility.

The powered two-wheeler (PTW) population, which includes motorcycles, scooters and mopeds, is constantly increasing and plays a significant role in mobility in many countries, particularly in many of the world's large cities.

Worldwide, the current production of PTWs is around 50 million units per annum, compared with around 65 million units for passenger cars. In the various OECD countries, PTWs account for between 2 to 31% of the motorised fleet; the highest percentage generally being found in countries with a mild climate. PTWs can be the dominant motorised transport mode in some developing and emerging countries, comprising up to 85% of motorised vehicles. In most OECD countries, the motorcycle fleet increased much faster than the passenger car fleet from 2001 to 2010. In France for example, the PTW fleet has increased by 48% in the last decade, while the car fleet increased by only 11%.

In many cities, PTWs have become a real alternative to passenger cars given the level of traffic congestion. Indeed, PTWs present a number of advantages, including flexibility, reliability of travel time, and lower cost of use compared to a private car. As a consequence, the PTW fleet has expanded very rapidly in some cities. As an example, in 2013 Rome was the European city with the largest PTW fleet, with about 700 000 PTWs (compared to 1.9 million passenger cars).

Some riders use PTWs as their primary form of transport, others more for recreation. For many it is the only affordable or practical means of individual motorised mobility. In Europe, PTWs are commonly used for commuting, but this is less common in the United States, Canada or Australia, where the primary purpose of PTW use is often recreational riding. In some low- and middle-income countries, PTWs are the main mode of individual motorised transport and considered to be the family vehicle.

The PTW rider population is composed mostly of males, but the trend is changing, with more and more females also riding. In many OECD countries, there is an increasing number of "returning" riders, i.e. typically males in the 40-50 year age group, who stopped riding a PTW for a period of more than 5 years, who usually return to riding on powerful motorcycles.

It is essential to take into consideration PTW needs in transport policy.

PTWs are becoming an important component of the transport system and in some cities represent up to 30% of the motor vehicle fleet. They present both assets for mobility, and also challenges in terms of traffic management and safety. However, only a few countries have in place a national transport strategy for PTWs; though several measures have been taken at local level.

Traditionally, the transport system in many countries has focused primarily on four-wheeled vehicle traffic. There would be many benefits, in terms of mobility and traffic management – as well as traffic safety – in a better integration of PTWs into mobility plans and in the development of national and local transport strategies.

Safety issues for powered two-wheelers

PTW riders are at far greater risk than car drivers

In OECD countries, PTWs represent on average 8% of the motorised vehicles but 17% of total fatalities. This share is much higher in low- and middle-income countries, where PTWs can represent up to 70% of road fatalities. They have not benefited at the same pace as car occupants from safety improvements over the recent decades. While, on average, OECD countries have seen a reduction of about 36% in the number of persons killed in traffic crashes in 2000-2010, the number of motorcyclists killed has decreased by only 13%. The discrepancy is particularly obvious in the United States, where the number of motorcyclists killed increased by 44% between 2001 and 2011, while the number of passenger car occupant fatalities decreased by 29%.

Per kilometre driven, PTW riders have a much higher risk of being killed than car occupants. For a motorcyclist the risk, depending on the country, is between 9 and 30 times higher. The increased risk is slightly lower for moped riders. PTW riders are also more likely to be very seriously injured, with long-term disabilities, in a road crash than other motorised road users. As the large majority of motorcyclists are younger than other motorised road users, this translates in many years lost, or with reduced capacities.

Addressing the safety issues of powered two-wheelers should be seen as a priority in all countries to improve overall road safety. It is one of the main challenges in the context of the UN Decade of Action for Road Safety.

In addition to the human tragedy associated with PTW crashes, their economic consequences are significant; therefore investing in PTW safety can bring important societal and economic benefits.

Poor perception and control are frequent failures that lead to PTW crashes

Poor perception and control are frequent failures that lead to PTW crashes. The most common PTW fatal crashes occur at intersections with other traffic, often involving a problem of perception and appraisal by the driver and/or the rider. The other most frequent crash type are single-vehicle crashes, notably due to intrinsic difficulties of riding a PTW (e.g. necessity to keep the balance) and to the higher sensitivity of riders to external perturbations (e.g. wind or poor pavement conditions). The consequences of crashes are particularly aggravated for PTWs by the aggressiveness of roadside obstacles.

The problem of perception is complex and involves a variety of parameters: the visual characteristics of PTWs, the sensory capabilities of the human perceptual system, the atypical behaviour of PTWs and the familiarity with PTWs in traffic.

As for other road users, speeding (i.e. driving above the speed limit or at inappropriate speed) and consumption of alcohol and drugs are critical factors in the occurrence and severity of crashes. Operating a PTW requires more co-ordination, balance and alertness than operating a car, which explains that impaired riding is even more problematic for PTW riders.

A more frequent combination of road crash contributory factors is found in PTW crashes compared to other road users crashes, which results in the multiplication of the relative risk of PTWs.

Human behaviours and conditions are the most frequently represented contributing factors in PTW crashes. However this does not mean that solutions to improve the safety of PTWs must only focus on behaviours. A Safe System approach is required: it can be more efficient to change crash and injury outcomes by implementing a range of interventions, including for road users, the infrastructure, the vehicle and the system as a whole.

PTW safety in the context of a Safe System

A Safe System approach is required to improve the safety of PTWs

The Safe System approach recognises the fact that road users can make mistakes, or take inappropriate decisions; the role of the system is first to minimise the production of these errors and secondly to prevent road users from death and serious injuries when errors occur.

Effective strategies have been shown to be based on specific targets. These should be supported by regular evaluation of progress against outcome measures relevant to each intervention. The results of the evaluation allow adjustments to plans to ensure on-going effectiveness of the strategy and continuous improvement in implementation.

Inclusion of PTW users into the Safe System yields two challenges. The first is the technical challenge of providing protection from physical harm at the speeds at which collisions with other vehicles or fixed objects are likely. While this could be solved by ensuring travel speeds of (and in the vicinity of) PTWs are much lower, this then amplifies the second challenge, which is to ensure that any measures taken to improve PTW safety are supported both by the broader community and by PTW riders in particular.

This leads to consideration of whether the conventional Safe System approach should be modified by recognising that in the short to medium term, PTW riding will remain an inherently risky activity and that measures should be taken to reduce risk. This may result in, for example, strategies that focus more on avoiding crashes rather than mitigating their effects.

Improving PTW safety is a shared responsibility between all stakeholders. A Safe System also calls for a shared responsibility on the road and to be accountable for one’s own actions. Improving the safety of PTWs requires all relevant stakeholders to be actively involved in the process of drawing up and implementing a shared road safety strategy, which includes safer behaviour of all road users, safer infrastructure, and vehicles with enhanced safety features. This shared responsibility should also extend to the planning for road safety and the implementation of road safety management systems. PTW safety is not only the responsibility of governments, administrations and manufacturers, but also PTW associations, insurance companies, the media, etc.

While a Safe System approach is adapted to all countries, whatever their level of development and safety performance, it must acknowledge that the usage of PTWs varies greatly in different parts of the world. A tailored approach is therefore required to take account of the local specificities.

A toolbox of measures is required to improve the safety of PTW riders

A toolbox of measures is required to improve the safety of PTW riders within the traffic system. These measures must take into account the specific challenges of PTW traffic, and also consider the variety of PTW users, insofar as some segments may be addressed with particular measures. A strategic approach should consider the most effective combination of measures according to the specific needs of individual jurisdictions. The measures are developed in the points below. Developing countries often lack basic standards for roads and road safety. In such cases, priority should be given to securing basic infrastructure and an inclusive approach taken towards motorcycling in transport policies, including training and education of riders, helmet law, etc.

Countermeasures

Promoting appropriate behaviours of road users

The Safe System approach assumes that road users will enter the system competent and will take measures to ensure that they remain compliant and alert. Licensing, training, education, and enforcement campaigns are essential tools for improving riding safety.

Licensing, training and education

Access to PTWs should be gradual, with a licensing system aiming to manage novice rider risks while riders are gaining experience and maturity. The licensing system should also ensure that mature novice riders directly accessing high-powered motorcycles possess the skills, knowledge and correct attitude to safely drive these vehicles.

Several countries have adopted graduated licensing schemes. These schemes are designed to provide new riders with driving experience and skills that can be developed gradually over time in low-risk environments. The rider obtains a licence by passing through a number of stages; restricted, provisional or probationary and full licence.

In Europe, Member States of the European Union have a harmonised licensing system. The 3rd Driving Licence Directive came into force in January 2013 and mandates a strict graduated approach towards heavier machines. The Directive requires a minimum age of 24 to ride the A category (> 35 kW). However, the subsidiarity principle applies and countries can adapt the Directive.

Training for riders and drivers, with the objective that they acquire a good appreciation of the road environment and its dangers, is an important step towards promoting safer behaviours. Riding a PTW requires technical skills – more so than for driving a car – and novice riders of every kind of PTW should be trained. This training should focus not only on basic manoeuvring skills and mastering traffic situations, but also on addressing attitudes towards safety, with a special emphasis on hazard perception and defensive riding. As an attitude, defensive riding enables the rider to systematically foresee what the riskiest scenario may be at any given moment. Defensive riding allows the PTW rider to avoid the riskiest situations, should they occur. Training should be conceived to promote safe behaviours; performance-focused training has not proved to be effective in increasing safety.

The training challenges for PTW safety do not address PTW riders only. The *curricula* for training and education of drivers in all other vehicle categories should also focus on risk awareness when dealing with PTWs, their vulnerability, and crash patterns.

Enforcement

Enforcement of traffic rules is an indispensable ally of other safety measures. PTW operators, as other operators of motorised vehicles, must comply with traffic rules and typical enforcement activities to control speeding, drink and driving, and non-respect of traffic rules. Intensive, visible enforcement accompanied by other measures, such as communication and publicity, has proven to have a strong deterrent effect by increasing the perceived likelihood of detection. In addition, the progressive adoption of automated speed enforcement has also proven its effectiveness in reducing speed. In this respect motorcyclist associations can also play an important role in making enforcement understood and accepted as an effective safety measure.

Communication campaigns

Communication campaigns addressing required behaviour change should be targeted at key groups of drivers, riders and other road users. Every road user should be made aware of the specific risks associated with PTWs' vulnerability and crash patterns. Facilitating a safety dialogue among the motorcycling community has proven to be an effective tool in conveying safety messages.

The helmet is the most important source of protection against severe injuries and death

The helmet is clearly the most important source of protection against injury for both motorcyclists and moped riders. It contributes to a dramatic reduction in the risk of being killed or severely injured. Helmets can prevent damage to the brain, which may result in very severe physical and psychological handicaps.

All countries should have and enforce a helmet law. A 100% wearing rate is the only acceptable objective. Still, not all OECD countries have a national helmet law. Enforcement and communication campaigns should not only focus on wearing but also on *proper* wearing of a helmet (i.e. with fastened chin strap) and on fighting, especially in low- and middle-income countries, against the proliferation of fake helmets.

Other protective equipment includes airbag jackets and protective clothing (gloves, jackets and boots). The Working Group recommends promoting the use of this equipment with adequate safety standards. Airbag jackets appear as a promising technology to minimise injury to the rider in case of a crash and further research is needed to evaluate their effectiveness.

Regarding high visibility clothing, research shows different results regarding their effectiveness in reducing conspicuity-related crashes, depending on time and location. The contrast with the road environment is the most important element: in short, when riding through highly dense traffic, a rider should wear bright clothing. When riding mostly in open-space (cruising) a rider is better off wearing darker clothing. At night reflective clothing is more effective.

Vehicles with enhanced safety features

There are a number of developments within the motorcycle industry for technologies to assist in the prevention of a crash (active safety) and to protect occupants and riders during a crash (passive safety). Some are already available and proposed as an option when purchasing the bike, while others are still at the development stage.

The Anti-lock Braking System (ABS) and Combined Braking System (CBS) are well proven technologies which can significantly improve the safety of PTWs in specific traffic situations involving emergency braking. While ABS is currently offered as an option on new bikes of major PTW manufacturers, with a slow penetration rate in most OECD countries, the Working Group considers that it can certainly benefit all PTWs and should become a standard. Cost is however an issue, and industry and government should work together to facilitate a quicker penetration of these technologies, which will become mandatory in some regions in the coming years (expected in the European Union for the year 2016). While this technology is mature for OECD countries, there might be other priorities in low- and middle-income countries especially for the light motorcycles, as the implementation of existing lighting regulation, or in other fields the generalised use of helmets.

Advances in car technology can also bring positive safety benefits to PTW users. There are a number of new technologies, such as forward collision warning, blind spot information and vulnerable road user protection systems, which can prevent collisions, including those with PTW riders, pedestrians and cyclists.

There is a consensus that there has been little advancement of intelligent transportation systems (ITS) research dedicated to motorcycle safety. ITS developed for motorcycles offer opportunities to improve the safety of the rider as well. There is, however, a number of constraints specific to PTWs that need to be carefully addressed, including the specificities of the vehicles and the riding task, and the challenges posed by the Human Machine Interface requirements, costs, and the required support from the motorcyclist community.

Self-explaining and forgiving roads contribute to lower crash risk

The road environment has a significant influence on the risk of crashes involving PTWs. Contributing factors include: road surface defects (such as roughness, potholes or debris on the road); presence of slippery material (water, oil) on the road; broad line markings or use of raised pavement markers; poor road alignment; presence of obstacles, roadside hazards and safety barriers, and interactions with other road users (including heavy vehicles, cars, cyclists, pedestrians and other PTWs).

PTW-friendly road design, maintenance and infrastructure generally benefit all road users. The aim is to ensure that the safety of PTW riders is considered in the design and maintenance of roads and the implementation of traffic management plans. The design of junctions (for example roundabouts), the choice of barriers and road surfaces, require an integrated impact assessment taking into account all roads users and local conditions. Special consideration is also required during periods of construction where temporary construction materials are used: the road surface properties during the works can be hazardous for motorcyclists.

A consistent road environment invites road users to adopt the appropriate behaviours for safe riding and driving. A self-explaining road allows road users to anticipate changes in the local road context. Infrastructure can be improved to guide drivers and riders to adopt appropriate behaviour, to prevent the occurrence of crashes and mitigate their consequences (forgiving roads).

Engineers, road designers and providers, local authorities, road safety auditors and inspectors should be trained to consider PTWs in the design, construction, maintenance and operation of roads, and be provided with the necessary risk assessment tools to make the right decisions based on an overall impact assessment.

Need for further research

Extending the knowledge on PTW mobility and crash mechanisms

Additional research is needed to better understand current challenges related to PTW mobility and safety problems. This involves a need to develop and apply relevant methods, tools and indicators to measure PTWs in traffic flows and analyse their mobility and behaviour (exposure data). More in-depth investigations will allow a better understanding of fatal and serious injury crash patterns and causes. Conspicuity and other perception problems deserve further study in order to identify key contributing factors and effective countermeasures.

Operational research and development is needed

Operational research and development is needed to achieve a traffic system which better integrates and protects PTWs in a cost efficient manner. A co-ordinated and concerted cooperation between a variety of disciplines (e.g. civil and mechanical engineers, economists, educationalists, psychologists, transport planners, lawyers etc.) is key to the development of a consistent set of measures to address real issues regarding the safety of PTW riders.

While Intelligent Transport Systems (ITS) offer opportunities to improve the safety of drivers as well as riders, they require more R&D on their capacity to prevent PTW crashes, as ITS applications for cars are not directly transferable to PTWs. Any ITS application which removes, or interferes with, the longitudinal or lateral control of the vehicle could have adverse effects. Further research is therefore needed on the challenges posed by the Human Machine Interface requirements, the impact on human behaviours, and adequate training for the riders.

Further research is required with regard to the content and effectiveness of training (including post-licence training) with the aim of improving the behaviour and safety of both drivers and riders.

Further research and development into protective clothing and equipment with lower weights and improved ventilation are needed and should be encouraged.

Working group members

Chair: Mr Pierre VAN ELSLANDE (France)

Australia	**Mr James HOLGATE** VicRoads
Austria	**Mr Martin WINKELBAUER** Kuratorium für Verkehrssicherheit
Belgium	**Mr Kris REDANT** Belgian Road Research Centre (CRR)
	Mr André TOURNEUR SPF Mobilité et Transports
Canada	**Mr Raynald MARCHAND** Canada Safety Council
European Commission	**Ms Cristina MAROLDA** European Commission, Directorate for Mobility and Transport
	Mr Casto LOPEZ BENITEZ European Commission, Directorate for Mobility and Transport
France	**Mr Bernard JACOB** Institut français des sciences et technologies des transports, de l'aménagement et des réseaux (Ifsttar)
	Ms Hélène DE SOLÈRE Centre d' Études sur les Réseaux, les Transports, l'Urbanisme et les Constructions (CERTU)
	Mr Pierre VAN ELSLANDE Institut français des sciences et technologies des transports, de l'aménagement et des réseaux (Ifsttar)
Germany	**Mr Kai ASSING** Bundesanstalt für Straßenwesen (BASt)
Greece	**Mr Dimitris MARGARITIS** Centre for Research and Technology Hellas (CERTH)
	Mr George YANNIS National Technical University of Athens (NTUA)

Israel	**Mr Shlomo ZAGMAN** Israel National Road Safety Authority
Italy	**Mr Luca PERSIA** University La Sapienza, Rome
Mexico	**Mr Emilio MAYORAL** Instituto Mexicano del Transporte (IMT)
	Mr Rodrigo ROSAS OSUNA Centro Nacional para La Prevención de Accidents (CENAPRA)
The Netherlands	**Ms Saskia DE CRAEN** SWOV Institute for Road Safety Research
New Zealand	**Mr Wayne JONES** Ministry of Transport
Norway	**Mr Lars INGE HASLIE** Road Directorate
Portugal	**Mr João DIAS** Technical University of Lisbon
Spain	**Mr Juan MUGUIRO** ATOS Consulting
	Mr Fernando RUIZ Direccion General de Trafico
Sweden	**Mr Per-Olov GRUMMAS GRANSTRÖM** Swedish Transport Administration
United Kingdom	**Mr Andrew COLSKI** Department for Transport
United States	**Ms Linda DODGE** Department of Transportation
	Mr Craig MORRIS Research and Innovation Technology Administration (RITA)
	Ms Carol TAN Federal Highway Administration
	Mr Diane WIGLE National Highway Safety Administration (NHSA)
ITF/OECD	**Ms Véronique FEYPELL-DE LA BEAUMELLE**
	Mr Stephen PERKINS

Members of the Editorial Committee

The report was drafted primarily by members of the Editorial Group:

Mr James HOLGATE (Australia), Mr Kris REDANT (Belgium), Ms Hélène DE SOLÈRE (France), Mr Pierre VAN ELSLANDE (France), Mr Dimitris MARGARITIS (Greece), Mr George YANNIS (Greece), Ms Saskia DE CRAEN (the Netherlands), Mr Lars INGE HASLIE (Norway), Mr Juan MUGUIRO (Spain), Mr Per-Olov GRUMMAS GRANSTRÖM (Sweden), Ms Véronique FEYPELL-DE LA BEAUMELLE (ITF/OECD)

Other contributors

Ms Debbie ASCONE (NHTSA, United States), Ms Hildga GOMEZ (CAF Latin American Development Bank), Ms Magali JAFFARD (Ifsttar, France), Mr Michael JORDAN (NHTSA, United States), Ms Mandy JUTSUM (Department for Transport, United Kingdom), Ms Eleonora PAPADIMITRIOu (NTUA, Greece), Mr Thierry SERRE (Ifsttarr, France), Mr Davide SHINGO USAMI (University La Sapienza, Italy).

Peer review

The report was reviewed by Professor Narelle HAWORTH (Queensland University of Technology, Australia) and Professor Claes TINGVALL (Swedish Transport Administration). The Working Group and the Secretariat are very grateful for their comments and suggestions to improve the quality of this final publication.

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OECD PUBLISHING, 2, rue André-Pascal, 75775 PARIS CEDEX 16
(75 2015 02 1 P) ISBN 978-92-82-10793-5 – 2015

International Transport Forum

Improving Safety for Motorcycle, Scooter and Moped Riders

The global fleet of powered two-wheelers (PTWs) is constantly increasing. In many countries, motorcycles, scooters and mopeds play a significant role in mobility, particularly in many of the world's large cities. As such, PTWs are becoming an important component of the transport system. However, they represent an important challenge for road safety. PTW riders are at far more risk than car drivers per kilometre ridden in terms of fatalities and severe injuries entailing long-term disability. Moreover, they have not benefited from safety improvements at the same pace as car occupants over recent decades. Addressing the issue of PTW safety is thus an essential contribution to the success of the United Nations' Decade of Action for Road Safety, which aims at halving the expected number of road deaths worldwide by 2020.

This report reviews recent trends in powered two-wheeler crashes, the factors contributing to these crashes and their severity. It describes a set of countermeasures targeting user behaviours, the use of protective equipment, the vehicles and the infrastructure. Finally, it discusses motorcycle safety strategies in the context of a safe system.

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International Transport Forum
2 rue André Pascal
75775 Paris Cedex 16
France
T +33 (0)1 45 24 97 10
F +33 (0)1 45 24 13 22
Email : itf.contact@oecd.org
Web: www.internationaltransportforum.org

9 789282 107935
(75 2015 021 P1)
ISBN 978-92-821-0793-5
2015-09 /Photo credit: Roberto Muñoz, gettyimages