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.

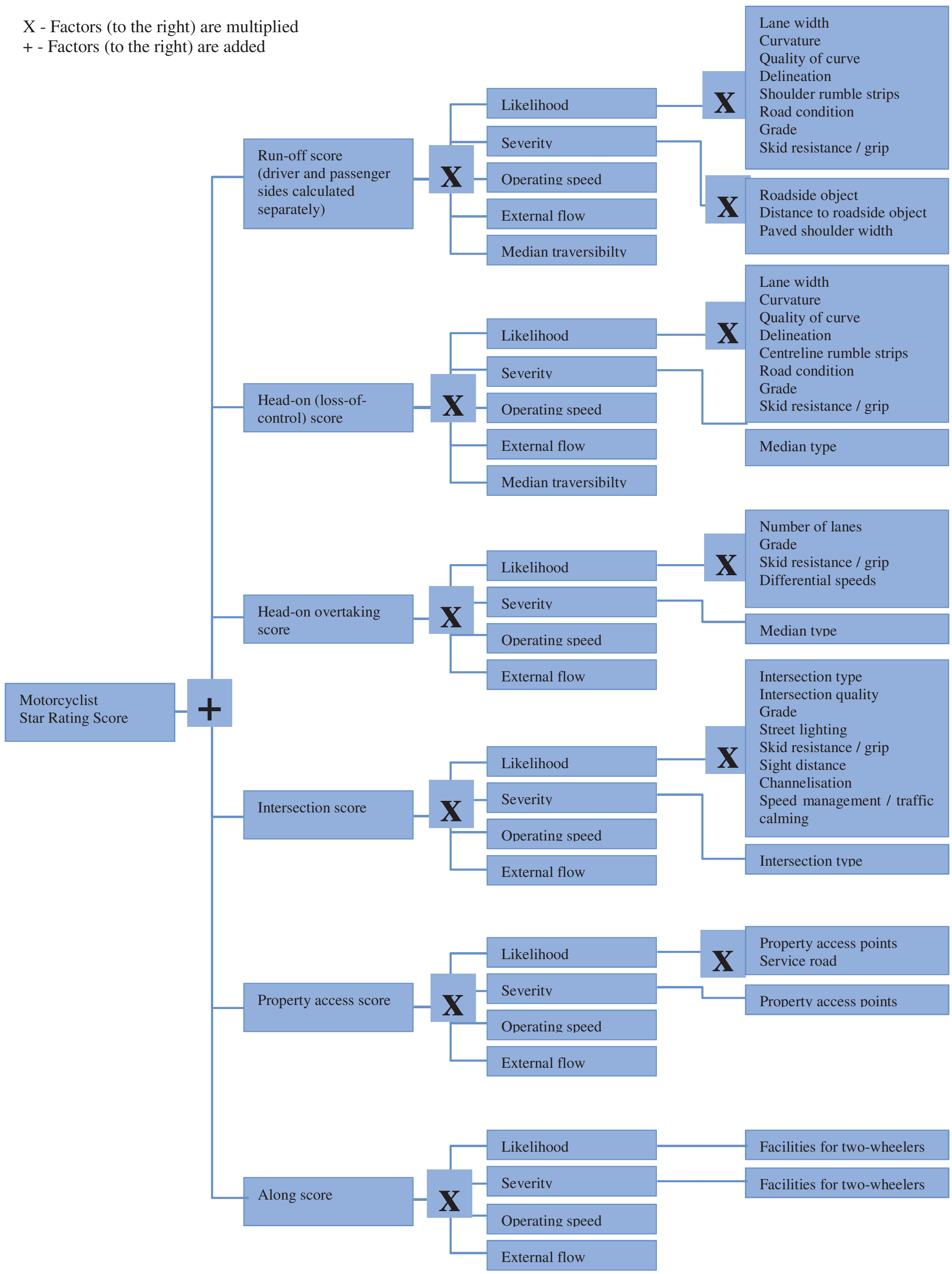
Road safety audits and inspections

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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