Powered Two Wheelers in a changing world - Challenges and Opportunities

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Research highlights

- Most PTWs are in Asia but most of the research comes from Europe and North America
- The safety challenges and mobility opportunities vary greatly across the world
- Better PTW usage information is needed to assess safety and mobility effects
- PTW use will continue to grow and evolve

ABSTRACT

Powered two wheelers (PTWs) come in diverse forms and are used for a range of purposes in very different parts of the world. In many parts of the world, the forms and uses of PTWs are changing, influenced by social, economic and demographic changes. Most of the challenges associated with PTWs relate to safety, while the majority of the opportunities relate to mobility. The challenges for improving safety relate to the PTW user, other road users, the road environment, the vehicle, data and research, and socio-political dimensions. The relative importance of particular challenges varies between developed and developing countries, and among developing countries according to whether PTWs are largely used for recreation or for transport. PTWs present a range of psychological, transport, economic and environmental opportunities to individuals and societies. The fun and excitement of riding PTWs is a major motivator for their purchase and use for recreational purposes, both off-road and on-road. The transport and economic advantages to the individual also need to be considered. At a societal level, research has examined the potential for increasing PTW volumes to reduce fossil fuel use and traffic congestion in busy cities. The future of PTWs may differ greatly between countries and environmental and technological changes are leading to an evolution in the form of PTWs to encompass new modes of personal transportation.

Keywords: Powered two-wheelers, safety, mobility, motorcycle, moped, scooter

1. Introduction

Powered two-wheelers (PTWs) play an important role in both transport and recreation around the world, but at considerable social cost. It is estimated that more than 180,000 PTW users die as a result of road crashes annually, with most deaths occurring in middle income countries (Naci, Chisholm & Baker, 2009). PTW users are certainly vulnerable road users, with death rates as a function of distance travelled generally found to be about 30 times greater than for car occupants (Johnston, Brooks & Savage, 2008; National Center for Statistics and Analysis Research and Development, 2008). The number of PTWs is increasing in many developed and developing countries (Jamson & Chorlton, 2009; Paulozzi, Ryan, Espitia-Hardeman & Yongli, 2007; Shankar & Varghese, 2006) and their usage is changing. This paper sets out to describe the pattern of use of PTWs, the challenges and opportunities they present, and to identify likely trends into the future.

1.1 Definitions and scope

The term PTW is used to refer to mopeds, scooters, and motorcycles; and commonly includes similar three-wheeled vehicles. Mopeds and scooters are PTWs of 'step-through' design, usually with automatic transmission, while motorcycles must generally be straddled by the rider and have manual transmissions. The use of mopeds is generally restricted to low speed zones in urban areas, by a combination of legislation and rider discretion, while larger scooters are typically capable of highway speeds and in some cases long distance touring. Many jurisdictions define mopeds in

terms of engine capacity (usually lower than 50 cc) and top speed (often lower than 50 km/h). There is currently no official definition of a scooter in Australia or elsewhere (Haworth & Nielson, 2008), but a scooter is usually treated as a motorcycle in crash and registration data.

The focus of this paper is the on-road use of PTWs, but it is acknowledged that a large proportion of sales in many developed countries are for off-road use. For example, motorcycles for off-road use represent more than 50% of all PTW sales in Australia (FCAI, 2010) and 22% in the United States (Morris, 2009). Additionally, the number of off-road injuries can be almost as great as those sustained on-road (Henley & Harrison, 2009).

2. PTWs across the world

Most of the world's PTWs are in Asia. Figure 1 (from www.worldmapper.org) shows the world in terms of the numbers of PTWs in each country. The land mass of each country has been adjusted to represent the percentage of the world's PTWs in that country as taken from World Bank Development Indicators 2005 (based on 2002 data). It shows clearly the importance of Asia with 65% of the world's PTWs. The motorcycle industry estimates that there are 313 million motorcycles in the world of which 77% are in Asia, 5% in Latin America, and 2% in North America (Rogers, 2008). Europe and North America comprise only 16% of the world motorcycle fleet. Within Asia, China has the most motorcycles (about 100 million), followed by India (about 40 million), Indonesia (about 30 million) and Thailand, Vietnam and Japan (about 15 million) (Rogers, 2008). Asian countries are also the largest producers of

motorcycles. In 2006, the top five PTW producing countries were China, India, Indonesia, Japan and Taiwan. Thailand, Vietnam and Malaysia were also among the top 10 PTW producing countries (Rogers, 2008).

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It is perhaps not surprising that most of the world's PTWs are in Asia, given that a very large proportion of the world's population live there. Figure 2 shows the 10 countries with the highest numbers of PTWs per 1,000 of population and the 10 countries with the lowest numbers (from www.worldmapper.org, based on 2002 estimates of PTW numbers from World Bank Development Indicators 2005 and 2002 population estimates from UN Development Program Human Development Report 2004). Four Asian countries (Malaysia, Thailand, Cambodia and Japan) feature among the top ten, with four European countries (Greece, Italy, Switzerland and Latvia). Interestingly, there is a mix of high, medium and low income countries in the top ten. In contrast, many of the countries with the fewest PTWs per thousand population are low income countries in Africa. The relative lack of popularity of PTWs in Africa is also evident in Figure 1.

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3. Diversity of PTW styles, uses and operating environments

Powered two wheelers (PTWs) come in diverse forms and are used for a range of purposes in very different parts of the world. Strifelt (2008) stresses the importance of

recognising differences among riders, in terms of why they ride, whether or not they belong to organised rider groups and their level of safety awareness. The types of PTWs and their main purposes of use also differ markedly among and between developed countries and emerging and developing countries. In large cities of some developed countries (particularly European countries), PTWs are commonly used for commuting, while in other developed countries (such as the US and Canada), touring is more common than commuting. In the latter countries, many PTWs are leisure vehicles with large engine capacities. In emerging and developing countries motorcycles are largely used as a means of mobility and most PTWs are low and medium engine capacity motorcycles and scooters (Rogers, 2008). Perversely, larger motorcycles in developed countries tend to be used by single riders, while the smaller motorcycles and scooters in developing countries frequently carry passengers and are used with a variety of attachments for carriage, delivery, vending and passenger transport.

Rogers (2008) noted that enjoyment was an important factor in many high-income countries (such as United States, Canada, Australia and New Zealand) but that employment/entrepreneurship was important in many low- and middle-income countries (such as Indonesia, Mexico, the Philippines and Thailand). Ease of use is an important factor in locations where significant traffic congestion exists. Economy of purchase and use is also an important factor in many low and middle-income countries.

4. Economic and social changes affecting PTW use

A range of economic and social changes is considered to have contributed to the growth in the use of PTWs. Increases in fuel prices, traffic congestion and parking difficulties in many cities have been identified as encouraging PTW use for urban commuting (Blackman & Haworth, 2010; Coxon, 2002; Transport for London, 2004). The increase in incomes and degree of motorisation in many developing countries has led to more PTWs in these countries, often as a replacement for human-powered two-wheelers or to supplement inadequate public transport (Sperling & Salon, 1992; University of California, 1992).

Internationally, the number of PTWs has grown, with the largest increases in Asia. According to industry estimates (Rogers, 2008, based on the Honda World Motorcycle Facts & Figures 2007 and SIAM estimates), the PTW fleet increased from 20 million to about 100 million in China from 1995 to 2006. During the same period, the PTW fleet approximately doubled in India and tripled in Indonesia. In contrast, production has decreased in Japan and Taiwan since 1996.

There has been a large growth in motorcycling in many developed countries in the last decade. In Australia, the number of motorcycles and scooters registered increased by 57.5% from 396,309 in 2004 to 624,090 in 2009 (ABS, 2009) - the strongest growth of any vehicle type. Motorcycle registrations in the United States increased by 75% from 3,826,373 in 1997 to 6,678,958 in 2006 (Morris, 2009). The growth in motorcycling has been accompanied by a lesser increase in rider fatalities and injuries from 224 to 239 (DITRD&LG, 2010). In the US, the number of motorcyclists killed increased by 144% from 2,116 in 1997 to 5,154 in 2007 (Morris, 2009).

In addition, the profiles of types of PTWs across economies are changing. Japan has seen motorcycles of over 250cc engine capacity increase from 13% of sales in 1978 to 20% in 1994 to 59% in 2006 (Rogers, 2008), reflecting a shift from primarily use of motorcycles as transport to leisure use and more older riders. Congestion does not appear to have boosted sales in Japan, where sales have been falling since 1982. Scooter and moped sales have increased in Australia (Haworth & Nielson, 2008), with a suggestion that this may be part of an increase in use of motorised two-wheelers for transport (rather than recreation). With increasing fuel prices, commuting to work on a scooter or moped may be increasingly attractive. Furthermore, with the increasing expense and space limitations of parking in metropolitan areas, commuters may be looking toward two wheeled transport as a means of reducing parking costs (Wigan, 2000).

There is also some evidence that motorcycle and scooter use by women is increasing. Rogers (2008) reports that the percentage of riders in the US who were females increased from 2% in 1990 to 10% in 2005. There have been claims of increased numbers of female riders in Australia (MSCC, 2009) but little objective data is available. There was a 6.9% increase in female motorcyclists hospitalised from 1999-2000 to 2003-04, compared with a 4.2% increase in male motorcyclists hospitalised (Johnston et al., 2008).

In developed countries, women make up a larger proportion of scooter riders than riders of traditional motorcycles. In Queensland, Australia, females comprised 38% of moped riders in crashes, compared with 7% of motorcycle riders in crashes (Haworth & Nielson, 2008). The growth in the popularity of scooters and mopeds in

developed countries suggests that the number of female riders will continue to increase.

5. Different perspectives

Most of the challenges associated with PTWs relate to safety, while the majority of the opportunities relate to mobility. Much of the controversy surrounding PTWs relates to the different perspectives that individuals and organisations bring. Safety professionals see the challenges, while transport professionals and PTW enthusiasts embrace the opportunities.

To a large extent, people's views on PTWs are determined by the questions that they ask. For those professionals who ask questions about the transport outcomes associated with PTW use, the answers show that the average speed of PTWs in congested traffic is greater than that of cars with resultant travel time savings, and several PTWs can occupy the space used in the transport system by one car (Wigan, 2000). For those who ask about safety outcomes, the answers are mixed. Safety professionals examine data and see increases in the numbers and percentages of fatally and seriously injured PTW occupants (Morris, 2009; DITRD&LG, 2010; Johnson et al., 2008). The fatality and injury rates of PTWs are worse than for car occupants, whether the denominator is registered vehicles, licensed riders, or distance ridden. Yet transport professionals and motorcycle enthusiasts examine the same data and find evidence that motorcycling is becoming safer. This can be demonstrated using data from Australia as an example. Figure 3 shows the increase in the number of motorcycle registrations (including scooters but not mopeds) in Australia from

297,000 in 1995 to 624,000 in 2009 (ABS, 2009), while the population increased from approximately 18 million to 20 million in the same period (ABS, 2008). Figure 4 shows that the number of motorcyclists (riders and passengers) killed over the same period changed little (DITRD&LG, 2010). Figure 5 shows the percentage of all road fatalities who were motorcyclists. This increased from about 10% in 1995 to about 15% in recent years and has led to much concern about motorcycle safety. However, these numbers simply reflect the greater achievements in safety for car occupants than for PTW riders. This is demonstrated in Figure 6 that compares the fatality rate per 10,000 registered motorcycles (the solid line) with the percentage of road fatalities who were motorcyclists (the dashed line). The fatality rate indicates that motorcycle safety is improving, but – as reflected by the dashed line - motorcycle fatalities are becoming a more important issue (relative to fatalities of other road users).

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However, this Australian paradox is not consistent across all developed countries. Figure 7 shows the relevant data for the United States. In the U.S. both measures of motorcycle safety have been deteriorating since the 1990s when mandatory helmet laws started to be repealed or weakened in many US States (Morris, 2009).

6. Safety challenges

The challenges for improving the safety of PTW use relate to the PTW user, other road users, the road environment, the vehicle, data and research, and socio-political dimensions. The relative importance of particular challenges varies between

developed and developing countries, and among developing countries according to whether PTWs are largely used for recreation or transport.

6.1 Challenges associated with the PTW user

In some countries, there is a challenge to gain rider acceptance for proven safety measures (e.g. helmets) even when they are affordable and practical. In other countries, the issue is not so much one of rider acceptance, but of affordability or even of comfort in very hot environments (WHO, 2006). There is a challenge to persuade riders to wear protective clothing and to persuade apparel manufacturers to produce safer products (de Rome, Stanford & Wood, 2003).

In many developed countries, one of the major challenges is how to improve the safety of mature people who are returning to riding, or taking up riding for the first time. Most licensing and training systems were designed to suit an earlier population of young applicants who did not have a car licence and were expected to continue riding regularly once licensed. Thus, motorcycle and scooter licences remained valid as long as the car licence was renewed and so allowed many inactive riders to return without any training or testing being required.

There remains a challenge in motivating riders to ride in a way that minimises risk, rather than riding for the excitement of the moment. People are attracted to motorcycling for a variety of reasons including image, the thrill of riding, the feeling of freedom, and to impress others (Watson, Tay, Schonfeld, Wishart, Tunnicliff, Lang & Edmonston, 2003) and people with an increased propensity for risk taking may be attracted to motorcycling (Horswill & Helman, 2003; Tunnicliff, 2005). Riders'

motives and subjective views of risk often do not readily reconcile with expert perceptions of risk (Bellaby & Lawrenson, 2001). Unfortunately, the performance characteristics of high-powered motorcycles (top speed, acceleration, ability to fit in lateral gaps too small for cars) that can attract risk-taking also make enforcement to curtail extreme speeds and other high-risk behaviours difficult. There is a challenge to develop more effective forms of enforcement to reduce illegal risk taking by riders.

Inexperience has been shown to be a major factor in motorcycle crashes worldwide and the current graduated licensing systems appear to have had limited success in ensuring the safety of learner riders (Haworth & Rowden, 2010). Whilst rider training is often perceived by the public and promoted as an effective crash countermeasure (Baer, Cook & Baldi, 2005), past evaluations have generally not found any reduction in crashes for formally trained riders compared to those who have *not* undertaken a formal training course (for reviews see Haworth & Mulvihill, 2005; Simpson & Mayhew, 1990). Indeed some studies have found higher crash rates for trained riders (Savolainen & Mannering, 2007). While some of these discrepancies may reflect differences in evaluation methodologies (Watson et al., 2003; Simpson & Mayhew, 1990) or differences between programs, a key issue for novice rider training is that training may be undertaken (or provided), in some cases, with the motive of passing a test or meeting licence competencies, rather than to become a safe rider. Where training is voluntary, motivating riders (particularly those with little interest in safety) to participate poses an additional challenge.

6.2 Challenges associated with other road users

Most analyses of PTW crashes conclude that operators of the other vehicle are at fault in the majority of PTW-Other Vehicle crashes (ACEM, 2004; see summary in APROSYS report). Often the operator of the other vehicle fails to see and give way to the PTW user, whether for reasons associated with the visual characteristics of the PTW or because of a lack of expectancy (as currently being investigated by the European 2BESAFE project). While there are often calls from PTW groups for education of other road users to address this issue and programs have been developed to increase caution when motorcycles are present (Harrison, 2005), such education may not have long-lasting effects where PTWs remain a small minority of vehicles.

6.3 Challenges associated with the road environment

PTW users are relatively more affected by characteristics of the road environment in terms of crash causation and severity of injury outcome than other road users (Li et al., 2009). There is a challenge for this to be recognised by road designers and maintenance authorities and for procedures to be put in place to ensure that loose material is swept up after road repairs are made. On a larger scale, hazardous locations for PTWs can be identified and treated to improve rider safety. A Motorcycle Blackspot Program comprising better signage on curves, enhanced delineation, improvements to road surfaces, and protective materials on roadside barriers in the Australian State of Victoria resulted in a 24% reduction in PTW casualty (fatal and injury) crashes at those locations (Government of Victoria, 2009).

Another challenge for countries with high aspirations for road safety is how to provide – in an affordable and feasible manner - a road infrastructure that is forgiving for PTW riders and still functions well for other road users. There has been much

concern expressed by PTW users about the dangers they see in the use of wire rope barriers, despite published data showing strong benefits of these barriers for vehicle occupants (Candappa, Larsson, & Corben, 2009).

6.4 Challenges associated with vehicles

There are challenges associated with improving the active and passive safety of both PTWs and other vehicles that collide with them. While many of the technical challenges associated with improving the active safety of PTWs such as ABS and linked braking systems and newer systems are being addressed, there appears limited market penetration of such improvements. While cost may play a role, it seems that there is little demand among many riders who value the physical challenges of riding a PTW and do not want these challenges removed. Improvements to the active safety of other vehicles may benefit PTW users. These include ambitious systems to detect PTWs that are being developed by some car manufacturers. While there are no data specific to their effect on PTWs yet, current features on cars such as traction control and enhanced stability control may prevent cars from losing control and having head-on collisions with PTWs.

Particularly in developing countries, there are challenges in ensuring that PTWs are adequately maintained to allow safe operation and in reducing overloading of PTWs.

7. Other challenges

In addition to the safety challenges outlined above, challenges exist in terms of constraints in knowledge about PTW use and its impacts, and in relationships between PTW users and governments.

7.1 Knowledge constraints

As outlined earlier in this paper, most of the PTW use occurs in the developing world. However, most of the research into the safety and mobility of PTWs comes from the developed world (e.g. ACEM, 2004; Hurt et al.,), with the exception of some studies of helmet use from Asia (see WHO, 2006) and a large crash study from Thailand (Kasantikul, 2002). Thus, much of the research focuses on aspects of PTWs as a minority vehicle, with much riding being for recreation. While the fundamental biomechanics of injury are likely to be similar, the large differences in the roles played by PTWs, their extent of representation in the traffic mix, and the characteristics of riders and other road users suggest that caution should be exercised in generalizing research across countries.

From the viewpoint of research informing policy, there appears to be a shortage of evaluations on which to base recommendations of effectiveness (with the exception of helmets) and of implementation strategies. This is particularly the case in terms of licensing and training systems (Haworth & Mulvihill, 2005).

The paucity of data relating to patterns of use of PTWs and the characteristics of their riders has led to difficulties in estimating and interpreting crash and injury rates for PTW users (Haworth, 2003). Basic data relating to how far PTWs travel and on what types of roads often needs to be collected by surveying owners, because many

automated vehicle detection systems cannot adequately count PTWs. Once data relies on surveys, then issues of representativeness begin to be debated. Even crash data has important limitations, in that mopeds and scooters cannot be distinguished from motorcycles in the crash data in many jurisdictions.

In many countries (such as the US and Australia), the most recent comprehensive in-depth studies were conducted decades ago (Haworth, Smith, Brumen & Pronk, 1997; Hurt, Ouellet & Thom, 1981) and rider and PTW characteristics have since changed. Yet it remains difficult to secure funding to undertake the necessary research, and gaining the necessary approvals appears to be even more problematic.

7.2 Societal issues

Challenges exist in building relationships of trust between governments and rider organisations. In some developed countries, PTW users are suspicious of the motives of governments, interpreting changes in licensing or other regulations as threatening the continuing viability of PTWs. Government organisations are aware of this and tend to develop policy with minimal consultation to avoid political embarrassment or delay. Rider suspicion of government is often fuelled by political decisions that have been made without reference to the published evidence or to the government's own advisers.

8. Mobility opportunities

The pattern of use of PTWs across the world is evidence of the mobility opportunities that they provide. In many countries, PTWs have a current or future potential for reducing traffic congestion in busy cities. They also offer opportunities to individuals

to be able to park (or park more cheaply) and opportunities to cities to use less area for parking.

PTWs provide a form of personal transport that uses less fossil fuel than automobiles. However, information about modal shift patterns needs to be collected before assuming that this will provide a large benefit, because some evidence suggests that the increasing use of scooters for commuting may reflect a change from public transport, rather than from the private car (Blackman & Haworth, 2010).

PTWs can provide an affordable means of transport to poorer people in both developed and developing worlds, particularly where public transport is not well suited to reaching employment.

These are some of the potential mobility benefits of PTWs but relatively little quantification has occurred in order to compare them with the safety costs.

8. Issues for the future of PTWs

In the developed world there is pressure, particularly in Europe, for PTWs to become cleaner, greener, and quieter. Manufacturers are responding by developing electric PTWs and other new forms of technology. Many applications of Intelligent Transport Systems to PTWs have been proposed and some developed, but rider acceptance may limit their market penetration unless adoption is forced by regulation.

In addition to technological improvements to PTWs, there are also many new vehicles being developed that do not easily fit into current vehicle classifications, some of

which are uneasily falling into the motorcycle or moped category. There are relatively few external or performance difference between some electric (or petrol) bicycles and mopeds, which causes difficulties for regulation and enforcement. This "morphing" of vehicle categories is likely to continue into the future and may lead us to abandon our current prescriptive vehicle classifications in favour of a performance-based system with consequences for operator licensing and training, and vehicle registration.

Issues for the future in developing countries may differ greatly among countries, particularly in the shorter term. There are developing countries where PTW use is likely to continue to increase for at least the next decade, and others that appear to be moving away from PTWs to cars (such as China). The challenge in developing countries will be to adopt suitable strategies to manage these changes, in terms of the safety of PTW users and other vulnerable road users. Improving public transport may be needed if PTWs cannot provide safe multi-user transport, and safer, suitable helmets remain an important area of development and promotion.

9. Conclusions

The total number of PTWs has and will continue to grow as they play an important role in both transport and recreation across the world. Their patterns of use differ markedly between and among developed and developing countries and this affects the safety challenges and mobility opportunities that they represent. There is a challenge to implement what is known and to improve our understanding of what we do not know about PTWs.

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FIGURES

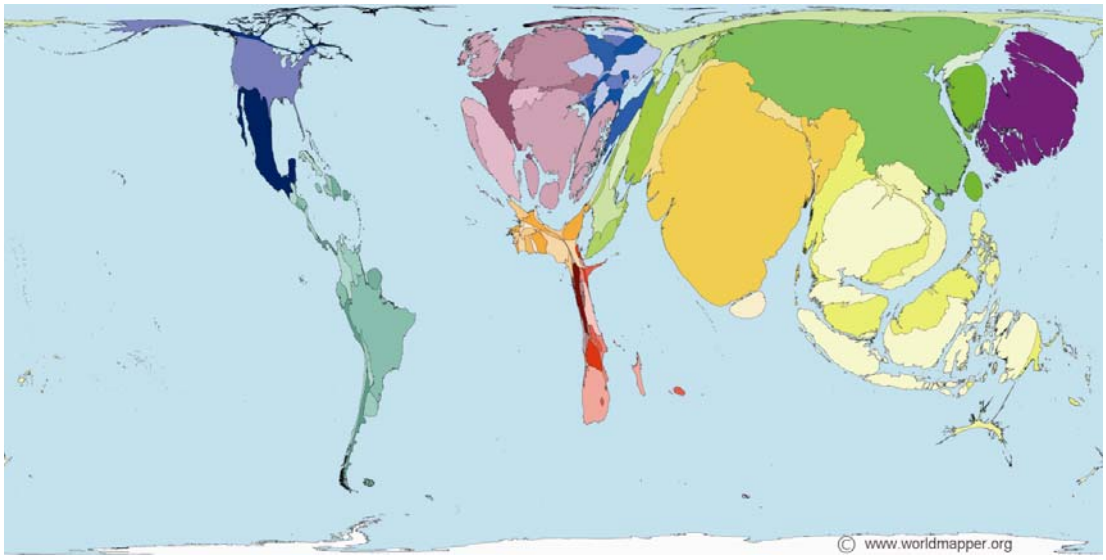

Figure 1. The world according to PTW ownership. From www.worldmapper.org

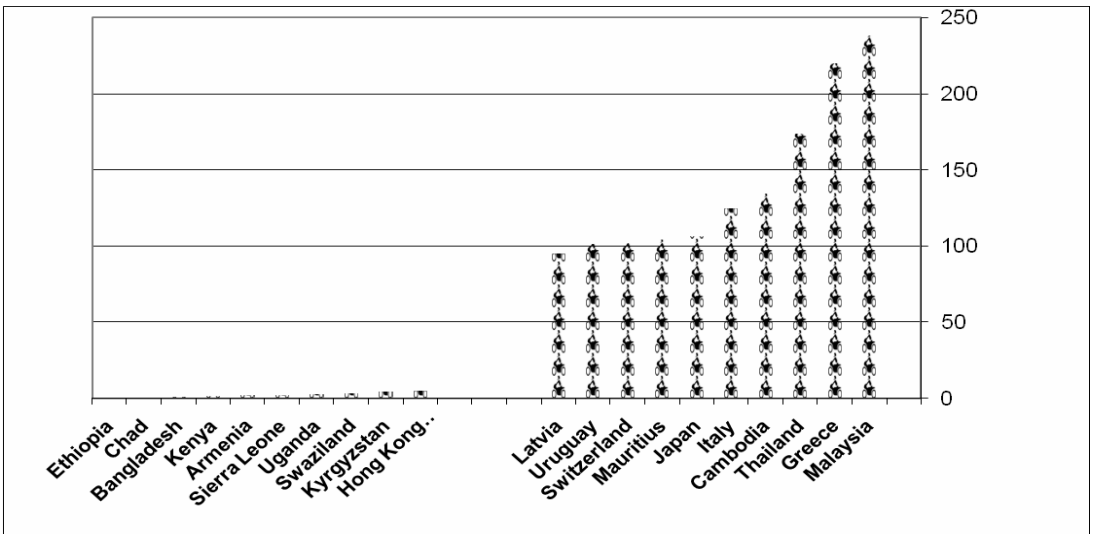

Figure 2. The 10 countries with the greatest number of PTWs per 1,000 population and the 10 countries with the lowest number of PTWs per 1,000 population. From www.worldmapper.org

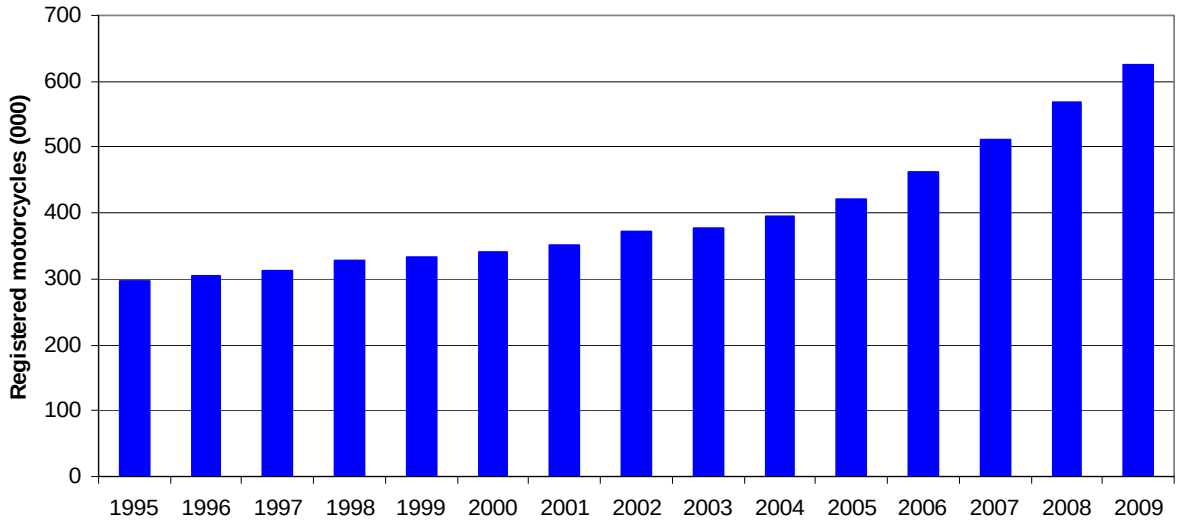

Figure 3. Number of motorcycle registrations in Australia from 1995 to 2009. From ABS, 2009.

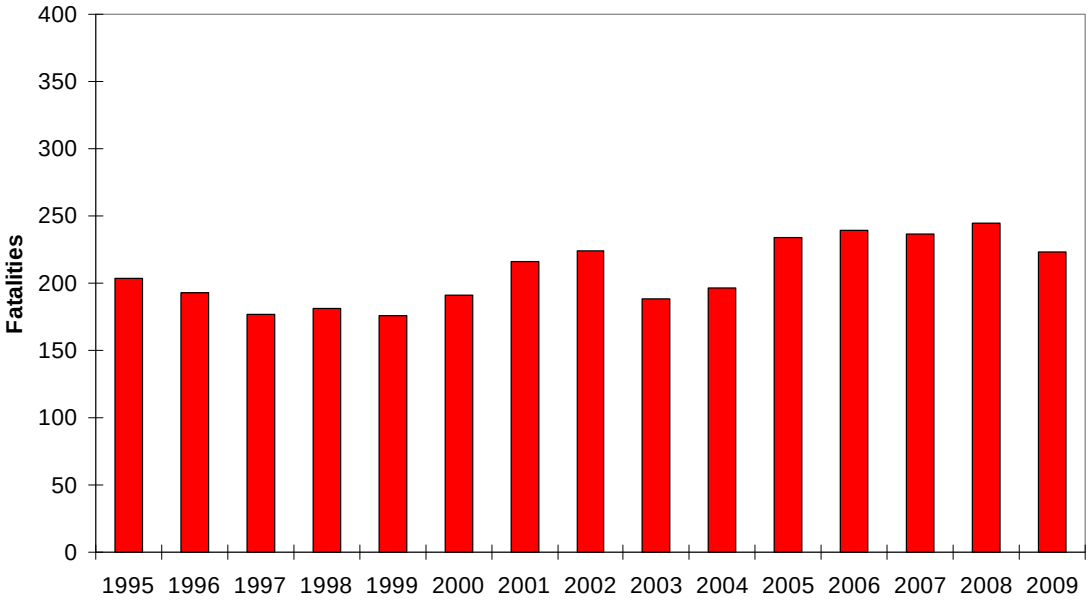

Figure 4. Number of motorcyclists (riders and passengers) killed in road crashes in Australia from 1995 to 2009. From DITRD&LG, 2010.

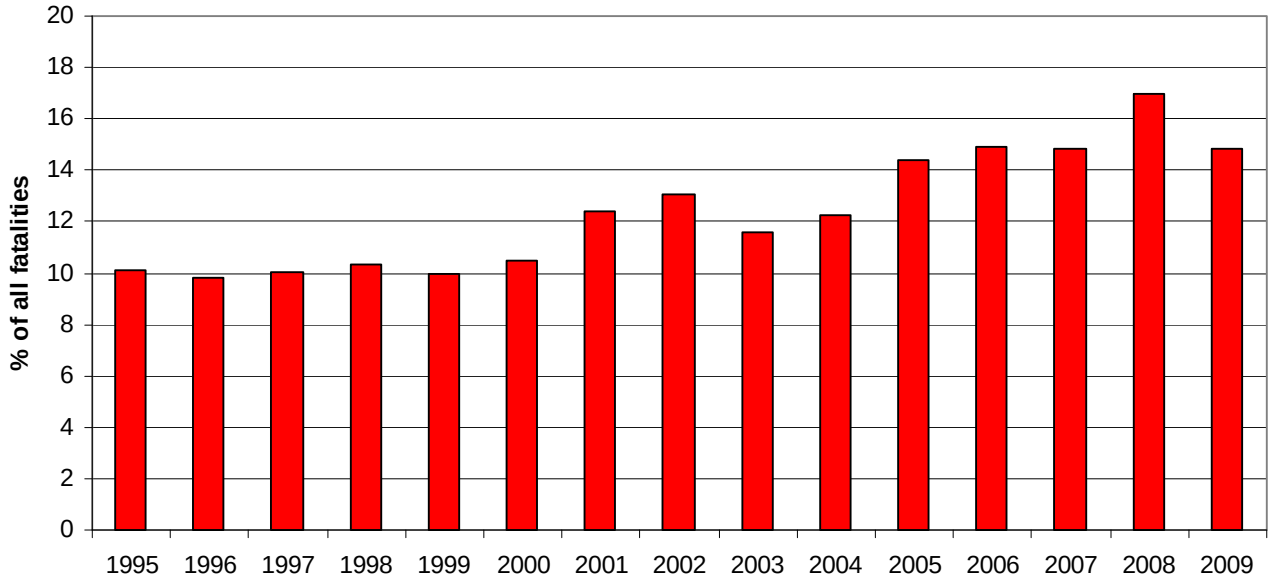

Figure 5. Percentages of all road users killed in road crashes in Australia from 1995 to 2009 who were motorcyclists (riders or passengers). From DITRD&LG, 2010.

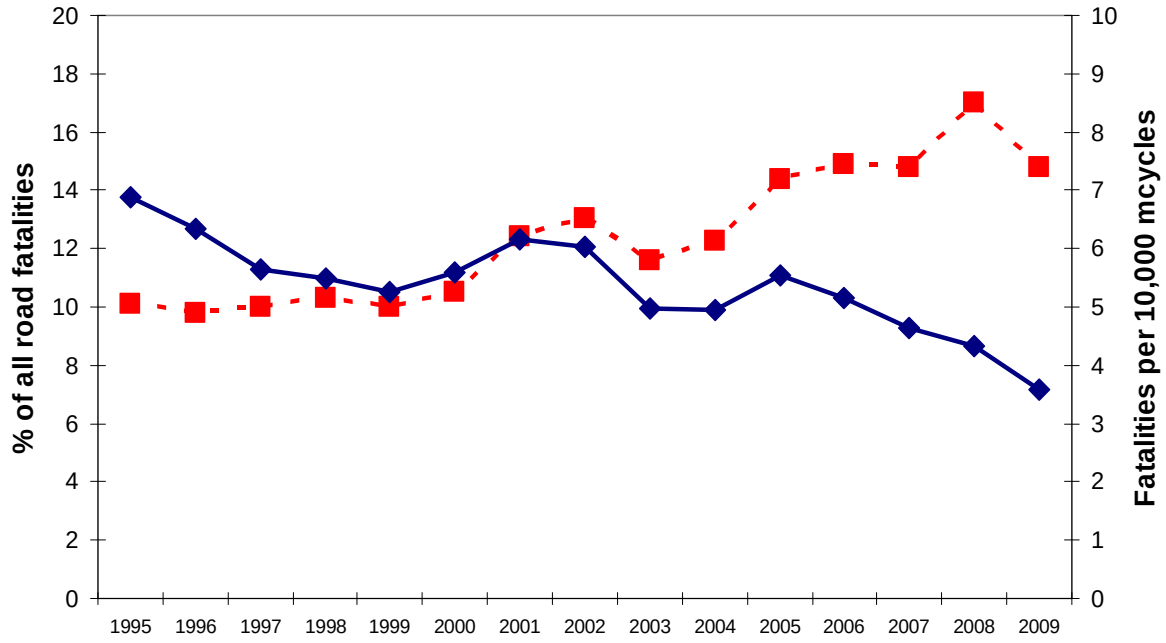

Figure 6. Number of motorcyclists killed per 10,000 registered motorcycles (solid line) and percentage of all road users killed in road crashes in Australia from 1995 to 2009 who were motorcyclists (riders or passengers) (dashed line). From ABS, 2009 and DITRD&LG, 2010.

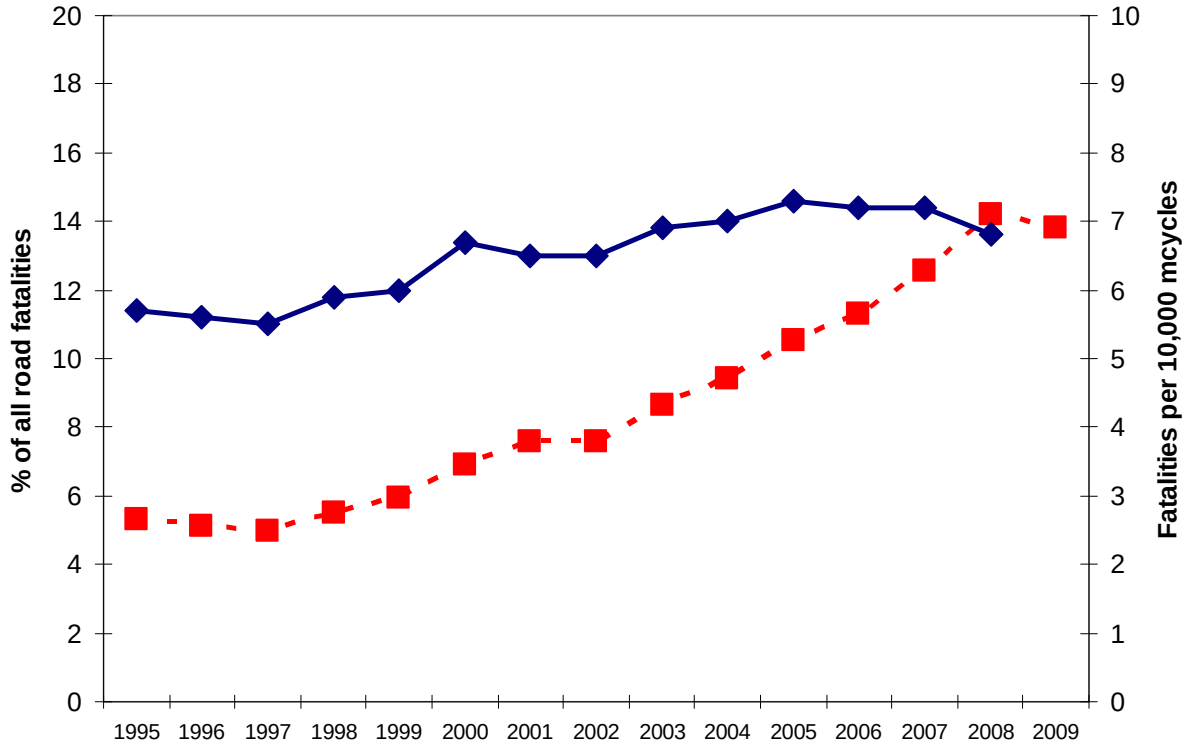

Figure 7. Number of motorcyclists killed per 10,000 registered motorcycles (solid line) and percentage of all road users killed in road crashes in the United States from 1995 to 2009 who were motorcyclists (riders or passengers) (dashed line). From Morris, 2009.