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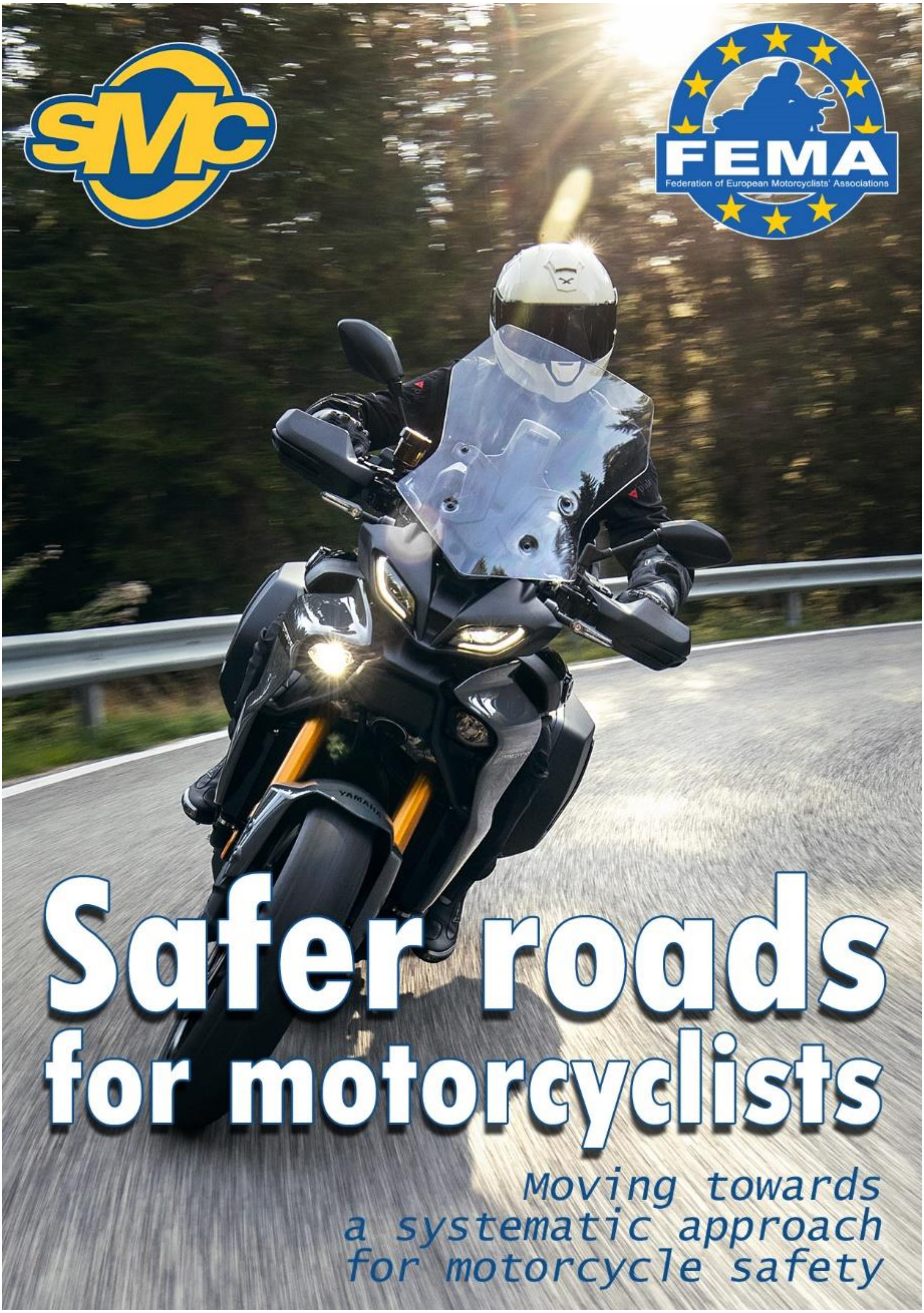

Safer roads for motorcyclists

Moving towards a systematic approach for motorcycle safety

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FOREWORD IRAP

A safe system is where everyone, regardless of mode, can use road and transport links without risk of serious injury and death. It is one in which human behaviour, vehicle design and road infrastructure come together to reduce the risk of things going wrong and manage the consequences when they do.

Like other vulnerable road users, understanding and implementing a safe system approach for motorcyclists remains a challenge. Registrations for motorcycles - which are typically a more affordable mode with lower emissions compared to other motor vehicles - have been increasing at a rate of approximately one percent per year across Europe, although this rate varies greatly at the national level (1).

Yet fatal crashes are disproportionately high for motorcyclists. About 15% of road fatalities across Europe are motorcyclists, and a further 3% are moped riders while their total share is 12.4% of all vehicles in Europe. While the number of motorcyclist fatalities fell overall, their proportion has increased relative to overall road fatalities in Europe (2). Crash data shows that three out of four fatal motorcycle crashes occur on road stretches away from intersections and in dry conditions. They are up to two times more likely on weekends than weekdays (3).

The European Union aims to reduce fatal and serious injuries caused by road crashes by 50 percent by 2030 and eliminate road deaths by 2050 (4). To achieve these targets, more needs to be done to ensure motorcycle safety is routinely considered at every stage of road planning, design, construction, management, and maintenance. Increased uptake of existing evidence-based road safety assessment methodologies which consider the needs of motorcyclists, such as iRAP's Motorcycle Star Ratings and Investment Plans, provide an immediate opportunity for positive impact. Where they are used, the investment in motorcycle-specific countermeasures must be implemented alongside treatments for vehicle occupants and all other road users.

The European Road Infrastructure Safety Management Directive (5) defines procedures to improve safety of the trans-European road infrastructure (TEN-T) and primary roads and reduce fatalities and serious injuries. An amendment to the directive came into effect in late 2019 and had to be implemented in national regulation by the end of 2021.

The amended directive requires public authorities in EU Member States to undertake a network-wide road assessment of the TEN-T and primary road network in each country to identify high-risk road sections. The assessments must then be followed up by targeted road safety inspections that identify and prioritize road infrastructure safety improvements for all road users.

Motorcycle crashes, while fewer in number, tend to result in more significant injuries, and hence result in much higher crash costs. Insurance data shows that median insurance claim costs for motorcyclists is approximately four times that of other road users (6).

Improving road safety for motorcyclists will therefore help reduce the disproportionately high costs to society of motorcycle road crashes.

This document aims to build on the EuroRAP position paper *Barriers to Change - Designing Safe Road for Motorcyclists* published in 2008. Barriers to Change (7) was a result of the work of an appointed Motorcycle Safety Review Panel, which included representatives from motoring clubs, manufacturers, riders' organisations, practitioners, transport specialists in research institutions and professional associations, and national and regional road authorities. Its recommendations are still relevant.

However, the high injury risk for motorcyclists still exists, resulting in fatalities and life-long injuries to riders and passengers. This paper is the result of an expert working group convened by the Swedish Motorcyclists Association (SMC).

It aims to reinvigorate discussion, prioritization, and action for motorcycle safety. It captures the latest progress in motorcycle and PTW research and practice in the planning, building and maintenance of road infrastructure.

As the research and crash data both show, safe roadsides and surface friction remain the critical issues for reducing fatal and serious motorcycle crashes, and as such, these areas are the primary focus of this paper. Moving Towards a Systematic Approach for Motorcycle Safety is relevant to a broad range of stakeholders, road authorities and policy and decision makers, through to researchers and investors.

iRAP congratulates and supports SMC in its initiative to bring together leading experts to produce this paper, which will play an important role in informing future research, policies, and investment in motorcycle safety.

Rob McInerney,
CEO iRAP

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TERMINOLOGY AND ACRONYMS

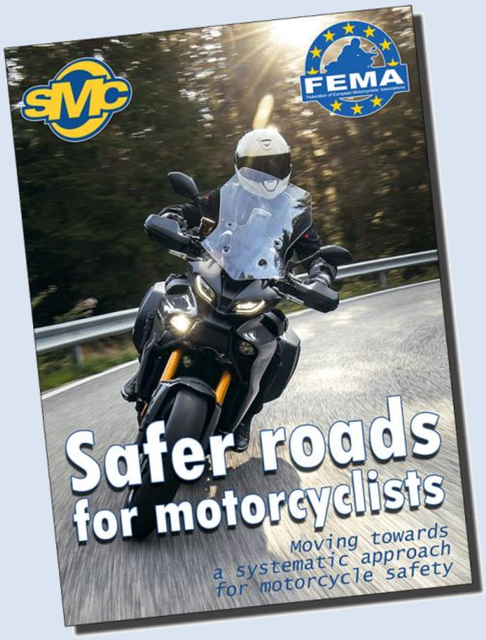
The terms motorcycles and powered two-wheelers (PTW) are often used interchangeably. Motorcycle usually refers to all two-wheeled vehicles with an engine, but it can also be used exclusively for vehicles on two wheels with a combustion engine of more than 50cc or an electric equivalent. PTW is a more recently adopted term used to refer to all motorized two-wheeled vehicles with a design speed of more than 25 km/h. This can lead to confusion as it is not always clear what is meant with the word motorcycle or powered two-wheeler, particularly in studies and reported statistics.

The types of motorcycles and PTWs, including the terms used, can also be unique to countries and regions. Across the world, terms such as scooter, moped and e-bike may all refer to a type of powered or motorized two or three-wheeler that fits the conventional definition in terms of power and speed, but in other places they do not. Sometimes, but not always, three-wheeled vehicles are included. This inconsistency in terminology leads to difficulties in comparing data from different sources. In the context of road engineering, the terms twin track vehicle and single-track vehicle are occasionally used to reflect the fundamental design differences between motorcycles and other motor vehicles. Throughout this paper the term 'motorcycle' is used to cover all forms of powered two wheelers (PTW) with an engine and a design speed of more than 25 km/h from the smallest mopeds, through scooters to the largest sports and touring machines.

Acronyms

ACEM	European Association of Motorcycle Manufacturers
ARRB	The Australian Road Research Board
CARE	Community database on road accidents (EU)
CRS	Centre for Road Safety (Australia)
EDSP	Motorcycle Protection System Euskirchen Plus
EU	European Union
EV	Electric vehicles
FEMA	Federation of European Motorcyclists' Associations
FSI	Fatal and serious injury ratio
G	G force
GDP	Gross domestic product
GIDAS -	German in depth accident study
HIC	High income country
ICE	Internal combustion engine
IMMA	International Motorcycle Manufacturers' Association
iRAP	International Road Assessment Program
ITF	The International Transport Forum
KSI	Killed and Seriously Injured
LMIC	Low income country
MAIDS	Motorcycle accident in depth study
MIP	Motorcyclist impact padding (discontinuous MPS)
MPS	Motorcycle protection system
NHTSA	National Highway Traffic Safety Administration
NZTA	New Zeeland Transport Agency
OECD	Organization for Economic Co-operation and Development
PTW	Powered two-wheeler.
SMC	Sveriges MotorCyklister (the Swedish Motorcyclists' Association)
SRN	Strategic road network, UK
TEN-T	Trans European Road Network
UNECE	United Nations Economic Commission for Europe
VRS	Vehicle Restraint System
WHO	World Health Organization

EXECUTIVE SUMMARY



With 28% of the global fatalities being riders or passengers on motorcycles, road safety for motorcyclists is an important issue. Motorcycles are used for different purposes, from commuting to leisure and in different environments.

This means that there is a large variety of motorcycles and motorcyclists, but the needs for road safety and the challenges they are confronted with are the same.

Motorcycle organizations feel that the existing road safety programs like Vision Zero, Sustainable Roads and Safe System do not fully consider the specific situation and needs of motorcyclists. Especially when it comes to the road infrastructure this means that there is not enough attention for problems with the road surface friction and road infrastructure furniture.

Road surfaces can be slippery or in bad condition with potholes. Roadsides often have obstacles that are too close to the lane or that are not shielded. Road infrastructure furniture are often obstacles on the roadsides or barriers that are unsafe for motorcyclists or installed in an unsafe manner, suited, and tested for those who travel in cars.

Solutions for these situations are available, evaluated and described. In several countries, governments, road safety organizations, researchers and motorcycle experts have cooperated to draft road safety and infrastructure guidelines. Motorcycle safety is also part of the iRAP safety Star Rating assessment methodology.

Nevertheless, more action is needed in harmonizing of standards, researching the causes of motorcycle crashes, the consequences of crashing into barriers and other obstacles as well as planning, building, and maintaining roads with vulnerable road users on motorcycles in mind.

The motorcycle community can help to pinpoint the bottlenecks and offer solutions. This paper is the outcome of a working group assembled by SMC, which included motorcycle and road safety experts from several continents. The paper collates the available information about road infrastructure in relation to motorcycle safety, identifies the key obstacles to achieving safer roads for motorcyclists, and proposes solutions and recommendations for road authorities.

THIS PAPER OFFERS THE FOLLOWING RECOMMENDATIONS:

1. Governments and road authorities must include motorcyclists as a road user group when planning, building, and maintaining road. Thus, motorcyclists need to be included in national laws and regulations.

2. Update the Safe System with the inclusion of motorcyclists together with other vulnerable road users.

3. Road authorities need to be using road risk assessment methodologies which consider motorcyclist safety, such as iRAP Star Ratings or similar.

4. Specifications and standards for barriers and other motorcycle protection systems need to be developed and updated to extend the usage for a safer road environment.

5. Data collection for motorcyclists' needs to be improved and coordinated (road surface friction condition, effect of road restraint systems on motorcyclists' safety, safe road design, general effect of road infrastructure furniture on motorcyclists' safety (obstacles, visibility), effects of roadworks on motorcyclists' safety, etcetera).

6. Existing knowledge about safety measures which has proven to minimize injury risk for motorcyclists needs to be highlighted and spread as good examples to governments and road authorities.

7. There are still motorcycle safety treatments and approaches that need to be developed or where there is a need of more research, for example computer simulation with barrier crashes.

8. The socio-economic cost for injuries and fatalities should be included when roads are planned and built as well as the Life Cycle Cost of different roadside measures, like choice of barrier, distance to obstacles, width of paved shoulder or forgiving roadsides.

9. The measure method for friction, which is based on cars, needs to be developed to meet the needs of single-track vehicles with two wheels that uses the entire road.

10. There is a need for policies at national and regional levels, e.g., that all new barriers are safe for motorcycles, that checklists are used to include the needs of motorcyclists when planning, constructing, and maintaining roads.

11. Audits, warnings, and alerts are important measures to reduce the risk of crashes.

12. More resources are made available to road engineers and designers which include best practice for motorcycle safety and/or update the Road Safety Toolkit with solutions presented in this document.


TRIUMPH
1

PART 1 - THE CONTINUING CHALLENGE OF MOTORCYCLE SAFETY

CHAPTER 1. INTRODUCTION

Like everyone, motorcyclists want to arrive at their destination and return home safely afterwards to their loved ones. There are currently around one billion motorcycles in the world and the usage have increased during the last decades (8). Popularity of motorcycling continues to grow, in part because of the rising costs for four-wheeled vehicles (including ICE and EV) and fuel.

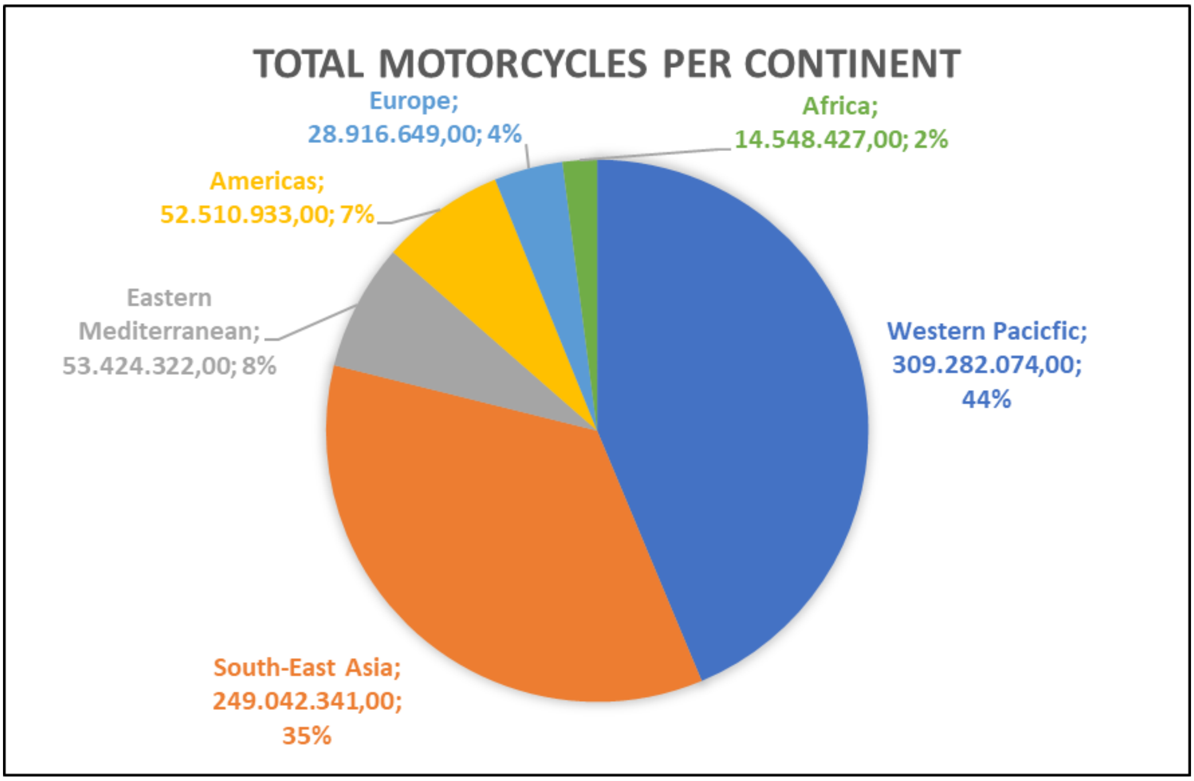


Figure 1. Motorcycles in use (source: www.riders-share.com)

In some parts of the world motorcycles are the dominant mode of transport. In other parts, motorcycles are mainly used for commuting or leisure trips. Regardless of where motorcyclists are, they share distinct needs in terms of safety.

Motorcycle riders are different from drivers of cars, vans, or heavy goods vehicles. Motorcyclists have no protective cage around them which makes them more vulnerable when being struck by other vehicles or hitting objects on the roadside. Road restraints systems, such as barriers, may improve safety for a car, but may lead to increased levels of severe injury and death for a motorcyclist if it is not designed for them. Poor road surface friction may lead to a higher risk of loss of control for a car, but the risk and consequences of losing balance is much higher for motorcyclists.

The growing number of motorcycle riders has, unfortunately, been reflected in recent casualties. 28% of the global traffic fatalities are among passengers and riders on motorcycles (8,9).

The number of fatal and serious injury (FSI) crashes involving drivers and passengers in cars has been reducing in many countries due in part to numerous safety measures made by the car manufacturers and huge investments for safer infrastructure for motorists. However, at the same time, the share of fatalities among riders and passengers on motorcycles is rising even if the absolute numbers are dropping (9). Research shows that in Australia, for example, the rate of motorcyclist fatalities is approximately 30 times that of car occupants, and 41 times higher for serious injuries (133, 134).

The large number of motorcyclists and their vulnerability shows that motorcyclists and their specific needs must be taken seriously at all levels in the traffic environment, by all road authorities, and by society at large. This is unfortunately not the case today.

The Second Decade of Action for Road Safety 2021-2030 aims to reduce these numbers by 50 percent. In recent years, UNECE, WHO and OECD/ITF have highlighted the need for vulnerable road users to become a priority in road safety.

Road safety has been declared as a human right by the United Nations (UN) and riders and passengers on motorcycles are recognized as vulnerable road users by UNECE, WHO, Austroads, NHTSA and the European Union. However, even if the road safety focus is changing to improve infrastructure for vulnerable road users, too often only non-motorized road users are considered as vulnerable. One example are the guidelines that were published in January 2023 by the European Commission on a methodology for network-wide road safety assessments. The guidelines have no proposals to improve road safety for riders and passengers on motorcycles and mopeds. The only vulnerable road users that are mentioned and cared for to a large extent are bicyclists and pedestrians. There is no explanation for the exclusion of mopeds and motorcycles (10).

In February 2020, the Third Global Ministerial Conference on Road Safety marked the end of the first Decade of Action for Road Safety 2011–2020 and reiterated commitment to the 2030 targets in the statement of the conference outcomes (the Stockholm Declaration). The Academic Expert Group for the Conference submitted its recommendations regarding a second Decade of Action for Global Road Safety.

An international workshop on safety for motorcyclists, Riding in a safe system, was held in June 2021 (8.) The workshop was co-organised by the International Transport Forum, the Swedish Transport Administration (VTI), the International Motorcycling Federation (FIM), and the motorcycle manufacturers associations (IMMA and ACEM). It focused on the recommendations of the Academic Expert Group and their application to motorcyclists' safety. The workshop identified eight priority actions to achieve the integration of motorcycles in the safe system by 2030. The eight actions build on the Stockholm declaration and the recommendations of the Academic Expert Group. They are (8):

- Move to sustainable practice
- Adopt safe vehicles and equipment
- Redesign infrastructure
- Protect children
- Support modal shift
- Educate safe riders
- Ensure safe speed
- Increase knowledge.

1.1 MOTORCYCLISTS IN VISION ZERO

In the 1990s Vision Zero was implemented in Sweden. Vision Zero is a strategy to eliminate all traffic fatalities and severe injuries, while increasing safe, healthy, equitable mobility for all. Vision Zero does not aim to avoid accidents, but the goal is to avoid fatalities and severe injuries. From a motorcyclist's perspective however, riders must avoid being involved in crashes at all since for them crashes will almost certainly result in serious injuries or fatalities. This is a discrepancy that needs attention. The strategy is now the most common road safety strategy worldwide. Related to the Vision Zero concept and that of the Dutch Sustainable Safety strategies (based on classifying and planning roads by their main use with a corresponding speed limit) is that of the Safe System. Safe System embraces well-established safety principles and building on demonstrably effective practice using innovative solutions and new technologies. The Safe System approach is very similar to that of Vision Zero but takes more in account the needs of vulnerable road users, like pedestrians and bicyclists.

1.2 NOTABLE ADVANCES IN RESEARCH

In the last two decades research in motorcycle safety has advanced significantly. Stakeholders in Europe, Australia and USA have conducted studies based on collisions with motorcycles and barriers. The outcome of these studies points to the same conclusions:

- Forgiving roadsides, obstacle free zones near the road, can reduce the severity of motorcyclist crashes compared to roadsides with fixed objects.
- Median and roadside crash barriers can increase the risk of injuries for motorcyclists, but the risk can be reduced by equipping them with Motorcycle Protection Systems (MPS), and
- A safety zone between the barrier and roadway can reduce the severity of motorcyclist injuries in the event of a crash.

Research also highlights the role of road surface friction in reducing the likelihood of crashes. According to several reports, there is a correlation between road friction and the number of crashes, although the effect of poor friction is difficult to single out, because drivers try to adjust their speed to the circumstances.

Forgiving roadsides are better than zones with fixed obstacles. Barriers increase the risk of injuries, but the risk can be reduced by equipping them with Motorcycle Protection Systems (MPS), and a safety zone between the barrier and roadway.

The need for good friction to avoid crashes has also been highlighted in the last decades. According to a Swedish literature study states that there is a correlation between road friction and the number of crashes, although the effect of poor friction can be difficult to single out, because road users try to adjust their speed to the circumstances (11).

Many crashes are a result of the fact that motorcycle riders lose control due to loss of friction. Some of the crashes occur after road maintenance where the site has been left without cleaning the road or from debris that originates from roadsides and unpaved exits (12, 25).

Another notable advance in the research has been in the socio-economic impacts of motorcycle crashes. In Australia, for example, research shows that the social cost of crashes is twice as high for motorcyclists compared to that of car occupants on a vehicle kilometre travelled basis (135).

1.3 DATA AVAILABILITY AND MULTIPLE DATA SOURCES FOR TRAFFIC SAFETY RESEARCH

Highly relevant for further steps within road safety research and the increase of the state of the art, as well as opportunities developing new, innovative safety measures, are the possibility to use existing data (public or stakeholder-owned). Road authorities, road operators, service providers, infrastructure and vehicle industry are collecting large amounts of various data on a regular basis, for example about friction, potholes, crashes and roadside environment.

Data, which feed their own systems, models, and investigations – e. g. predictive road maintenance systems, using road surface condition data; or map /navigation system providers, collecting route and vehicle dynamics data of the road users; can be used to identify new patterns and relevant safety trends for different stakeholders dealing with different part of the transport system.

A smart correlation, joint analytics and interfaces between different data bases and sources, will open new opportunities for predictive safety systems, that integrate safety forecasts such as assistant systems, that include road, traffic, and weather information. When using multiple data sources, it is possible to provide a completer and more accurate picture of road safety issues. Each data source has its strengths and weaknesses and combining them can help compensate for any limitations and provide a more comprehensive understanding of road safety issues.

Using different data sources also allows cross-validation of results, which helps to ensure that findings are robust and reliable. If multiple data sources are showing similar results, it increases confidence in the findings. Any cross-link of different parameters enhances the chance to calculate or simulate new interrelations, dependencies, and potential risk causal correlations, which are the baseline for future risk mitigation measures.

Floating vehicle data, cloud-based information, netwide measurement data, and others must be made available for road safety experts and research purposes, to develop smart safety systems and solutions, e. g., working in real-time or to be used as training material for self-learning (AI) systems. The overlaying of data sets helps to improve the quality of the data itself, due to identifying inconsistencies and errors in data sets.

The overall benefit of using multiple data sources, is the possibility to provide a more robust evidence base to support cost-efficient, eco-efficient and sustainable decisions, while improving road safety.

1.4 OBJECTIVES OF THIS WORKING GROUP & TARGET AUDIENCE

The working group-has prioritized the most relevant risks for motorcyclists that are related to the infrastructure and propose workable solutions. These solutions aim to reach everyone involved in infrastructure and road safety systems such as engineers, planners, lawmakers, enforcement agencies, highway operators, entrepreneurs, auditors, road safety strategists and others.

1.5 HOW CAN THIS WORK CONTRIBUTE TO MOTORCYCLE SAFETY IMPROVEMENTS.

Road safety measures that improve the road environment for riders and passengers on motorcycles will improve the road conditions for all road users. However, motorcyclists are often not included in planning, building and maintenance of roads. When motorcycles are excluded from planning, building, and maintaining infrastructure they also decide that riders and passengers on motorcycles will continue to travel with an increased risk of being killed or severely injured in case of an accident.

Our aim is that this paper will contribute to motorcycle safety improvements when the proposed measures are introduced. It highlights best practice from around the world, the tools, and resources available, what research is telling us, it builds the case for why addressing MC safety is fundamental to achieving road safety targets, and why it is important economically. Such motorcycle safety improvements are best undertaken in cooperation with the motorcycle community in each country.

There is a need to create a relevant document that is focused on motorcycle safety and to present a systematic approach for motorcycle safety in the safe system. This document is aiming to reach everyone involved in infrastructure and road safety systems such as engineers, planners, lawmakers, enforcement agencies, auditors, road safety strategists and others. We collected the current available information on road infrastructure with as focus on roadside infrastructure and road surface. This paper mainly focus on the priority action redesign infrastructure and remaining research gaps, needs and recommendations to improve motorcycle safety regarding infrastructure.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CHAPTER 2. MOTORCYCLE SAFETY IN FIGURES

The use of motorcycles has increased in all parts of the world, representing a huge and varied user population. The highest proportion of registered motorcycles can be found in the South-East Asia Region followed by the Western Pacific and Eastern Mediterranean Regions. Regrettably, the proportion of deaths among motorcyclists globally increased from 23% to 28% between 2013 and 2016. This increase is observed in all WHO regions, with the South-East Asia Region having the highest increase from 34% to 43% in 2016. Whilst the age distribution of motorcyclists killed does differ significantly between countries, the number of killed motorcyclists remained consistently high across the age group of 25-34 years. This represents more than a quarter of all road traffic-deaths in that year and motorcycle safety is a concern to all WHO regions (8).

2.1 THE IMPACT OF INFRASTRUCTURE ON MOTORCYCLE SAFETY

Compared to research for car occupants, and other 'vulnerable' users, bicycles, and pedestrians it is difficult to find research on the extent to which specific infrastructure features contribute to FSI crashes for motorcycles. However, crash data points out common infrastructure factors that are often present at motorcycle crash sites internationally.

Europe: The Association of European Motorcycle Manufacturers (ACEM) conducted the Motorcycle Accident In-Depth Study MAIDS, during the period 1999-2000 in five sampling areas located in France, Germany, Netherlands, Spain, and Italy. A total of 921 crashes were investigated in detail, resulting in approximately 2000 variables being coded for each crash. The roads were dry at 84.7% of the time at the time of the crash, the road surfaces had defects in 30% of cases and roadside barriers accounted for 60 injured riders. Road related factors was noted as a significant secondary contributory factor on injuries (15).

Australia: The share of single-vehicle motorcycle collisions with fixed objects in Australia account for 39 % of the fatalities. Trees, utility poles, posts and barriers are the most common fixed hazards with 77 %of them (16). A 2013 study based on crash data from USA and Australia found that fixed hazards in the roadway environment present a substantial risk to motorcyclists and that a holistic system approach which included the four system cornerstone areas in the safe system (roadways, speed, vehicles and people) would reduce the risk of serious injury to motorcyclist collisions with fixed objects from as high as 82% down to 23% (17). Road surface hazards like potholes and loose gravel were found in 20% of single vehicle crashes 2006-2010 in New South Wales, resulting in nine fatal and 911 injured motorcyclists in urban and rural areas. New Zeeland Transport Agency, NZTA, identified that 8,5% of urban and 14,6% of rural motorcycle crashes were caused by road conditions (18).

USA: The Hurt Report, officially *Motorcycle Accident Cause Factors and Identification of Countermeasures,* was a motorcycle safety study conducted in the United States, initiated in 1976 and published in 1981. The report is described as "the most comprehensive motorcycle safety study of the 20th century". It stated that one-fourth of the motorcycle crashes were single vehicle crashes involving the motorcycle colliding with the roadway or fixed object in the environment. Roadway defects (pavement ridges, potholes, etc.) were the crash cause in 2% of the crashes. Intersections are the most likely place for the motorcycle accident, with the other vehicle violating the motorcycle right-of-way, and often violating traffic controls. The typical motorcycle accident allows the motorcyclist less than 2 seconds to complete all collision avoidance action (19). In the USA the National Highway Traffic Safety Administration, NHTSA reported about motorcycle accidents in the annual report Traffic Safety Facts 2020. Motorcycles were more frequently involved in fatal collisions with fixed objects than other vehicle types. Twenty-five percent of motorcycles involved in fatal crashes in 2020 collided with fixed objects, compared to 18 percent for passenger cars, 14 percent for light trucks, and 5 percent for large trucks (20). In 2018, motorcycle riders accounted for 40% of all fatalities resulting from a guardrail collision while motorcycles only comprise 3% of the registered vehicles (21).

UK: The *Guide to designing for motorcyclists, Highways England 2021* references collision data for the Strategic Road Network, SRN between 2015 and 2019. It states that in 60% of all collisions involving a motorcycle with fata or serious injuries, the rider collided with a fixed object in the roadside, such as signs, lighting columns, telegraph or electricity poles and trees. The share for motorists during the same period was 30% fatal or serious injuries. Although motorcycle traffic only makes up 0.4 percent of traffic, they account for 13 % of all fatal barrier collisions. Between 2015 and 2019 there were 166 motorcycle collisions involving barriers, 71% of which resulted in fatal or serious injuries (22).

Norway: An analysis of fatal crashes with motorcycles in Norway in 2005-2014 concludes that road related factors have contributed to the fatal crash outcome in 36-40% of crashes. The most relevant factors were guardrails (17 %), light or sign poles (9%) and trees (6%) (23).

Sweden: Defects in the road contributed to about ten percent of the fatal motorcycle crashes in Sweden 2005-2013. The defects were poor friction, gravel, and track deformation (24). Gravel is a contributing factor in 25% of the crashes with seriously injured (25). The most common cause in single vehicle crashes with fatal outcome are barriers, followed by trees and poles which are involved in about 40% of the fatalities. An average of 10% of the fatalities among motorcyclists every year are killed after a crash with a barrier (26).

2.2. SOCIO-ECONOMIC COSTS OF FATALITIES AND SERIOUS INJURIES

As mentioned in chapter 1.1 the socio-economic impacts of motorcycle crashes are probably higher for motorcyclists. Australian research shows that the social cost of crashes is twice as high for motorcyclists compared to that of car occupants on a vehicle kilometre travelled basis (135).
There have been several attempts to calculate the general costs of fatalities and injuries in traffic. One study compared 17 countries, of which eight Asian countries, six European countries, Australia, New Zealand, and the USA (27). The studies have used the following cost components:

- Medical costs: costs resulting from the treatment of casualties, e.g., costs of hospital stay, rehabilitation, medicines and adaptations and appliances for the handicapped.
- Production loss: loss of production and income resulting from the temporary or permanent disability of the injured, and the complete loss of production of fatalities.

- Gross production loss includes consumption loss.
- Human costs: immaterial costs through suffering, pain, sorrow, and loss of life or of quality of life
- Property damage: damage to vehicles, freights, roads, and fixed roadside objects.
- Administrative costs: in this category the costs of police services, fire brigade services, law courts and administrative costs of insurers are considered.

The overview of the total costs of road crashes are found to be 2.7% of the gross domestic product GDP in the HICs and 2.2% of GDP in the LMICs. Half of the costs of road crashes is related to injuries, in both HICs and in LMICs. The share of fatalities in the costs is 23% in HICs whereas in LMICs 30% of the costs is related to fatalities. This may indicate that the efforts in HICs to prevent fatalities have been effective, resulting in a lower economic burden of fatalities.

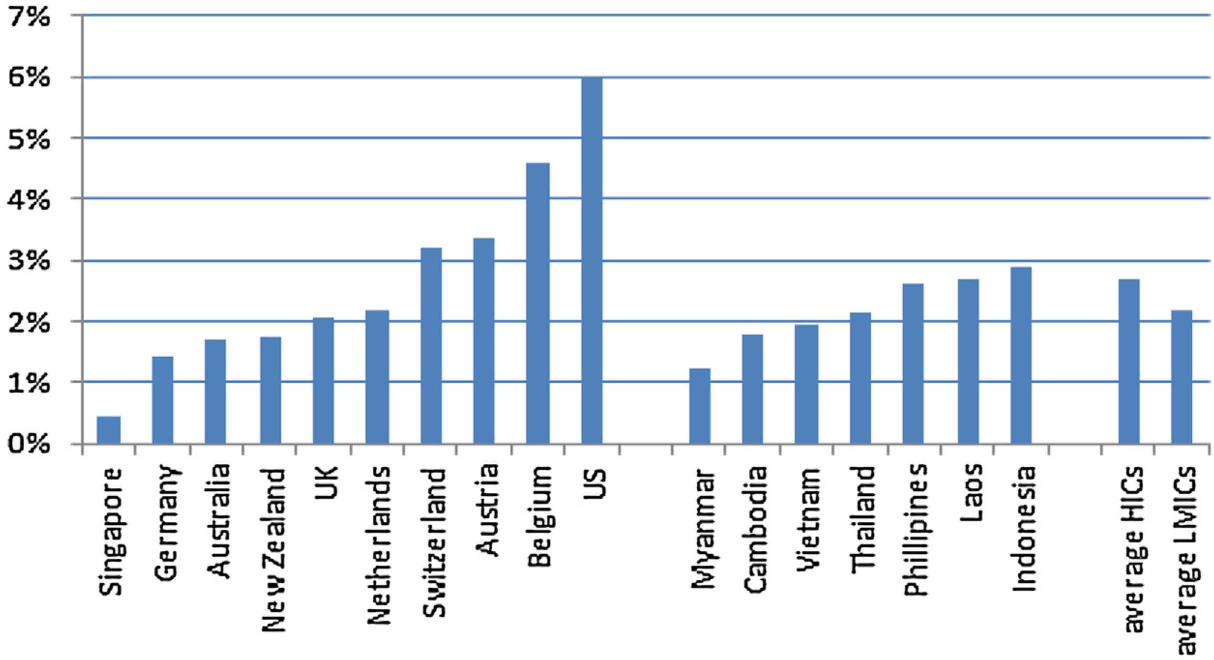


Figure 2. Costs of road crashes as a % of GDP (27)

A European comparison (28) shows huge differences in official estimates of road crash costs. Total costs range from 0.4% to 4.1% of GDP. E.g., In Bangladesh, the costs of road crashes are estimated at "over" 1.5% of GDP. Still, for motorcyclists alone this means a cost of € 808,436,292 in 2022. The cost per fatality ranges from €0.7 million to €3.0 million, the cost per serious injury ranges from 2.5% to 34.0% of the costs per fatality, and the costs per slight injury from 0.03% to 4.2% of the costs per fatality.

The differences are largely explained by differences in methodologies, whether a willingness to pay method is applied to estimate human costs, differences in costs components that are included, different definitions of serious and slight injuries and differences in reporting rates of crashes and injuries. The fact that underreporting is not considered in cost estimates in most countries, implies a serious underestimation of total costs in these countries. Moreover, several countries do not include property damage, only crashes in total costs, implying a further underestimation of total costs. More than half the total costs of road crashes are attributable to serious road injuries.

2.2.1 WHO BEARS THE ROAD CRASH COSTS?

Road crashes generate extensive direct and indirect costs. Direct costs are those born by the crash victims and families directly, or by public bodies. They typically include emergency service response

(police, ambulance, fire services), medical care, long term care (such as rehabilitation), medication, insurance administration, road clean-up crew costs, cost of repairing street furniture, coronial and funeral costs, legal and correctional costs, vehicle repair and temporary replacement, and towing costs. Indirect costs are those born by victims, their families and communities, and society more broadly. Examples include loss of income, loss of productivity, costs related to grief, pain and suffering, time delays caused by road traffic crashes, rising insurance costs and so on (136).

The economic cost of road crashes is estimated to equate to between 2% and 7% of GDP of countries around the world, totally over $2 trillion per annum (137).

One example is an analysis of crashes in the Netherlands (29) which shows that the social costs of road crashes in 2020 are estimated at € 27 billion, equivalent to 3.3% of the GDP (29). In Australia, road crashes cost approximately AU$27 billion in 2020 (136), and in the United States, road crashes are estimated to cost USD $242 billion per year (138).

The costs for the Netherlands are about € 6.5 million per road death and € 0.7 million per serious road injury. Most of the road crash costs, 90% (€ 24 billion), are borne by private individuals. This is mainly caused by the human costs which account for a large share of the total costs. In addition, part of the vehicle damage and medical costs are borne by individuals in the road casualties. People who aren't involved in a road crash also bear part of the costs, via for example congestion fees and insured costs. The latter are indirectly paid by means of insurance premiums by all insured individuals. A small share of the costs, an estimated 1% (€ 350 million), is borne by the government.

Private individuals also bear the brunt (58%) of the costs when the human costs are excluded, such as vehicle damage and insurance costs. The cost share for companies is 20% and only 5% is borne by the government (29). This relation of the shared costs is probably more or less the same for road crashes in Europe since the Motor Vehicle Insurance Directive (EU) 2021/2118, which demands that all motor vehicles are insured, is valid in all EU countries. The directive demands that the insurance covers the costs for everyone involved in the crash, except the driver/rider.

2.2.2 RECOMMENDATION

Fatalities and serious injuries among motorcyclists not only cause suffering and losses of loved ones. The costs for the society are huge but most of the costs are borne by the road users themselves which includes the motorcyclists. We also know that crashes with motorcycles tend to be more severe, with longer time spent in hospital, longer periods of rehabilitation and increased rates of fatalities which means that motorcycle crashes costs individuals and societies more than car crashes per crash.

The cost in low- and middle-income countries, is disproportionately born by those who cannot afford motor vehicles. A Dutch analysis shows that the share of road crashes that is paid by the government is only one percent. An important factor shows the importance to improve safety for riders is to include the socio-economic cost of human lives and serious injuries at all stages from planning to building and maintaining. Motorcyclists must be included in laws and regulations to create a safe road environment based on their needs of safety.

There are numerous safety measures described in this document which are known to reduce the likelihood and severity of motorcycle crashes. The cost for them is often less that the cost of one dead or seriously injured motorcyclists. The costs would become lower if the right measures were taken when a road is planned, built, and maintained. With an increased demand on accessories for motorcycle safety the costs would probably be even more reduced though an increased demand and development of new products.

PART 2- BEST PRACTICES IN MOTORCYCLE SAFETY TREATMENTS

CHAPTER 3. GLOBAL, REGIONAL AND NATIONAL GUIDELINES ON MOTORCYCLE SAFETY

3.1 MOTORCYCLES IN THE SAFE SYSTEM

The Safe System was mentioned in chapter 1.1 evolved from Sweden's Vision Zero. Although the definitions for the Safe System differ, the main idea is that mobility should not lead to fatalities or serious injuries. It involves a shift from trying to prevent all crashes to preventing death and mitigating serious injury in road traffic collisions.

According to iRAP, a Safe System approach has the following characteristics:
- Mistakes, errors of judgment and poor decisions are intrinsic to humans. The road system needs to be designed and operated to account for this.
- Humans are fragile. Unprotected, we cannot survive impacts that occur at greater than around 30km/h.
- The 'engineered' elements of the system – vehicles and roads – can be designed to be compatible with the human element, recognizing that while crashes might occur, the total system can be designed to minimize harm, particularly by making roads self-explaining and forgiving of human error.

Road safety is a responsibility shared between those who use roads and those who manage, design, build and maintain the road system and those who provide post-crash care.

Commonly recognized are the five pillars of the Safe System Approach. These are:
- Safer vehicles
- Safer speeds
- Safer roads and roadsides
- Post-crash care
- Safer road users.

However, for example, Transport Research Laboratory, TRL, uses a slightly different setup as is shown in figure 3.

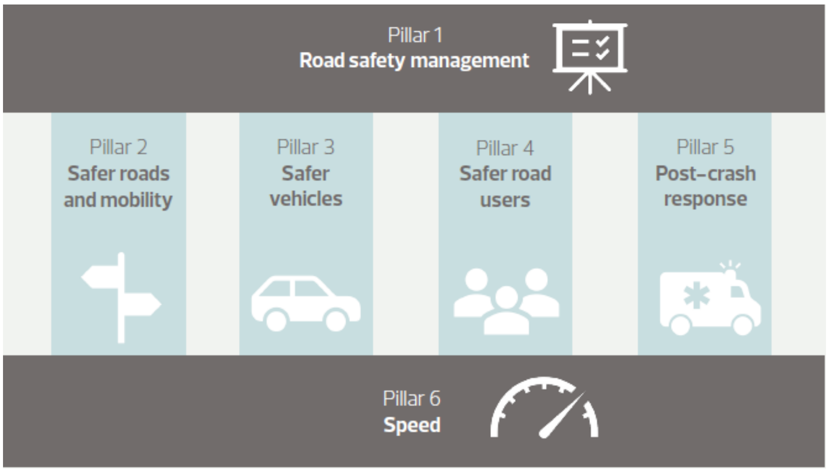


Figure 3. The Safe System Pillars (131)

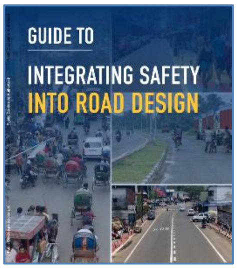
The Safe System approach is the base of almost all current road safety strategies and programs. However, the existing strategies and programs reveal that they are mainly aimed at car occupants and lately also at pedestrians and cyclists. The latter two categories are included by aiming at separate lanes for cyclists and reducing the speed limit on roads with mixed traffic. Few dedicated provisions are seen for motorcyclists. A crash does not have to mean injuries for car occupants who are protected by a designed cage and crumple zones. Motorcyclists do not have these provisions and a crash means death or serious injuries more often compared to car occupants. Also, because motorcycles have only one track, there is a risk of losing balance on e.g., slippery road surfaces. Therefore, motorcyclists need an approach that is primarily aimed at avoiding crashes. This starts with education and training, but just as safe vehicles, these aspects are out of the scope of this document.

The road infrastructure plays an important role in avoiding crashes which was already. Already the Hurt report from 1981 (19) mentioned the element of infrastructure. Good examples of safe roads for motorcyclists are mainly to be found in some European countries like Norway, Germany, the Netherlands, Slovenia, Austria, and France, where dedicated road safety strategies for motorcycles exist and are in effect. However, many countries do not have dedicated motorcycling safety strategies in place. The reasons for the lack of inclusion of motorcycles in road safety programs differ per country. It can just be that motorcyclist, due to relatively low numbers and lack of a lobby, are overseen, it can be because authorities do not understand the importance of dedicated measures, it can be that motorcycles and motorcyclists have a bad image or that crashes are due to the behaviour of the motorcyclists themselves (139).

Unlike the traditional approach to road safety, the Safe System approach recognizes that human error is no longer the primary cause of crashes. Rather, a failure of the road system is the cause of many collisions that result in death or serious injury (140). Thus, it is important to recognize that motorcyclists need to be protected against unnecessary road crashes, their needs and include this in guidelines at all stages of transport policies.

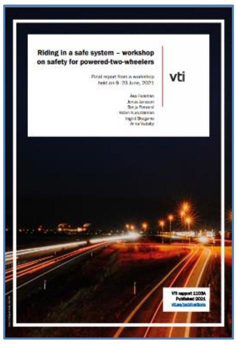
3.2 GLOBAL GUIDELINES RELEVANT TO MOTORCYCLE SAFETY

There are several documents at the global and regional level which aim to help countries address motorcycling safety. A summary of the key ones is provided below.



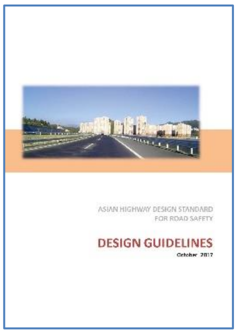
The World Bank "*Guide to integrating safety into road design"* has one chapter that describes the need of motorcycles in different parts of the world. The document also gives examples for improved motorcycle safety (30).

The 2022 WHO document Powered two- and three-wheeler safety: a road safety manual for decision-makers and practitioners, 2nd edition states that road traffic injuries are a major public health problem and a leading cause of death and injury around the world requiring appropriate and targeted action urgently. The manual was initially published in 2017 and provides guidance to countries wishing to improve road safety organization and to implement specific road safety interventions outlined in The World Report on Road Traffic Injury Prevention (9).



The report “Riding in a safe system – workshop on safety for powered-two-wheelers” was the outcome of the 2021 workshop on motorcycle safety, as a follow-up to the Third Global Ministerial Conference on Road Safety in Stockholm 2020. One of eight priority actions was redesign and improve infrastructure safety for motorcyclists. Governments and road authorities are actively encouraged to consider the latest standards and update their road manuals and design and maintenance guidelines to include best practice and safe system principles for motorcycles (8).

“Policy recommendations to enable infrastructure improvements to reduce motorcycle crash risk at a network level” were presented by David Milling, ARRB, at the International Transport Forum Summit in 2018. The paper concludes that motorcycle crash risk can be reduced when providing targeted treatments or improvements to road infrastructure elements. As each element is developed, designed, and managed by multiple road engineering disciplines a logical conclusion would be that motorcycle crash risk could be reduced through a collaborative approach, achieved through changes in practice across all road engineering disciplines. Given that the benefits of managing, designing, and improving road infrastructure to reduce motorcycle casualties can be proactively quantified it would seem logical to include motorcycles as a design vehicle that should be catered for in transport and infrastructure policies at all levels of governance. Changes in policy to identify motorcycles as a design vehicle should enable significant improvements to road infrastructure to reduce motorcycle casualties at a network level (31).



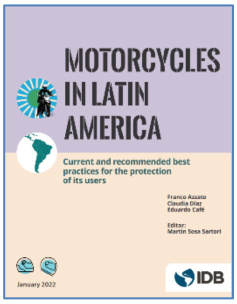
In October 2022, the Asia-Pacific Road Safety Observatory convened a *Global Dialogue on Powered Two-Wheeler Safety.* The meeting statement calls on governments, funding bodies, road operators and industry to holistically address PTW safety through investment, research, policies, and standards (145). Specifically, it requires road owners and operators to address infrastructure safety by:

- Separating PTWs from heavier traffic and other vulnerable road users
- Requiring that road safety audits are performed for all designs such that they reach 3-stars or better.
- Regularly undertaking safety assessments of existing roads and implement speed management, maintenance, and safety upgrades so that 75% of travel occurs on roads rated 3-stars or better.
- Working with development partners to implement demonstration and evaluation projects to show what works and facilitate wider adoption of successes.

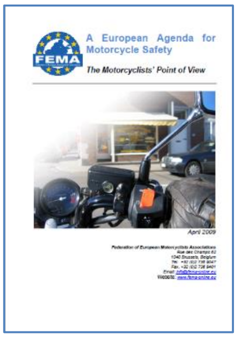
To support discussions on the safety of motorcyclists during the Dialogue, iRAP provided an interactive Powered Two-Wheeler Insights report which provides an interactive analysis of road infrastructure data from around the world which is collected during iRAP safety Star Rating assessments (146).

3.3 REGIONAL GUIDELINES RELEVANT TO MOTORCYCLE SAFETY

In 2018 the UN in Asia Pacific (UNESCAP) adopted *Asian Highway Design Standards for Road Safety* for the Asian Highway network which spans 140,000km across 32 countries. The document is based on the Safe System approach and specifically addresses the safety of motorcyclists (141).



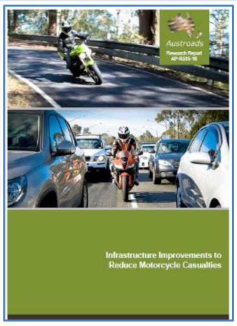
Current and recommended best practices for motorcycle safety in Latin America was published in 2022 and is based on the Safe System approach. It aims to improve motorcycle safety; it examines best practices in all areas and outlines policy recommendations for Latin American and Caribbean countries. One part is about motorcycle infrastructure and policy planning.



FEMA has played an important part when it comes to motorcycle safety in Europe. The European Agenda for Motorcycle Safety was published in 2009 (142). The aim with the document was to provide a brief summary of why motorcycle crashes happen from a rider's perspective and recommendations how to improve motorcycle safety in some selected areas of particular concern to legislators, decision makers, and all stakeholders dealing with motorcycle safety.

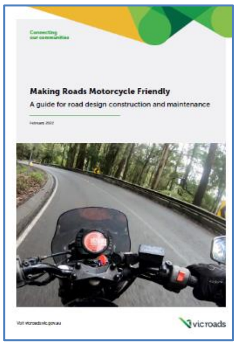
In 2015 FEMA presented RIDERSCAN after scanning Europe for information in various ways and from different stakeholders. The project included identification and comparison of national initiatives on PTWs and best practices. Existing knowledge was collected and structured at European level Finally, and to identify critical needs for policy action at a European or national level (143).

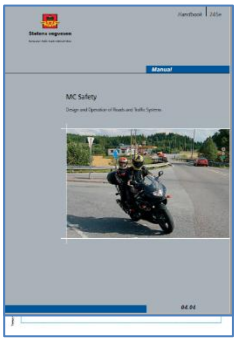
3.4 NATIONAL GUIDELINES FOR MOTORCYCLE SAFETY



Australia

The most comprehensive example is *Infrastructure improvements to reduce motorcycle casualties, Austroads Research Report AP-R515-16* (32). This report was published in 2016 after a two-year long process of literature review, crash analyses and explanations of why, and how, road infrastructure elements influence motorcycle crash risks. It also identifies how the design and condition of road infrastructure elements can influence either the likelihood of a crash occurring or the resulting severity of a crash. The study has built up a compendium of treatments, presented in a way that engineering decisions to manage these elements can be justified. The guidelines are not included in general demands for planning, building and maintaining roads in Australia but are used for locations where measures to improve motorcycle safety have been decided (26). Several jurisdictions in Australia have published guides about improving the infrastructure for motorcyclists. The most comprehensive is the one from Vicroads "*Making roads motorcycle friendly, A guide for road design construction and maintenance*". The latest version is from 2022 and includes advice to road authorities, contractors, and important issues from construction to maintenance phase. The guide includes a check list (Annex 1) to assist with designing and maintaining roads in order to consider the needs of motorcyclists (33).



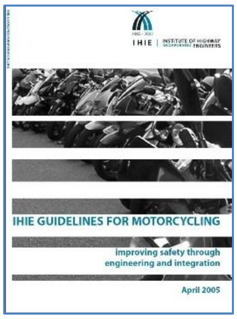


Germany

The German Forschungsgesellschaft für Straßen- und Verkehrswesen (FGSV) presented revised guidelines in 2021 *'Merkblatt zur Verbesserung der Straßeninfrastruktur für Motorradfahrende. improving road infrastructure for motorcyclists MVMot'.* The document describes crashes, where they occur and how to prevent them or minimize the injury severity. Since the German system of road authorities and their responsibilities is quite complex with different road owners and different regulations and guidelines, a formal decree was issued in May 2021 by the German Federal Ministry of Transport to implement MVMot 2021 on all roads within their responsibility on highways and federal roads. In addition, the Ministry recommended that the Federal State Ministries should implement these guidelines in their area of responsibility as well and to further ask the counties and communities to do the same. It is up to the jurisdictions to follow this recommendation (34).

Austria

Austria published their first guidelines in 2010, "*Empfehlungen zur Verbesserung der Sicherheit für den Motorradverkehr* (*Recommendations to improve safety for motorcycle traffic)*". The guidelines are presently being revised and it is hoped they will be published in 2023. The document has looked at crashes at popular motorcycle roads and proposes different measures to prevent them or minimize the risk injuries.



United Kingdom

The UK Institute of Highway Engineers IHE published its *Guidelines for Motorcycling* (147) in 2005 with the aim to support the Government's Motorcycle Strategy and 'mainstream' motorcycles into core transport policy. The IHE Guidelines were the first such publication to set out practical guidance for policy makers, transportation professionals and users on providing a safer environment for motorcycles, mopeds, and scooters. Its' individual chapters cover Policy; Road Design; Road Safety; Travel Plans; Parking; Maintenance and Road Safety Audit. The Guide has been produced to provide advice to designers to ensure that the issues experienced by motorcyclists are known when developing highway schemes and to help achieve strategic road safety targets. The "*Guide to designing for motorcyclists*" provides information on infrastructure measures and supports design requirements and advice contained within the Design Manual for Roads and Bridges (DMRB) and is tailored to specifically improve highway layouts for motorcyclists. (22).

The *Urban Motorcycle Design Handbook* was published by Transport for London in 2016 and developed with input from stakeholder groups. It sets out the key highway design requirements for motorcycle safety in London. The key design issues for motorcyclists are friction, visibility, road-side features, traffic calming and filtering. The aim of the handbook is to increase understanding for all concerned with planning, design, construction, operation, and maintenance (35).

Norway

In 2007, the Norwegian Public Road Administration published the guidelines *MC safety Design and Operation of Roads and Traffic Systems.* The document has been used as a guideline since then and the document was revised in 2014 in a Norwegian version *MC Sikkerhet* (36).

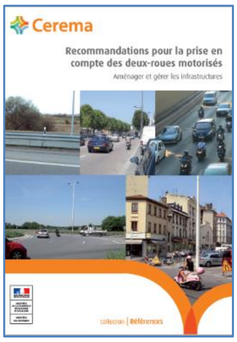
Several ongoing infrastructure improvements for motorcyclists are presented in the *Norwegian National Plan of Action for Road Safety 2022-2025*; road inspections and thematic inspections with a particular focus on critical issues relating to the road, the side terrain and optical guidance for motorcycles; survey side terrain route by route for the potential establishment of motorcycle protection devices or facilitation of forgiving terrain and a pilot to test measures to prevent motorcycle off-the-road crashes, including clearly visible and flexible delineator posts to improve optical guidance at unexpected curves (37).

Slovenia

Slovenia has published *Guidelines for motorcycle safety* written in cooperation between Slovenian Infrastructure Agency, Universities of Maribor and Ljubljana and DRI investment management, Ltd. The guidelines have been implemented and evaluated in areas with many crashes among riders. Investigations of high motorcycle traffic and crash risk were made to identify exposed road sections in terms of motorcyclist safety, where the guidelines have been implemented. The guidelines include several pragmatic solutions for improving motorcyclists' safety on the roads and it is very important for road safety engineers to implement and use systematic and feasible solutions on existing roads and in the design or construction phase (38).

The Netherlands

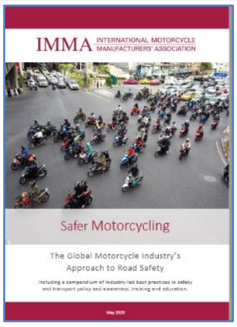
In the Netherlands, the traffic department, in cooperation with the Motorplatform (cooperation of all parties that are involved in motorcycle road safety) published its first *Action plan for improving road safety for motorcyclists* in 2010. It's been followed by a second action plan in 2018 (39).



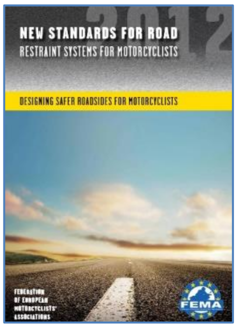
France

In France, a first version of a methodological guide of recommendations for the consideration of motorcycles was presented in 2011. A revised version completed by the results of research and technical expertise was consolidated in 2018 with the help of user associations and representatives of the various authorities in charge of infrastructure and land use planning, *Recommendations pour la prise en des deux-roues motorisés* (*Recommendations for the management of motorized two-wheelers).* It is a decision-making tool, an incentive to improve the consideration of motorized two-wheelers in the management of existing infrastructures, but also for development projects, based on the quality approach to road safety, which has been in place in France since 2001. The recommendation has been updated with new recommendations in terms of road design to consider the safety of riders via recent publications and new reference safety studies. These recommendations also incorporate basic elements on the particularities of motorcycles and the impact on riding, but especially on the vulnerability of users in traffic due to road infrastructure. It also introduces the unsafe conditions for two-wheeler users (weather conditions; slippery road due to weather conditions or road markings; road surface condition; traffic; safety rails; roundabouts/intersections) with recommendations to ensure road safety quality for existing infrastructure and future projects (40).

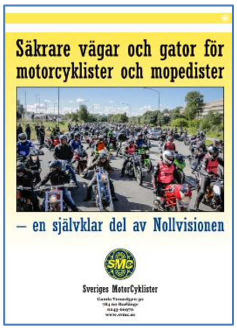
3.5 GUIDELINES FROM MOTORCYCLE ORGANIZATIONS



Motorcycle safety is not only a concern for road authorities. Motorcyclist organisations such as FEMA and SMC who are responsible for this document and industry groups have made significant contributions to advancing the cause. One example is *"Safer motorcycling, the Global Motorcycle Industry's Approach to Road Safety*" which was published by the IMMA in 2019. The chapter "Road infrastructure must be designed and maintained with PTWs in mind" describes infrastructure as a factor in motorcycle crashes and examples of best practice (41).



In *New standard for road Restraint Systems for motorcyclists* the Federation of European Motorcyclists Associations, FEMA, i2012 presented how safety for motorcyclists could be improved concerning barriers. Examples from European countries were described and the need for a new standard (42).



The Swedish Motorcyclists Association, SMC, has published and distributed the leaflet *Safer roads and streets for riders and passengers on motorcyclists* to members, politicians, local authorities, regional authorities, road authorities and entrepreneurs for several years. The document contains a description of the most common motorcycle crashes, how to improve road environment to reduce the number of crashes and minimize the injury risk in collisions with roadside furniture (43).

All examples mentioned above show that there are plenty of good examples and guidelines around the world which can increase motorcycle safety.


4

PART 3 - IDENTIFYING MOTORCYCLE SAFETY

CHAPTER 4. WHERE DO MOST INCIDENTS AND CRASHES OCCUR?

Members of the European Union, EU, report road crashes to the database CARE. There are three crash locations specified: rural, urban and motorways. Studies and research of fatal crashes in different countries (for example Australia, Austria, Sweden, Norway, Germany, Slovenia) indicates that there are two locations where most fatal and serious motorcycle crashes occur: curves and intersections. Serious crashes also occur on straight roads with high speed. Regardless of where the crashes occurred, it is crucial to properly investigate every motorcycle and other vehicle traffic crash from various aspects. It is important to understand the reason behind the crash to understand the cause and find the best solutions.

4.1 CURVES

The most typical run-off motorcycle crashes where the rider leaves the road lane on the outside of a curve. The crashes are often caused by high-speed relative to riding skills and/or unforeseen road conditions. A common contributing factor is loss of friction due to spills, dirt, or gravel on the road. The outcome of the crash is often determined by the presence of roadside hazards such as barriers, poles, and trees.

The other common type of crash on curves is head-on collisions with an oncoming vehicle. In these collisions, the rider was close to the centreline or on the wrong side of the road. A common factor in these crashes is high-speed of the motorcyclist (and thus 'cutting the corner'), The causes of these crashes are often the same as above, high speed, lack of riding skills and loss of control due to poor friction. Poor forward visibility and difficulty in predicting the entire bend are also common contributing factors.

4.2 INTERSECTIONS

Another key location for crashes is at intersections. The typical motorcycle crash here is a head-on crash with a large vehicle where the driver fails to yield where required. Common scenarios are drivers, whilst making a turn from a main road onto a side road, overlooks the oncoming motorcycle on the main road. Another typical crash is a sideswipe, where a driver turning from a side road onto a main road overlooks a motorcycle approaching on the main road.

Data from Swedish insurance companies on intersection crashes between motorcyclists and large vehicles show that the other vehicle driver caused the crashes between 67-93% of crashes (44).

4.3 STRAIGHT ROADS

There are several different reasons behind crashes on straight roads. Some examples are excessive speed, reckless riding, loss of control due to poor friction and defects on the roads. The risk for serious injuries increases when there are obstacles near the road or roadsides, such as barriers, trees, and poles. Another common crash type is a shunt crash where a motorcyclist crashes into the rear of a vehicle travelling in the same lane. Lack of crash investigation and research into these types of crashes means that there are no sufficient understanding of causes and thus the solutions.

4.4 SPEED AND MOTORCYCLE CRASH OUTCOMES

Speed not only increases the likelihood of crashes occurring, but it also has a determining role in the severity of the crash outcome. An Australian study (45) investigated the survivability of motorcyclist crashes with fixed objects at crashes with fixed object. The study used the findings to develop a predictive model for FSI risk as a function of travel speed that may be useful for road safety practitioners. The result shows that

- the fatality risk remains relatively low below a pre-crash travel speed of 100 km/h, however above this speeds the risk rises sharply,
- the serious injury risk is significantly greater than the fatality risk and is above 20% even for low-speed crashes,
- motorcyclists with a pre-crash travel speed less than about 55 km/h, could be expected to survive a collision with a fixed object (45).

A series of tests were made at the Centre for Road Safety (CRS) in Australia 2017 to evaluate MPS for use on W-beam barriers. The results showed that those with MPS had a greatly reduced injury risk for a motorcyclist impact at 60 km/h and a greatly reduced injury risk while an impact at the same speed into w-beam barriers without MPS where likely to be fatal (46). These results show how important it is to consider motorcyclists safety on decision about roadside measures, choice of barriers, and the distance between objects and road edge to reduce the risk of injuries and fatalities. This importance grows as speed limits increase.

A study based on motorcycle injury crashes from the German In-Depth Accident Study (GIDAS) database for the period 1999–2017 found a strong relationship between relative speed and injury severity in motorcycle crashes was demonstrated. At 70 km/h, the risk for serious and fatal injuries at collisions with wide objects, crash barriers and narrow objects was 20%, 51%, and 64%, respectively. Head-on collisions between motorcycles and cars, traveling at 60 km/h present a 55% risk of at fatal or serious injury to the motorcyclist (48).


5
HONDA

CHAPTER 5. ADDRESSING MOTORCYCLE SAFETY

ITF stated at the workshop in 2021 that addressing the safety of motorcyclists is essential to meet global road-safety targets and helping create a Safe System for all users. One of the eight priority actions from the workshop was to redesign infrastructure to increase motorcyclist safety:

"Infrastructure must be safer for PTW users, starting with the design of roads and traffic systems. Governments and road authorities should comply with the latest infrastructure safety standards related to PTW use and update documentation to reflect best practice and Safe System principles. Infrastructure managers, researchers and institutions should update and promote road design standards, manuals, and guides to reflect best practice knowledge on PTW safety. All stakeholders should develop new ideas to rethink the traffic system, for example regarding space re-allocation and infrastructure design. Researchers, manufacturers, and governments should share knowledge of safe and efficient infrastructure solutions which support the mix of PTWs, other vehicles and other vulnerable road users in road traffic."

Today, motorcycles are not given enough attention in many countries when it comes to all stages of infrastructure like planning, building, maintaining and inspections. Motorcycle safety needs to be included in the safety routines, to undertake a safety assessment and evaluate the need for additional motorcycle safety measures. To do this, particular attention needs to be given to understanding where motorcycle crashes are occurring, why they are occurring and how to address them.

5.1 INCLUDING MOTORCYCLE SAFETY IN THE PLANNING, CONSTRUCTION AND MAINTENANCE OF ROADS.

Motorcycle safety should be included in considerations in the safety routines, to undertake a safety assessment and evaluate the need for additional motorcycle safety measures. Even if motorcycles aren't included in all aspects of the road environment there are some good examples. The Norwegian handbook for motorcycle safety (36) presents several measures during road works and maintenance to improve motorcycle safety.

The Norwegian handbook states that there can be a particular need to assess motorcyclist safety, both when auditing construction plans and auditing constructed roads before being opened. Auditors must ensure that details regarding location and design will not create significant problems to motorcyclists. Two checklists are included in the handbook for auditors, one for the construction phase and one for existing roads (Annex 1). Special chapters about cleaning the roads after maintenance to minimize the crash risk and the need of predictable friction is also a part of the handbook. The Vicroads guide for making roads motorcycle friendly also contains a checklist (Annex 1) for designing and maintaining roads with consideration to motorcycle safety (33).

Another good example is Slovenia where the guideline for motorcyclists includes both the construction and the maintenance phase. The following situations/locations/elements are defined as dangerous and need to be eliminated as soon as possible: obstructed visibility in bends, guardrails with no underrun protection in dangerous bends, dangerous draining systems, height difference between carriageway and shoulder, damaged or slippery pavements, road patches, obstructed visibility in bends, dangerous patchwork, and serious flaws in the road pavement like patches of varying grip, lane ruts and patchwork repairs (38).

The Australian report (32) about infrastructure improvements to reduce motorcycle casualties recommends that the following general measures are considered by practitioners in safety, design, asset management, maintenance, pavement technology road engineering disciplines:

- Motorcyclists should be recognized as a unique road user group and have specific needs about road infrastructure.
- The likelihood of a crash occurring, and its likely severity are both important considerations, however with more focus on treating road infrastructure elements that affect likelihood further crash reductions can be achieved.
- It might be more economical to treat road infrastructure elements that effect the likelihood of a crash. Greater reductions in fatal or serious injury crashes may be achieved through a targeted focus on reducing the likelihood of a crash occurring as well as reducing the severity of a crash.
- As the proposed mitigation measures are road infrastructure-based treatments, over time they can be integrated into existing practice and therefore existing funding.
- Motorcycle crash risk should be proactively identified, and a remedial action program developed through motorcycle focused network safety assessments or road safety audits.

5.2 CRASH MAPPING, CRASH INVESTIGATIONS AND 'BLACK SPOT' MANAGEMENT

It is important to collect and analyse data from crashes to find the spots where most crashes occur, to find out why the crashes happened and what measures that need to be taken. There are several examples of this in the USA (California), Australia (Victoria), UK, and Norway (49-50).

Collection of crash data in Germany, Slovenia, Norway, Austria, UK, and other countries has resulted in addressed measures on road stretches with many crashes, "black spot management". Black spot is sometimes seen as a reactive' approach where crashes have already happened which cost lives and injuries. However, the effects of measures taken in areas with high crash figures show good results. Slovenia has for example added signage before curves, installed soft roadside pollards, MPS on barriers and installed red and white elements on barriers in curves with many crashes. These measures have reduced speed as well as motorcycle crashes. Several of the guidelines that have been mentioned in this document are using black spot management on popular motorcycle roads to improve the safety for motorcyclists (38).

The Norwegian Trafikksikkerhetshandboken (Road Safety Handbook) concludes, by using different calculation examples, that that in most cases it can be assumed that the benefit of improving crash points and sections clearly exceeds the costs of the measures (51). An important factor to improve safety for riders is to include the socio-economic cost of human lives and serious injuries at all stages from planning to building and maintaining.

5.3 ROAD SAFETY AUDITS AND INSPECTIONS

Road safety audits and inspections are described as “a formal, systematic, and detailed examination of road safety concerns by an independent and qualified team of auditors.” (52) It involves a review of road designs and inspections at specific locations of a new or upgraded road to identify potential safety concerns and opportunities to eliminate or mitigate risk. They are carried out by experienced auditors and look at cross-cutting issues, such as road safety engineering, design, and local road user behaviour (301). It is not guaranteed that motorcycle safety is included in all audits but there are several good examples from USA, Norway, Austria and UK. The audits in Norway are done by national, regional and local road authorities in cooperation with the motorcycle organisation NMCU. Certain roads are inspected to propose the most efficient measures which are budgeted in the Norwegian National Plan of Action for Road Safety 2022-2025 (37.

As addition, a semi-automatic inspection can be done, using a specific motorcycle for safety inspections, for example the Austrian MoProVe motorcycle, is The MoProve motorcycle is a sensor-equipped motorcycle, that is used for risk analyses and safety inspections, based on collected vehicle dynamics data. The MoProve is a rolling road infrastructure laboratory which makes it possible to create risk maps and risk models, based on processed data. It can also deliver objective and comparable observations of safety relevant parameters. The integrated use of AI-methods opens the field for data cross-validation, big data analytics and risk prediction models (53).

5.4 ROAD SAFETY ASSESSMENTS AND THE IRAP STAR RATING

Unlike reactive approaches to known crash locations, proactive risk assessment approaches, such as Star Ratings, help road authorities address risk before crashes happen.

The European Commission published guidelines on a methodology for network-wide road safety assessments in January 2023. The guidelines are not mandatory but aim to help public authorities in EU Member States to carry out the safety assessments of their road networks as required under the Road Infrastructure Safety Management Directive where motorcyclists are considered as vulnerable road users. The amended article 6b states that the Member States shall ensure that the needs of vulnerable road users are considered in the implementation of the procedures set out in Articles 3 to 6a.

The guidance documents comprise a framework addressing both a reactive (crash based) and a proactive (feature based) safety assessment, covering issues such as the lane width, road curvature, design of junctions, roadside layout and potential conflicts between motorized vehicles and vulnerable road users. The guidelines have no proposals to them member states how to improve road safety for riders and passengers on motorcycles and mopeds. The only vulnerable road users that are mentioned and cared for to a large extent are bicyclists and pedestrians (10).

To address these risks for motorcyclists, it is imperative the approach includes a motorcyclist-specific component which can detect the infrastructure-related hazards particular to this road user group (54).

iRAP's road safety Star Rating methodology is a free tool to assess the safety of roads worldwide.

Star Ratings can be used by road authorities and others to proactively and objectively address high risk sections of the road network. Data about the features of a road is collected via a road survey, and then Star Ratings are produced to represent the risk of crashes along the road. Star Ratings includes a specific component for motorcyclists, which means that the safety of the road for motorcyclists and PTW can be analysed and addressed independently from other road user types.

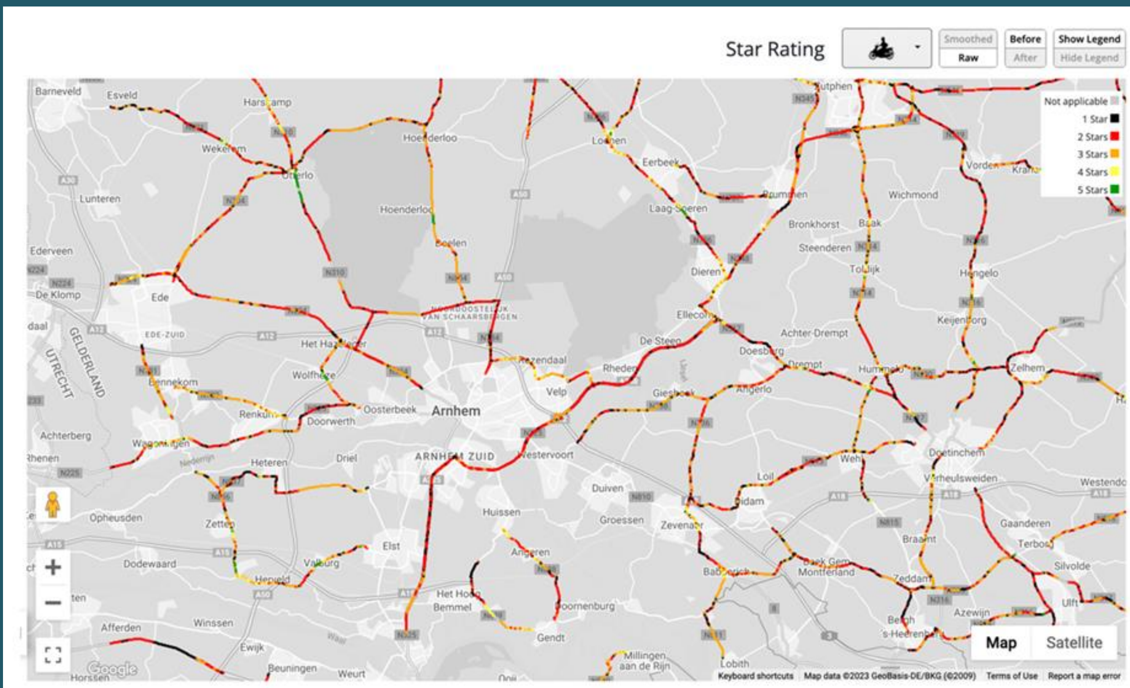
Star Ratings objective measure of the likelihood of a road crash occurring and the severity of the outcome. The focus is on identifying and recording the road attributes which influence the most common and severe types of crash, based on scientific evidence-based research.

In this way, the level of risk to a road user on a particular road section or network (or road design) can be defined without the need for detailed crash data, which is often the case in low- and middle-income countries where data quality is poor. Research shows that a person's risk of death or serious injury is highest on a 1-Star road and lowest on a 5-Star road. Star ratings are produced for vehicle occupants, motorcyclists, pedestrians, and bicyclists.

There are advantages to this approach. First, the level of risk to a road user on a particular road section or network can be defined using Star Ratings without the need for detailed crash data. This is particularly useful where there is low crash frequency, where there is poor or incomplete crash data, or for urban road networks where crashes tend to be distributed throughout the network making it difficult to identify specific locations to treat.

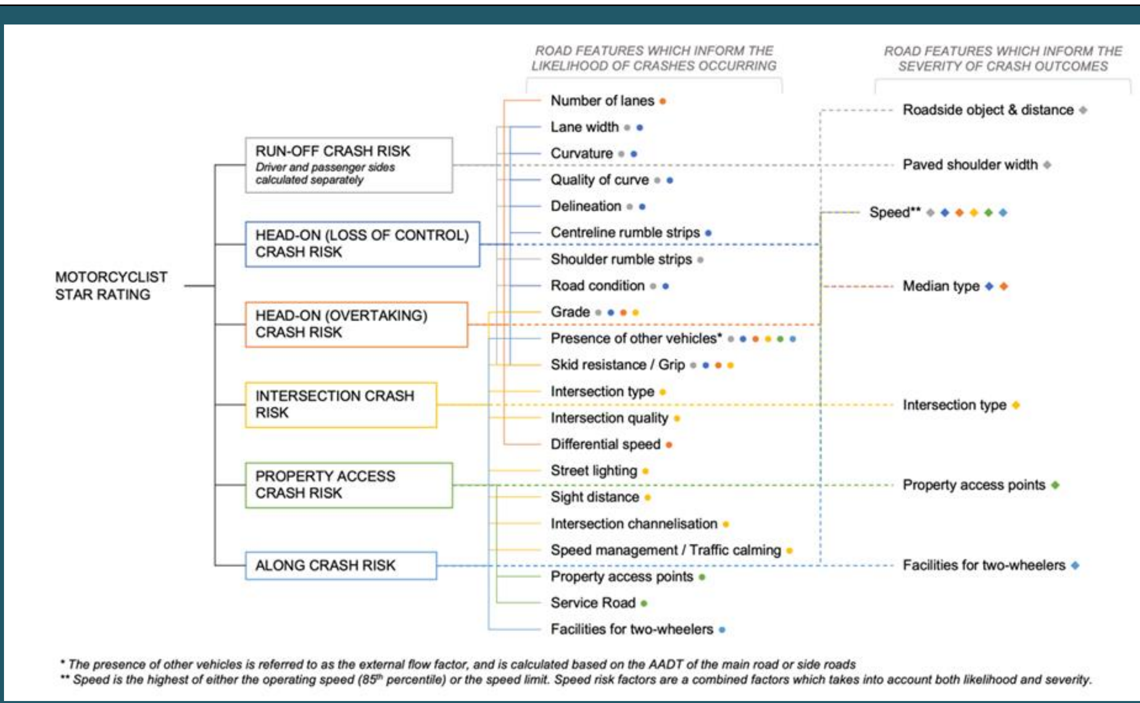
Another advantage is that only one assessment is required for Star Ratings across all road user types. That is, no additional data is required to produce them for motorcyclists. This makes it easier for road authorities to undertake a single assessment but isolate the results and analysis for motorcyclists.

Example of a motorcyclist Star Rating map from an assessment of secondary rural roads in The Netherlands (from 2014)



For each road user types, the model selects the relevant road features to inform specific crash types and calculates the likelihood and severity for each. The motorcyclist model has six crash types: run-off crashes, head-on crashes from a loss of control, head-on crashes from overtaking, intersection crashes, property access crashes and crashes while travelling along the road. Each crash type is then calculated using the likelihood and/or severity factors associated with particular road characteristics, and which are based on scientific evidence-based research. These are shown in the figure below.

Road features which inform the motorcyclist Star Rating Score equation



Using Star Ratings to estimate the number of fatal and serious injury (FSI) crashes. Star Ratings represent the risk of a fatal injury to an individual road user. For example, for motorcyclists, Star Ratings equate to the number of deaths and serious injuries per vehicle kilometre travelled on a road. Collective risk, that is the number of fatalities and serious injuries of a road, is a function of individual risk (Star Ratings) and traffic volume.

Star Ratings are paired with flow data (e.g., the total number of motorcyclists using a road section) to understand the collective risk. This is referred to as FSI Estimations. Similar to Star Ratings, these can be mapped across a road network to understand road sections where there are likely to be high rates of motorcycle crashes.

Safer Roads Investment Plans

From the FSI Estimation, a Safer Road Investment Plan (SRIP) can be developed. A SRIP is a prioritized list of safety treatments that can cost-effectively improve a road or its design Star Ratings to reduce road user risk. SRIPs are based on an economic analysis of a range of safety treatments which compares the cost of the treatment with the reduction in crash costs that would result from its implementation.

5.5 COOPERATION WITH THE MOTORCYCLE COMMUNITY

The input from motorcyclists is crucial for enhancing the safety of the road infrastructure. No one knows better the effects of for example a slippery road, potholes, rutting and obstacles on and near the road, than the motorcyclists themselves. This knowledge is based on own experience and information from other motorcyclists. In many countries, recognizing hazardous or potentially hazardous situations is part of the training. In some countries it is initiatives from the motorcycle community that has started the work to improve motorcycle safety with different measures to reduce the injury risk. National motorcyclists' associations play a special role in building a safer infrastructure since they collect the knowledge and translate it into concrete action. The outcome can be in form of general recommendations, awareness actions, publications, a hotline for hazardous road infrastructure and political actions.

Concrete examples are:

- The hotline that the Dutch Motor Actie Groep (Motorcycle Action Group, MAG NL) had for a long time where motorcyclists could call in with complaints about infrastructure that were forwarded to the road authorities and followed up by MAG NL.
- Reports with recommendations of national associations in cooperation with researchers and experts like it is done in Germany with MVMot
- Guidelines drafted by road authorities with input from motorcyclists' associations which is done in the UK, Norway, and the Netherlands.
- Working groups with road authorities and motorcyclists who annually prioritize the measures that should be taken with the dedicated funds for motorcycle safety like the MC Forums in Norway
- Motorcycling researchers from several universities with cooperation from the motorcycling community and government officials published infrastructure guidelines in Slovenia that were partially based on real life tests.
- Other examples of activity from the motorcycling community are political actions from many national motorcyclists' associations like the Swedish Motorcyclists Association SMC and international associations like the Australian Motorcycle Council (AMC), the Federation of European Motorcyclists' Associations (FEMA).
- To our knowledge, there is little involvement of the motorcycle community in the design and maintenance of infrastructure in developing countries.


6

CHAPTER 6. ROAD SURFACE FRICTION

Surface friction is crucial for the safety of all road users at all locations. It is even more important for motorcycles than for two-track vehicles, since loss of grip may lead to instability, loss of balance and crashes. Riders must be aware of dangerous surface conditions, how to detect them and ride in a speed where he/she can maintain the ability of either stopping in advance or swerving around low-friction areas. However, poor friction cannot always be detected by visual scanning and there is no possibility of a correct estimation of a wet road's friction coefficient with the eyes only.

The TRB's National Cooperative Highway Research Program NCHRP Guide for Pavement Friction mentions several sources that indicate a direct relation between road surface frictions and crashes. A comprehensive evaluation of friction measurements and crash rates revealed that increasing pavement friction reduces crash rates significantly (55). This chapter describes common causes for loss of control due to poor friction and measures to minimize the crash risk.

Friction Interval	Crash Rate (injuries per million vehicle km)
< 0.15	0.80
0.15 – 0.24	0.55
0.25 – 0.34	0.25
0.35 – 0.44	0.20

Correlation between friction and crashes (56).

6.1 ROAD MARKINGS, DRAIN COVERS, TRAM RAILS AND CATTLE GUARDS

Road markings, drain covers, tram rails and cattle guards tend to be more slippery than the rest of the road surface, especially when wet. For motorcyclists these areas can create problems, especially when the rider needs to brake and turn.

Possible solutions

There are several documents which presents solutions to the problems. The following comes from the Norwegian handbook for motorcycle safety, but the content is similar to the advice from Vicroads in the guide for Making Roads Motorcycle Friendly (33, 36).

- Select road marking material with best possible friction. This is especially important in areas where motorcyclists must brake and/or turn.
- Include a minimum friction requirement on road marking in EN 1436:2018 - *Road marking materials - Road marking performance for road users and test methods.*
- Placement of pedestrian crossing on a curve should be avoided. Motorcyclists may skid on the slippery markings and because the visibility to pedestrians and cyclists is poor.
- Avoid pavement markings in the lanes closer than ten meters from a stop or yield line which will give the motorcycle an adequate area for braking and turning at intersections.
- Avoid cattle guards around curves.
- Avoid drain covers on roads and streets, particularly on curves and intersections within carriageways. Crash risk of existing drain covers on roads should be minimized by installing them at the same level as the rest of the road, using anti-skid drain covers and repair broken covers as soon as possible.

6.2 URBAN AREAS

Solutions for increased friction to reduce the crash risk and other useful measures to improve motorcycle safety in urban areas can be found in the Transport for London's *Urban Motorcycle Design Handbook.* The Handbook recommends that (35):

- Block paving and stone sett entry treatments are positioned away from areas where motorcyclists are required to turn. At intersections this can be achieved by locating ramps further into the side road.
- Surface materials are laid on a robust sub-base, with an appropriate flush edge detail provided at the transition point between the surface types.
- A regular inspection, maintenance and repair regime is employed to ensure carriageway defects likely to affect motorcycle stability are identified and repaired in time.
- As to the extent to which on-road markings are required, the Handbook recommends that:
    - The level and size of markings is proportional to the degree of potential hazard and consistent along the route (i.e., remove/do not provide unnecessary markings).
    - Consideration is given whether advanced warning and direction signs can be used to minimize the need for surface markings.
    - Where possible, position markings are positioned away from motorcycle steering, braking, and accelerating zones and suitably placed in advance of bends or junctions rather than within them.
    - Markings have a similar skid resistance to the surrounding road surface.
    - Future maintenance regimes – avoid repeated application of road marking material as this can form ridges that can cause deviation of a motorcycle.
    - The use of black paint to cover over markings that are no longer required is avoided as this can form a skid hazard.

6.3 LOSS OF FRICTION DUE TO GRAVEL FROM UNSEALED SHOULDERS AND ONCOMING GRAVEL ROADS

Gravel from unsealed shoulders and side roads is a hazard for all road users but especially motorcyclists. This problem, which can cause loss of friction, is most likely to happen in intersections and curves where gravel is dragged out on the road from roadsides and side roads by by cars and heavy traffic using the roadsides on narrow roads. Gravel roads are more common in areas with a low population density. Gravel and dirt from these roads can be dragged out on the asphalt roads by vehicles which can cause loss of friction as well as water from rain or snow. A study in 2017 commissioned by the Sveriges MotorCyklister (SMC) showed that loose gravel on asphalt leads to a reduction of friction from 0.8 to 0.35, which is comparable to winter conditions (57).

Possible solutions

Sealing the shoulder at higher-risk locations, such as on curves and parallel to side roads, will remove loose material from the roadside. This is a targeted infrastructure treatment that significantly reduce the risk of loose material being on the road surface at high surface friction demand locations where motorcycles are leaning through a curve. A risk-based approach could be adopted for shoulder sealing activities. Slovenia has used grid plates which turned out to be effective since gravel and sand were eliminated and cost-efficient with no need of maintenance work (36, 38, 39).

6.4 LOSS OF FRICTION DUE TO PATCH REPAIR AND BITUMEN

Crack sealing prevents water from entering the pavement causing other hazards such as potholes and tracks. Pavement damage can greatly affect the handling of a motorcycle which increases the risk of crashes, particularly on curves. Poor and/or wrongly performed patching can also result in an increased crash risk as the tar and bitumen repairs can become slippery in hot or wet conditions.

Possible solutions

Patching methods and materials used should give a lasting and safe result. When properly done, the patching material must be at the same level with the adjoining pavement and have a similar friction. The patching and repair of cracks done with bitumen is prohibited in several jurisdictions. If it is undertaken, however, it is essential that the material is treated with sand or other material in a correct manner to ensure the same friction as the adjoining pavement. In Slovenia the cracks need to be sprinkled with crushed stone of silicate origin (38). Loose material from the maintenance shall never remain at the site when it has opened to traffic or be removed as soon as possible. It is desired that they should be used as little as possible: this could be achieved by greater use of surface coatings.

6.5 LOSS OF FRICTION DUE TO GRAVEL FROM SURFACE DRESSING

Maintenance methods that include a gravel surface or loose gravel applied on top of asphalt and/or bitumen is known as surface dressing. It is an acceptable method for the short to medium term if carried out correctly. If not correctly undertaken, it can significantly increase the risk of loss of control for motorcycles. A preferred solution would be is to lead riders to other roads to avoid the area under road repair entirely. The time frame varies depending on the maintenance method. One common cause of poor friction are failures during and after road maintenance activities. This is the case in Sweden where gravel, mainly from road repair, is the most common cause for single vehicle as crashes according to a leading insurance company Svedea 2014-2021 (58).

A recent study based on seriously injured vulnerable road users registered in the Swedish accident database Strada for the years 2014–2019 shows that loose grit was the most common cause for crashes among moped riders and motorcyclists. The study found that 21% of the motorcyclists and 22% of the moped riders were seriously injured due to a crash caused by gravel (25).

Possible solutions

When surface dressing or similar techniques are used it is important that the road is mechanically swept after the gravel has been rolled and that the road is routinely cleaned until all surplus gravel is gone. This must be done within the decided time limits in the contract. Warning signs should alert drivers and riders to lose gravel conditions on the road.

In Norway, the National Motorcycle Strategy stipulates that the maximum length of a maintenance work with loose gravel on bitumen is five kilometres, then the road must be cleaned. This is a part of the national motorcycle strategy. Norway has also introduced new methods for maintenance where all gravel is removed immediately during the maintenance (36).

6.6 LOSS OF FRICTION DUE TO BLEEDING ASPHALT AND SEALINGS

Asphalt bleeding (also known as flushing) is where the asphalt binding agents liquify and rise to the surface of the tarmac. It appears as a glassy, highly reflective surface that looks like it is wet or oily. As the binding agents do not reabsorb, they can build up over time.

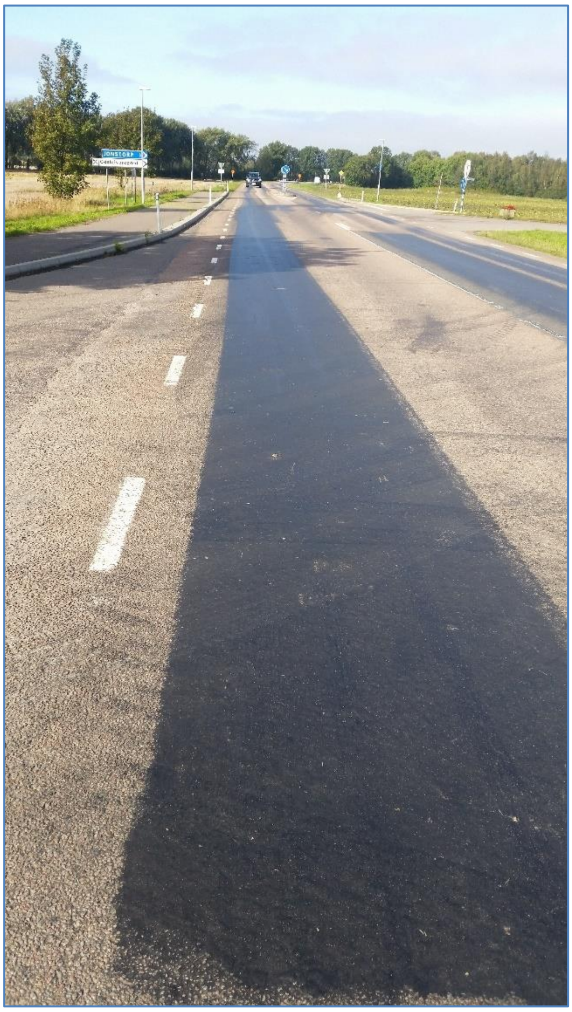
Bleeding asphalt is dangerous to riders and is often impossible for a rider to see. In wet conditions the friction can become comparable to winter with snow and ice. Asphalt bleeding can occur on roads with a new layer, but it can also appear during a heatwave or when the rain starts to fall after a long hot period. Asphalt bleeding may also be the result of poor manufacturing or installation. Another problem are longitudinal sealings between the lanes as they can be very slippery and have caused several severe and fatal crashes in Sweden. This is a part of the maintenance where one of two lanes on 2+1-roads are paved with new asphalt (59).

The Slovenian guidelines highlights that improper repair of cracks represents a danger for motorcyclists, especially if the repairs are done on a curve. This unexpected situation with bituminized lines of cracks offers significantly less grip than the road surface, especially in wet conditions (38).

Possible solutions:

- Friction tests should occur on a regular basis on roads with high loss-off-control motorcycle crash risk, based on motorcycle volumes, curve size and frequency and crash history.
- Use asphalt with good frictional properties (i.e., aggregates with low polishing values, high micro-texture subsurface draining asphalt or spray seals with large aggregate), especially when paving curvy road sections. It must be emphasized that the pavement shall have good frictional properties both when newly laid and after having been trafficked worn.
- When paving is terminated on a curve or at an intersection, altered friction or pavement joints can create problems for motorcyclists. Such resurfacing should, therefore, continue through bends.

- With structural or horizontal pavement milling, a significant frictional improvement can be achieved, especially on pavements with a wet surface. This can reduce the probability of motorcycle crashes also those involving other vehicles. Milling, however, should not be with a coarse pattern that inexperienced motorcyclists will become insecure and lose control.
- Operators of road networks must always be prepared for parts of the road network having frictional conditions that will be hazardous to motorcyclists. When an acute frictional problem is identified, for example in conjunction with diesel fuel spills or paving, immediate action is needed. It may be necessary to direct traffic to other roads or to stop motorcyclists manually. Signs must be put up and good and lasting improvement measures must be implemented as quickly as possible.
- The overflow of bitumen in sealings and cracks can be minimized with regulations and if there is an overflow, instant sanding must be done and removed later (60). Bituminizing of lines of cracks must immediately be followed by spreading of crushed quartz with fractions of 0.3-1.2 mm and not rock dust, since the latter does not ensure adequate grip (38).



6.7 LOSS OF FRICTION DUE TO DIESEL SPILLAGE

Diesel spills can occur because of crashes but tend to be more common in the vicinity of gas stations and garages for buses and lorries. It can be caused by overfilling of tanks or that the tank cap in trucks and buses are poorly fitted or damaged. This might lead to leakage in the first curve, intersection, or roundabout after the gas station. This is a common cause of motorcycle crashes since the spill is often not visible.

A study commissioned by the Sveriges MotoCyklister (SMC) in 2017 showed that diesel spills on asphalt lead to a reduction of friction from 0.8 to 0.3 (54). Data from motorcycle crashes in the UK 2005-2008 shows that diesel and/or oil spillage was a factor in 25-30% or 806 accidents where a motorcyclist was injured. The estimated cost for these injuries was £50 million. (127).

Possible solution

Diesel spillage not only led to loss of friction and crashes, it also damages road surfaces. Therefore, preventing spills is critical. Highways England has developed guidance for commercial vehicle drivers and operators to prevent diesel spills (61). This guidance includes educating the heavy goods vehicle on the environmental impacts and recommends daily inspection of vehicles and the carrying of spill kits. Other measures include fitting fuel caps with anti–syphon devices and self-sealing tanks and installing guard rails and other protections around the fuel tank to prevent damage.

6.8 MEASURING SKID RESISTANCE

Measuring skid resistance is an effective way to monitor the friction of the road surface and upgrade those roads if necessary. Maintaining good surface friction is critical for motorcyclist safety.

There are several instruments and methods which are commonly used, such as the Sideway-force Coefficient Routine Investigation Machine (known as SCRIM) and the British Pendulum Method in the UK. The present methods typically measure friction for specific parts of the road lane for twin track vehicles (usually the outer wheel track) in wet conditions. Motorcyclists, which are single track vehicles, typically use different parts of a lane to cars, especially when it is necessary to avoid rutting caused by cars and trucks. Furthermore, current approaches often exclude sealing and patch repairs (62). This means that skid resistance measurements may not be capturing the friction measurements needed for understanding the risk to motorcyclists. Furthermore, current approaches exclude sealing as well as patch repairs with bitumen (62). This means that skid resistance measurements may not be capturing the friction measurements needed for understanding the risk to motorcyclists.

Possible solutions

Consideration should be given to the measurement of skid resistance across the full width of carriageway, especially on the approach and exit of bends. The reporting of Skid resistance should be in discreet short lengths rather than average over 20-meter lengths. This will allow for more accurate consideration and auctioning of works where lengths of skid resistance are poor. It is possible to measure every meter and to use a friction average of for example two meters instead. New methods to measure the skid resistance of the road surface will have a potential to improve friction and reduce crashes. Partially this could be solved by making use of camera- and lidar techniques (3D scan) as are already used in small scale in several countries.

Another example is the sensor-equipped Austrian MoProVe motorcycle, which is used for risk analyses and safety inspections, based on collected vehicle dynamics data (53). The MoProve ia a rolling road infrastructure laboratory which makes it possible to create risk maps and risk models, based on processed data.

Current laser profilers can measure with resolutions smaller than 0.1 mm. These technologies typically collect measurements for both wheel paths and report an average at the 100 m level. Reporting individual wheel paths with an indicator that short poor performing sections would be a quick adaptation to cater for motorcycles. This needs to be further investigated (63).

6.9 ROAD ALERTS, WARNINGS, AND INSPECTIONS

The need for inspections of roads is essential. Who or which part that oversees the inspections varies between countries as well as the liability of the road conditions when crashes occur. Roads are monitored via cameras, road user reporting and the different road operators. Reports must be processed. There are several examples in Sweden where alarms were neglected, and poor friction led to loss of control among riders which ended with crashes involving lifelong injuries and fatalities (64).

Possible solutions

When there are fluids, debris, gravel, or other obstacles on the road it is important to have a warning system in place. This is usually a function owned by the responsible local, regional, or national road owner. Reports can be made via e-mail, apps, or phone. The motorcycle community can be invited to cooperate which has been a fact for many years in Norway and Germany (59).

The alert function must be aware of the potential risks that different obstacles on the road might have for motorcycles. The alert function must also take the alerts seriously, make sure that measures are taken to clean the roads to prevent crashes and follow up on the actions taken.

CHAPTER 7. THE NEED FOR ROADSIDE SAFETY ZONES

Research from several countries show the need for a safety zone next to the roadway for all road users but in particular motorcyclists. Roadside safety zones free from obstacles such as trees, barriers, and poles create a more forgiving environment. It allows motorcyclists to take evasive action if something unexpected happens on the road. Several studies describe that higher demands on the roadway and roadside width will increase safety. (51, 65).

The WHO states that roadside hazards (such as trees, posts, barriers, poles, unprotected gullies etc) represents a significant risk for motorcyclists. A crash involving a roadside hazard is 14 times more likely to be fatal than a crash to the ground with no physical contact with a fixed hazard (9).

The definition of a safety zone for motorcycles will not always be the same as for motorists (9). Studies from NZ and Australia conclude that many of the roadside measures such as poles and barriers provide protection for cars but can be fatal and hazardous to motorcycles. All studies show that a removal of roadside hazard would reduce the injury risk for all road users but especially for motorcycles.

The World Bank states that the road environment has a particular influence on the risk of crashes for motorcyclists and lists one of the contributing factors to be roadside hazards (30). To cater fully for the needs of motorcyclists, the road design needs to consider the type and placement of street furniture, including how safe they are in the case of a motorcyclist crash. It is crucial to minimize the number of obstacles, especially on bends, and to use poles that do not shear off leaving sharp remains or protrusions that could snag a fallen rider. On higher-speed roads consideration must also be given to the “swept path” of the rider leaning into bends to avoid roadside features and oncoming traffic.

A policy recommendation from the ITF Forum in 2018 concludes that each road infrastructure element presents a unique level of crash risk, with the level determined by/dependent upon how the element was originally designed and its condition (31). Different scenarios were collated, iRAP risk factors were applied to each of these to demonstrate the effects the design or condition of infrastructure elements have on the likelihood of a crash occurring and the severity of a crash should it occur. The results indicated that the likelihood of a crash occurring increased as various road infrastructure elements were either at minimum standards (e.g., lane width and curvature) and/or if more than one element was in good or poor condition. The results indicated that in addition to the roadside objects crash severity risk factor, the distance from the lane and available paved shoulder width contributed to crash severity.

The Norwegian Road Safety Handbook states that safety zones beside the roads without fixed hazards will reduce the number of serious run-off crashes in rural and urban areas and that the need for a roadside safety zone is higher in curves (51).

Possible solution

The research consistently shows that roadside safety zones without fixed hazards reduces the risk of serious crashes for motorcyclists. As such, roadside safety zones should be included in national design standards and implemented to improve safety. This is particularly important for high-speed roads. The higher the allowed speed is and the number of vehicles using the road, the greater the need is for a safety zone beside the edge of the road. SWOV recommends safety-zones varying from 2.5 meters (on roads with speed limit of 60 km/h to 14.5 meters on roads with a speed limit of 130 km/h (66).

A forgiving roadside design guide was published in November 2012 by CEDR. It is mainly focusing on the safety for motorists but a design guide for motorcyclists would be an excellent way forward (67).

7.2 THE NEED FOR A WIDE PAVED SHOULDER

Paved shoulders (which are clear of gravel and debris) offer the safest option for a recovery zone (32). They allow a motorcyclist to take evasive action without losing friction.

The need for a paved recovery zone, especially in curves, is highlighted in a Swedish study (68). The study conducted tests where tests based on accident crash data to identify the performance characteristics of different motorcycles and their riders. At speeds between 60- 80 km/h, the riders required at least 1.5 seconds to react, counter steer and recover from an avoidance manoeuvre. The times were longer in curves and required significant lateral acceleration to ensure vehicle stability. While reference acceleration for passenger cars in smaller curves are approximately 0,2 g (g force), motorcyclists will require at least 0.4 g -to 0.5 g, to ensure stability.

Lateral displacements of the motorcycles were 0.6-1 m during the avoidance manoeuvres which indicates that there is little chance to avoid a fixed hazard positioned 0.5 m from the lane edge. A Life Cycle Cost model was also developed in the project with a paved shoulder in outer curves with different recovery areas widths instead of a guardrail. The construction costs would be lower than the cost of one minor injury accident for the curve.

Another reason mentioned above is the need to minimize the gravel from unsealed shoulders which causes many motorcycle crashes (36, 38, 69). They also provide space for vehicles which need to stop due to break down or any other reason. Four persons per year are killed on Swedish motorways and 2+1-roads after they´ve stopped on the narrow shoulder. The width is allowed to be 0,5 meter on rural roads and on 2+1-roads with a side barrier where the allowed speed is 100 km/h (VGU 2022, 6.1.1.3). Thus, the Swedish Transport Administration urges all road users to leave the road as soon as possible when the vehicle stops (70). The recommended width on a hard shoulder on motorways in the UK is 3,3 meters.

7.3 OTHER ROADSIDE OBSTACLES

Roadside safety zones which are free from obstacles next to the roadway reduces the severity of motorcyclist injuries in the event of a crash, particularly on roads with high-speed limits. According to WHO, roadside hazards (trees, posts, barriers, poles, unprotected gullies etcetera) represents a huge risk for motorcyclists. A crash involving a roadside hazard is 14 times more likely to be fatal than a crash to the ground with no physical contact with a fixed hazard. The definition of a safety zone for motorcycles will not always be the same as for motorists (9). Studies from NZ and Australia conclude that many of the roadside measures such as poles and barriers provide protection for cars but can be fatal and hazardous to motorcycles. All studies show that a removal of roadside hazard would reduce the injury risk for all road users but especially for motorcyclists.

American research looking at US motorcycle crashes, concludes that the risk of a motorcyclist dying as a result of impacting a tree as opposed to impacting a W-Beam barrier is double, i.e., there is half the risk of dying colliding with a roadside barrier as opposed to running off the road and colliding with a tree. Similarly, the risk of dying when striking a signpost, utility pole or other support is 1.5 times the risk of dying when striking a W-beam (98).

Data from Australia where crashes with roadside obstacles were compared to crashes with barriers shows that trees were significantly associated with a greater fatality risk than barriers, where collisions with trees are around 3.5 times more likely to result in a fatality than striking a barrier. Poles were also likely to be associated with a greater fatality risk than barriers. Other types of fixed objects were not found to be significantly associated with a greater or lesser fatality risk than barriers (122).

Collision data for the Strategic Road Network, SRN in UK, between 2015 and 2019 inclusive, indicates that 60% of all collisions which involved a motorcyclist colliding with a feature in the roadside, such as signs, lighting columns, telegraph or electricity poles and trees, resulted in fatal or serious injuries. For the same period, collisions involving cars colliding with a roadside feature resulted in 30% fatal or serious injuries. This demonstrates the vulnerability of motorcyclists when roadside features are present (22).

Possible solutions for safer roadsides

The English design guide for motorcyclists has an action plan in four steps to reduce the injury risk with obstacles on the roadsides: remove the hazard - relocate the hazard- reduce the hazard - protect the hazard (22).

The Slovenian guidelines has a similar approach: identification of danger - remove danger - move danger - protect from danger - indicate danger. The Slovenian guidelines also includes general conditions and a method of setting up safety equipment (guard rails with MPS, impact pads and passive safety poles) for motorcyclists. The locations that are mentioned are curves and exits from (38).

The Norwegian Handbook has a section about possible conflicts and proposes that there is a joint review through a planned road system from the various users' point of view, that look at the risks and what can be the resulting consequences. Where there are different options available, attempts should as far as possible be made to describe what the various solutions can result in in terms of future motorcycle crashes as a part of the basis for decision when safety is being assessed against other considerations and against costs. The decision maker needs to know what a chosen solution means risk-wise and where motorcyclist safety conflicts with safety of other road users. If road safety is threatened when considered against other, such as aesthetics or financial limitations, the choice of solution and choice of risk must be taken at a sufficiently high level and the decision maker must take responsibility for a conscious choice of risk of future crashes (36).

All available national guidelines have similar advice and examples to improve motorcycle safety in curves. They are:

- avoid trees near the road and if they are planted – at what distance.
- eliminate vegetation and whatever impairs forward visibility to detect hazards.
- remove fixed hazards and minimize objects on the roadsides.
- install objects as far away from the road as possible.
- consider the use of passively safe road furniture.
- avoid placing road furniture on the outside of curves like barriers, lamp poles, and road signs,
- choose barrier type with minimum injury risk for motorcyclists and install them as far as possible from the edge of the roadway.
- install flexible w-beam barriers with MPS and attach pole and post padding where barriers, poles and posts can't be relocated.
- look at other measures like flatten ditches and embankments and smoothing and covering rock cuts with soil.

7.4 SOFT ROADSIDE FURNITURE

The risk of a motorcycle crash is highest in curves. If posts and signs must be installed in curves, the injury risk can be minimized by using posts and poles that are frangible for motorcyclists which otherwise is not the case. These kind of passive safety poles, PSP, are used in several countries, for example Slovenia, Germany, Australia, Austria, and England. In Germany and Slovenia, they are used frequently as a part of the guidelines for motorcycle safety in curves where a lot of crashes have occurred. Evaluation shows that the PSP pollards can reduce the likelihood of crashes on these roads (123-124).

Possible solutions
The use of PSP is described in detail in the Slovenian guideline (38). They are seen as efficient since they are made of materials and designed structurally so that they have less rigidity than metal and thereby offer greater elasticity (temporarily) and plastic deformation upon impact. They are designed so that above the line of the ground they have no sharp external edges. Their surfaces have the largest possible radii of curvature within the geometric constraints and in relation to parts of the human body. They don't break or become damaged upon impact leaving hard and sharp edges. The passive safety poles are also a method to help the riders to keep the right line on the road.

In Slovenia the passive safety poles are installed where:
- In the event of impact with a motorcyclist the installation of guard rails would cause greater harm than if there were no guard rail
- In the event of impact with a motorcyclist the installation of traffic signs with or without a guard rail would cause greater harm than if they had not been installed,
- The carriageway has a large-radius blind curve and
- Junctions are not easily visible.

Passive safety poles are installed on the shoulder or verge of the carriageway to indicate the flow of the road and/or draw attention to possible danger. They are situated on the outer side of the curve at regular intervals depending on the radius of the curve and are white. Passive safety poles are used as a "self-explaining" visual guidance for motorcyclists (as well other drivers) through curves and serve as pro-active measures for road safety.

7.5 IMPROVED VISIBILITY TO AVOID CRASHES.

Visibility is particularly important for motorcyclists. Unlike other larger vehicles on the road, motorcycles have a small profile which makes them difficult to see, especially if obscured by roadside features such as plantings, fencing, barriers, signage, or parked vehicles. A motorcycle can also be hidden by a part of a car, most frequently the A-pillars that supports either side of the windscreen and are known to create blind spots for drivers. Motorcyclists also need to see the road clearly ahead to avoid any hazards such as surface defects or other vehicles. The need for good visibility must be considered at intersection and roundabout design. The need for good visibility is mentioned in all national guidelines, as well as the global recommendations from the World bank and WHO.

Possible solutions

Several guidelines have included measures to improve the visibility of motorcycles. These are the most common measures mentioned in Norway, Slovenia, Australia, and England.

- Ensure a clear view for road users at critical locations such as roundabouts, intersections or on curves.
- Sight zones must be free of sight reducing obstacles so that motorcyclists can see and be seen.
- Vegetation, noise barriers, guardrails and signs must not be placed in such a manner that motorcycles partly or fully «disappear» behind. This is especially important in intersections and curves.
- Intersection design must provide crossing traffic the opportunity to see the whole motorcycle in the entire sight zone.
- T-intersections should be constructed so that those required to yield will see traffic from the side, not frontally.
- Consider if right turn lanes/deceleration lanes can be separated from through lanes. or be removed.
- Install longer keep clear zones, especially at uncontrolled intersections to provide greater visibility for motorcyclists and other road users.
- Trim vegetation where visibility is impaired especially at curves and intersections.
- Introduce advanced stop lines for motorcyclists in urban areas which have reduced crashes with 39% in Malaysia and Indonesia (22, 32, 36, 38).
- Open bus lanes for motorcycles to improve their visibility and reduce the risk of injuries (8, 21, 33, 125).

CHAPTER 8. BARRIERS AND MOTORCYCLISTS

The purpose of road safety barriers and guardrails is to protect the road users from hazards on the roadside when an adequate clear zone cannot be provided. Barriers are also installed in the middle of the central reservation of roads to prevent head-on collisions. The installation of barriers presents a new hazard to motorcyclists, who are at greater risk of fatality and serious injury in the event of a collision with the barrier.

According to Fredriksson et al. (2015), the best barrier for a motorcyclist is “no barrier at all,” and if the barrier itself is more dangerous than what it is designed to protect, no guard rail should be installed (71). Since there are bridges, trees, steep mountain roads, culverts or gullies, oncoming traffic and other obstacles in the road environment, there will always be a need for barriers to protect road users. For motorcyclists a barrier is never completely safe since they do not benefit from the protection of the bodywork and passive safety systems offered by a passenger car. The best solution is to ensure that barriers, where they are needed, are positioned further away from the road lane (to allow for an adequate safety zone) and are of a design that does not pose undue risk of injury to a motorcyclist.

8.1 INJURY AND FATALITY RISK

Barriers are common obstacles in fatal motorcycle crashes. Research from around the world dating as far back as the 1980s has consistently showed that barriers pose a much higher risk of injuries and fatalities compared to other road users, including that:

- They are designed and installed with cars and heavy vehicles in mind. Road restraint systems are a factor in 8 to 16 percent of motorcyclist deaths (72, 73).
- Motorcyclists are 15 times more likely to be killed than a car occupant in barrier collisions (74).
- The injury risk of off-road crashes with a barrier is twice that of crash where the motorcyclists do not collide with a barrier (76).
- Motorcyclist injuries can be up to five times more severe in a barrier collision than if the rider had hit the rigid object that the barrier was guarding against (74, 75).
- US data shows that one in eight motorcyclists who struck a guardrail were fatally injured which gives a fatality risk that is 80 times higher than for motorists (77).

The injury risk increases by 200 % in off-road accidents compared to a crash where the rider doesn’t collide with a barrier (76). American data shows that one in eight motorcyclists who struck a guardrail were fatally injured which gives a fatality risk that is 80 times higher than for motorists (77).

More recent US data from 2018 showed motorcycle riders accounted for 40% of all fatalities resulting from a guardrail collision and that motorcyclists are highly overrepresented in the number of fatalities in guardrail crashes terms of fatalities per registered vehicle. Cars compose about half of the vehicle fleet (46%) while motorcycles comprise only 3% of the registered vehicles (78).

A 2015 comparison between the car and motorcycle fleet in traffic compared to fatality data shows that the risk for a fatal crash with a barrier in Sweden is 27,7 times higher for those riding a motorcycle compared to those who are traveling in a car (71).

An online survey in 2019 of 1,578 motorcyclists from 30 different countries who had been involved in a crash found that four percent (n=57) of the respondents crashed with a barrier (83). The percentages crashing into roadside barriers were lower compared to other studies, which might reflect the survey method (since self-reported crashes cannot include those with fatal outcomes or severe neurological injuries) or the lower presence of roadside barriers in the countries of the survey respondents (83).

8.2 CRASH SEQUENCE

Studies of motorcyclist collisions with barriers show that motorcyclists collide with barriers in different ways. In approximately half of the crashes, the motorcyclist was sitting on the motorcycle upon collision with the barrier. In this case, there is a risk that the motorcyclist is thrown over the barrier. In the other half of crashes, the motorcyclist was sliding on the ground into the barrier having fallen from their vehicle. The risk for a fatality or serious injury is higher when a motorcyclist is sliding on the ground and collides with the poles of the barrier.

Studies of collisions with barriers in different countries show that the collisions occur at angles less than 15 degrees. (79, 80, 81) For example, of 78 surveyed fatalities in Australia, the average angle was 15.4 degrees, and the average speed of the motorcyclists upon impact was 100.8 km/h.
The average distance from impact to stop was 28.9 meters for a seated motorcyclist, 26.3 meters when the motorcyclist scraped, rolled, or slid along the guardrail top and 12.7 meters for the motorcyclist who slid along the ground (82).

8.3 WHERE DO MOST BARRIER COLLISIONS OCCUR?

Motorcycles are especially vulnerable to collisions on bends and curves, where acceleration or deceleration occurs, or where the stability of the motorcycle is at stake and loss of control is more likely. A disproportionately high number of impacts happen on exits with a tight radius and on roundabouts (84). The highest risk for motorcyclists colliding with barriers are in tight and long curves (85, 86).

The high risk in curves is the main reason behind the decisions and legislation in different countries for general guidance for when and where to install MPS (Slovenia, Portugal, Germany, Austria, France, Spain, Norway). Fatality data from Sweden is however different to the rest of Europe and Australia. Over half 55 of the fatal barrier collisions took place on motorways and 2+1-roads. These are mainly straight roads with a speed limit of 100-120 km/h with median and side barriers installed close to the road edge on both sides (87).

8.4 DIFFERENT BARRIER TYPES

Common barrier types are the w-beam, cable and concrete barriers. There are other different barrier types which may be specific to some countries and design specifications. For example, ellipse and pipe barriers are often used in urban areas on bicycle roads and on bridges for aesthetic reasons (88). Due to the type of impact of a motorcyclist and the lack of protections, barriers need to be as smooth as possible and with no sharp, aggressive surfaces to reduce the injury risk in motorcycle crashes.

W-beam
The most common barrier in the world is the post and rail barrier, frequently known as 'w-beam'. This type of barrier consists mainly of a horizontal steel beam held in position by vertical posts fixed to the ground. Typically, single sided barriers are used on the road shoulder and symmetrical, double-sided guardrails are used in the central reserve. For motorcyclists who crash into the barrier, although the beam itself presents a smooth, relatively unaggressive surface, the rigid, vertical posts are relatively aggressive as they result in concentrated impact loading at the collision. They are most often made entirely of steel but can also include timber components or cladding. Barrier height varies between countries as well as the use of a block-out to offset the horizontal barrier from support posts when installing the barrier. A w-beam barrier with a block-out gives a better chance to install MPS below the beam, providing the distance to the ground is high enough.

Cable barriers
A flexible cable barrier frequently known as wire-rope barrier, consists of long lengths of horizontal, pre-tensioned steel cable, held at the desired height by posts that rest on the ground. These systems are designed to restrain with relatively low levels of deceleration – however, their flexibility means that a relatively wide area is needed. The cable represents a potential source of concentrated impact loading for a motorcyclist in contact with it, although the cable is relatively flexible. The cable is often seen as major potential risk of severe abrasions to motorcyclists (132), however there are currently still diverging views about how hazardous the cable is. The posts do not represent the same rigid obstacle to motorcyclists as guardrail posts do. On the other hand, the post extremities, and any protrusions, such as hooks and sharp edges, are hazardous if left exposed as they can cause snagging of body parts resulting in serious injury. Also, it is not possible to fit motorcycle protection on cable barriers.

Cable barriers are commonly used in some countries, for example Sweden and Australia but are not used at all in other countries. Installation of cable barriers is prohibited in for example Ireland, Norway, Germany, and the Netherlands.

Concrete barriers
Concrete barrier can be composed of modular elements linked together or can be cast in place on the road surface or verge. They are used on the verge and in the central reserve of roads and modular systems are commonly installed temporarily to protect work zones. Concrete barriers can be rigid or, in the case of unanchored, modular systems, less rigid. However, due to their weight they remain rigid from the point of view of an impacting motorcyclist although they present a smooth impact surface.

Various accessories (e.g., signposts, reflectors) are often fitted to road safety barriers after their installation. The possible risk to an impacting motorcyclist should be considered when planning the use of such accessories.

8.5 THE INJURY RISK FOR DIFFERENT BARRIER TYPES

Several US studies by Gabler et al. found that the risk of being killed in collision with a W-beam barrier is 12 percent, compared to 8 percent for a concrete barrier. The studies found no significant difference in collision with a cable barrier compared to the W-beam barrier (96, 97, 98). Whatever the barrier types, the presence of rigid protrusions and sharp edges is hazardous for impacting motorcyclists.

In general, it is the barrier poles, not the longitudinal barrier beams that causes the most serious injuries on the motorcyclist. Smooth barriers without unprotected posts and protruding parts, provide less risk of injury (89, 90, 91).

In a collision where the rider is sitting, sharp edges and corners as well as posts sticking up over the barrier have a major significance for the outcome of injuries. The cutting and snagging effect are common in collisions with cable barriers and W-beam barriers (87, 92, 93, 94).

A Swedish study of 20 typical motorcycle crashes against various barrier types showed that the rider was sitting on the motorcycle at most collisions which resulted in injuries on legs and feet. Head, neck, chest and pelvis injuries dominated in the fatal crashes. In the most severe crashes, limbs were torn off. The motorcyclists had been caught in the barrier in all fatal barrier collisions (93).

The distance between the barrier and the edge of the road is important. An increase in the distance between the barrier and the road edge (median and side) showed a reduction in both crash and injury risk for all crashes. The average reduction in crashes is between 1,9 - 5,1% per meter increase of distance (102, 103, 104).

The height of a barrier can also determine the severity of motorcyclist crash outcomes. A Norwegian study (101) concluded that a low barrier increases the risk for motorcyclists of falling over it in case of a crash and hit the object it is intended to protect the road users from. An American study identified the traffic barrier height as one of the most significant variables impacting the severity of box beam barrier crashes. The injury risk would be higher if the barrier was below 63 cm compared to if it was higher, 63-79 cm (101).

Accessories such as signposts or reflectors fitted to road safety barriers after their installation have the potential to cause further injury risk for motorcyclists in the case of a crash.

8.6 MOTORCYCLE PROTECTION SYSTEM, MPS

Motorcycle Protection System, MPS is an element of roadside infrastructure designed specifically to reduce run-off-road crash severity for motorcyclists or other powered two-wheelers should a safety barrier be struck, or to protect motorcyclists from more severe hazards such as cliffs, trees or poles. It can also prevent head-on collisions from a fallen motorcyclist sliding under a median barrier into the path of on-coming traffic.

MPS may include:
▪ Additional rail on the lower section of the standard road safety barrier system (under-run).
▪ Frangible/lower strength posts.
▪ Energy absorbent post covering and
▪ Device to remove sharp edges from barriers (105).

According to all tests carried out and available research, barriers with MPS gives a lower risk of injury, whether the rider slides into the barrier or is sitting on the motorcycle (94, 106, 107).
Most commonly, steel guards, mesh systems or plastic tubes that are fitted below the existing safety barrier, preventing riders from sliding under the barrier beam element and offering protection from the steel support posts. This is known as 'continuous MPS. MPS protects riders from the barrier posts, it absorbs kinetic energy, it allows riders to decelerate more slowly and redirect them along the barrier. MPS is meant to prevent a sliding motorcyclist to crash with the posts. It also reduces the injury risk where the riders are sitting on the motorcycle since body parts are not caught in or between the poles or caught by protruding parts on the guardrails.

Discontinuous MPS or Motorcyclist Impact Padding (MIP) refers to protection around the individual poles. For this reason, it is a significantly less effective measure of ensuring safety for motorcyclists but can be useful where continuous MPS is not possible. For example, MIP is installed in Slovenia on existing or new guard rails on curves where due to the geometric elements of the road it is not possible to develop greater speeds (sharp curves and serpentines). It is also used in conjunction with the continuous MPS for exposed posts and barrier terminals rails, where they cannot be installed in their full length due to the end elements, and it is not possible to protect the supporting post in front of the beginning of the motorcyclist barrier (38). However, results of simulations in Slovenia shows that only continuous MPS provides sufficient protection for a human body.

Yet there are no MPS devices to protect motorcyclists from protruding parts on the top of the barrier, although some designs have been proposed, including System Euskirchen Plus (EDSP). The Texas A&M Transportation Institute is undertaking a project in 2023 for the development and full-scale crash testing of an improved railing system for use on top of barriers (108).

8.7 INSTALLATION OF MPS - WHERE AND WHEN?

Whilst there is no country which demands that only barriers with MPS are installed, several countries have implemented national laws and guidelines requiring their consideration. In France there has been a national regulation requiring the use of MPS on guardrails in high-risk areas since 1999. Portugal was the second European country to introduce this in 2004. Other countries have introduced similar rules for the installation of MPS in particular areas since then.
A report from FEMA in 2012 gave examples about where and when MPS should be installed. The report describes alternative solutions from European countries to identify the most critical road sections for installation of MPS. MPS is suggested on:
- External/outside shoulder side of highways where the radius is equal to or less to 400 meters,
- On other roads in the external side of bends with a radius equal or less to 250 meters,
- Deceleration lanes on exits, on single carriageways with shoulder over 1.5 meters when the radius is lower than 250 meters and,

- On any other highway with a speed reduction at curve higher than 30 km/h.

The location for installation of MPS in the Netherlands are defined in a simple decision tree (Annex 2). which includes provisions to identify a site for MPS in the short term, medium term and no action for now. In Germany roads are identified as motorcycle roads after an investigation in several curves with a radius under 180 meters. These roads are prioritized for MPS installations (109). Some German Federal States have implemented investment programs during the last years to retrofit existing guardrails with MPS on roads with extensive motorcycle traffic. Portugal states that MPS must be placed on all roads wherever necessary.

An Australian based technical guide (110) identifies and prioritizes where MPS should be provided based on curve radius, road alignment, lane width surface condition and available sight lines and stopping distances. It also provides design guidance to hazardous end terminals to be installed outside of an errant motorcycle's impact zone.

A new handbook for safe roadsides and road equipment was released in Norway in December 2022 stipulates that MPS are installed on outer shoulders on both new and existing roads depending on curve radius, on locations where there is a high risk for motorcyclists to crash and collide with barriers. Barriers with protruding parts and sharp edges are not allowed on roads with a great need for motorcycle safety and protection (111).

The Slovenian guidelines for motorcycle safety recommends MPS on curves with certain radius for roads with high motorcycle traffic (200 per day) or at least four motorcycle crashes the last three years (38).

8.8 MAINTENANCE OF BARRIERS WITH MPS

Once MPS are deployed, it is important to check and maintain them. In many cases, the presence of excessive vegetation or accumulated soil or leaves can hinder the proper deflection of an MPS during impact which can have negative consequences for its performance.

The Swedish Transport Administration installed MPS protection in 2012 and monitored their resistance to damage due to maintenance. While the evaluation found that no damage in winter, there was an accumulation of debris, gravel and leaves on the ground against the side of the road which requires increased maintenance compared with barriers without MPS (120). The Slovenian guidelines has a chapter about the need of maintenance before installing MIP as well as regular inspections and maintenance after the installation (112).

Since during impact the MPS interacts, in some way, with the barrier to which it fitted, it should not be assumed that one MPS will function correctly on any barrier. Therefore, it is important to assess the performance of an MPS fitted to each type of barrier on which it will be deployed.

8.9 MPS TECHNICAL SPECIFICATION

In the late 1990s, a test protocol for MPS to be fitted to barriers was developed in France by the LIER test center and INRETS, the French national transportation research institute. Defined based on French accident data, the test method consisted of two impacts with an instrumented crash dummy sliding along the ground and impacting the MPS. The protocol was used in France to evaluate MPS for steel guardrails and as a basis for the approval of systems for use on the French road network. Several years later, the Spanish national standard, UNE 135900, for MPS testing and evaluation was developed, subsequently coming into force for the approval of MPS to be installed on Spanish roads. The Spanish standard took the French test method as a basis and developed it further, changing one of the test dummy test impact configurations, considering the evaluation of discontinuous MPS (localized protection of barrier posts rather than a protective device running continuously along the guardrail), and adding a second, higher test impact speed. Subsequently, requirements for MPS evaluation were also introduced in Italy and Portugal, both based on the sliding dummy test configurations previously adopted in France and Spain. In Germany, the BASt developed a test protocol for the evaluation of MPS in the case of a motorcyclist impacting the system upright whist still on the motorcycle.

At the request of FEMA, CEN agreed to undertake the development of a standardized, European test method for the evaluation of MPS for barriers. To deliver a test method as soon as possible, and to avoid undermining the existing various national regulations, it was decided to build on the existing sliding rider test configuration with the possibility of adding an additional upright configuration in the future if this was deemed necessary. The resulting test method, CEN/TS 1317-8, was published in

2012 and was later redesignated CEN/TS 17342, *Road restraint systems - Motorcycle road restraint systems which reduce the impact severity of motorcyclist collisions with safety barriers* which is the only internationally approved evaluation protocol for MPS, and it is used in Europe, Australia, and New Zealand. Despite its availability since 2012, the use of this assessment method, and of the existing alternatives, remains limited.

The specification contains performance classes, impact test acceptance criteria and test methods for barriers where the test dummy is in a sliding position. The protection systems are those fitted to barriers or barriers that have an inherent rider protection or risk reduction capability. For systems designed to be added to a standard barrier, the test results are valid only when the system is fitted to the model of barrier used in the tests since the performance will not necessarily be the same if the system is fitted to a different barrier.

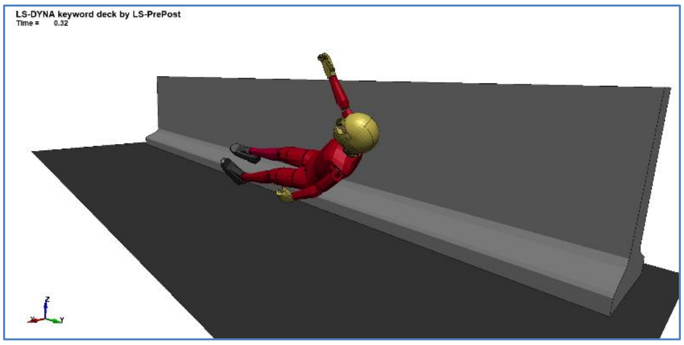
CEN/TS 17342 has its limitations. The crash test dummies (correctly known as anthropomorphic test devices) are also limited for simulating the human body impacts of motorcycle crashes. There is no crash test dummy yet developed or validated for use in the type of impact configuration required for MPS testing. Furthermore, the test method in CEN/TS 17342 does not specify a thorax injury criterion, despite studies showing that the thorax region of motorcyclists had the highest incidence of injury in barrier crashes (82). According to Bambach et al, a quarter of the motorcyclists crashed with the barrier in an upright position with the rider sliding and tumbling along the top of the barrier. Others, like Berg et al. (92), Grzebieta et al (98) and Rizzi et al (95) mention a higher number. In a FEMA study of 2018 (114) the conclusion was that most crashes occur when the rider still sits on the motorcycle. Thus, an additional test should be developed, which requires the rider to be in an upright position when striking the barrier and then slide along the top of the barrier (82).

Additional tests are also required for types of impacts not currently covered, particularly for barrier crashes where the motorcyclist is in an upright position and then slides along the top of the barrier (82). This would be helpful in the development, testing and commercialization of new MPS for the top of roadside barriers (such as EDSP).

Despite its limitations, there are no doubts that MPS that have been approved as a result of testing, have saved lives and reduced injuries to motorcyclists who have crashed with the MPS, both sitting on the motorcycle and sliding on the road when colliding with the barrier.

Possible solutions

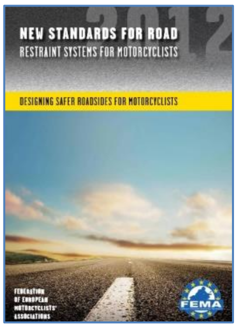
There is a need for investment in the development of protection systems and evaluation protocols for the motorcyclist crash mode in which the motorcyclist collides with the roadside barrier in the upright position. However, without a crash test protocol to assess MPS for reducing such injuries, there is currently no mechanism to develop, test and validate such systems. Several countries have made notable steps towards developing MPS for top protection to guardrail systems, such as the successful studies noted previously in Germany (Euskirchen Plus), the Texas A&M Transportation Institute and VTI, Linkoping, Sweden. Testing methodologies developed in these studies may be useful in establishing testing protocols for the upright crash mode, which could potentially be included in international specifications or standards for roadside barrier testing.



A valuable tool in the development and evaluation of MPS and barriers that are more motorcyclist-friendly is virtual testing using computer simulations (Annex 2). This allows MPS and the test dummies used in physical crash testing to be modelled allowing so-called virtual tests to be performed. The use of virtual testing for the development of MPS, and to some extent for the validation of systems on a national basis, has been developing over recent years and its use as an additional evaluation tool should be considered in the future (102).

8.10 NATIONAL LEGISLATION

MPS is required systematically on guardrails in high-risk locations on the French road network since 1998. Portugal, Spain, France, the Netherlands, Germany, Norway, Slovenia, Austria, and UK (115) have also introduced requirements for MPS although the requirement remain quite diverse.
For example, in Australia there is no requirement for MPS, but technical guidance presented in 2020 defines MPS and provides a decision process tree for where and how MPS should be installed (105).



As a technical specification, the use of CEN/TS 17342 is entirely voluntary. Upgrading the TS to a full European Standard would mean that any CEN member state requiring the assessment of MPS would be bound to assess based on the method defined by the European Standard. International uniform assessment methods would encourage the development of MPS.

Possible solutions

- Write a 'general' European specification matching EN1317 and CEN/TS 17342 that can support authorities to have proper technical national laws and specifications on motorcycles and barriers.
- Promote a standard or specification which is based on computer simulations beside real life tests to enable MPS to be installed on different barriers.
- Promote road authorities to adopt these general guidelines until there is a proper standard for MPS.

8.11 COST OF MPS

A common argument for using MPS to make barriers safer for motorcyclists is the increased costs. The cost to buy land and clear the roadsides is higher compared to an installation of a roadside barrier.

Installing MPS can result in higher investment costs in road construction and upgrades. Adding MPS on a w-beam barrier in Sweden 2023 increase the cost from €40 per meter to €60 per meter. The cost in Sweden for concrete barriers per meter is €175 (121). National legislation requiring routine installation of MPS would improve the predictability of market demand for MPS products, which would likely reduce costs (121).

8.12 RECOMMENDATIONS TO REDUCE THE INJURY RISK IN COLLISION WITH BARRIERS

When decisions are made about the choice of barriers and roadsides are made it is crucial to include the needs of motorcyclists to minimize the injury risk, since there are no compulsory test protocols that demands safe barriers for motorcyclists. These solutions are based on global existing knowledge, research and statistics presented above and checklists in use *(Annex 1).*

- Don't install a barrier if the barrier itself creates a higher injury risk compared to what it is supposed to protect the road users from
- If possible, create forgiving roadsides instead of side barriers.
- Include motorcycles in the planning stage.
- Include motorcycle safety when choice of barrier is made, use checklist, and include legal demands and regulation.
- Include motorcycle safety when the decision is made of the distance between barrier and road edge.
- Include demands for a hard paved shoulder between the road edge and barrier.
- Choose the right barrier when roads are built and rebuilt.
- Include the Life Cycle Cost (including investment, maintenance, and socio-economic costs) when the choice of barrier is made.
- Include a block-out on w-beam barriers which will increase the possibility of adding MPS at a later stage.
- Choose a smooth barrier without protruding parts on the side and top where motorcyclists can't get caught.
- Choose a barrier with a height that minimize the risk of falling over and hit the obstacle the barrier is protecting road users from
- Use crash data to find out where to install the barriers which minimize the injury risk.
- Use barriers with MPS in curves and at high-risk locations.
- Use rumble strips instead of median barriers on narrow roads.
- When a median barrier is installed, choose the barrier that not only prevents from head-on collisions but only presents the minimum injury risk in collisions for all road users, including motorcyclists.
- Investigate the possibility of earth berm instead of barrier.


9

CHAPTER 9. GUIDANCE BEFORE CURVES

Curves are a common location for motorcycle crashes. While roadside safety zones and MPS on barriers can help reduce the severity of crashes, guidance and warning for motorcyclists can reduce the likelihood of crashes occurring.

9.1 HAZARD MARKING POSTS AND LINE MARKING

Motorcycle riders are often taught as part of post license training about the vanishing point where the horizon and tangent of a bend meet. If the vanishing point appears to be moving away the approaching bend is opening, if it is steady then the bend is likely to be constant and if moving towards the rider the bend is tightening. If a roadside object interrupts the vanishing point, then motorcyclists may turn towards that object, which can result in a loss of control collision. Thus, motorcycle trainees are often taught the “Where You Look Is Where You Go - principle” to reduce this risk. The addition of soft pollards as marker posts some distance before, through and beyond a treated bend (see chapter 10.3) can also be used to draw the focus of motorcyclists to the vanishing point of the bend and prevent distraction by roadside objects (22).

9.2 ROAD MARKING IN CURVES

Inconsistency in line marking or guideposts can make it difficult for motorcyclists to anticipate and react to changing road geometry and conditions. Good delineation provides the rider with information about the road environment. The inherent instability of a motorcycle means that information about the road can be critical in judging speed and direction (33).

The two most common types of motorbike crashes are "falling off the vehicle" and "leaving the road to the right in a left-hand bend". It has been shown that cornering often is the starting point for such crashes. In an Austrian study (126), 5 out of 6 motorcyclists drove so far to the left that they would have had to correct their trajectory in case of oncoming traffic. In most cases, motorcyclists manage to avoid oncoming traffic, but the second necessary correction of the trajectory fails due to "lean angle anxiety".

In 2017, new road markings were added to eight popular motorbike routes in Austria, predominantly on blind left-hand bends and in the form of bars or ellipses. This measure was successful in encouraging motorcyclists to avoid driving over the road markings. The riders' trajectories significantly changed towards a safer lateral position in the outside part of their lane. Since then, more bends have been equipped with markings in Austria, in Luxembourg, in Slovenia and Germany. During the summer of 2019, 19 bends were equipped with road markings as one of the activities of a motorbike safety program of the Tyrolean regional government with immediate impact as the main goal.
On average, there were 13 injuries and 0.6 deaths annually during a seven-year (before) period on these bends. In the 2.5-year after-period, 4 injuries were registered. After accounting for the massive impact of the Covid 19 pandemic on exposure (approx. 10% less commuter traffic, 40% less leisure riding), an 80% decrease in injuries was observed, and there were no more fatalities on the bends with road markings. The application of road markings is also extremely cost-effective, especially compared to the cost of crashes: to tape a bend with film, one usually gets by with material worth less than 1,000 euros, and the use of paint material is even cheaper.

9.3 WARNING SIGNS

Motorcyclists are generally aware of warning signs that provide information about a change in the road environment. If warning signs are inconsistent or missing riders may be surprised by hazards which increases the risk of a crash.

On the other hand, excessive road signage can distract or confuse a motorcyclist and is also a potential strike hazard for an errant rider. Another problem is warning signs that are left year after year without any purpose.

The Austrian study about road markings (chapter 10.2) found that motorcyclists do not take general danger signs seriously. Ordinary danger signs and regulations often had no effect. In contrast, the road markings studied clearly communicate that their message is aimed at motorcyclists, and this may even be the reason for their effectiveness. It was obvious that a motorcyclist-specific message should be conveyed, for example a sign that clearly shows the radius of the curve. By adding a pictogram of a motorbike to other traffic signs, this aim could also be achieved using other signs (126).

POSSIBLE SOLUTIONS GUIDANCE

Treatment Options:

- Ensure consistency of line marking, especially along popular motorcycle routes.
- Introduce new road markings in blind left-hand bends and in the form of bars or ellipses.
- Road safety audits to check for missing or misleading signage and for sign consistency.
- Use special motorcycle high risk warnings signs for hazards that are a particular issue for motorcyclists.
- Remove superfluous signs and consolidate the signs in use to reduce the injury risk for motorcyclists and validate the sign for all road users.
- Increase the use of soft roadside furniture and hazard marking posts.
- Use motorcycle route-based signage for high-risk routes.
- Trim vegetation where visibility is impaired.


10

CHAPTER 10. RECOMMENDATIONS

The United Nations Sustainable Development Goal 3.6 aims to reduce fatal and serious injuries caused by road crashes by 50 percent by 2030. Crashes involving motorcyclists resulting in fatalities and life-long injuries continues to be a devastating reality for victims, their families, and communities. Understanding and implementing a safe system approach for motorcyclists remains a challenge. This paper aims to reinvigorate discussion, prioritization, and action for motorcycle safety. It captures the latest progress in motorcycle and powered two-wheeler research and practice in the planning, building and maintenance of road infrastructure.

As the research and crash data both show, safe roadsides and surface friction remain the critical issues for reducing fatal and serious motorcycle crashes, and as such, these areas are the primary focus of this paper. Moving Towards a Systematic Approach for Motorcycle Safety is relevant to a broad range of stakeholders, road authorities and policy and decision makers, through to researchers and investors.

To summarize and build on the specific issues and measures discussed throughout the paper, the key recommendations for reducing motorcyclists' FSIs and achieving the Sustainable Development Goal are as follows:

- Governments and road authorities must include motorcyclists as a road user group when planning, building, and maintaining road. Thus, motorcyclists need to be included in national laws and regulations.
- Update the Safe System with the inclusion of motorcyclists together with other vulnerable road users.
- Road authorities need to be using road risk assessment methodologies which consider motorcyclist safety, such as iRAP Star Ratings or similar.
- Specifications and standards for barriers and other motorcycle protection systems need to be developed and updated to extend the usage for a safer road environment.
- Data collection for motorcyclists' needs to be improved and coordinated (road surface friction condition, effect of road restraint systems on motorcyclists' safety, safe road design, general effect of road infrastructure furniture on motorcyclists' safety (obstacles, visibility), effects of roadworks on motorcyclists' safety, etcetera).
- Existing knowledge about safety measures which has proven to minimize injury risk for motorcyclists needs to be highlighted and spread as good examples to governments and road authorities.
- There are still motorcycle safety treatments and approaches that needs to be developed or where there is a need of more research, for example computer simulation with barrier crashes.
- The socio-economic cost for injuries and fatalities should be included when roads are planned and built as well as the Life Cycle Cost of different roadside measures, like choice of barrier, distance to obstacles, width of paved shoulder or forgiving roadsides.
- The measure method for friction, which is based on cars, needs to be developed to meet the needs of single-track vehicles with two wheels that uses the entire road.
- There is a need for policies at national and regional levels, e.g., that all new barriers are safe for motorcycles, that checklists are used to include the needs of motorcyclists when planning, constructing, and maintaining roads.
- Audits, warnings, and alerts are important measures to reduce the risk of crashes.
- More resources are made available to road engineers and designers which include best practice for motorcycle safety and/or update the Road Safety Toolkit with solutions presented in this document.

APPENDIXES

ANNEX 1.
CHECKLIST FOR ROAD SAFETY AUDITORS, NORWEGIAN HANDBOOK FOR MOTORCYCLE SAFETY 2014

1. MOTORCYCLIST SAFETY CHECKLIST WHEN AUDITING ROAD PLANS AND COMPLETED ROAD CONSTRUCTION.

When auditing construction plans and auditing constructed road before being opened, there can be a particular need to assess motorcyclist safety. Auditor must ensure that details regarding location and design will not create significant problems to motorcyclists. With such work the following checklist can be used:

- Is the geometry predictable?
- Are T-intersections designing such that yielding vehicles can see approaching vehicle from the side and not the front?
- Are roundabouts designed to provide adequate signals regarding correct speed adaptation?
- Are sight zones free of sight reducing obstacles where motorcyclists need to be seen?
- Are signs located such that they do not restrict motorcyclists from seeing or being seen?
- Are safety zones prepared and made «forgiving» with motorcyclists in mind?
- Have alternatives to guardrails been considered where there is a particular risk of motorcyclists riding off the road?
- Where guardrail cannot be avoided, is it placed as far away as possible from the edge of the pavement?
- Has the terrain behind the guardrail been assessed regarding motorcyclists being thrown over the guardrail?
- Has the installation of guardrail and other road equipment been avoided where the risk of a crash is particularly great? This is especially in outer curves and on a stretch of 20 meters from the curve.

- Are types of guardrails and road equipment selected that will not inflict unnecessary severe injuries to motorcyclists?
- Are manhole covers, pedestrian crossings, directional arrows and other road markings placed in a manner that will not create poor friction for motorcyclists at critical locations?
- Do bridges on sharp curves have asphalt pavement?
- Is the road planned so that gravel, sand, and water from attaching roads will not pour out on the main road? A possible solution is to pave 5 meters on the side road.
- Do bridges have curbs to stop motorcyclists from hitting guardrail posts or fall off the bridge?
- Is termination of curbs and bridge railings designed not to represent an unnecessary risk to motorists?
- Is the transition between new road and existing road free of unexpected and
- abrupt changes in standard such as jump in pavement standards?
- Is the transition between open ditch and covered culvert at exits and road junctions designed with slope 1:6 in the ditch longitudinal direction?
- Is motorcycle safety included in the project safety routines?

2. TRAFFIC SAFETY AUDIT OF EXISTING ROAD, NORWEGIAN HANDBOOK FOR MOTORCYCLE SAFETY 2014 - CONSIDERATION TO MOTORCYCLE SAFETY WHEN AUDITING EXISTING ROAD CAN CONTRIBUTE TO LESS CRASHES

Checklist

- Is the pavement condition adequate and predictable so that motorcyclists will not encounter unexpected problems with changes in friction, cracks, rough spots, potholes, surface water, gravel, dirt, oil spills etc.?
- Are the guardrails designed and installed so that they do not represent an unnecessarily increased accident risk to motorcyclists?
- Can guardrail be replaced by alternative solutions which increases the safety for motorcyclists?
- Are side slopes properly designed to prevent motorcyclists from suffering injuries when driving off the road at locations where the probability of such accidents is large? This is especially important in outer curves and transitions from curves to straight road.
- Are signs and other road equipment installed so that they do not represent an additional hazard to motorcyclists? This is especially important in outer curves and transitions from curves to straight road.
- Are signs important to motorcyclists visible enough?
- Is there a need for supplementary signing, possibly including additional warning signs for motorcyclists?
- Is the illumination adequate in tunnels and at locations where road conditions change, or should illumination be improved or supplemented with for example guide-lights or retro-reflective devices?
- Is there a need for measures against crashes with wild animals, for example by clearing of forest, wild game fences or road lighting?
- Is there a need for sight clearance on inner curves so that motorcyclists and other road users can obtain a better view of the road and the traffic in front?
- Is the road planned so that gravel, sand, and water from attaching roads will not pour out on the main road? A possible solution is to pave 5 meters on the side road.
- Are there curves where the risk of off-the-road motorcycle crashes is high and where there is a need for a motorcyclist protection system, MPS?
- Is the transition between open ditch and covered culvert at exits and road junctions designed with slope 1:6 in the ditch longitudinal direction?

ANNEX 2. CHECKLIST FROM VICROADS, MAKING ROADS MORE MOTORCYCLE FRIENDLY - A GUIDE FOR ROAD DESIGN, CONSTRUCTION AND MAINTENANCE.

ROAD DESIGN & ROAD SURFACE

- Are pit lids located away from vehicle travel lanes? If this is not possible, do the pit lids have a skid-resistance surface?
- Are shoulders sealed, especially in curves?
- If kerbs have been specified, should they be of the mountable type?
- Is there a change in road surface type (i.e., friction level)?
- Is there a clear view for road users at roundabouts?
- Is there a clear view for road users at intersections?
- Is there a clear view for road users on curves?
- Does the design avoid compound curves?
- For passive intersections, are the sightlines clear of obstructions?
- For passive intersections, is the speed of the priority road appropriate from a Safe System
- perspective?
- Can intersections be controlled with traffic signals?
- Can median breaks be closed?
- Are bell mouths, side roads and shoulders sealed to minimize gravel carry over?

ROADSIDE DESIGN

- If vegetation is specified, will it impair sightlines when matured?
- If there are multiple signs present, can they be consolidated?
- Has the use of plastic break-away, rubber self-righting or flexible posts been considered for signs?
- Would special motorcycle high risk warning signs assist motorcyclists?
- Are intersections well-lit it at night?

- Are there roadside hazards that can be moved or removed? If not, should an appropriate guardrail and rub rail be installed?
- Can MPS be installed where guardrails are present?

ROAD MAINTENANCE

- Is the road surface along and around tracks unbroken?
- Is the road surface along and around tracks level with the tracks?
- Will a warning sign assist a motorcyclist in areas where tracks are present?
- Are pit lids cracked?
- Is there road surface cracking around pit lids?
- Do pit lids have a skid resistance surface?
- Has loose aggregate been removed from the road?
- Has loose aggregate been moved away from the road, especially in curves where they may blend in with the road surface colour?
- Can metal signposts be replaced with plastic break-away, rubber self-righting or flexible posts?
- Are compound curves signposted?
- Can motorcycle friendly underrun protection (e.g., subrail) be installed where guardrails are present?
- Is rutting present? If so, can this be corrected?
- Is cracking present? If so, can this be patched?
- Is patching level with the road surface and of similar friction value?
- Is the edge drop off sufficiently low so that a motorcyclist can safely steer an errant motorcycle back onto the road?
- Are bell mouths, side roads and shoulders sealed to minimize gravel carry over?
- Are regular inspections of the roads scheduled, especially during September to May?
- Is vegetation regularly removed, especially during September to May?
- Are the roads inspected after rain or storm events?
- Does vegetation need trimming so that motorcyclists are not obscured?

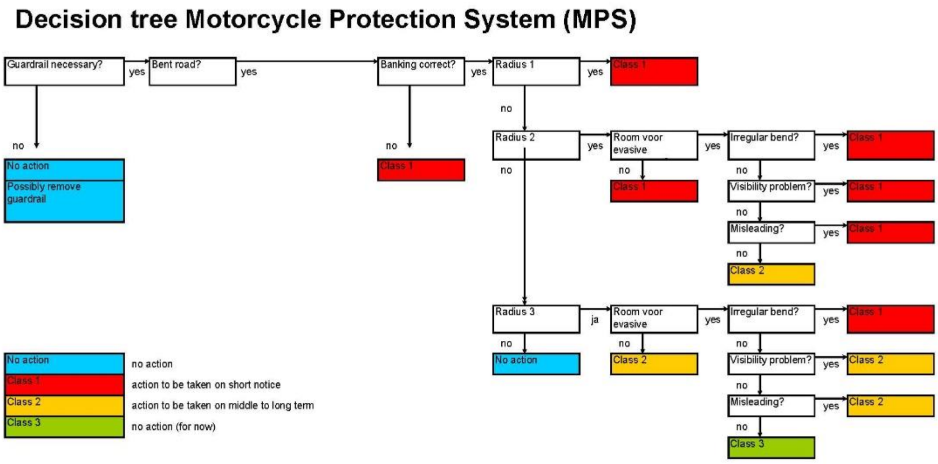
WORK ZONES

- Is loose material on road surfaces regularly removed during and after works?
- Are warning signs needed to warn riders of poor road surface conditions?
- Are wheel washes required when vehicles leave the construction zone?
- Do metal covers have a skid resistance surface?
- Can protruding bolts be eliminated?
- Is temporary lighting required, especially in areas of significant risks?

ANNEX 3.
DECISION TREES BARRIERS

Decision trees is a model that is used in the Netherlands and Australia. The tree is used to choose the location for installation of MPS on barriers. This is defined in the decision tree) which includes provisions to identify a site for MPS in the short term, medium term and also a no action for now.

DUTCH DECISION TREE



Classification of arc radii

	Radius [m]
Radius 1	R < 100
Radius 2	100 < R < 250
Radius 3	250 < R < 400

Visibility problems

To determine wether there is a sight or visibility problem here is a table with the minimum sight distances for different situations.

	sight distances in different situations [meters]		
design speed [km/h]	road course continuous situation	sight on traffic jam	sight on obstacle on one lane
120	165	260	235
90	120	135	165
70	90	80	100
50	55	40	70

Space for evasive maneuver

There is sufficient opportunity to evade if a paved strip of at least 1.75 meters is present on the outside of the arch between the inside of the edge line and the guide rail.

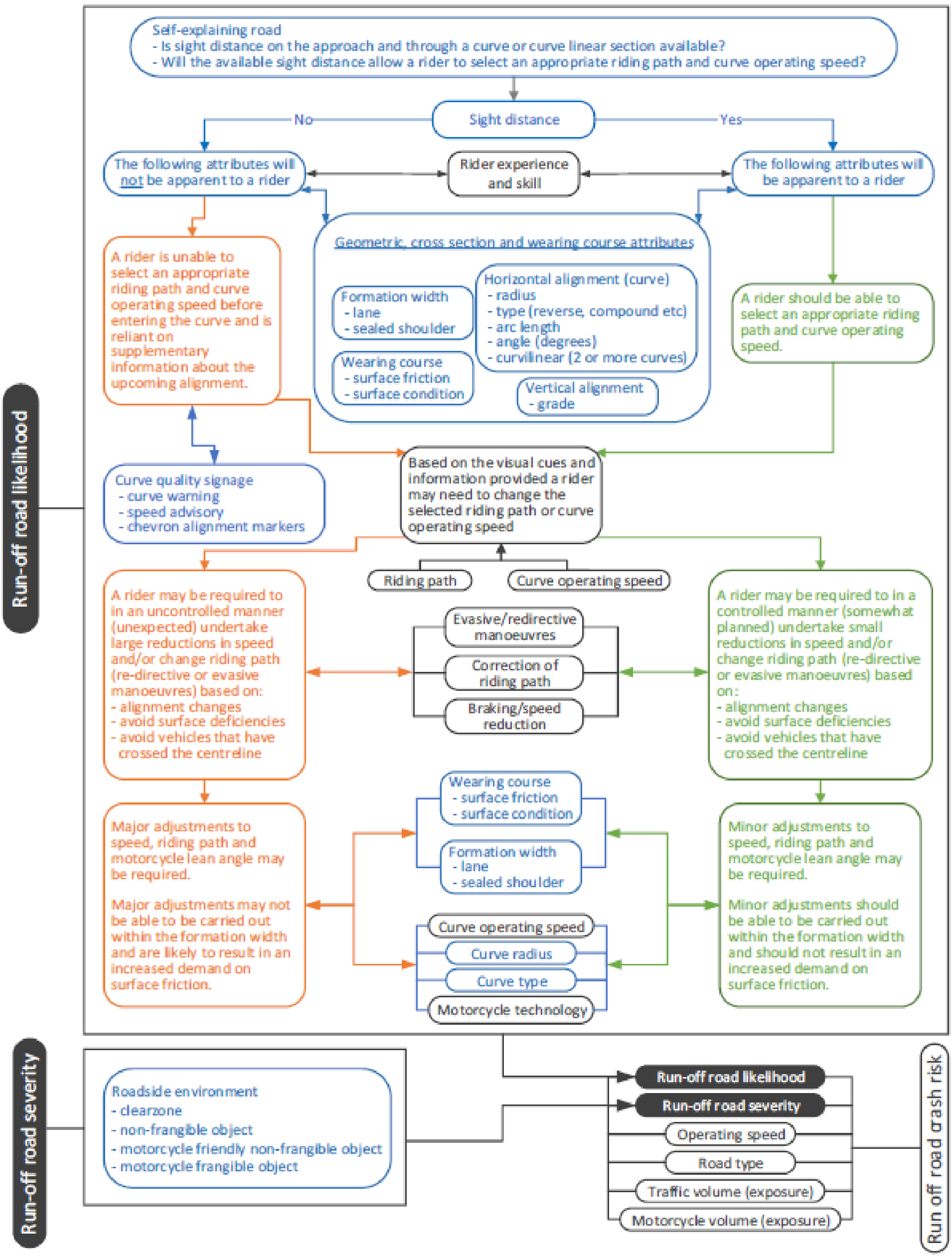
Irregular running

There is an irregular course of the road if the alignment does not comply with the guidelines (ROA, part II - alignment); this is the case, for example, if the radius of curvature suddenly changes value.

Deception

We speak of deception if the road image suggests something other than the actual course of that road. This is often the case when vertical elements (trees, lampposts) follow a different course than the pavement. The guidelines state a few things about this (ROA, part II - alignment).

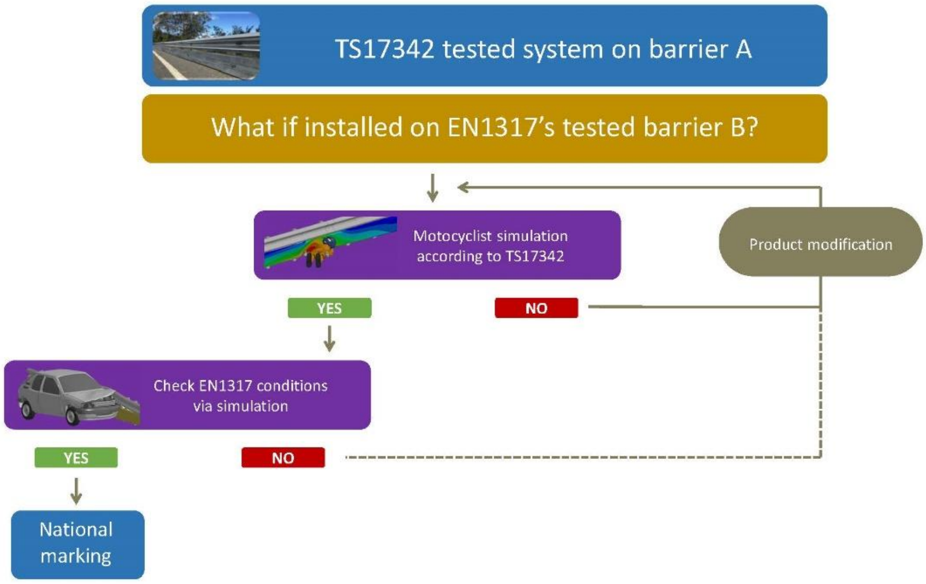
Figure 3.2. Pre-crash motorcycle run-off road crash flow chart



Notes:
- Blue text represents infrastructure crash factors.
- Black text represents non-infrastructure related crash factors.
- Considers risk adverse riding only, e.g. with 85th percentile of riders whom are not affected by drugs or alcohol etc.

PROPOSAL FOR DECISION TREE WITH COMPUTER SIMULATIONS

Computer simulation can be a way forward in the development and evaluation of MPS and barriers that are more motorcyclist friendly. With computer simulation barriers MPS and the test dummies used in physical crash testing can all be modelled allowing so-called virtual tests to be performed. The use of virtual testing for the development of MPS, and to some extent for the validation of systems on a national basis, has been developing over recent years and its use as an additional evaluation tool should be considered in the future. This is a proposal for how computer simulations can be used.



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