

MOTORCYCLE PROTECTION SYSTEMS & SAFETY ASPECTS OF MANAGEMENT OF TRAFFIC FOR MOTORCYCLES

A PIARC SPECIAL PROJECT



STATEMENTS

The World Road Association (PIARC) is a nonprofit organisation established in 1909 to improve international co-operation and to foster progress in the field of roads and road transport.

The study that is the subject of this report was defined in the [PIARC Strategic Plan 2024-2027](#) and approved by the Council of the World Road Association, the members of which are representatives of the member national governments. The members of the Technical Committee responsible for this report were appointed by the member national governments for their special competences.

Any opinions, findings, conclusions and recommendations expressed in this publication are those of the authors and do not necessarily reflect the views of their parent organisations or agencies.

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International Standard Book Number: 978-2-84060-790-8

Front cover © Motorcyclists lane splitting in Bangkok, Thailand; Author Roland Dobbins, Singapore

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AUTHORS / ACKNOWLEDGEMENTS

The special project Motorcycle Protection Systems & Safety Aspects of Management of Traffic for Motorcycles was initiated and supported by the World Road Association (PIARC).

This document has been prepared under the joint collaboration between the Faculty of Mechanical Engineering of the University of Ljubljana (UL), and the Faculty of Civil Engineering, Transportation Engineering and Architecture of the University of Maribor (UM).

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The editor of this report is the World Road Association (PIARC).

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Finally, the authors are grateful to all participating PIARC member countries and organizations who provided data, case studies, and insights that were essential to the success of this study.

In the final stage of the editing process, the document was proofread by a professional linguist Slobodanka Ivanjić Kostrešević.

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A PIARC SPECIAL PROJECT

This document is the outcome of the PIARC Special Project on Motorcycle Protection Systems and Safety Aspects of the Management of Traffic for Motorcycles, conducted under the framework of the PIARC Strategic Plan 2024–2027. The study was initiated by the World Road Association (PIARC) in response to the continuing global challenge of improving the safety of powered two-wheeler users, who remain one of the most vulnerable groups of road users worldwide.

The content of this report has been prepared by a multidisciplinary team of experts from the University of Ljubljana, Faculty of Mechanical Engineering (UL-FME) and the University of Maribor, Faculty of Civil Engineering, Transportation Engineering and Architecture (UM-FCTA), with oversight from the designated PIARC Technical Committee. The authors were appointed based on their expertise in motorcycle safety, roadside infrastructure, traffic engineering, biomechanics, and traffic accident research.

The purpose of this report is to provide evidence-based knowledge, case studies, and recommendations that can support PIARC member countries in addressing motorcyclist safety through both infrastructure measures (e.g., crash cushions, upper guardrail protections) and traffic management strategies (e.g., lane splitting, lane sharing, dedicated motorcycle lanes, advanced stop lanes, filtering). The scope of the study includes literature reviews, international surveys, stakeholder interviews, and numerical/experimental analyses.

This publication forms part of PIARC's broader mission to promote the Safe System approach and to contribute to the global vision of reducing road fatalities and serious injuries. By gathering and disseminating international experiences, it aims to foster mutual learning and support the development of context-appropriate solutions, especially in low- and middle-income countries (LMICs) where motorcycles are a predominant mode of transport.

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1. INTRODUCTION

The interest in using Powered Two-Wheelers (PTWs) is on the rise. There are several reasons for this trend, specifically traffic congestion in big cities and underdeveloped public transportation systems.

Powered two-wheelers (PTWs) is a term used in the motorcycle industry that includes motorcycles, mopeds and scooters.

PTWs provide essential mobility for commuters and professional drivers for delivery and first responder services (e.g., traffic police, medical assistance and fire fighters), as well as tourism, leisure and sport. The affordability, flexibility and performance of PTWs in dense traffic have contributed to their increased use, particularly in low- and middle-income countries.

The International Transport Forum of the Organisation for Economic Co-operation and Development (OECD/ITF) report on motorcycle safety categorises PTWs as shown in Figure 1.1 [3] and [8].

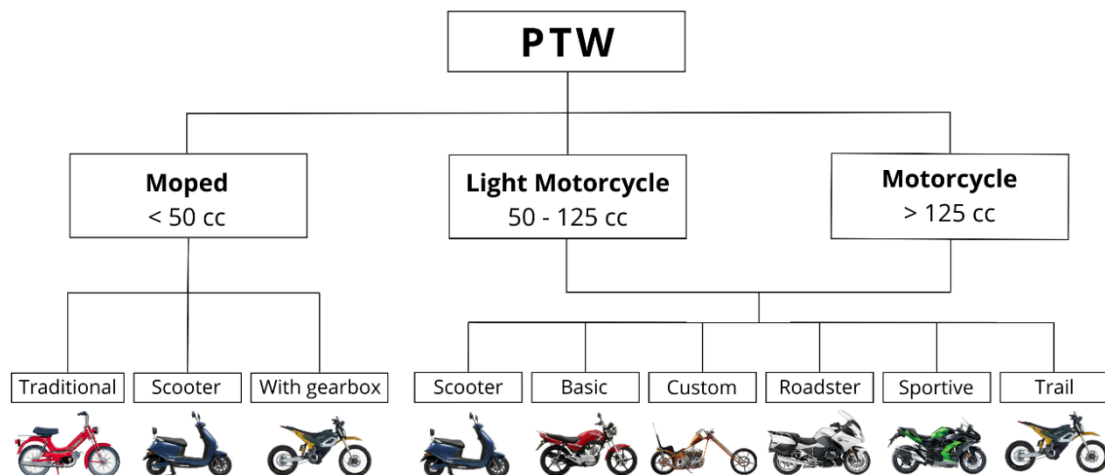


Figure 1.1: The categorisation of PTWs

Some of the advantages of riding PTWs are [3] and [4]:

- in general they take up less space on the road and contribute less to traffic congestion; motorcycling substantially increases capacity on congested urban roads;
- they can 'double-up' in a lane or 'filter' through congested areas (filtering and lane splitting) and contribute to alleviating gridlocks on roads with a high volume of traffic;
- in congested areas, they take approximately 16-48% less time to cover the same urban trip compared to a car;
- on average, motorcycles consume between 55-81% less fuel than passenger cars on the same journey;
- they cause a fraction of the damage to roads compared to other motorised forms of transport, thus accounting for just a small percentage of the maintenance costs;
- motorcycles occupy less physical parking space than passenger vehicles;
- they may support greater access to mobility due to lower costs than other motorised vehicles and ability to traverse challenging terrain where road systems are less developed;

- they may enable faster delivery of goods and services, including healthcare (blood, organs);
- they may be cheaper to maintain than some other vehicle types.

Due to the aforementioned advantages, some countries encourage the use of motorcycles, mopeds and scooters, in certain ways, rather than passenger cars.

Regardless of the above, there are also disadvantages of riding PTWs including [3] and [4]:

- they do not have a protective 'shell';
- they mostly do not have airbags; although nowadays they are available especially in motorcyclists' vests;
- they have a low mass relative to other types of vehicles approaching from the opposite direction, which poses significant danger to motorcyclists in the event of a head-on collision;
- they have a small silhouette relative to other types of motorised vehicles and are consequently less visible;
- power-to weight ratio;
- (only) two (small) tyre contact patches through which forces are transferred from motorcycle to carriageway and vice versa;
- steel crash barriers are designed with only cars and heavy vehicles in mind and may pose a danger for single-track vehicles;
- when driving through a curve, all of motorcyclist's longitudinal and transverse forces must be in balance. Therefore, even a very small longitudinal (e.g., sudden braking) or transverse force (e.g., sudden avoidance of an obstacle) can cause loss of control over the motorcycle.

There is plenty of evidence pointing to the vulnerability of PTWs [5]:

- Motorcycling safety differs significantly between regions. The share of PTW fatalities ranges from around 10% in Africa and Europe to over 40% in Southeast Asia;
- In Africa, Asia and Latin America, PTWs are the only affordable mode for millions of people, providing access to education, work and medical care. Several countries have also seen a sharp increase in the use of PTWs for urban deliveries, especially since the Covid-19 pandemic. As a result, the share of PTWs in traffic is extremely high in some countries, for example in India (72%) and Indonesia (80%);
- In the European Union, PTW riders are one of the most vulnerable groups of road users. They are often involved in road crashes resulting in serious injuries or fatality. Some EU studies of PTW crashes have reported that approximately 96% of PTW riders involved in traffic accidents are at great risk of suffering certain types of injuries. Other studies show that in as many as 50% of such accidents, serious injuries or even death occurred;
- In the EU, the number of fatalities per 100,000 registered motorcycles is twice as high for motorcycle riders as for car passengers per 100,000 registered cars (data for 2021);
- According to the most recent WHO data, riders of powered two- or three-wheeled vehicles account for almost 30% of all road-traffic deaths worldwide. This percentage has remained unchanged in the past decade. In some countries, however, PTW users represent more than 70% of road deaths.

In light of all of the above, The International Transport Forum (ITF) - an intergovernmental organisation with 64 member countries and administratively integrated with the OECD/ITF - has prepared a document entitled “Improving Safety for Motorcycle, Scooter and Moped Riders”, which summarises the current extent of PTW usage worldwide, highlights pressing safety issues for motorcyclists and presents priority actions for improving motorcycling safety [8].

The Research Report provides nine recommendations for governments, road safety authorities, fleet owners, manufacturers and riders’ groups. These actions mirror the recommendations of the Academic Expert Group, with the overall aim of integrating PTW safety in the Safe System approach, including:

1. Implement a Safe System approach that caters for the safety needs of powered two-wheelers
2. Involve all stakeholders in sharing responsibility for the safety of powered two-wheelers
3. Make the needs of powered two-wheelers an explicit part of transport policy
4. Create a toolbox of measures to improve the safety of powered two-wheelers riders
5. Promote appropriate behaviour of powered two-wheeler riders and road users generally
6. Make the use of helmets compulsory for all riders of powered two-wheelers
7. Enhance safety features in vehicles
8. Reduce crash risk for powered two-wheelers by introducing self-explaining and forgiving roads
9. Do more research to extend understanding of powered two-wheeler mobility and crash mechanisms.

1.1. MAKE SMARTER USE OF URBAN SPACE

Governments should support shifts both away from and where appropriate towards PTWs, to improve the overall safety, efficiency and sustainability of urban mobility. This means rethinking infrastructure and urban planning and reallocating road space to include sustainable and safe use of PTWs.

Manufacturers and researchers must strive to improve and demonstrate the safety and environmental footprints of PTWs as a space-efficient mobility mode. It is also important that city planners enable better connection of PTWs with public transport.

Local governments must work on improving the management of PTW parking capacity, especially at public transport hubs to enable modal shift from and to PTWs. Other measures include preserving pedestrian access through better parking infrastructure design and enforcing parking rules.

Local and national governments must focus on increasing safe transport choices. Authorities should make more school buses available for small children to reduce their forced reliance on PTWs, which is a particular challenge in low- and middle-income countries.

1.2. REDESIGN INFRASTRUCTURE TO INCREASE MOTORCYCLIST SAFETY

Infrastructure must be safer for PTW users, starting with the design of roads and traffic systems. It is important that governments and road authorities comply with the latest infrastructure safety standards related to PTW use and update all relevant documentation to reflect best practice and

Safe System principles, especially in the context of LMICs, where rural mobility relies heavily on PTWs.

Infrastructure managers, researchers and institutions must update and promote road design standards in general (in urban and non urban areas), manuals and guides to reflect best practice knowledge on PTW safety.

All stakeholders must strive to develop new ideas to rethink the traffic system, for example regarding space re-allocation and infrastructure design.

It is important that researchers, manufacturers and governments share knowledge of safe and efficient infrastructure solutions which support the mix of PTWs, other vehicles and other vulnerable road users in road traffic.

1.3. PIARC SPECIAL PROJECT

With the existing problems related to the traffic safety of PTWs, PIARC announced a Special Project Motorcycle Protection Systems & Safety Aspects of Management of Traffic for Motorcycles, which address two specific aspects as described below (Figure 1.2):

A. Motorcycle Protection Systems,

especially three aspects that are not specified in standards or manuals such as the European Standard or U.S. Manual for Assessing Safety Hardware, regarding Motorcycle Protection Systems and safety barriers (guardrails):

- Motorcyclists' crash cushions (end terminals for motorcyclists)
- Upper guardrail protection for motorcyclists (Continuous Motorcyclist Protection System – CMPS on the upper side of a safety barrier),
- Safety performance evaluations of the reduction of severe injuries from motorcycle guardrail designs that have been used in various countries. Including influences on the safety of guardrail ends.

B. Safety aspects of traffic management for motorcycles

such as dedicated motorcycle lanes and lane splitting. The research will be extended to other well-known traffic management strategies for motorcyclists, including filtering, advanced stop lines, and lane sharing (indicated in grey on the Figure 1.2). Management of traffic for motorcycles and other powered two- wheeled vehicles and its implication in their safety. In North America and in some European countries, these vehicles need to stay in the lane and follow the same rules as a regular car, while in some countries, they are allowed to move in-between lanes when there is congestion. In France, a specific pilot project is being introduced to allow motorcyclists to drive between lanes in the expressway when the speed is under 50 km/h. In Southeast Asia, some infrastructures have been built with dedicated motorcycle lanes. In some regions of Africa, up to 85% of all vehicles are motorcycles. In some cities, motorcycles are accepted in the bus lanes to enhance their safety, while in other cities they are banned from these lanes. In Spain, traffic norms will be modified in the near future to allow motorcycles to drive on road shoulders when traffic is at a standstill, with a 30 km/h maximum speed limit [7]. These road stretches will be designated under the agreement of road administrators and the traffic agency and must be properly marked.

This project report aims to assess global practices in PTW protection systems and traffic management to support the PIARC special project on motorcycle safety.

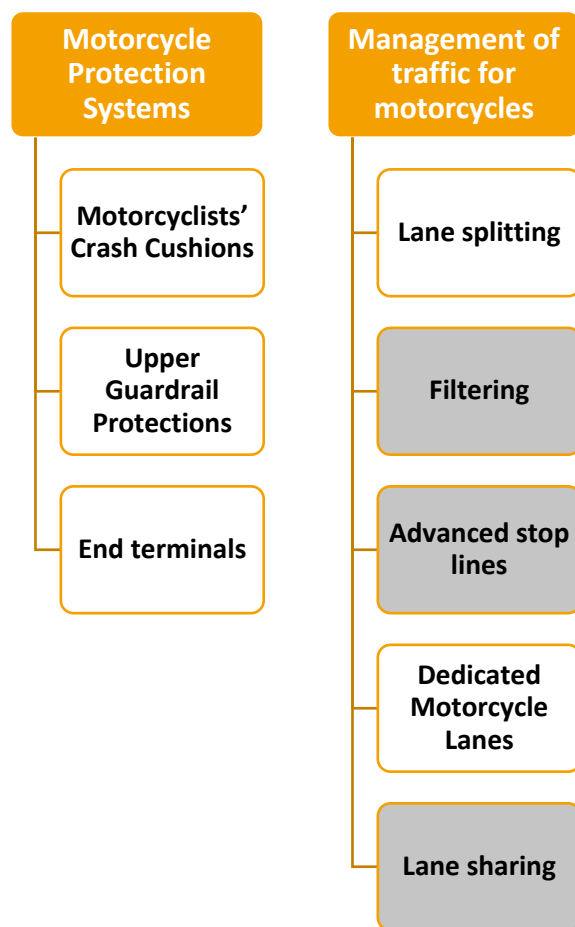


Figure 1.2: Topics of the PIARC special project

2. METHODOLOGY

- This project adopts a structured, multidisciplinary methodology to evaluate and improve the safety of PTWs, including motorcycles, light motorcycles, and mopeds, with a focus on two core areas: Motorcycle Protection Systems and
- Traffic Management for Powered Two-Wheelers.

2.1. DATA COLLECTION

The data collection phase consists of a detailed two-stage approach:

1. a comprehensive review of publicly available literature, completed project proposals, and market research for each safety measure and
2. a multilingual online survey.

2.1.1. A comprehensive review of publicly available literature

A comprehensive review of publicly available literature, completed project proposals, and market research was carried out for each safety measure:

- Motorcycle Protection Systems:
 - o Motorcyclists' Crash Cushions,
 - o End Terminals and
 - o Upper Guardrail Protections
- Traffic Management for Motorcycles:
 - o Dedicated Motorcycle Lanes,
 - o Lane Splitting,
 - o Filtering,
 - o Advanced Stop Lines (ASLs) and
 - o Lane Sharing.

This review identifies regulatory frameworks, safety standards, documented effectiveness, deployment experiences, and commercially available products.

2.1.2. Multilingual online survey

A multilingual online survey (English, French, Spanish) was distributed to stakeholders, including PIARC members, national road agencies, industry experts, EVU (European Association of Forensic Experts in Traffic Accident Investigation), ETSC (European Transport Safety Council), FEMA (Federation of European Motorcyclists' Associations), and AMA (American Motorcyclist Association) and academic institutions. The survey gathers information on:

- Current national practices and regulations,
- Pilot projects and national strategies,
- Evaluation of successful and unsuccessful implementations and
- Planned infrastructure investments and needs.

Questions regarding the evaluation of motorcycle protection systems, specifically motorcyclists' crash cushions, end terminals, and upper guardrail protections, refer to:

- Improving motorcyclists' safety,

- Complexity of installation,
- Design enables flexible use,
- Maintenance,
- Use of recycled materials
- Price - cost effectiveness and
- General evaluation.

Regarding the topic of traffic management for motorcycles, expert opinions are explored in relation to the following aspects:

- Traffic safety,
- Traffic flow,
- Compliance with traffic rules by motorcyclists and
- Compliance with traffic rules by other road users.

The survey was conducted in a way that allows the results to be compared based on:

- Gross National Income (GNI) per capita (Low-Income Countries – LIC, Middle-Income Countries – MIC, and High-Income Countries – HIC),
- Whether the respondent is a member of the PIARC association,
- Whether the respondent has professional experience with motorcycle protection systems and safety aspects of traffic management for motorcyclists,
- Whether the respondent is a motorcyclist or not and
- Continent origin.

Each motorcycle protection system and traffic management measure for motorcycles was evaluated by the respondent based on their knowledge and experience. The evaluation was conducted using a five-point scale to assess their impact as follows:

- Very bad: 1 point
- Bad: 2 points
- No difference: 3 points (neutral/midpoint)
- Good: 4 points
- Very good: 5 points

Alternatively, the respondent could choose not to evaluate a particular item by selecting 'No opinion'.

In its final form, including all criteria and sections, the survey consists of a total of 133 questions across 21 pages. Due to the length of the survey, respondents were allowed to pause and resume completion at a later time.

Particular attention was given to insights from LMICs. A centralized database was developed to consolidate all collected information, which then served as the basis for subsequent evaluation and analysis.

2.2. DATA ANALYSIS

The collected data was analysed using both qualitative and quantitative assessments. The objective was to identify key success factors and assess the effectiveness of various protective measures and

management systems. The findings informed tailored recommendations suitable for local socio-economic and infrastructural conditions.

2.3. CASE STUDIES

Up to 15 case studies were prepared, a maximum of five in each of the following areas: crash cushions, upper guardrail protections, and motorcycle traffic management. These were selected based on literature reviews and survey results, and critically analysed. Where possible, follow-up interviews were conducted to explore implementation details and contextual factors. Case studies were structured for direct inclusion in the PIARC Online Road Safety Manual.

2.4. OPPORTUNITIES, CHALLENGES, AND RISKS

Motorcycle use differs notably between High-Income Countries, where it is often recreational, and Low- and Middle-Income Countries, where it is a primary mode of transport. As such, a universal approach to motorcyclist safety is not applicable. The project focuses on identifying simple, cost-effective, and context-specific solutions that are feasible within local infrastructural and economic constraints.

Through a combination of literature review, survey data, simulations, and targeted interviews, the project assesses both successful and unsuccessful practices related to motorcycle protection systems and traffic management. The aim was to identify key opportunities, barriers to implementation, and potential risks.

Special emphasis was placed on direct engagement with stakeholders in LMICs to ensure that proposed measures are practical, adaptable, and aligned with real-world needs. This approach helped develop actionable, locally relevant safety recommendations.

2.5. MILESTONES AND DELIVERABLES

The project is structured into Work Packages (WPs), each linked to specific deliverables and milestones. Key outputs include:

- D1.2: Literature Review and Case Studies (W19),
- D3.1: Survey Database and Interim Report (W19),
- D3.2: Comparative Analysis between HICs and LMICs (W22),
- D4: Technical Recommendations (W27),
- D5.1: Presentation to PIARC Project Council (W32),
- D5.2: Results Presentation at PIARC Meeting (W35),
- D5.3: Conference Papers and Publications,
- D6: Final Technical Report (W30).

Monthly online meetings ensured continuous progress monitoring, and cloud-based collaboration tools will facilitate transparency and communication with the Project Oversight Team (POT).

2.6. PROJECT MANAGEMENT IN QUALITY ASSURANCE (QA) AND QUALITY CONTROL (QC)

The QA/QC process is built on:

- Defined quality criteria for each project phase and region-specific adaptability,

- Weekly internal progress reviews and monthly evaluation with POT,
- Continuous integration of stakeholder feedback into deliverables and
- Full documentation of processes, issues, and corrective actions.

The multidisciplinary team ensured that each solution undergoes rigorous evaluation from engineering, practical, and contextual standpoints.

2.7. MOBILIZATION OF SKILLS

The project brings together mechanical engineers, civil/traffic engineers, data analysts, simulation experts, forensic investigators, and road safety educators. Team members have a proven record of collaboration on national and international road safety projects.

This expertise ensures:

- Design of technically robust safety systems,
- Comprehensive data analysis,
- Development of evidence-based, region-specific recommendations,
- Effective stakeholder training and capacity building.

2.8. HOW THE STUDY WILL MAKE RECOMMENDATIONS

Recommendations are based on a triangulated analysis of:

- Literature and technical documentation,
- Survey results and
- Scientific and professional expertise of the research group in the field of traffic safety.

The findings are translated into clear, implementable actions for road agencies, PIARC members, and motorcyclist associations. A particular focus is given to scalable and cost-effective solutions for LMICs.

2.9. HOW THE STUDY WILL PROPOSE RECOMMENDATIONS

The study team maintained close contact with the PIARC Project Oversight Team throughout the project. Interim findings were presented at regular intervals, and the final results are aligned with the ongoing work of PIARC Technical Committee 3.1.

Recommendations are structured for inclusion in the PIARC Online Road Safety Manual to facilitate wide dissemination and practical uptake.

In addition to the final technical report and Council presentation, the project will:

- Provide individual feedback to survey participants and interested countries,
- Organize dissemination workshops and presentations and
- Publish findings in international journals and conferences.

All recommendations are grounded in evidence and contextualized for local conditions. Special emphasis is placed on practical guidelines that LMICs can adopt with minimal additional resources.

3. STATE-OF-THE ART

For each individual safety measure of Motorcycle Protection Systems and Traffic Management for Motorcycles, a comprehensive review of publicly available literature, completed project proposals, and market research has been performed.

3.1. MOTORCYCLE PROTECTION SYSTEMS

EN 1317-8 is currently the only European standard that defines performance criteria specifically for motorcyclist's safety in the event of a collision with a road restraint system. Importantly, it only addresses scenarios where a motorcyclist slides along the ground and impacts a longitudinal safety barrier—not upright impacts or other crash configurations [10]. The standard sets out:

- Performance classes based on impact speed and severity,
- Requirements for protective systems either integrated into or added to the existing barriers,
- Testing procedures using anthropomorphic test devices (ATDs) that simulate sliding motorcyclists,
- Evaluation criteria such as head acceleration and body kinematics.

It is designed to support safer infrastructure for Powered Two-Wheeler (PTW) users, especially in high-risk areas such as curves, exits, and rural roads. However, it does not assess the restraint performance for vehicles such as cars or trucks, which are covered by other parts of the EN 1317 series [11]. It is important to note that EN 1317-8 does not define the safety criteria for motorcyclist impacts with crash cushions, barrier terminals, nor for impacts with the upper edge of a single-sided barrier (SSB).

3.1.1. Motorcyclists' crash cushions

A crash cushion, also known as an impact attenuator, is a protective device installed at the ends of guidrails, barriers, or other roadside obstacles to absorb and dissipate the kinetic energy of an impacting vehicle (Figure 3.1). They are widely used in developed countries to protect vehicles against impacts with fixed, sharp, narrow, and rigid objects located at road exit locations, toll booths, workzones, barrier ends, and trees. These cushions are designed to mitigate crash severity through gradual deformation which helps prevent serious injuries and fatalities.



Figure 3.1 : The QuadGuard® Elite ; a redirective, non-gating crash cushion [12]

Crash cushions can be categorized into redirective and non-redirective types:

- Redirective crash cushions are designed to guide vehicles back onto the roadway or away from hazards.
- Non-redirective crash cushions absorb impact energy but do not control the vehicle's redirection.

Common types include sand barrels, water-filled attenuators, and metal or foam-based systems. They are commonly placed at highway exits, toll plazas, bridge piers, and sharp curves to enhance road safety. They are designed to absorb the energy of an impacting vehicle by using different material deformation mechanisms, such as metal plasticity supported by airbag folding or damping.

Impact performance evaluation of crash cushions are attained according to:

- The EN 1317-3 standard based on various speed limits and impact angles (Part 3 of EN 1317 standard, named “road-restraint systems—part 3: performance classes, impact test acceptance criteria and test methods for crash cushions”) [11].
- The Manual for Assessing Safety Hardware (MASH), which provides comprehensive guidelines for crash testing and evaluating crash cushions, among other roadside safety features MASH Standard (Traffix Devices) (superseding NCHRP 350) [13].

All standards have unique approaches (testing protocols, vehicle types, and impact conditions) to evaluating crash cushions. Listed below are the key differences.

1. Vehicle Types:

- EN 1317: Utilizes three vehicle types: a small car (900 kg), a medium car (1300 kg), and a large car (1500 kg)
- MASH: Updated vehicle types to reflect modern vehicles, including a small car (2,420 lbs (1,097 kg)), a pickup truck (5000 lbs (2,268 kg)), and a single-unit truck

(22,000 lbs (9,979 kg)); superseding NCHRP 350: Uses a small car (820 kg) and a pickup truck (2,000 kg) for testing

2. Impact Angles:

- EN 1317: Similar to NCHRP 350 but includes additional angles for specific tests (Figure 3.2)
- MASH: Increased the small car impact angle from 20° to 25° and adjusted other angles to better reflect real-world conditions; superseding NCHRP 350: Typically uses impact angles of 0° and 20°

3. Impact Speeds:

- EN 1317: Uses a range of speeds, including 50 km/h, 70 km/h, 80 km/h, 100 km/h, and 110 km/h
- MASH: Increased the impact speed for the single-unit truck test from 80 km/h to 90 km/h; superseding NCHRP 350: Standard impact speeds are 100 km/h for most tests

4. Evaluation Criteria:

- EN 1317: Emphasizes energy absorption and biomechanical parameters to ensure passenger safety
- MASH: Updated criteria to address modern vehicle dynamics and improve consistency in evaluations; superseding NCHRP 350: Focuses on structural adequacy, occupant risk, and vehicle trajectory

5. Containment Levels:

- EN 1317: Classifies devices with terms like N2, H1, and H2
- MASH: Retains the TL classification but with updated criteria; superseding NCHRP: Uses terms like TL3 and TL4 for containment levels

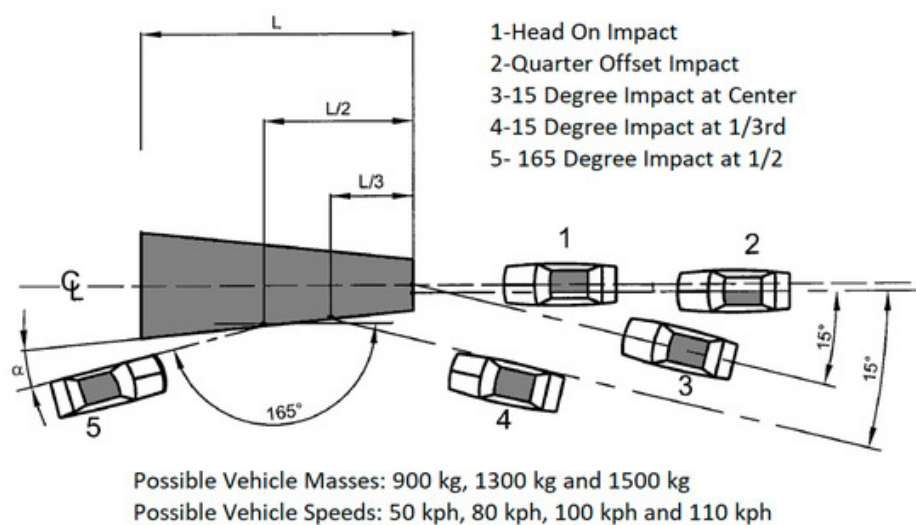


Figure 3.2 : Crash cushion test approaches in EN 1317 Standard Part 3 [14].

All standards and recommendations define performance evaluation for passenger vehicles, and some (such as MASH) also for heavy vehicles. However, no standard defines performance evaluation or design guidelines for impact attenuators that are safe for motorcyclists.

Therefore, almost all impact attenuators pose a danger to motorcyclists in the event of a crash — both in terms of their energy absorption capacity and their shape. In the event of a motorcycle collision, such attenuators behave as rigid, non-deformable obstacles, often featuring sharp or pointed rigid elements that can cause severe injuries to motorcyclists. However, based on a review of patents and manufacturers, the project team has identified the following examples that are of particular interest from the perspective of motorcycle safety.

3.1.1.1. Protective lining for road safety supports

- [1] Due to space limitations, only brief summaries and one image per item are provided in the following sections. The complete material is available through the links included with each item.
- [2] Source [14]: Cordeu L. M. (2007): ES1064957U Protective lining for road safety supports; <https://worldwide.espacenet.com/patent/search/family/038326738/publication/ES1064957U?q=pn%3DES1064957U>

Protective lining for road guardrail supports, of the type designed to cover the supports of the guardrails in order to cushion the blows that occur against them, characterized in that it consists of an element formed of flexible and elastic material, determining a plate (1), from which a series of fins (2) emerge on one side, the assembly of which can be curved like an accordion to be arranged around the guardrail supports (3) of application.

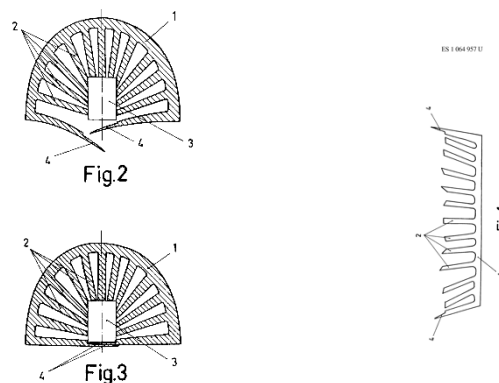


Figure 3.3 : Protective lining for road safety supports

3.1.1.2. Flexible valley ondulada

Source [16]: Calabuig V. V. (2010): ES2386561A1 Flexible valley ondulada; <https://worldwide.espacenet.com/patent/search/family/046604146/publication/ES2386561A1?q=pn%3DES2386561A1>

Wavy flexible fence comprising a front surface, with a geometric design curved in the form of concave and convex waves (1) to favor the absorption of impact energy and which can be fixed by rivets or through bolts (4) to an auxiliary structure (2) of longitudinal support formed by parallel tubular lines, and having in sections junctions (3) of smaller diameter, which in turn can allow or facilitate the deformation of the structural assembly in case of impact. It is intended that the whole set serves, in the event of crash, to reduce both the force of the impact of the driver of the two-wheeled vehicle, and reduce the presence of cutting elements in its structure and thereby eliminate

the possible risks that may occur the impact of the driver against the existing elements in the current guardrails. Protective lining for road guardrail supports, of the type designed to cover the supports of the guardrails in order to cushion the blows that occur against them.

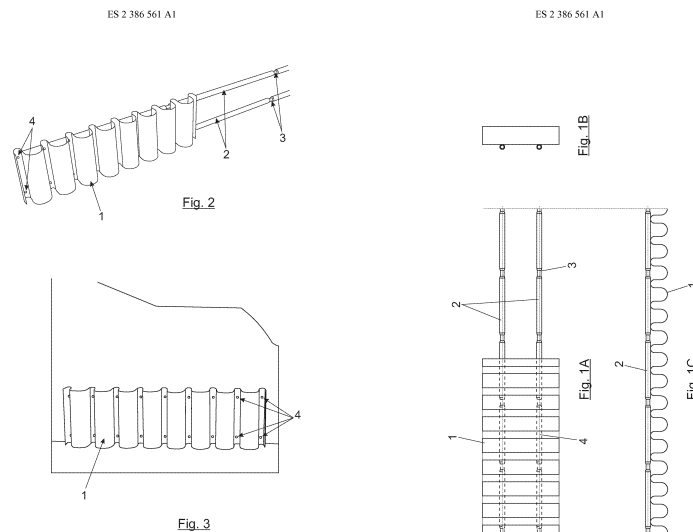


Figure 3.4 : Flexible valley undulada

3.1.1.3. RAPTOR[®] - a compact crash cushion

Source [12]: <https://www.valtir.com/product/raptor-crash-cushion/>

The RAPTOR[®] is a compact crash cushion made from durable HDPE which can be installed at sites that are lacking space to protect objects in the traditional manner. The system consists of two pieces which connect together and provide protection from a rigid object such as a pole or tree that is positioned within the central void. The RAPTOR[®] 600 has been tested based on the MASH Test Level 1.



Figure 3.5 : RAPTOR[®] - a compact crash cushion

3.1.1.4. Crash cushion Armadillo

Source[17]: <https://www.trafficsafetysystems.eu/en/crash-cushion-armadillo.html>

“Armadillo” is the first crash cushion designed for the protection of motorcyclists. “Armadillo” Crash Cushion is the only one that explicitly states it is designed for Protection of motorcyclists and according to EN 1317.

Did you know that collisions with obstacle protectors by motorcyclists are often fatal because they slide against the posts under the structure. With the new ARMADILLO crash cushion, the construction is completely protected, so that motorcyclists cannot slide under the construction and the risk of injury is minimal. The Armadillo has been tested according to EN1317 and provided with the CE marking. The dangers of collisions at a speed of 50 km/h or even slower are often underestimated. Research shows that low-speed collisions with fixed obstacles can cause serious injury and even death to motorcyclists, drivers and/or passengers. 60% of road deaths occur on roads within municipalities. Secure lamp posts, trees, lane dividers or other obstacles along roads with the Armadillo crash cushion, which has been specially developed for low speeds and is also motor-friendly. As an example of appropriate protection in the event of a motorcyclist collision, the ARMADILLO crash cushion was tested in accordance with the CEN/TS 17342:2019 standard (Figure 3.7).



Figure 3.6 : Armadillo” crash cushion



Figure 3.7 : Testing of the Armadillo crash cushion according to CEN/TS 17342:2019 Standard

3.1.2. End terminals

End terminals or guardrail end terminals are protective devices installed at the end of a guardrail or safety barrier to reduce the danger to vehicle occupants if the end of the barrier is struck.. Advanced types are designed to absorb and dissipate the kinetic energy of a collision significantly

reducing the impact of a crashing vehicle, enhancing road safety. They are designed to stop or deflect vehicles in the event of a possible collision in order to prevent serious damage to vehicles and occupants as well as to the crash barriers.

There are several types of end terminals. Some of them are bullnose end terminals, energy-absorbing end terminals, flared end terminals, fishtail end terminals, and bridge end terminals.

Selecting the appropriate guardrail end terminal is crucial for optimizing road safety. Factors such as traffic volume, speed limits, roadside conditions, and crash history should be considered when determining the most suitable guardrail end terminal type. Additionally, compliance with relevant safety standards and guidelines is essential to ensure effectiveness and reliability.

Standard for end terminals evaluation:

Impact performance evaluation is attained based on:

- CEN/TS 1317-7:2023 Specifies requirements, test/assessment methods, and acceptance criteria for safety barrier end terminals used on roads and in vehicle circulation areas [14], and
- Manual for Assessing Safety Hardware (MASH) is a current U.S. standard which has been applicable since 2009 (updated in 2016), superseding NCHRP 350. Provides uniform guidelines for crash testing permanent and temporary highway safety features and recommends evaluation criteria to assess test results.

All standards have unique approaches (testing protocols, vehicle types, and impact conditions) to evaluating crash cushions (key differences are the same as those for crash cushion evaluations).

2. Test Vehicles

- CEN/TS 1317-7:2023: Utilizes various vehicle masses, including light and heavy vehicles, as specified in EN 1317-2:2010 [14].
- MASH: Uses updated vehicle types: 1100C (1,100 kg compact car), 2270P (2,270 kg pickup truck).
- NCHRP 350: Used older and smaller vehicle types: 820C (820 kg compact car), 2000P (2,000 kg pickup truck).

3. Test Speeds

- CEN/TS 1317-7:2023: Includes various test speeds depending on the performance class, as defined in EN 1317-2:2010.
- MASH: Test speeds are 80, 100, and 110 km/h.

4. Impact Angles and Lateral Tests

- CEN/TS 1317-7:2023: Includes tests at various impact angles, including lateral tests, as specified in EN 1317-2:2010.
- MASH: Includes tests at angles between 5°–15°; side impacts are required.

5. Biomechanical Criteria

- CEN/TS 1317-7:2023: Uses THIV (Theoretical Head Impact Velocity) and ASI (Acceleration Severity Index) as per EN 1317-1:2010.
- MASH: Use Occupant Impact Velocity (OIV) and Occupant Ridedown Acceleration (ORA).

6. Terminal Displacement and Redirectivity

- CEN/TS 1317-7:2023: Specifies limits for terminal displacement and requirements for vehicle redirection after impact, as defined in EN 1317-2:2010.
- MASH: Include evaluation of terminal movement during impact and assessment of vehicle redirection.

3.1.2.1. Safe System Snippet #161 PolyBuffer

Source[18]: <https://safesystemsolutions.com.au/safe-system-snippet-161-polybuffer/>

None of the motorcycle underrun protection devices accepted for use have been tested on the end terminal of road safety barriers. As a result, they must terminate before the end terminal. This can result in strange and somewhat unintuitive applications.

As a temporary measure until a tested system is put to market, the Victoria state has allowed the use of a product called PolyBuffer that does not attach to the end terminal (Figure 3.8 and Figure 3.9). PolyBuffer sits in-front of the system and is expected not to affect the function of the end terminal during a strike by a passenger vehicle.

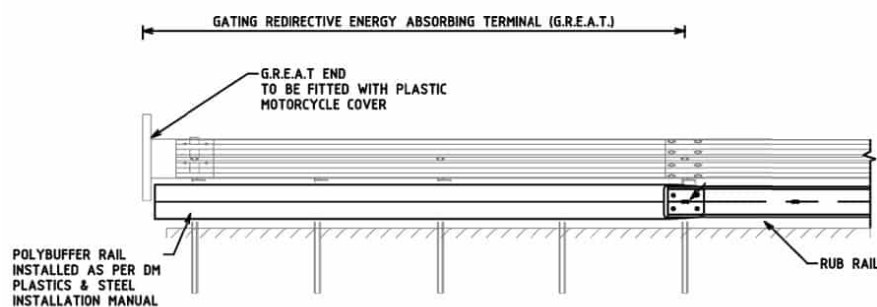


Figure 3.8 : Safe system Snippet #161 PolyBuffer - sketch



Figure 3.9 : Safe system Snippet #161 PolyBuffer

3.1.2.2. MAX-Tension® Terminal

Source[19]:

<https://www.safedirection.com.au/products/guardrail-products/road-barriers/guardrail-terminals/max-tension-terminal/#downloads>

The MAX-Tension® Guardrail End Terminal is an energy-absorbing, tangential end terminal, designed to minimize the severity of impacts occurring at the end of the safety barrier system (Figure 3.10).

When impacted head-on, the MAX-Tension® combines tensioned cables with Sabertooth™ technology to provide controlled vehicle containment. The narrow design of the impact head reduces the potential for nuisance impacts and is easily identified by the highly visible yellow nosecone.

Features:

- Accepted by the Austroads Safety Barrier Assessment Panel (ASBAP),
- Complies with MASH TL3 and MASH TL2,
- Complies with AS/NZS 3845.1 Road Safety Barrier Systems & Devices,
- Impact energy is dissipated by the combination of tensioned cables and Sabertooth™ technology,
- Narrow impact head.



Figure 3.10 : MAX-Tension® Terminal

3.1.2.3. Smart alignment of the road safety barriers

Some hazards can be avoided already in the road design phase, and they can also be corrected later when the road is already built. Therefore, with small changes to the alignment of the road safety barriers, the installation of end terminals can be avoided.

Regardless of whether about a straight section or a curve is being discussed, there are situations (conditions) where an SSB must be implemented.

Due to the intersection, an opening is created in the SSB. This interruption in the SSB (window) poses a danger to motorcyclists. The question is how to reduce this danger or how to decrease the likelihood of a motorcyclist crashing into the beginning (end) of the SSB.

One option is to redirect the course of the SSB at the intersection.

The redirection of the SSB can be implemented either in [20]:

- a semicircular (Figure 3.11 and Figure 3.12) or
- an angled manner (Figure 3.13 and Figure 3.14).

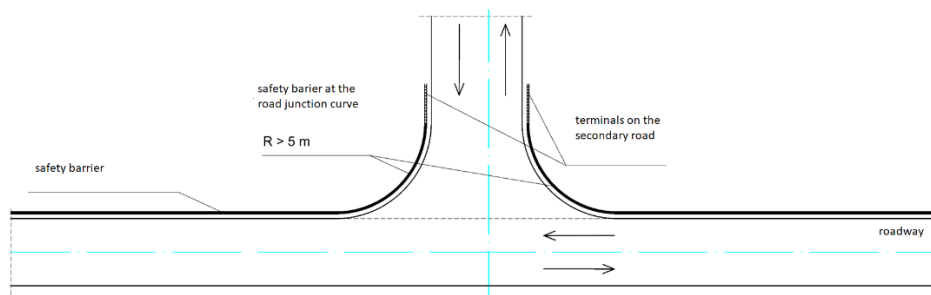


Figure 3.11 : The redirection of the SSB in a semicircular manner - sketch



Figure 3.12 : The redirection of the SSB in a semicircular manner - example

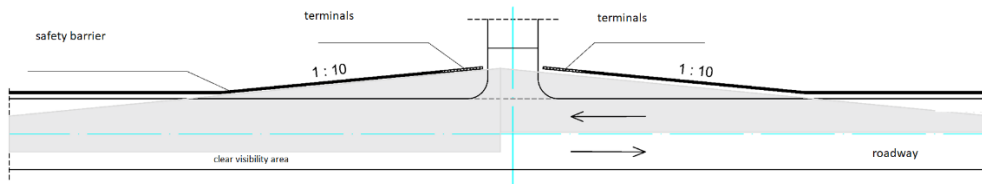


Figure 3.13 : The redirection of the SSB in an angled manner - sketch



Figure 3.14 : The redirection of the SSB in an angled manner-example

Even on highways (high speeds), it is not necessary to install an end terminal if the road is in a cut slope. In such a case, it is sufficient to "push" the SSB guardrail into the embankment (Figure 3.15).



Figure 3.15 : SSB guardrail finished into embankment - example

3.1.3. Upper guardrail protection

Riding through curves is a greatest pleasure but also major danger to motorcyclists, as all longitudinal and transverse forces must be in balance. If the balance of forces is disrupted, two situations can occur: a) a motorcyclist falls on his side and slides out of the curve (sliding crash) or b) a motorcyclist does not fall on his side but continues to ride out of the curve (upright-posture crash).

Research of the European Community's Directory General for Energy and Transportation, in collaboration with FEMA (Federation of European Motorcyclists Associations) shows that 10 to 15% of all fatalities amongst motorcyclists that collide against a crash barrier are due to the impact with this hard and sharp construction, in which the impact with the vertical posts is most problematic. Several recent research projects have led to a number of improvements in this matter.

It is more than obvious that the SSB was invented solely and exclusively with (heavy) two-track vehicles in mind, with the vulnerability of PTWs being neglected.

The experience in many countries shows that left-hand curves are more dangerous than right-hand ones.

In a right-hand bend, a motorcyclist can fall onto the right side and slide into the oncoming lane ("sliding crash"). The motorcyclist's chance of survival depends on whether a vehicle is approaching from the opposite direction at that moment and on the safety of the roadside on the left side of the road (Figure 3.16).

A first solution is to add a second horizontal beam or a horizontal structure underneath the already present horizontal beam (Figure 3.19). This prevents the motorcyclist from getting stuck underneath the horizontal beam and it also prevents any direct contact with the vertical support posts. A second solution is to surround the vertical support posts with shock absorbing material. In both solutions, the elements which are added to the crash barrier construction are attached to the vertical support posts (Figure 3.18).



Figure 3.16 : Motorcyclist sliding under the barrier and impacting the post of a SSB

In a right-hand bend, a motorcyclist can fall onto the right side and slide into the oncoming lane ("sliding crash"). The motorcyclist's chance of survival depends on whether a vehicle is approaching from the opposite direction at that moment and on the safety of the roadside on the left side of the road. The exact same situation occurs if a motorcyclist does not fall onto his side but instead directly into the opposite lane in a right-hand bend (Figure 3.17). There are no technical solutions for a right-hand bend that would prevent a motorcyclist from crossing into the opposite lane, as the traffic is coming from the opposite direction and therefore it is not possible to implement any physical measure to separate the traffic between the two lanes.



Figure 3.17 : Motorcyclist falls onto his left side and slides out of the left bend

In a left-hand bend, the situation is somewhat different. For the situation where a motorcyclist falls onto his left side and slides out of the left bend ("sliding crash"), already is a solution nowadays - the so-called "motorcyclists-friendly barrier". It is an additional guardrail on a steel safety barrier (SSB), which has two purposes:

- it prevents the motorcyclist's body from hitting the SSB post, and
- it prevents the motorcyclist's body from sliding between the two SSB posts into a dangerous roadside.

A second solution is to surround the vertical support posts with shock absorbing material. In both solutions, the elements which are added to the crash barrier construction are attached to the vertical support posts (Figure 3.18). This solution only prevents the motorcyclist's body from hitting the SSB post, but it does not prevent the motorcyclist's body from sliding between the two SSB posts into a dangerous roadside.



Figure 3.18 : Protective shock-absorbing elements mounted around the support posts of the SSB

However, factory products are not known yet for the case where, in a left-hand bend, a motorcyclist does not fall onto the carriageway and slide towards a SSB, but rather crashes directly into a SSB ("upright-posture crash") (Figure 3.19). In such a case, due to inertia, the upper part of the motorcyclist's body will bend over the upper sharp edge of the SSB guardrail. Which part of the motorcyclist's body will bend over the upper edge of the SSB guardrail depends on the height of a motorcycle and the height of a motorcyclist.



Figure 3.19.: Motorcyclist crashes directly into an SSB

As a rule, the motorcyclist's body bends over the lower ribs or internal organs, where injuries are most dangerous (Figure 3.20). In addition, the motorcyclist's head is protected by a helmet, hands by gloves, shoulders, elbows and knees by protectors, while the ribs and internal organs have no protection.

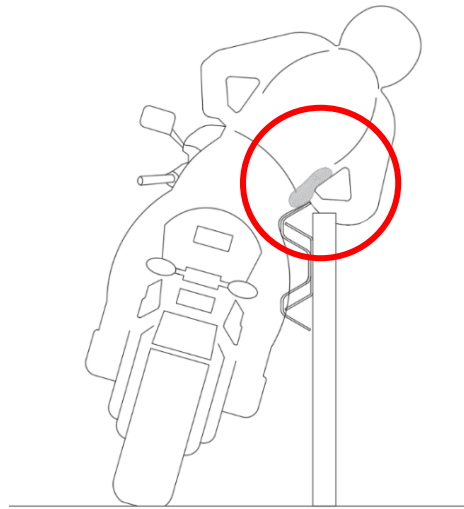


Figure 3.20 : Due to inertia, the upper part of the motorcyclist's body bends over the upper sharp edge of the SSB guardrail

Solutions that prevent the rider's body from tilting over the SSB bumper, or that reduce the consequences of this tilt, are not yet on sale.

As a result, researchers (and industry) have recently begun to consider upper guardrail protections. It is important to stress that these products are not yet in general use as they are not being produced, and are therefore not available on the market. Therefore, they cannot be seen in advertisements, factory catalogues, etc., nor can they be seen in a real environment.

Due to the aforementioned, this part of the research was initiated by conducting a search of the European database of patents and patent applications. This does not mean that such patents and patent applications do not exist in South America, Africa, and Asia, but the likelihood of this is low.

Therefore, the project team resorted to browsing the world wide web for the analysis, analysing patent applications and patents filed so far (Espacenet, Patent search). The following is a brief analysis of patent applications and patents on this topic.

3.1.3.1. The Swedish National Road and Transport Research Institute research

Source [21]: Bryshnikova, O. O., & Strugovshchikov, D. V. (2021). Improved design of motorcycles and road barriers. Bauman Moscow State Technical University.
<https://www.semanticscholar.org/paper/Improved-design-of-motorcycles-and-road-barriers/d67e998c5706c1877302cbc0cb50eef77ededc6f>

At VTI (The Swedish National Road and Transport Research Institute) in Sweden, research was done on motorcyclist crashes into a SSB, but they only dealt with lower limb injuries, depending on the design of the motorcycle engine itself (single-cylinder engine, V-engine or boxer-twin engine).

They conducted four crash tests and analysed the injuries on a “standard Hybrid III crash test dummy”, equipped with motorcycle clothing, a motorcycle helmet, and motorcycle gloves (Figure 3.21). The effect of the motorcycle engine design was analysed, or how it affects the impact in the event of a collision with a SSB with or without additional protection for a motorcyclist.



Figure 3.21 : Test dummy equipped with motorcycle clothing, a motorcycle helmet, and motorcycle gloves

The fourth test was carried out by installing another guardrail on the back of a SSB (a double-sided safety barrier), and a round plastic tube was installed between the two guardrails on the SSB posts (Figure 3.22 and Figure 3.23).



Figure 3.22 : Double-sided safety barrier with a round plastic tube



Figure 3.23 : Crash into the double-sided safety barrier with a round plastic tube

Test showed that this issue can be addressed by covering the top of the barrier “with some form of a smooth structure”. The purpose of this test was to demonstrate the principle of protecting the rider from the top of the posts, rather than testing a specific product or technical solution. However, the test showed that this principle is applicable and that the injury risks would be greatly reduced. The combination of boxer engine (BMW) and MPS protected the leg in the first collision, and the top protection made the dummy slide on the top of the barrier without getting stuck.

Conclusions:

- The author of the research states that "the purpose of the research was to demonstrate a possible way to protect a motorcyclist from hitting the top of a bumper, not to test a specific product or technical solution."
- The author notes that this principle is useful and that the risk of injury would be greatly reduced. The combination of the boxer engine and the MPS protected the leg, and the upper protection ensured that the dummy slid along the top of the barrier without getting stuck.
- The disadvantage of this solution is that the implementation of two guardrails on both sides of a SSB is only possible on motorways, but only in the case of a narrow median.
- The research results are presented in a paper by Matteo Rizzi: Improved design of motorcycles and road barriers can save lives, Folksam, which is no longer available online.

3.1.3.2. PROTECTION DEVICE FOR GUARDRAIL

Source [22]: Reggiani R. (2018) WO2020058935A1 PROTECTION DEVICE FOR GUARDRAIL, <https://worldwide.espacenet.com/patent/search/family/064607099/publication/WO2020058935A1?q=pn%3DWO2020058935A1>

This is one of the few solutions that solves the problem of hitting the upper edge of the SSB post. That is why more attention has been dedicated to it.

The protection device (1) for guardrail, wherein the guardrail comprises: a longitudinal barrier (21) having an outer surface (21a) facing a lane and delimited at the top and at the bottom by flaps (31); a supporting element (22) which can be anchored to the ground and connectable to the barrier (21) on the opposite side of the outer surface (21a); a protective body (30) associable with the barrier (21) for covering at least one portion of the barrier (21) (Figure 3.24).

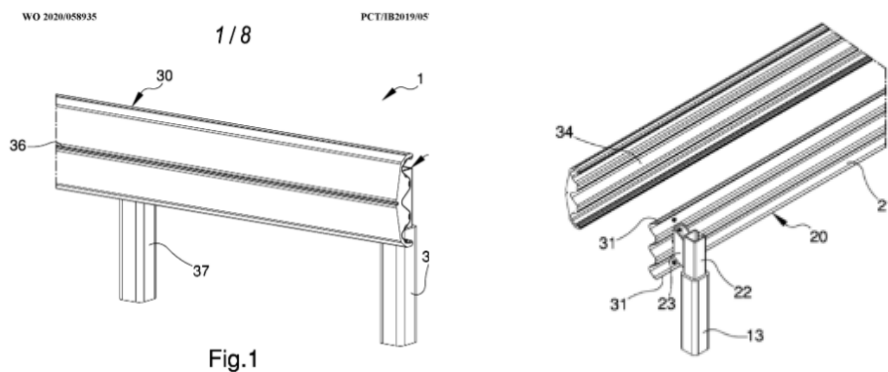


Figure 3.24 : An outer surface on basic guardrail

Within this aim, one object of the present invention is to provide safe protection for the parts of the guardrail without this requiring any structural change or alteration of the guardrail itself (Figure 3.24 and Figure 3.25).

Another object of the present invention is to provide a protection device for guardrails which is easy to fit and at the same time requires significantly lower production and fitting costs than known types of protective devices.

Another object of the present invention is to devise a protection device for guardrail that allows overcoming the aforementioned drawbacks of the prior art in a simple, rational, easy, effective to use and low cost solution.

The aforementioned objects are achieved by the present protection device for guardrail comprising at least one longitudinal barrier having an outer surface facing a carriageway and at least one supporting element which can be anchored to the ground and connectable to the barrier on the opposite side of the outer surface, characterized by the fact that it comprises contoured protection means which are adapted to cover at least partly at least the upper portion of the supporting element.

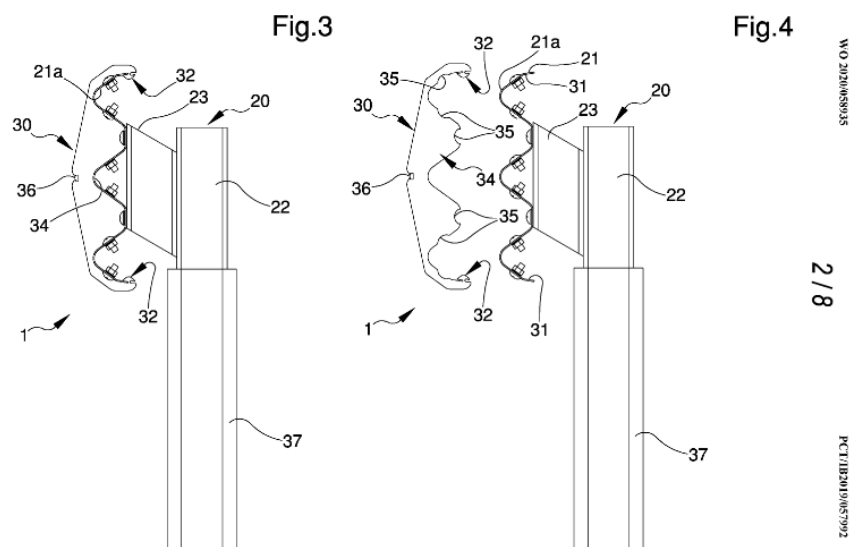


Figure 3.25 : Left: a side cross-sectional view of the device according to the invention applied to a guardrail; right: a partial exploded and side cross-sectional view of the device according to the invention applied to a guardrail

The outer surface 21 a is delimited at the top and at the bottom by flaps 31 (Figure 3.26).

The protective body 30 is usefully associated in adhesion with the barrier 21. Advantageously, the protective body 30 comprises polymeric material. This characteristic gives elastic properties to the protective body 30, useful both for cushioning impacts and for applying the protective body itself onto the barrier 21. In particular, the polymeric material comprises expanded polyurethane.

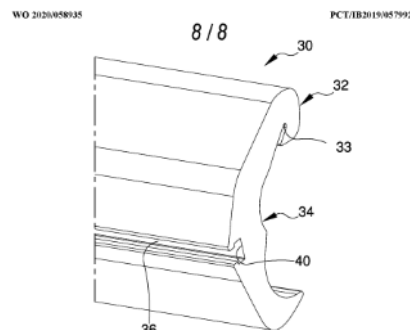


Fig.12

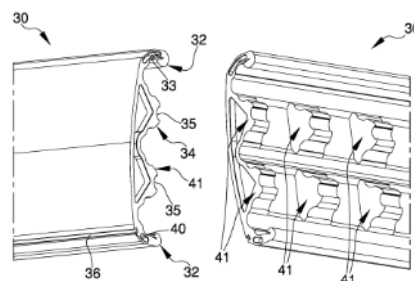


Fig.13

Figure 3.26 : The protective body

The patent application also includes a "cover" to protect the upper part of the SSB post, with or without a spacer (Figure 3.27).

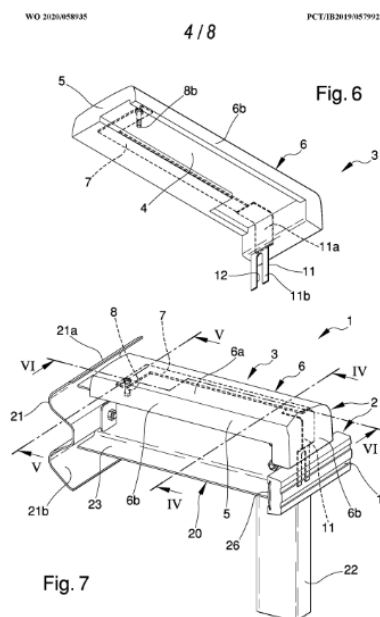


Fig. 7

Figure 3.27 : "Cover" for protection of the upper part of the SSB post

It is a shame that there is no more text written about this "cover" in the patent application (Figure 3.28).

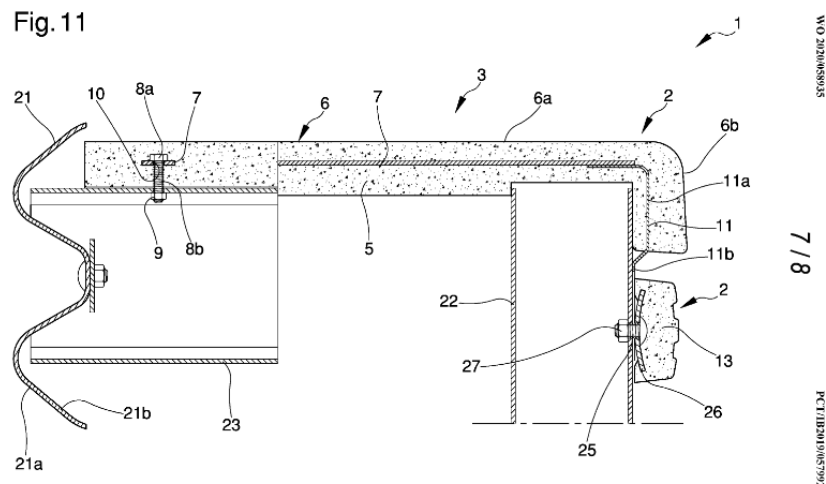


Figure 3.28 : "Cover" for protection of the upper part of the SSB post, with or without a spacer

Conclusions:

- This patent application is one of the few solutions that solves the problem of hitting the upper edge of the SSB post.
- The solution does not solve the problem of a motorcyclist hitting a SSB post, but that is not its purpose either.
- It is essentially a SSB guardrail cover, which also covers the upper and lower edges of the guardrail, with flaps.
- The guardrail cover is made of polymer material (expanded polyurethane).
- The outer side of the cover faces the road, and the inner side faces the guardrail, against which it is supported.
- The cover is installed on the guardrail only with flaps ("teeth") at the edges of the cover, without any screwing.
- It is intended to protect cyclists, pedestrians and motorcyclists.
- Installation is easy.
- The patent application also includes a "cover" to protect the upper part of the SSB post, with or without a spacer. This element is made of the same material as the guardrail cover (although it looks different in the pictures, we have to believe the patent applicant).
- One of the disadvantages is that a separate cover must be made for each type of guardrail (two-wall, three-wall, beta). But this is a problem with all kinds of additional protections.
- It can be assumed that the outer covering, in the event of a strong impact by a motorcyclist and with high friction, would easily come off.
- The connecting elements between the individual additional elements (covering) are also problematic.
- A metal element must be installed on the first lining (on the inside of the guardrail) to prevent the lining from coming off at the beginning.
- A bad solution in the case of winter road maintenance (plowing) as the plow can "scrape" the "coat".

- The applicant assures that the installation of the "coating" does not require additional SSB homologation, which is questionable, but possibly true.
- A poor solution insofar as the coatings are "cast" in the factory, which requires molds (for each type of guardrail separately).
- However, this is one of the few solutions that protects the upper edge of the guardrail and the upper edge of the SSB post.

3.1.3.3. Protection device on road safety barriers

Source [23]: Martinez G. E. (2007) ES2332553A1 Protection device on road safety barriers

<https://worldwide.espacenet.com/patent/search/family/041567131/publication/ES2332553A1?q=pn%3DES2332553A1>

This is one of the few solutions that solves the problem of hitting the upper edge of the SSB post. That is why more attention has been dedicated to it.

Protection device on road safety barriers that includes at least (Figure 3.29): a front part (1), in turn comprising a first outer wall (11) and a second inner wall (12); a back part (2); an upper part (3); a chamber (5), comprised between the first exterior wall (11) and the second interior wall (12) of the front part (1); and where the fence (4) is included in the space between the front (1), the back (2) and the top (3). All this in order to safeguard the problems derived from the direct impact of a human body on the fences on roads.

This device, in a first embodiment, is a system that takes account of the geometry of a fence and at the same time makes the clash with it as mild as possible, given the characteristics of the material. Its main purpose is to cover the space between the fence and the ground, covering the gap and the existing bionda. The entire holding post fence is covered and hidden. Leaving room for cleaning drains and the road.

In turn, the design can be C-shaped (convex curve) at the top and straight lengthwise, being the front convex, concave, straight, curved or shaped bionda where the back is straight.

These devices are designed for a better protection of motorcyclists in the case of a frontal or angular impact, by cushioning the blow, absorbing and, depending on the speed of impact, slowing down, absorbing the force, frontally or in lengthwise direction. Similarly, the design of the safety device allows the body to be guided along the line after braking.

The safety device is intrinsic to the design (Figure 3.29). It has three front walls that hold the impact and two air chambers in the middle, with an option for one more in the back, plus the space between the system. Also, the upper barrier rail and the post are covered. The material composition, dimensions and thicknesses thereof enable the impact to be absorbed leading to the collapse of the wall without any rupture.

The air chambers of the front wall are designed hollow, and can be optionally filled with one or more materials that make the damping functions.

The placement is done from top to bottom (Figure 3.30), being ready for use immediately and in a secure manner by clamping a flanged system. There is no need for the modification of the current SSB for the installation purpose. Optionally you could use different binding systems modules and sections that may or may not be used simultaneously.

The same applies to pins or other fastening systems. There are other designs as second embodiments, almost identical to the previous one, but with a particular feature that let cushion portion not come down from the top of the system, but it has a limited area to the bottom of the barrier. These designs are diversified in longitudinally continuous or crenellated types, covering areas in their high posts.

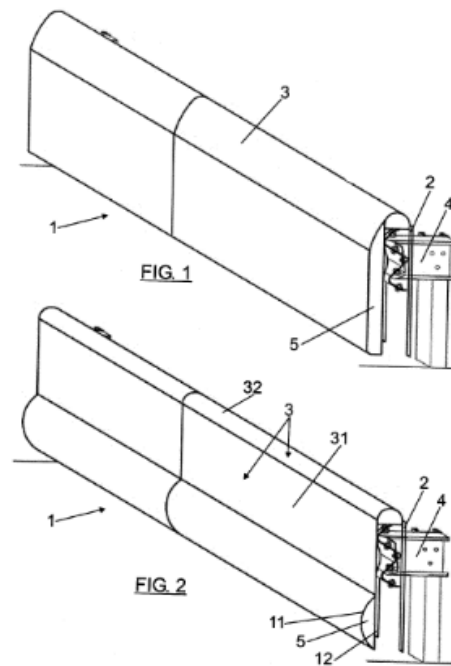


Figure 3.29 : Protection device on road safety barriers

There are different options at the bottom coverage, either in continuous mode or in the crenellated: concave curved, convex, bionda, straight (box), straight from above or curved, hollow or filled.

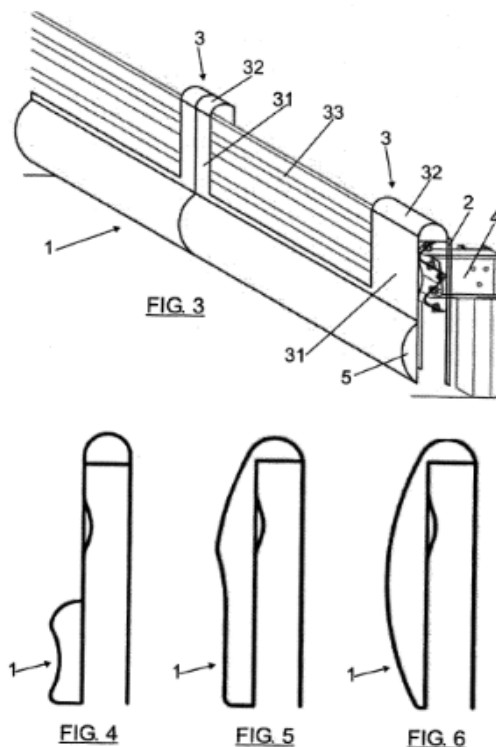


Figure 3.30 : Variations of the protection device on road safety barriers

Conclusions:

- This purpose of this device is also to protect the motorcyclist when leaning over the SSB guardrail.
- It is a protective device that is installed on the SSB and consists of a front part (comprising a first outer wall and a second inner wall), a rear part and an upper part.
- The existing SSB is covered with the proposed protective device.
- There is an air space between the first outer wall and the second inner wall of the front part of the protective device.
- The protective device does not interfere with the structural properties of the existing (already installed) SSB.
- The protective device is made of polymers and/or other recycled synthetic materials.
- The rear part of the protective device is less important because it is firmly connected to the guardrail post so it has no absorption function. Three possible solutions of an additional guardrail (bumper) are given. However, the upper part (which extends beyond the upper edge of the bumper) is important. The upper part is "C"-shaped, i.e. semicircular.
- However, this is a measure that can (according to the applicant) only be installed on the SSB on the motorway. It is not written why this is so.
- Nowhere is it stated exactly how these elements of the protective device are connected to each other longitudinally.
- The rear part of the protective device needs to be cut out where the spacer is.
- This solution does not allow snow to be plowed (between the SSB posts), nor grass to be mowed between the SSB posts or under the protection.
- Also, when plowing, the plow would tear all of this apart.
- This solution does not allow small animals to pass through.
- This solution is somewhat expensive.

3.1.3.4. Cover element for highway barriers or guardrails

Source [24]: Masinelli S. (2004) EP1484448A2 Cover element for highway barriers or guardrails:

<https://worldwide.espacenet.com/patent/search/family/033156360/publication/EP1484448A2?q=pn%3DEP1484448A2>

A cover element (1) for highway barriers or guardrails comprising (Figure 3.31): a first portion (10) that can be located on the front part (20) of a guardrail (2) facing the road (3) and having a height sufficient to cover the front part (20) of the guardrail (2) at least from the ground (4) to the maximum height of the guardrail (2) itself; a second portion (11), connected to the first portion (10), that can be located above the upper part (21) of the guardrail (2) and having a width sufficient to cover at least the entire width of the upper part (21) of the guardrail (2); means (12) for fixing the cover element (1) in position relative to the guardrail (2). The cover element (1) has a preset length, corresponding to at least one section of the guardrail (2), is manufactured in a partially shock-absorbent material (preferably rubber) and has, on the part opposite to the guardrail (2) and extending at least for the entire first portion (10) and the entire second portion (11), a continuous

outer surface without any sharp edges. One or more cover elements (1) joined together to form a cover module (8) for highway barriers or guardrails. A plurality of cover modules (8) can form a cover for highway barriers or guardrails.

The present invention relates to a cover element for highway barriers or guardrails. The present invention also relates to a cover module for highway barriers or guardrails comprising one or more of such cover elements, and also relates to a highway barrier or guardrail cover made from such elements or cover modules.

The aim of the present invention is to overcome the shortcomings described above by providing a cover element for highway barriers or guardrails which could be used to make cover modules or covers for motorway barriers or guardrails. These could be applied directly to the existing guardrails and thus reduce the hazard described previously.

A further aim of this invention is to provide a cover element for highway barriers and guardrails which has a simple structure and which is easy to apply following, in particular, a method described in this invention. A further aim of this invention is to provide a cover element for highway barriers or guardrails which could be manufactured, at least in part, with recycled material.

With reference to the accompanying figures, the cover element (1) for highway barriers or guardrails is made from material which is at least partially shock absorbent. The cover element (1) is made mainly from an elastic material, preferably rubber.

The cover element (1) has a preset length corresponding to at least one lengthways section of a guardrail (2) and comprises a first portion (10) and a second portion (11).

The first portion (10) can be located on the front part (20) of a guardrail (2) facing a roadway (3) and has a height sufficient to cover the front part (20) of the guardrail (2) at least from the ground (4) to the maximum height of the guardrail (2) itself.

The second portion (11) is connected to the first portion (10) and can be located over the upper part (21) of the guardrail (2) and has a width sufficient to cover at least the entire width of the upper part (21) of the guardrail.

Once applied, the cover element (1) has, on the part opposite the guardrail (2) and at least corresponding to the entire first portion (10) and the entire second portion (11), a continuous outer surface that is without sharp edges.

There are also fixing methods (12) for attaching the cover element (1) to the guardrail (2).

In this way, it is possible to cover the guardrail section with the cover element so that it does not present a cutting or serious injury hazard for a motorcyclist or cyclist who might collide with the guardrail for any reason.

For this purpose, the cover element also comprises a third portion (13), connected to the second portion (11), that can be located on the rear part (22) of the guardrail, opposite the roadway (3) and which has a height sufficient to cover the rear part (22) of the guardrail at least up to a preset distance of the maximum height of the guardrail itself. Preferably, the third portion (13) extends at least to the ground (4). Furthermore, the continuous outer surface without sharp edges of the cover element can be extended for the entire third portion (13). This maximises the protection offered to the body of any person who might collide with the section of guardrail covered by the covering element 1.

The fixing methods (12) can be of various types known to expert persons. The means can act between the body of the cover element and the parts of the guardrail, or between the body of the

cover element and the ground. It is of the greatest importance that they do not have sharp or protruding parts facing directly towards the roadway (3) and are not covered by the first and second portions (10, 11).

In this regard, a convenient feature of the first portion (10) comprises a contact flap (100) in contact with the ground (4) which is bent towards the guardrail when the cover element is applied to the guardrail. The most frequent fixing method (12) (for example, one or more pins, bolts or screws) includes connecting the flap (100) to the ground, whereby the bolts or pins are hidden from the roadway (3), behind the first part (10), as illustrated in figures. Furthermore, in this embodiment, the cover element is fixed to the ground without leaving any potentially hazardous cutting edges at the level of the ground.

A matching flap (130) can be provided on the third portion (13) in the case where the third portion is extended to the ground. In this case, however, it will not be necessary to fold the flap towards the guardrail when the cover element is applied to the guardrail itself. A further advantage here is that the matching flap (130) is folded away from the guardrail (in other words, folded in the same way as flap (100)) in order to facilitate the fixing of the third part (13) to the ground.

In a preferred embodiment of the invention, the cover element comprises at least one flexible sheet (14) of elastic material (preferably rubber) that is bent over the guardrail so as to define at least the first and second portions (10, 11) of the cover element. In this case, the flap (100) can be obtained by directly folding the sheet (14) along its edge on the part corresponding to the first portion (10).

In order to fulfill this purpose, the sheet (14), once it has been bent over the guardrail, has a height sufficient to extend over the rear part (22) of the guardrail at least to a distance determined by the maximum height of the guardrail. Preferably, the sheet (14) should extend so that it at least touches the ground on both sides of the guardrail. In this way, the sheet (14) defines the first and second portions (10 and 11) and at the same time the third portion (13) of the cover element 1.

The sheet (14) can be a solid, single layer material or, preferably, it can be a material with a layered structure. With reference to figures, the sheet material comprises at least a first and second layer (140, 141) firmly joined together. The primary purpose of the first layer (140) is to give the cover element a continuous outer surface without any sharp edges, thereby making this characteristic substantially independent of the structure of the second layer (141).

Preferably, the second layer (141) includes a composite layer. In particular, the second layer comprises first strips (142) of an elastic material which are parallel and substantially adjacent to each other and which are of a preset thickness and width. Furthermore, the first strips (142) are made from material taken from used motor vehicle tyres (5). In particular, as illustrated also in the figure, the first strips are made from a portion of tread (50) of used tyres (5), removed from the tyres (5) and laid flat. The portion of tread (50) includes at least part of the reinforcing fabric thus advantageously giving the sheet (14) a particular mechanical resistance. The portions of tread (50) used for the first strips (142) are removed from radial tyres (5). The first strips (142) obtained in this way have a very limited curvature across their lengthways extension so that once they are laid flat, practically their entire width can be used without creating any flatness problems to the second layer (141) or as a consequence to the sheet (14). Using worn tyres (5) requiring recycling is particularly advantageous. Used tyres (5) are produced in enormous quantities given the large number of motor vehicles in circulation. The recycling of used tyres, in the absence of partial recycling solutions such as the one proposed in the present invention, is a serious and costly problem. The basic material for making the first strips (142) is therefore in plentiful supply, easy to obtain and economical.

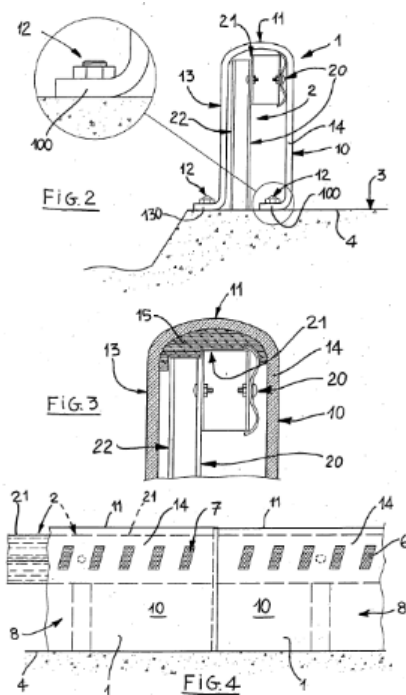


Figure 3.31 : Cover element for highway barriers or guardrails - a side view and partial cross-section of the cover element according to the invention, applied to the guardrail with a detail view for the ground fixing

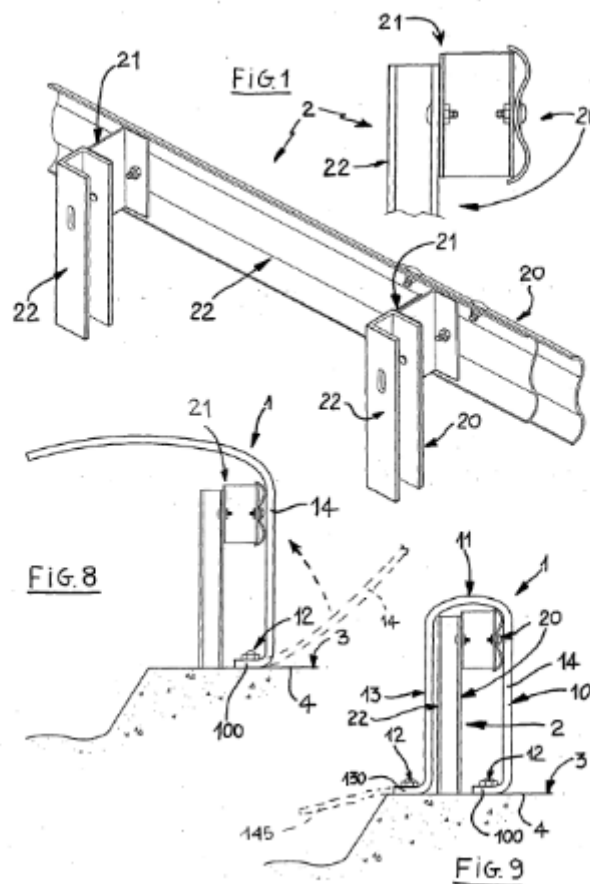


Figure 3.32 : Installation process

Conclusions:

- More focus is placed on this patent application for several reasons.
- The first reason being that it is one of the rare examples of patent applications that actually provides protection for the guardrail and the upper edge of the SSB post. The second reason is that it is an "ecological story" or how to get rid of worn tires.
- The third reason is that the proposed solution is very realistic or feasible.
- The element is made in two layers, from two different materials: the first layer is made of a material that partially absorbs shocks (e.g., recycled rubber or worn tires), and the second one is made of composite materials.
- However, the proposed solution also has many shortcomings:
- The patent author does not take into account that the tires are round (semicircular), and the figures present the tires as flat. So, if we want to make a flat shape from a semicircular shape, we obviously have to heat these tire pieces first to flatten them, which leads to more costs!
- It is intended for screwing into reinforced concrete (e.g., on bridge structures - bridges and viaducts), but not for the case when SSB columns are driven into the ground.
- Installing the cover element is very complicated: first you have to screw the screw on the inside of the SSB (under the guardrail) and then on the back side.
- There is no explanation on how the elements are longitudinally connected with each other.
- There is an error in the text: The fasteners (12) are not intended for attaching the cover element to the SSB (2), but to the ground (4)!
- The solution is useless during winter maintenance, because the plow will remove the cover.

3.1.3.5. METHOD FOR MAKING A PROTECTIVE DEVICE FOR GUARDRAILS, AND A PROTECTIVE DEVICE FOR GUARDRAILS

Source[25]: Masinelli G., Roberto P., Italia (2004), US2006083588A1 Method for making a protective device for guardrails, and a protective device for guardrails: <https://worldwide.espacenet.com/patent/search/family/035695861/publication/US2006083588A1?q=pn%3DUS2006083588A1>

Patent US2006083588A1 is another solution that solves the problem of hitting the upper edge of the SSB post, named as the "method for making a protective device for guardrails, and a protective device for guardrails" (Figure 3.33).

The protective device comprises at least one flexible sheet, which can be wrapped between two zones of a guardrail. In particular, the first zone of a guardrail around which the flexible sheet is wrapped is at least one portion of the longitudinal rail of a guardrail. The second zone around which the flexible sheet is wrapped is at least one portion of a lower longitudinal element located between at least two guardrail uprights. It should be noted that the term longitudinal rail of a guardrail refers to the bumper or buffer zone of the guardrail, positioned at a predetermined height from the ground, normally coinciding with the height of the center of gravity of the most common models of cars and supported by the uprights.

The term lower longitudinal element refers to an element which extends substantially parallel with the guardrail rail, extending at a height from the ground lower than that of the longitudinal rail and which is integral with at least two guardrail uprights.

Said lower longitudinal element is normally part of the guardrail structure and is called an anti-intrusion element. In this case, the flexible sheet may be wrapped around said anti-intrusion element.

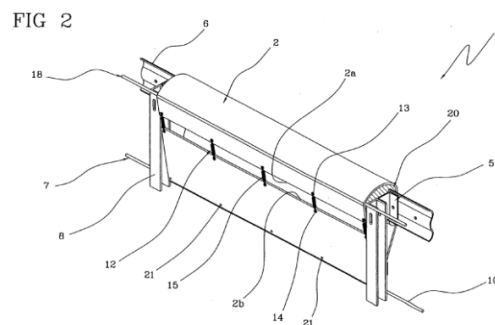


Figure 3.33 : Method for making a protective device for guardrails, and a protective device for guardrails'' according to E01F15/0423

Advantageously, if the anti-intrusion element is not present or is positioned at an unsuitable height, the device comprises at least one first rod-shaped element, which can be firmly bound to at least two uprights on the guardrail at a predetermined height, other than zero, from the ground. In any event, the height of the rod-shaped element must be such that it prevents a person of medium build from slipping between the rod-shaped element and the ground after falling from his vehicle. In particular, the rod-shaped element is bound to the uprights at a height of 20 mm to 200 mm from the ground, preferably 50 mm (Figure 3.34).

The device enables adjustable tension loads operating on the flexible sheet to adjust the tension of the flexible sheet wrapped around the guardrail.

FIG 4

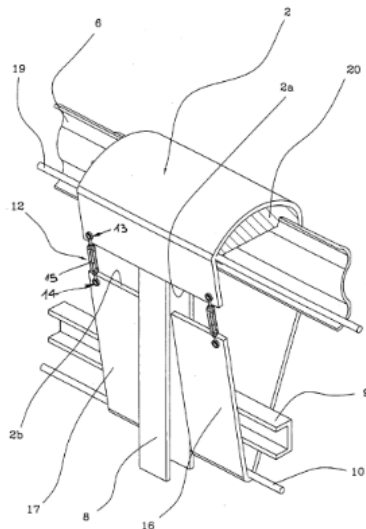


FIG 3

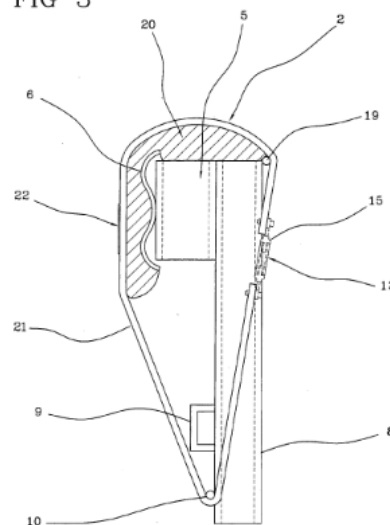


Figure 3.34 : Method for making a protective device for guardrails, and a protective device for guardrails; according to E01F15/0423

Conclusion:

- This solution is very complicated (requires a lot of fieldwork).
- It also requires additional elements to be installed on the SSB (since these are steel - rigid elements, they certainly change the properties of the SSB).
- All in all, this solution is probably quite expensive.

3.1.3.6. PROTECTIVE ELEMENTS FOR METALLIC GUARD-RAILS IN ROADS

Source [26]: Garcia B. A., Spain (1997), EP0780518A1 Protective elements for metallic guard-rails in roads:

<https://worldwide.espacenet.com/patent/search/family/027240534/publication/EP0780518A1?q=pn%3DEP0780518A1>

Patent EP0780518A1 is another solution that solves the problem of hitting the upper edge of the SSB post, named “protective elements for metallic guard-rails in roads” (Figure 3.35).

The invention refers to a series of protective elements made of flexible material used to cover the cutting edges of the metallic parts which constitute the metallic guard-rails found in roads, including both the rail itself as well as the vertical posts, with the object of reducing the severity of the injuries which a motorcyclist could suffer upon impact against the SSB.

This idea consisting of lateral protective elements (which cover the lower section of the post, i.e. the vertical section which protrudes in relation to the rail), and of a protective element at the head, or protective cap (configured by two half-pieces which fit with each other and over the upper part of the vertical section which protrudes from the rail).

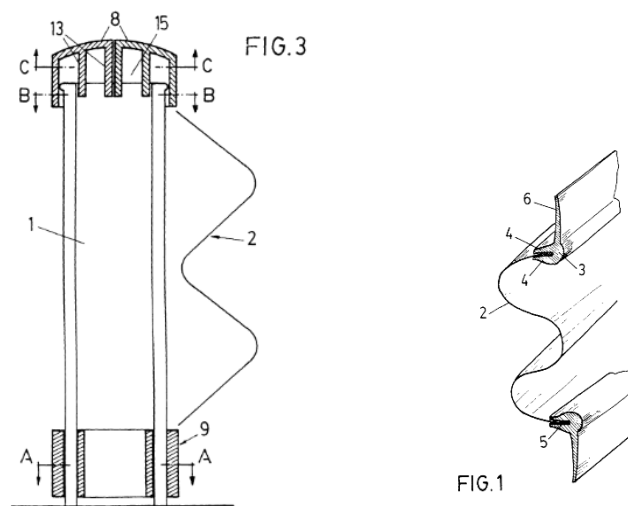


Figure 3.35 : Protective elements for metallic guard-rails in roads, according to EP0780518A1

These elements are made of a soft material, obtained preferably from the recycling of tires, and they adapt to the configuration of the guardrails, with the object absorbing the shock from possible impacts and reducing the consequences of an undesired collision. This device is also comprised by a wing-like extension (Figure 3.35 - right) which projects from the head section and upon which it is possible to attach road-marking equipment.

This idea is a little bit expensive, as it consists of additional lateral protective elements (which cover the lower section of the post).

It is not clear from the pictures (it is not drawn) how additional (wing-like) elements are installed on the SSB posts.

A good feature of this solution is its "ecological story", as it involves the use of worn-out tires.

3.1.3.7. Protection of the upper edge of the SSB with perforated sheet

The project team has also found photographs of the protection of the upper edge of the steel safety barrier, taken during a crash test with a passenger car. Unfortunately, additional data was not available. Based on the photographs, however, we can conclude the following can be concluded.:

- This application is one of the few solutions that solves the problem of impact with the upper edge of the SSB post, as well as the motorcyclist's collision under the barrier into the SSB post.
- Protection against motorcyclist impact with the upper edge of the SSB barrier and the SSB post is implemented using two separate safety elements.
- The protection is made of perforated steel sheet, curved with a radius so that it protects the upper edge of the SSB barrier and extends over the upper rear edge of the post. This effectively prevents contact and impact of the motorcyclist with the upper edge of the barrier and the post.
- The perforated protection behaves very rigidly, as seen in the photographs, being made of thicker sheet metal, which results in poor absorption of the motorcyclist's impact.
- The perforated protection is installed behind the SSB barrier; during a motorcyclist's impact, the protection deforms or shifts away from the barrier, creating a gap between the upper edge of the barrier and the perforated protection. This gap can cause injury if the motorcyclist gets caught in it.
- The perforated sheet with sharp edges can also cause injuries to the motorcyclist when sliding over it, and parts of the motorcyclist's body or equipment may get caught in the perforated holes.
- The longitudinal interconnection of the perforated protection is poorly executed, as the additional element with sharp edges also presents a hazardous area.

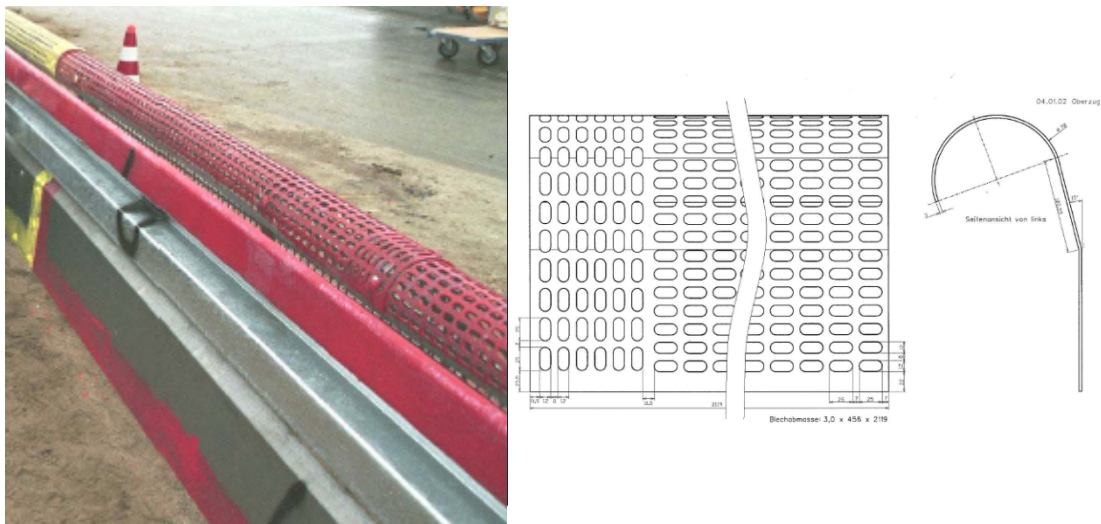


Figure 3.36 : 3.1.3.7. Protection of the upper edge of the SSB with perforated sheet

3.1.3.8. Protection element for motorcyclists on SSB

Source [27]: Unavailable because it is in the patent application phase.

Recorded: P202500009 2025-2-12, Tollazzi T., Kunc R., Slovenia (2025)

The task of the invention is therefore to design a SSB or an additional element that will reduce the severity of surface injuries and injuries to the motorcyclist's internal organs if the motorcyclist's body leans over the upper sharp edge of the SSB guardrail.

The invention provides protection for the motorcyclist against a) a collision with the upper sharp edge of the guardrail and b) a collision with the upper edge of the SSB post.

The invention is based on the idea of protecting the upper edge of the guardrail (crash barrier beam) of a steel safety barrier (SSB) and the upper edge of the SSB post by installing one or more protective elements along its length or in certain more exposed road sections, which would provide a greater chance of survival for a motorcyclist if the body were to lean or "break" over the SSB guardrail or its upper sharp edge.

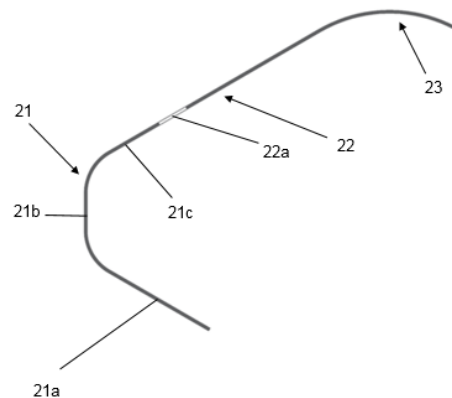


Figure 3.37 : Motorcycle protection element

The motorcyclist protection element contains (Figure 3.37):

- a first part, adapted for attaching the motorcyclist protection element to the SSB guardrail, wherein the first part has a convex shape that matches the shape of the upper convex part of the SSB guardrail, and wherein the first part for attaching the motorcyclist protection element to the SSB guardrail may have two oval openings on each side at locations and mutual distances adapted to coincide with the locations of screws on the guardrail through which a screw can be inserted for attachment to the existing SSB guardrail, whereby an already existing screw connection is used by which the SSB guardrails are interconnected,
- a second part, which continues obliquely from the upper part of the first part and has such length that it extends beyond the SSB post to which the guardrail is attached, whereby the second part may be equipped with at least one opening through which two elements for protecting a motorcyclist are interconnected by means of a screw or rivet connection,
- a third part, which is rounded and curved downwards to provide additional protection for a motorcyclist when leaning over the guardrail and the SSB post, as it covers any protruding or sharp parts of a SSB,

- optionally a fourth part (Figure 3.38), which continues from the lower part of the first part and is shaped to match the shape of the SSB guardrail, and equipped with an opening adapted to receive a mounting screw, so that the protective element can be attached to the guardrail even in places where reflectors are installed.

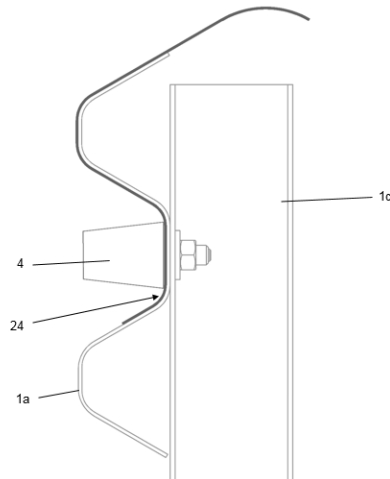


Figure 3.38 : Cross-section of the second option of the motorcyclist protection element

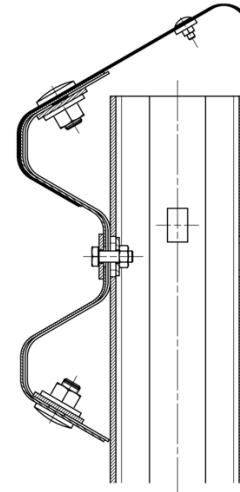


Figure 3.39 : A way of attachment

In the event of a collision, the upper part of the element also bends over the upper edge of the SSB post, thus preventing a motorcyclist from coming into contact with the upper edge of the guardrail and the SSB post, and reducing the possibility of injuries, or at least severity thereof.

The protective element can be attached (Figure 3.39):

- with the existing screws to connect two guardrails,
- with additional rivets (this requires drilling at the installation site).

In the case where the motorcyclist protection element has a fourth part, the attachment of the protection element can be carried out:

- with the existing screws for connecting two guardrails,
- with additional rivets (drilling is required at the installation site),
- with the existing screws for connecting the guardrail to the support post,
- with screws for attaching the reflector.

After testing a large number of materials, galvanized steel sheet proved most suitable, both from the point of view of the above characteristics and the existing production lines of SSD guardrails. The minimum thickness of galvanized steel sheet is 0.5 mm, the preferred thickness is in the range between 0.5 and 3 mm, and even more preferably, the thickness is either of the following: 1, 1.5, 2, 2.5 and 3 mm.

The additional element is mounted very quickly and easily onto the existing guardrail. The existing bolts are used to mount the additional element (the bolts that attach the base guardrail to the SSB post). The additional element is made of galvanized steel sheet. The solution is also cost-effective.

Conclusions: Since the patent applicants are also collaborators on this project or the main leaders, it is best to avoid drawing any conclusions [28].

3.1.3.9. Flexible cable barriers ("rope barriers")

One type of steel safety barriers are flexible cable barriers ("rope barriers").

Flexible cable barriers (Figure 3.40) are designed to allow even higher deflection than steel safety barriers (semi-rigid barriers).



Figure 3.40 : Flexible cable barrier - "rope barrier"; Sweden

Consequently, a flexible barrier allows energy dissipation mainly through deflection of the system. Cable barriers and weak post W beam guardrail systems are examples of flexible barriers. While a weak post guardrail poses the concern of impacting the rails as noted previously, cable barriers also pose a concern for impacting the thin cables. Decapitations and amputations have been reported in the literature related to extreme speeds and cable barriers in Australia and New Zealand, but the same study also identified decapitations and amputations based on guardrail impacts.

Cable barriers are provided with continuous rope-wire elements acting as a beam to contain motor vehicles. However, these rope-wires are perceived to induce a "cheese-cutter" effect on motorcyclists when impacting such barriers. The contact area with a motorcyclist would be concentrated in the small wire diameters upon impact. Although the wire-rope barriers are provided with continuous cables, they have a large portion of the posts exposed to the motorcyclist in case of an impact event. This can again result in discrete post impact resulting in fatalities. Furthermore, the supports on which the ropes are suspended pose a great danger to motorcyclists in the event of a collision.

Despite great efforts, no solution was found that would improve motorcyclist safety in the event of a collision with this barrier.

3.1.3.10. Example of simulated motorcyclist impact with a concrete barrier

Potential innovations in concrete safety barriers were analyzed, noting that steel barriers are standard in Europe, while the U.S. situation differs. In 2021, The Federal Highway Administration issued a synthesis report on barrier design for motorcyclist safety, which reviews new and retrofit barrier systems aimed at improving motorcyclist safety, highlights research gaps—especially the lack of U.S. testing standards—and summarizes key testing parameters for future studies [29].

The report covers topics such as motorcycle safety considerations, barrier types (rigid, semi-rigid, flexible, and signposts), performance evaluations, and future research needs. It is a comprehensive and high-quality resource.

Crash statistics show that motorcyclists, though only 3% of registered vehicles and 0.6% of vehicle miles travelled, account for over 14% of U.S. road fatalities. In 2017, 5,172 motorcyclists were killed, as motorcyclists are 37 times more likely to die per mile travelled than car occupants. While overall motorist fatalities have decreased, motorcyclist fatalities have doubled over two decades, indicating that their safety has been overlooked.

Barriers are intended to improve roadside safety but can also pose greater risks to motorcyclists—fatality risk is much higher for them than for car occupants. Studies show that guardrails and sign supports are among the most harmful crash events for motorcyclists, and in the U.S., motorcycle-guardrail crashes result in more fatalities than any other vehicle-guardrail crash. Common barriers (concrete, guardrails, cables, signposts) are designed for general safety but may introduce new risks for motorcyclists, highlighting the need for targeted research and improved standards.

Motorcyclists also suffer a high rate of incapacitating injuries in barrier-related crashes. U.S. studies show that such crashes resulted in serious injury or death in 32% of cases in Washington State, 57% in Ohio, and an average of 37% across North Carolina, Texas, and New Jersey. Clearly, barrier impacts can be lethal, and barrier type plays a key role.

A study by Daniello and Gabler analysed 951 motorcycle-barrier crashes across three states: 38% involved rigid (concrete) barriers, 57% semi-rigid (guardrails), and 5% flexible (cable). Fatality rates were similar across types—around 36–40%. However, helmeted riders were 1.4 times more likely to suffer severe injury in guardrail crashes compared to concrete barriers. No significant difference was found between guardrails and cable barriers.

Each barrier type has pros and cons. Concrete barriers are costly but low-maintenance; crashes often result in riders being ejected. Guardrails are most common and involve both sliding and upright impacts. Cable barriers and signposts typically result in head-on collisions. The report distinguishes cable barriers from discrete posts due to concerns in the motorcycle community that cable barriers pose more than just post-related risks.

Researchers are working with TxDOT engineers (Texas Department of Transportation) to develop computer simulation plans that include proposed nominal impact conditions (e.g., speed and angle), critical impact points, and Anthropomorphic Test Device (ATD) containment and redirection. This is important since U.S. standards for motorcycle testing do not exist. A chain link fence system was preferred over other options since it was more economical with good availability as well as easier to install and maintain. Seven pendulum tests were performed and determined a 2x2 chain link mesh size, and top and bottom steel horizontal rails with discrete steel connections spaced. The simulation used a 32 inches (813 mm) high concrete barrier installation that was rigidly installed and had a radius of curvature of 500 feet (152 mm). A retrofit U-shaped post design minimized the likelihood of an errant upright motorcycle rider directly impacting the discrete posts of the chain link fence system. The simulation showed no interaction between the ATD and the retrofitted U-shaped post. The U-shaped off-set posts were designed with the distance from the barriers similar

to the distance a road sign would be if attached to the concrete barrier. See Figure 3.41 and Figure 3.42 for the design.

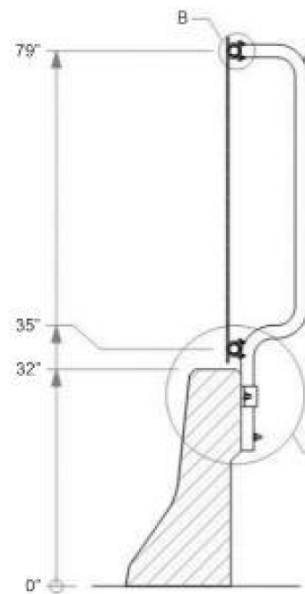


Figure 3.41 : Design of retrofitted u-shape post with barrier



Figure 3.42 : Tested retrofitted design on the test site

The photos presented in Figure 3.43 show a motorcycle test conducted at TTI's testing facility. The figure shows that the motorcyclist does not come in contact with the posts, which was a concern of which the engineers and researchers were mindful. The retrofitted U-Shaped Post and mesh fence containment system was considered suitable for implantation at locations where an upright motorcycle rider containment option is needed and/or desired. MASH TL-3 compliance testing is still needed to evaluate the structural integrity of the system, occupant risk, and vehicle deformation.



Figure 3.43 : Motorcycle and dummy impacting the concrete and chain fence barrier during the crash test; Source: Texas A&M Transportation Institute

3.2. SAFETY ASPECTS OF MANAGEMENT OF TRAFFIC FOR MOTORCYCLES

Motorcyclists in most parts of the world, especially in European countries, have certain "indulgences" or "privileges":

- motorcyclists are usually the first to board and disembark the ferry,
- in a queue for a ferry or car-train, motorcyclists can usually pass waiting vehicles,
- the police usually tolerate motorcyclists parking on the "hatched" ("shevroned") areas on the road,
- in many countries, motorcyclists have free parking on specially marked parking places,
- the police tolerate if motorcyclists, in the event of hail or heavy rain, stop under a motorway overpass, mark their motorcycles and wait below the overpass, on the other side of the safety barrier,
- the police tolerate if motorcyclists, in the event of hail or heavy rain, stop at a bus station and wait (or change into rain suits) in the bus shelter,
- the police generally tolerate if motorcyclists stop at an interesting traffic sign to take photos, etc.

Motorcyclists are therefore not treated the same as other motorized road users. The same applies to certain traffic rules and some traffic regulations. Within the framework of Traffic Management for Motorcycles, an in-depth investigation of the following measures will be conducted:

- Dedicated Motorcycle Lanes (DMLs),
- Lane Splitting,
- Filtering,
- Advanced Stop Lines (ASLs) and
- Lane Sharing.

3.2.1. Dedicated Motorcycle Lanes (DMLs)

Dedicated motorcycle lanes (DML) are traffic lanes on which only PTWs are permitted. These solutions are not known in Europe, but they are very widespread in Asia (Malaysia, Taiwan, Indonesia, Vietnam, etc.) and other developing countries. According to one research, they are also well known in India, Thailand, Sri-Lanka, and Philippines as well as in China [30] [31].

There are two types of such lanes: Inclusive (non-exclusive) (IMCL) and Exclusive Motorcycle Lanes (EMCL).

Inclusive motorcycle lanes are installed on the existing roads and are usually located on the outside of the main carriageway for each direction of traffic flow (Figure 3.44). Motorcycle lanes may be separated from the rest of the carriageway by painted lines or physical barriers. At intersections, Inclusive Motorcycle Lanes re-connect with the main carriageway and crashes can occur.



Figure 3.44 : A non-exclusive motorcycle lane in Malaysia, Source: Malaysian Institute of Road Safety (MIROS)

Exclusive motorcycle lanes (Figure 3.45) require a carriageway completely separate from that used by other motorized vehicles. Exclusive motorcycle lanes minimise crashes between motorcycles and other road users at intersections.



Figure 3.45 : Exclusive motorcycle lane

Benefits of dedicated motorcycle lanes are:

- separates motorcyclists thereby preventing interaction and potential conflict with larger, heavier vehicles,

- reduced vehicle to motorcycle crashes,
- can improve traffic flow if well designed.

First, we need to understand what they are intended for and why Exclusive Motorcycle Lanes are carried out. In developing countries, the traffic conditions are highly heterogeneous. The roads are full of a wide variety of vehicles such as cars, motorized two-wheelers, motorized three-wheelers, heavy vehicles, light commercial vehicles, buses, and non-motorized vehicles, etc.. In South-Asian countries, the share of motorcycles in the total road traffic is high compared to other modes of road transportation.

There are many reasons for this high share: it is a cheap mode of transport compared to other modes, provides door-to-door connectivity, it is small in size, and has high manoeuvrability. In developing countries such as Malaysia and India, the share of motorcycles in total registered vehicles is very high, i.e. 47% and 73.8%, respectively.

A high percentage of motorcycle (motorized two-wheeler) traffic also increases the probability of a motorcycle being involved as one of the users in a road crash. In India, 35.2% of road crashes were reported involving motorcycles as one of the road users, whereas in Malaysia, this number was 60%. On the other hand, this share is 76% and 70% in Thailand and Indonesia, respectively. Motorcycle crashes are a major problem in Asian countries.

Among all the strategies, segregation of motorcycles from the main traffic by providing an Exclusive Motorcycle Lane (EMCL) has proven to be most beneficial. In brief, EMCL is a separate lane dedicated to motorcyclists, isolating them from all other traffic mixes and reducing the conflicts between a motorcycle and other road users under heterogeneous complexities [32]. The exclusive lanes provide safe (14% lower injury likelihood) and fast movement (increased travel speed approximately by 10 km/h) to motorcycle riders and reduce motorcycle crashes with other road users [32]. EMCLs are constructed with the objective of providing mobility and security to motorcyclists. Although, no specific standard geometrical design considerations have been reported in the literature for such lanes [33].

A code for Malaysian roads named The “Geometric Guidelines for Exclusive Motorcycle Lanes” is, however, an exception and first of its kind guidelines. Moreover, Malaysia proposes dedicated motorcycle lanes on all roads to halve road deaths by 2030 [34].

The concept of providing exclusive lanes for a particular vehicle category is well known. The first type of exclusive lane was established as a bicycle lane in the year 1885. Later, in 1940, an exclusive bus lane was developed in Chicago, USA. The first EMCL was constructed in Malaysia along federal highway 2(F02) in the early 1970s. Despite EMCL being established in 1970, it is still not very popular in developed countries. One of the primary reasons for this is a low share of motorcycles in the road traffic compared to Asian countries. As per the World Road Statistics, the percentage of passenger cars is higher in developed countries compared to developing countries. In contrast, developing countries are leading in the number of motorcycles per 1,000 inhabitants.

The separate motorcycle lanes can be designed as inclusive (shared) as well as exclusive lanes. Inclusive or shared lanes are separated by painted markings or shading on the road, and they can be shared with other motor vehicles during peak hours. On the other hand, exclusive lanes are physically separated or isolated from main traffic streams to restrict the entry of other motor vehicles in the motorcycle lane during peak and off-peak hours. Such lanes help reduce conflicts with other motor vehicles and improve motorcyclists’ safety [35].

Geometric design elements of exclusive motorcycle lanes are of high importance.

The geometric elements of a road, such as cross-section elements, sight distances, horizontal and vertical alignment, lateral and vertical clearances, etc., are essential factors for the economical and safe design of the road. In all the cross-sectional elements of the road, lane width (Figure 3.46) is one of the important elements, which is computed based on the vehicle width and minimum side clearance provided for safety. In the road design process, lane width has to be designed first, and it should be designed in a way that makes it comfortable for the road users as well as economical [36].

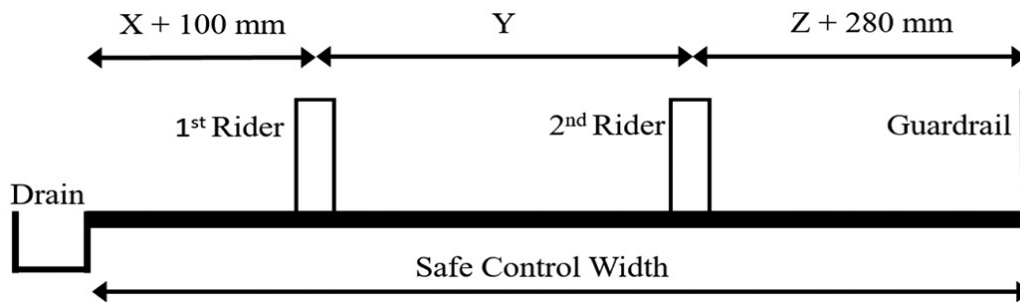


Figure 3.46 : Comfortable two-lane exclusive motorcycle lane [36]

It seems that inclusive motorcycle lanes also have their drawbacks. Although in some countries city authorities make great efforts to improve motorcyclists' traffic safety, in some cases, they simply do not comply with the regulations that apply to inclusive motorcycle lanes (Figure 3.47). [37]



Figure 3.47 : Inclusive motorcycle lane ignored by motorists, Jakarta

On the other hand, there are also countries that are satisfied with Inclusive Motorcycle Lanes (Figure 3.48, Figure 3.49), even though they do not place them on the side of the carriageway (which is safer).



Figure 3.48 : Inclusive motorcycle lane; Manila, Philippines



Figure 3.49 : Inclusive motorcycle lane; Brazil

The following videos are recommended to watch for a better understanding of this solution:

- [Exclusive Motorcycle Lane Guidelines | Motoring Forum - YouTube](#)
- [The Dangers of the Federal Highway Bike Lane in Malaysia - YouTube](#)
- [DOTr mulls dedicated lane for motorcycles in EDSA | ANC - YouTube](#)

3.2.2. Lane splitting

Traffic jams on highways and motorways most often occur during the summer tourist season, when highways and motorways, in addition to local traffic, are further burdened with transit traffic. The summer tourist season is closely linked to high temperatures, which have a tiring effect on PTW riders, and fatigue is closely related to traffic safety.

For safety, a motorcyclist wears a long-sleeved jacket, long pants, gloves, boots, and a helmet, and sits above a hot engine. As a result, PTW riders get tired more quickly while driving. The greater the motorcyclist's fatigue, the lower the level of his/her safety.

Although modern summer motorcycle clothing is light and breathable, it loses its properties if a motorcyclist is standing still. After an hour of waiting in traffic, a motorcyclist will be tired and

stressed, so his level of road safety will certainly be much lower than if he/she were riding the entire time, even at a slow speed.

To avoid subjective reporting, detailed results of the analysis conducted by FEMA in 2022 are provided below. It should be noted that the basic data is from 2022, so the situation regarding 'lane splitting' may be (already) different in some countries (Table 1, Figure 3.50).

Accordingly, with the help of ETSC representatives in some countries, the table has been updated to reflect the situation as of March 2025.

Table 1: The status of 'lane splitting' in EU countries and some other countries

Country	Lane splitting
Austria	YES
Belgium	YES
Bulgaria	NO DATA
Croatia	NO
Cyprus	YES
Czech Republic	NO
Denmark	NO
Estonia	NO DATA
Finland	NO
France	YES
Germany	NO
Greece	NO
Hungary	YES
Iceland	NO
Ireland	YES
Italy	NO
Latvia	NO DATA
Liechtenstein	NO DATA
Luxembourg	NO DATA
Malta	NO DATA
Netherlands	YES
Norway	YES
Poland	NO
Portugal	YES
Romania	Presumably NO (very poorly written)
Serbia	NO
Slovenia	NO
Slovakia	YES
Spain	YES
Sweden	YES
Switzerland	NO
Turkey	YES
United Kingdom	YES

Note: The table has been updated with information obtained by the project developers through surveys of ETSC representatives in some countries.

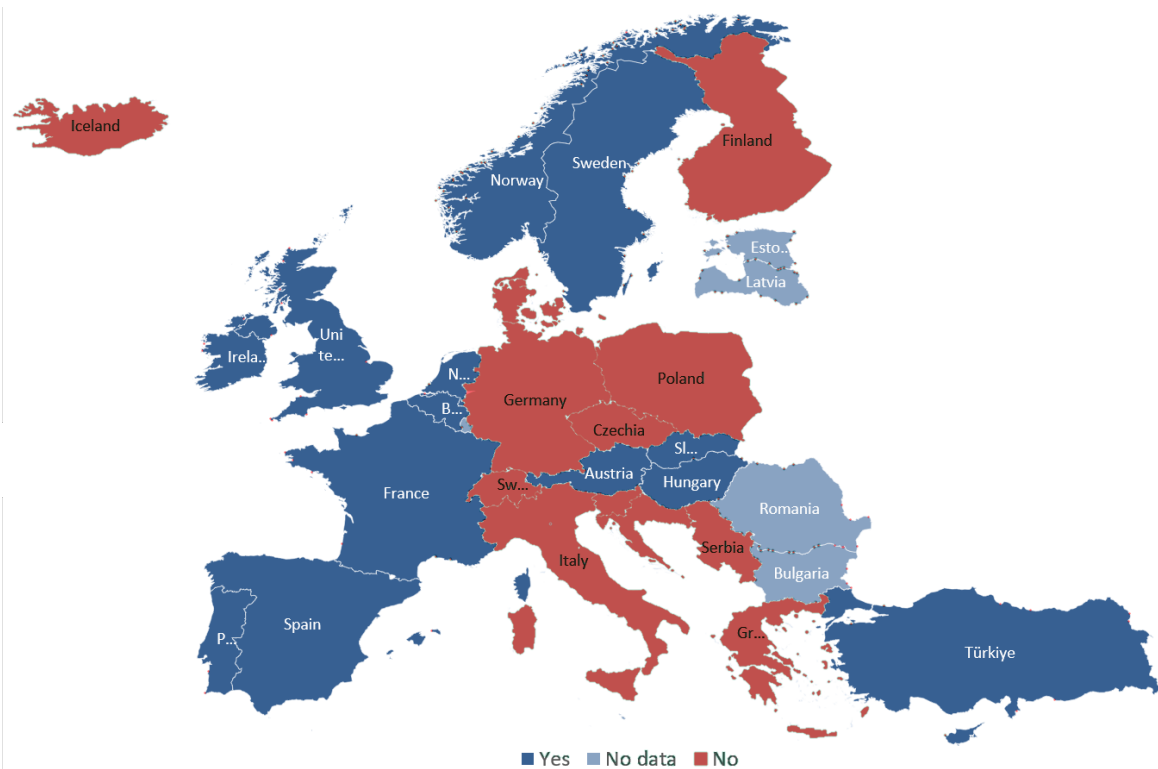


Figure 3.50 : Status of 'lane splitting' in EU countries

Provided here are examples of how 'lane splitting' is legally defined in some European countries (Figure 3.50). [40][41]

The **Belgian** 'Traffic Rules Act' is very precise regarding the 'lane splitting' (free translation):

- Motorcyclists must ride between the two lanes furthest to the left. When riding between two rows of cars, motorcycles must not exceed 50 km/h, and the difference between their speed and that of the cars they are passing must not exceed 20 km/h.
- In Belgium, starting from September 1, 2026, riders of single-track motor vehicles will be allowed to overtake other vehicles on the 'emergency lane' on roads with at least two lanes in the same direction.

The situation is almost identical in the **Netherlands** (Figure 3.52). The regulations state that this traffic maneuver is allowed, but only under the following conditions:

- A motorcyclist is allowed to ride between two lanes of vehicles. The speed difference between the motorcyclist and other vehicles must not exceed 10 km/h.
- Motorcyclists must use the space between the two leftmost lanes for such traffic maneuvers.
- When they need to merge back into one of the traffic lanes, they must indicate this with their turn signals.
- Their automobile and motorcycle association goes even further with the interpretation and statess: Turning on all four turn signals can be useful when approaching a traffic jam to alert other road users of your presence. However, when riding between two lanes, the four turn signals must be turned off.

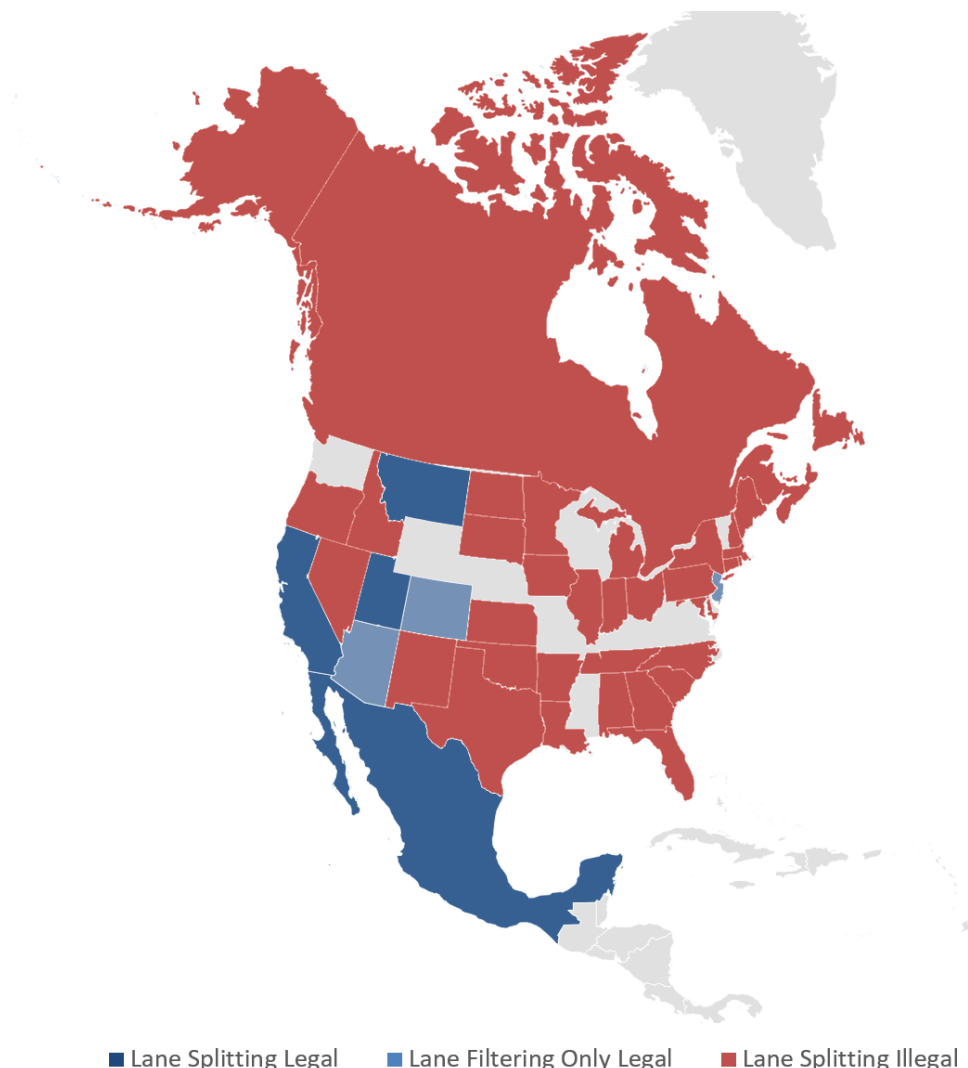


Figure 3.51 : Status of 'lane splitting' and 'filtering' in North America



Figure 3.52 : Lane Splitting on the Dutch highway (Source: A. Delhaye)

In **France**, 'lane splitting' was tested in 2016. Motorcyclists were allowed to overtake stationary or slowly moving traffic in 11 departments under certain speed conditions until 2021. The rule was then revoked, as the authorities recorded an increase in traffic crashes involving motorcyclists during that period. The most common cause of the chushes was the maneuver made by other drivers when changing lanes.

Due to the resistance of motorcyclists, with 20,000 riders protesting in the streets, the authorities adjusted the trial and repeated it in 21 departments. At the same time, they incorporated congestion riding techniques into motorcycle training schools. The trial period ended at the end of 2024, and based on this, a permanent decision was made in France.

In **France**, starting from 2025, motorcycles are allowed (Figure 3.53) to ride between two traffic lanes on four-lane roads (Figure 3.54) [38] and [39].



Figure 3.53 : Lane splitting on the French highway

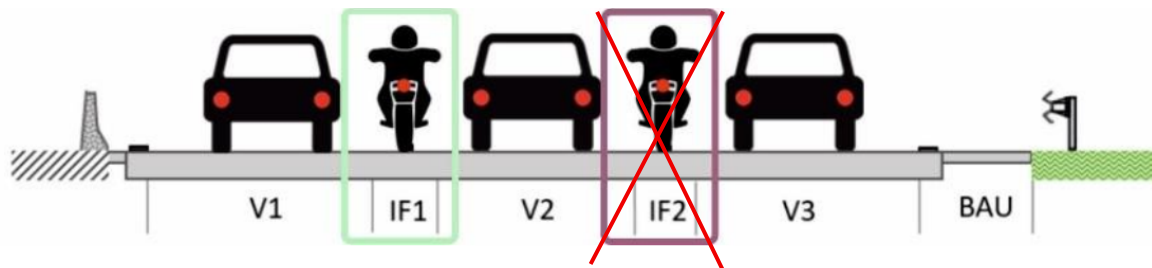


Figure 3.54 : Lane splitting on the French highway [39]

In **France**, the rules for 'lane splitting' are also very clear and unambiguous, allowing for safe and controlled (by the police) implementation (Figure 3.55):

- In the case of a slow moving traffic jam on roads with at least two lanes in one direction, motorcyclists are allowed to ride between the two leftmost lanes of vehicles, but they must not exceed a speed of 50 km/h.
- In the case of a stationary traffic jam, motorcyclists are allowed to ride between vehicles at a maximum speed of 30 km/h.
- It is forbidden to overtake a motorcycle that is already riding between two lanes of vehicles.
- When traffic resumes, motorcyclists must immediately return to one traffic lane.
- This is controlled by the police, and high fines are also foreseen for non-compliance with the previously mentioned rules (135 € and 3 penalty points).
- To make the 'rules of the game' for 'lane splitting' clear to all road users, France has a special traffic sign at highway entrances (Fig. 3), the purpose of which is to inform all road users.



Figure 3.55 : A special traffic sign at highway entrances that defines 'lane splitting' in France

In **Austria**, this regulation is even 'broader.' A free translation reads:

- At front (traffic light-controlled) intersections, in traffic jams, at railway level crossings, and in similar cases, motorcycle riders who arrive later are allowed to ride between vehicles that have already stopped.
- They are allowed to do so if they have enough space for this and if they do not obstruct other drivers who want to turn left or right.

Portugal has lane splitting arranged similarly to Austria, with the only difference being that Austria has the same regulations for all situations, while Portugal has them organized separately for situations 'off the highway' and 'on the highway'. Below, only the regulations for lane splitting on the highway are presented.

Article 15.:

1. In case of congested traffic, motorcycles and mopeds are allowed to ride between rows of vehicles if the following conditions are met:
 - a) The maximum speed must not exceed 30 km/h;
 - b) A motorcyclist must maintain a sufficient lateral safety distance to avoid collisions with surrounding vehicles;
 - c) Overtaking on the right is prohibited, except in situations where traffic is stationary and the maneuver can be performed safely.
2. Anyone who violates the provisions of this article shall be fined from 120 to 600 euros.

In **Spain and Great Britain**, at the time of writing this document, preparations are underway for a legislative change that will allow motorcycles to ride on the hard shoulder, at a maximum speed of 30 km/h, in the case of stationary traffic on four-lane roads with a hard shoulder.

3.2.3. Lane sharing

Lane sharing with public (passenger) transport (Figure 3.56 and Figure 3.57) is a traffic regulation where other road users (usually taxis, but also cyclists and PTWs) are allowed to drive on lanes designated for public passenger transport. In this case, the separate lanes for public passenger transport are an integral part of the carriageway.



Figure 3.56 : Separate lane for buses, taxis, cyclists and PTWs, London



Figure 3.57 : Separate lane for buses, taxis and PTWs, Madrid

The essence of lane sharing is to allow PTWs to share a traffic lane with other vehicles instead of being stuck in traffic jams. This practice can improve traffic flow, reduce congestion, and shorten travel times for PTWs. However, it requires clear traffic regulations and caution to prevent dangerous conflicts with other road users.

Allowing PTWs to travel in bus lanes (Figure 3.58) is not necessarily a measure to improve safety, but rather to improve traffic flow. It has safety implications, however. Several cities have allowed PTWs to use bus lanes, including London, Oslo, Norway and Madrid. Other cities are opposed to such a measure.

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

According to OECD, International Transport Forum [3], the research conducted in Paris has demonstrated that driving in a bus lane offers some advantages for PTW riders, including better peripheral vision of the surrounding traffic and a feeling of being better protected, but it can lead to a higher speed of PTWs, which can endanger safety at intersections in particular.

On the other hand, a recent epidemiological study conducted in the city of Marseille in France concluded that for PTW riders driving in bus lanes the risk of being involved in an injury-causing crash is more than three times higher than the risk the riders driving in general traffic lanes are exposed to. This higher risk is partly due to the risk of collisions between car (or truck) drivers turning right and PTWs driving in the bus lane who continue straight ahead. Hereinafter presented are some experiences and research conducted in London, Barcelona and Vienna, which show some

diverging results, with a negative safety impact in Barcelona and no safety impact in London or Vienna.



Figure 3.58 : PTWs are allowed to use bus lanes in Porto, Portugal

In London, the use of bus lanes by PTWs depends on the specific lane and its location. Some bus lanes allow PTWs, while others do not. This is usually indicated by traffic signs at the beginning of the bus lane [42].

Following the completion of two trials, in January 2012, PTWs were given permanent access to bus lanes on the majority of the Capital's red routes. The two trials have shown reduced journey times and environmental benefits with no significant safety issues ensuing for motorcyclists and other vulnerable road users. As part of the second trial, Transport for London (TfL) increased enforcement measures specifically at locations with a high collision history involving motorcycles. In line with the increased enforcement measures, the average speed for motorcyclists in bus lanes reduced by 6.5 % during the trial, with the proportion of motorcyclists exceeding the speed limit decreasing by one fifth (51% in September 2010 down to 41% in September 2011). The scheme run by TfL covers with-flow bus lanes on the strategic road network, but not those on most borough roads. A few boroughs have also allowed PTWs in their bus lanes, but one, Ealing, has already abolished motorcycle access to bus lanes. Several other cities in England have also introduced motorcycle access to bus lanes.

Things are somewhat different in Barcelona, Spain. RACC (Automobile Association in Cataluña) presented (2010) Barcelona City Council its report about PTW users' utilisation of bus lanes. The most representative conclusions were:

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

To summarise, the probability of collision with buses, cars or other PTW vehicles would raise significantly. As of 2013, PTWs were not allowed to use bus lanes.

It seems that Barcelona and Madrid are not the only cities that have implemented this system, but there is very little documentation about it (Figure 3.59 and Figure 3.60). [43][44]



Figure 3.59 : Implementation of the experiment in the city of Santander (SOLO BUS TAXI MOTO)
[43]



Figure 3.60 : Zaragoza, Spain [44]

In Vienna, Austria, the situation was also different. In 2005, a pilot was launched to allow PTW riders to use bus lanes. There are three test sites. The administration carefully selected the places where

there are no pedestrian crossings, no oncoming left turn traffic and no induction loops under the road surfaces for prioritising public buses at traffic lights. On these test sites, there were no severe (injury-causing) crashes before starting the pilot and, as of June 2013, there has been no crash since implementation. There are, however, no plans to extend the experiment.

3.2.4. Filtering

There is a big difference between lane splitting and filtering.

Lane splitting refers to riding a PTW between two columns of moving vehicles on roads with at least two lanes in one direction. Filtering refers to riding a PTW between two columns of stationary vehicles (on four-lane roads) or riding past a single column of stationary vehicles on two-lane roads (in front of a traffic light intersection, road construction site, at a traffic light level crossing of a road with a railway/tram, or something similar).

However, many people confuse these two terms. Especially journalists, if they are not motorcyclists. Because of this, it is difficult to analyze in which countries this is allowed and in which it is not.

Hereinafter, the correct interpretation will be adopted.

- Filtering on the highway:
 - riding a PTW between two columns of stationary vehicles
- Filtering off the highway (on two-lane roads):
 - riding past a single column of stationary vehicles:
 - before reaching the traffic lights intersection,
 - at a road construction site (where one traffic lane is closed, and traffic is managed by a traffic light with alternating use of one traffic lane),
 - at a traffic light level crossing of a road with a railway or tram,
 - in other similar situations.

3.2.4.1. Riding past a single column of stationary vehicles before reaching the traffic lights intersection

It refers to "filtering" or the movement of motorcyclists who arrived later, passing by stationary vehicles waiting at a red traffic light (Figure 3.61).

In most countries, this traffic manoeuvre must be performed by the motorcyclist on the left side. When motorcyclists pass the queue, they must stop in front of the first waiting vehicle.

There are two options for this: the motorcyclist stops at the pedestrian crossing (prohibited, but tolerated by the police) or in the "bike box" ("advanced stop box").

When the green light turns on, motorcyclists start first.



Figure 3.61 : PTWs waiting at a red traffic light

3.2.4.2. Riding past a single column of stationary vehicles at a road construction site

This situation occurs in the case of roadworks on a two-lane road when one lane is closed, and traffic is managed by a traffic light with alternating use of one traffic lane (Figure 3.62).

When a motorcyclist arrives later, they can pass the already stationary vehicles (usually on the left side) and position themselves in front of the first waiting vehicle. When the green light turns on, motorcyclists start first.

In this case there is no difference between the traffic light intersection and road construction site - the traffic rules are the same.



Figure 3.62 : Motorcyclist is waiting in front of traffic light at a road construction site

3.2.4.3. Riding past a single column of stationary vehicles at a traffic light level crossing of a road with a railway or tram

The same rules apply here as at traffic lights and roadworks (Figure 3.63).

When a motorcyclist arrives later, they can pass the already stationary vehicles (usually on the left side) and position themselves in front of the first waiting vehicle.

When the railway barriers rise, motorcyclists start first.



Figure 3.63 : Motorcyclists start first at a traffic light

The sections below, present how this rule is regulated in certain countries.

In **France**, this is regulated by a very simple rule that regulates all situations:

In the case of a stationary traffic jam, motorcyclists are allowed to ride between vehicles at a maximum speed of 30 km/h.

In **Portugal**, in their Highway Code, the following is stated.

Article 2: Reserved spaces for motorcyclists before reaching the traffic lights intersection

1 - On roads with heavy traffic, spaces reserved for motorcyclists must be created before reaching the traffic lights intersection, to increase the safety and visibility of motorcyclists in relation to other vehicles.

2 - The spaces referred to in the previous paragraph must be duly signposted, and it is the responsibility of local authorities and the relevant bodies to ensure their signing and maintenance.

Article 15 - Whenever there is heavy traffic, motorbikes and mopeds may be driven between rows of vehicles, provided the following conditions are met.

- a) The maximum speed may not exceed 30 km/h;
- b) The driver must maintain a safe lateral distance sufficient to avoid collisions with surrounding vehicles;
- c) Overtaking on the right is prohibited, except in situations where traffic is stationary and the manoeuvre can be carried out safely.

3 - Whenever there are spaces reserved for motorbikes and mopeds before the traffic lights intersection, motorcyclists and moped riders must use them to position themselves in front of vehicles while waiting for the signal to change.

4 - Anyone infringing the provisions of this article shall be penalised with a fine of 120 to 600 euros.

In Austria, this regulation is even 'broader'. A free translation reads as stated below.

- In front of (traffic light-controlled) intersections, in traffic jams, at railway level crossings, and in similar cases, motorcycle riders who arrive later are allowed to ride between vehicles that have already stopped.
- They are allowed to do so if they have enough space for this and if they do not obstruct other drivers who want to turn left or right.

In conclusion, countries can be divided into three groups according to how they regulate filtering (and the same applies to lane splitting):

- countries where this is strictly prohibited, and the police penalize such traffic maneuvers,
- countries where this is prohibited, but the police tolerate such traffic maneuvers,
- countries where this is allowed, but under certain conditions.

3.2.5. Advanced stop lines

Advanced stop lines - also called "advanced stop box" or "bike box", are a type of road marking at signalised road intersections, allowing certain types of vehicles a head start when the traffic signal changes from red to green. They are most commonly associated with bicycles, however, they may also be provided for motorcycles.

There are two parallel stop lines at the intersection, the first one at which all traffic except that for which the facility is provided must stop, and a second one closer to the intersection to which only specified vehicles may proceed.

If the signals change to red when a vehicle is crossing the first line, the driver must stop at the second line. The area between the stop lines is the "reservoir" or "box".

Advanced Stop Lines (ASL) permit PTWs to stop in front of other vehicles at traffic signals, allowing motorcycles and mopeds to manoeuvre more safely without conflicting with other road users when the light turns green. This is clearly comfortable for PTW users. However, careful consideration should be given to traffic signalling calibration to avoid conflicts with pedestrians, as PTWs can accelerate very quickly, which may surprise pedestrians. In addition, when the advanced stop line is shared with cyclists, careful consideration should be given as both users have very different acceleration capacities.

This type of traffic management for motorcycles is very popular in Western Europe, mainly in the UK, Spain and France.

In the UK, a combination of advanced stop lines for cyclists and PTWs (Figure 3.64) was introduced in 2008. At the very beginning, in London.

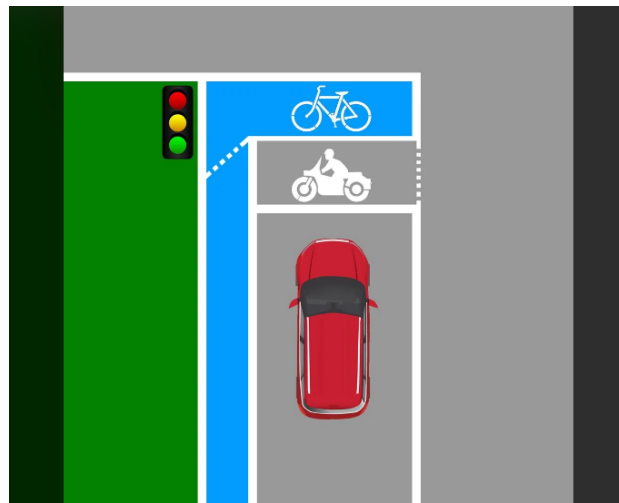


Figure 3.64 : A combination of advanced stop lines for cyclists and PTWs

As the responses on the blog show, the users were not satisfied.

Cyclists were especially unsatisfied:

- "This picture makes no sense. How does this work? Got a link to something that describes it?"
- "Cars will just stop in that box instead of the cycle one."

- “I think this is a good concept, but if people pay attention to stop lines in the UK like they do in the US, these will not help much.”
- “How about cyclists just stay to the side, or at least behind the motorcycles, because, you know THEY ACCELERATE SLOWER THAN PRETTY MUCH EVERY MOTORIZED VEHICLE ON THE ROAD.”

Motorcyclists also reacted angrily.

- “So, they are proposing to give special privileges to bicyclists? I do not understand why they cannot just stop at the front of their lane without getting in front of the motor vehicles and slowing them down.”
- “It makes more sense for motorcycles to be in front, because they generally can outrun cars at lights like this. But bicycles should stay on the sides, because they simply cannot, and large paved roads are not for bicycles, they are for vehicles that travel fast and weigh a lot.”
- “Why would they give cyclist the entire width of the lane? That would slow traffic once the light changes. Cyclists should have their own lane on the side of the street at all times.”
- “It makes more sense for motorcycles to be in front, because they generally can outrun cars at lights like this. But bicycles should stay on the sides, because they simply cannot, and large paved roads are not for bicycles, they are for vehicles that travel fast and weigh a lot.”
- “That is retarded. It will make bicyclists even more entitled.”

It is true that this solution is somewhat unusual and can also be dangerous. Apparently, the main criterion in the design was the "quantity" rather than the "acceleration magnitude". By this logic, motorcyclists should be first, with cyclists behind them.

We have not found any information on the web about how this story ended.

They have no issues with advanced stop lines for PTWs in Spain (Figure 3.65).



Figure 3.65 : Advanced stop line for PTWs ("Avanzadilla Motos") in Madrid, Spain

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

According to some sources, the first advanced stop lines for motorcycles were implemented in Barcelona, in 2009. In 2019, a study was published in the Journal of Transport & Health evaluating the effectiveness of advanced stop lines (ASLs) for motorcycles and mopeds in preventing road traffic injury collisions after their implementation in Barcelona in 2009–2010. [45]

On working days in Barcelona, more than 400,000 journeys are done with two-wheeled motor vehicles, representing almost 30% of all journeys in private motor vehicles (more than 1.5 million journeys). In Barcelona between 2003 and 2009, the number of motorcycles increased by 38% mainly due to a national law passed in 2004 allowing car drivers in possession of a driver's license for at least 3 years to drive a light motorcycle (engine capacity 51–125 cc) without an additional license or test. In 2003, there were 148 two-wheeled motor vehicles per 1000 habitants and in 2009 that number increased to 177. This was correlated with an increase in the number of injury-causing collisions with motorcycles.

Within this context, Advanced Stop Lines (ASL) for two-wheeled motor vehicles were implemented in Barcelona to improve vehicles mobility in the city, and to help them avoid invading pedestrian crossings. ASL for two-wheeled motor vehicles was an innovation, with no previous experiences, except within the framework of bicycle mobility.

The results of a study conducted in 2019 were not promising. It was found that: ASL for motorcycles are not effective in improving road safety as they can increase the risk of crashes in the preceding area in some streets. Results suggest the need to revise the design of ASL and their situation.

We were unable to find any information online on why the situation has changed since then and why ASLs are now implemented at almost every signalized intersection in Madrid.

A similar situation can be found in France, especially in the southern (coastal) part (Figure 3.66).



Figure 3.66 : Advanced stop line for PTWs in France

Although one of the developers of this project saw many such solutions while riding a motorcycle along the French Riviera, there are no photos or articles about it available online.

ASLs are also widely used in Vienna, **Austria**.

PTWs are allowed to filter between queues of cars, which have come to a complete stop. However, they must not impede drivers wanting to change direction. This does not apply to motorways and PTWs must not travel on the hard shoulder or within the emergency corridor. There is an increasing number of “advanced stop lines”. Primarily introduced for the sake of bicyclists’ safety, PTW riders are in favour of these as well.

ASLs are also very popular in **Portugal**. They seem to be most common in big cities such as Lisbon (Figure 3.67) and Porto.



Figure 3.67 : Advanced Stop Line for PTWs in Lisbon, Portugal

Article 2: Reserved spaces for motorcyclists before the traffic lights area

1 - On roads with heavy traffic, spaces reserved for motorcyclists must be created before the traffic lights area, to increase the safety and visibility of motorcyclists in relation to other vehicles.

2 - The spaces referred to in the previous paragraph must be duly signposted, and it is the responsibility of local authorities and the relevant bodies to ensure their signing and maintenance.

Article 15:

3 - Whenever there are spaces reserved for motorbikes and mopeds before the traffic lights area, motorcyclists and moped riders must use them to position themselves in front of vehicles while waiting for the signal to change.

4 - Anyone infringing the provisions of this article shall be penalised with a fine of (euro) 120 to (euro) 600.

Traffic management measures can have two purposes: facilitating PTW traffic and increasing safety. Further research is needed on the safety impact of measures such as advanced stop lines. When implementing a new measure in favour of PTW mobility, it is important that the solution does not add pose additional risk for any road users.

4. RESULTS OF THE SURVEY

A total of 258 respondents began completing the LEGAL survey. Of these, 221 respondents from 71 different countries completed the survey correctly (Figure 4.1). Among them (Figure 4.2):

- 121 respondents (54.8%) were from 28 European countries,
- 30 respondents (13.6%) from 11 African countries,
- 28 respondents (12.7%) from 11 Asian countries,
- 7 respondents (3.2%) from 2 North American countries (without Mexico),
- 16 respondents (7.3%) from 9 Latin American countries, and
- 19 respondents (8.6%) from 3 Oceanian countries.

Based on the World Bank's 2025 fiscal year classification of Gross National Income (GNI) per capita, we divided the countries into three groups [46]:

- Low-Income Countries (LIC: GNI per capita $\leq$ \$1,135)
- Middle-Income Countries (MIC: \$1,136 $\leq$ GNI per capita $\leq$ \$13,935) and
- High-Income Countries (HIC: GNI per capita $>$ \$13,935).

Accordingly, 43.1% of the respondents were from HIC, 38.9% from MIC, and 18.1% from LIC (Figure 4.2).

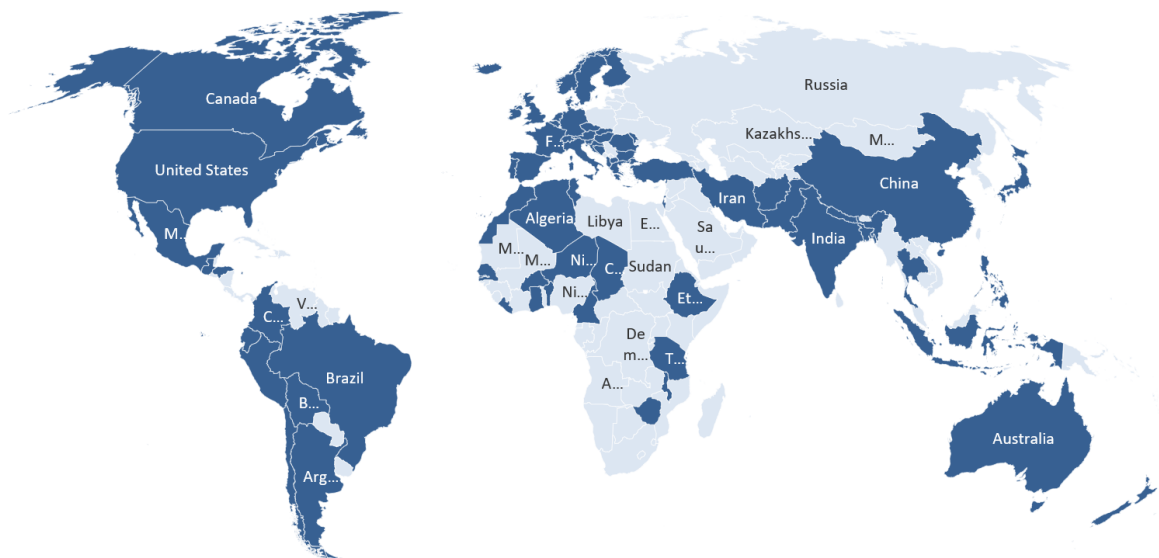


Figure 4.1 : Participating countries

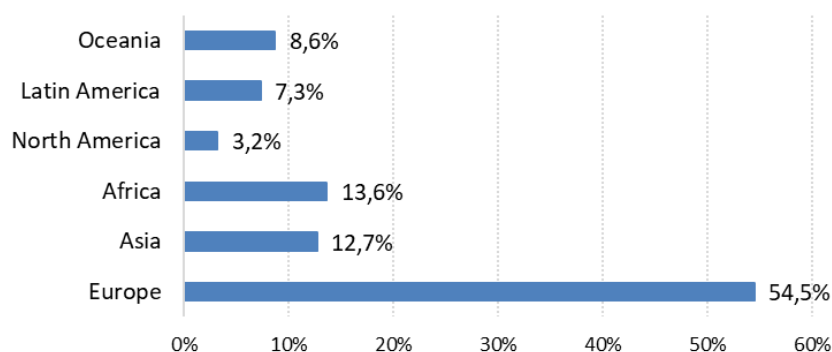


Figure 4.2 : Participating countries by continent

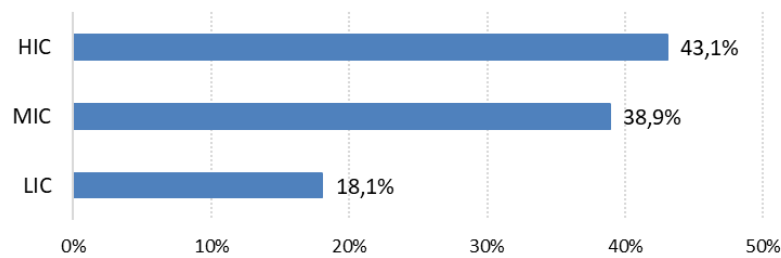


Figure 4.3 : Participating countries according to GNI

34% of all respondents are members of the PIARC association, 50% are not, and 16% are unsure whether they are members or not (Figure 4.4). Furthermore, 64% of all respondents have professional experience with motorcycle protection systems and safety aspects of traffic management for motorcyclists (Figure 4.6).

44% of all respondents are motorcyclists themselves (Figure 4.5).

Member of the PIARC association?

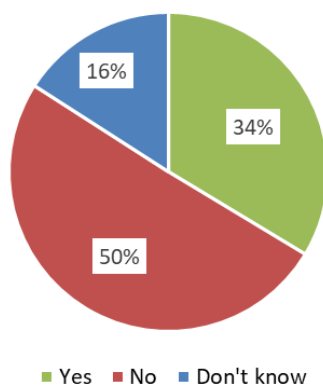


Figure 4.4 : Share of PIARC association

Motorcyclist?

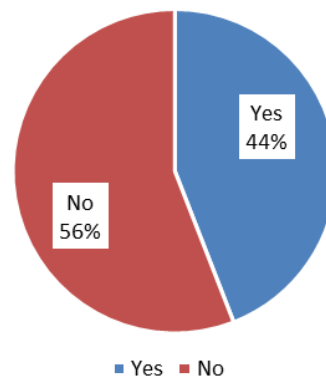


Figure 4.5 : Share of motorcyclists

Do you have any professional experience with motorcycle protection systems and safety aspects of traffic management for motorcycles?

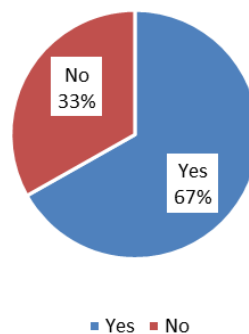


Figure 4.6 : Professional experience

Each Motorcycle Protection System and Traffic Management measure for Motorcycles has been evaluated by the respondents based on their knowledge and experience. The evaluation has been conducted using a five-point scale to assess their impact as follows:

- Very bad: 1 point,
- Bad: 2 points,
- No difference: 3 points (neutral/midpoint),
- Good: 4 points and
- Very good: 5 points.

Alternatively, the respondents may choose not to evaluate a particular item by selecting 'No opinion'.

4.1. MOTORCYCLE PROTECTION SYSTEMS

4.1.1. Motorcyclists' crash cushions

As part of the survey, only two crash cushions were evaluated:

- ARMADILLO; designed for the protection of motorcyclists and
- RAPTOR® – COMPACT, which, in our opinion, can also effectively protect motorcyclists in the event of a point impact.

It should be noted that more than 31% of respondents did not provide an answer or responded with "No opinion" to individual questions regarding the evaluation of End terminals and their specific impact on Improving motorcyclists' safety, Complexity of installation, Design enables flexible use, Maintenance, Use of recycled materials, Price – cost effectiveness, and General evaluation (Figure 4.7).

In the evaluation, both crash cushion variants were rated very well and similarly, with the highest scores in Improving motorcyclists' safety, where both received a rating of 4.3 out of 5, classified as very good (Figure 4.8).

The overall assessment of both types of crash cushions was 3.5 out of 5, classified as good and the Armadilo crash cushion was rated only 0.04 points higher than the RAPTOR® – COMPACT system (Figure 4.9).

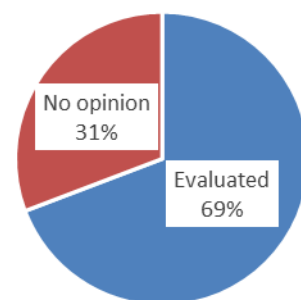


Figure 4.7 : Professional experience

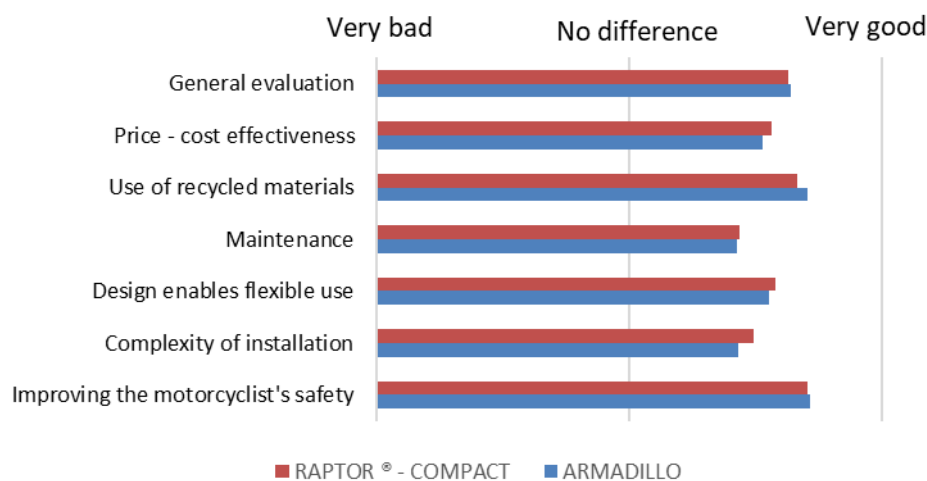


Figure 4.8 : Comprehensive evaluation of motorcyclists' crash cushion

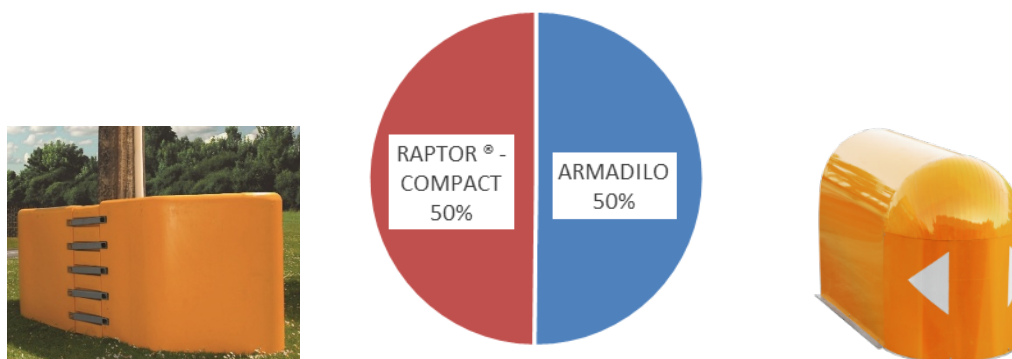


Figure 4.9 : Overall assessment of motorcyclists' crash cushion

4.1.2. End terminals

As part of the survey, only two end terminals were evaluated:

- PolyBuffer and
- MAX-Tension®.

It should be noted that more than 31% of respondents did not provide an answer or responded with “No opinion” to individual questions regarding the evaluation of end terminals and their specific impact on Improving motorcyclists' safety, Complexity of installation, Design enables flexible use, Maintenance, Use of recycled materials, Price – cost effectiveness, and General evaluation (Figure 4.7).

In the evaluation, both end terminals did not receive high ratings, with overall scores only slightly above the threshold indicating that the installation of such terminals does not have a positive impact. Specifically, the PolyBuffer end terminal received an overall score of 3.9 out of a maximum of 5, while the MAX Tension end terminal was rated at 3.7 out of 5, placing it slightly below the 'Good' category (Figure 4.11). The PolyBuffer terminal was rated highest in the category 'Improving motorcyclists' safety', where terminals received a score of 4.2 out of 5, classified as slightly above 'Good' (Figure 4.10).

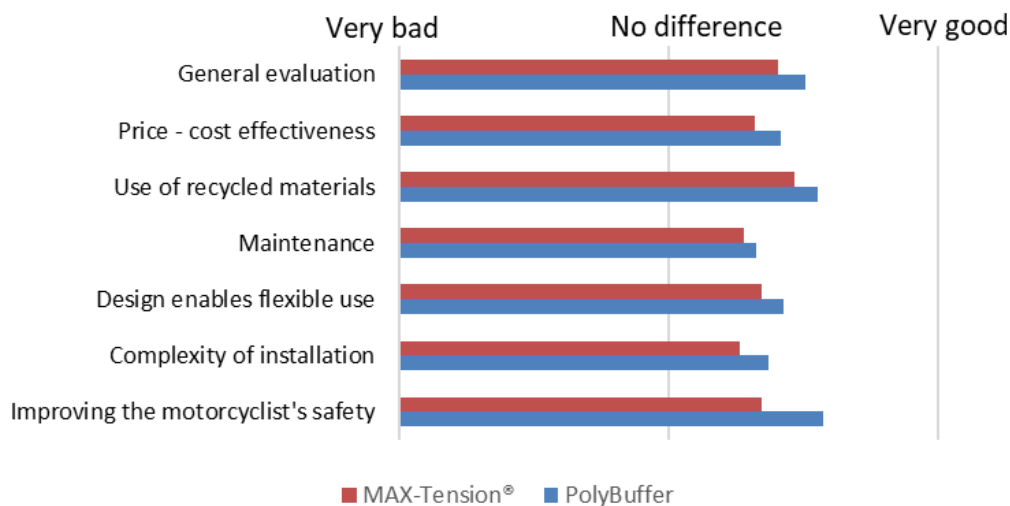


Figure 4.10 : Comprehensive evaluation of end terminals

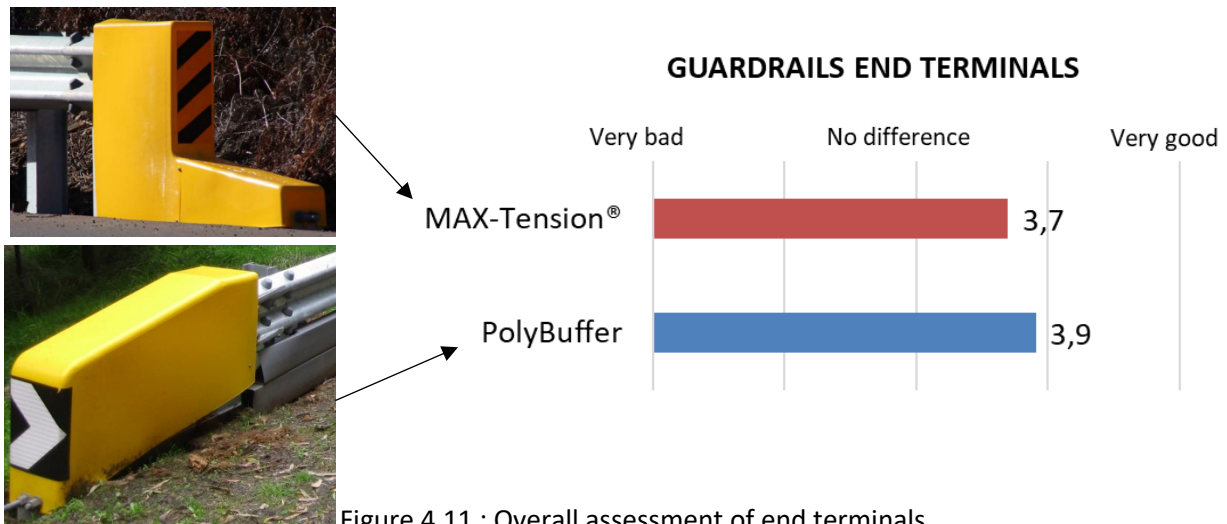


Figure 4.11 : Overall assessment of end terminals

4.1.3. Upper guiderail protection

Based on a comprehensive review of publicly available literature, completed project proposals, and market research, we were able to find a few solutions for the protection of a motorcyclist against an impact with the upper ledge of the guiderail. Most of these solution have only been patented and not implemented. For this project, we have selected six of what we believe to be the best solutions available (Table 1):

- Protection for Double-sided SSB (VTI),
- Protection device for guardrail (WO2020058935A1),
- Protection device on road safety barriers (ES2332553A1),
- Cover element for highway barriers or guardrails (EP1484448A2),
- A protective device for guardrails (US2006083588A1),
- Protective elements for metallic guard-rails in roads (EP0780518A1) and
- Protection Element for Motorcyclists on SSB (P-202500009).

It should be noted that more than 36% of respondents did not provide an answer or responded with “No opinion” to individual questions regarding the evaluation of Upper guiderail protection and their specific impact on Improving motorcyclists' safety, Complexity of installation, Design enables flexible use, Maintenance, Use of recycled materials, Price – cost effectiveness, and General evaluation. This represents a notably high percentage — more than one third of all respondents.

In the evaluation, all considered protection elements received their highest scores in the category Improving motorcyclists' safety, with ratings exceeding 4.0 out of a maximum of 5, which classifies them as better than 'Good' (Table 1, Figure 4.12 : Comprehensive evaluation of). The highest scores were given to the systems Protection device on road safety barriers (ES2332553A1) and Cover element for highway barriers or guardrails (EP1484448A2), both rated above 4.3. It is important to note that these two systems provide protection not only against impact with the upper edge of the guardrail but also with the SSB post.

However, a drawback of these systems is their Complexity of installation, particularly for the Protection device on road safety barriers (ES2332553A1), which does not offer protection against impact with the upper edge of the post. On average, none of the evaluated protection solutions received a 'Poor' rating in any of the criteria.

Overall, the highest average score of 3.9 out of 5 — classified as 'Good' — was awarded to the following protection elements (Table 1, Figure 4.13):

- Protection device on road safety barriers (ES2332553A1) and
- Protection Element for Motorcyclists on SSB (P-202500009).

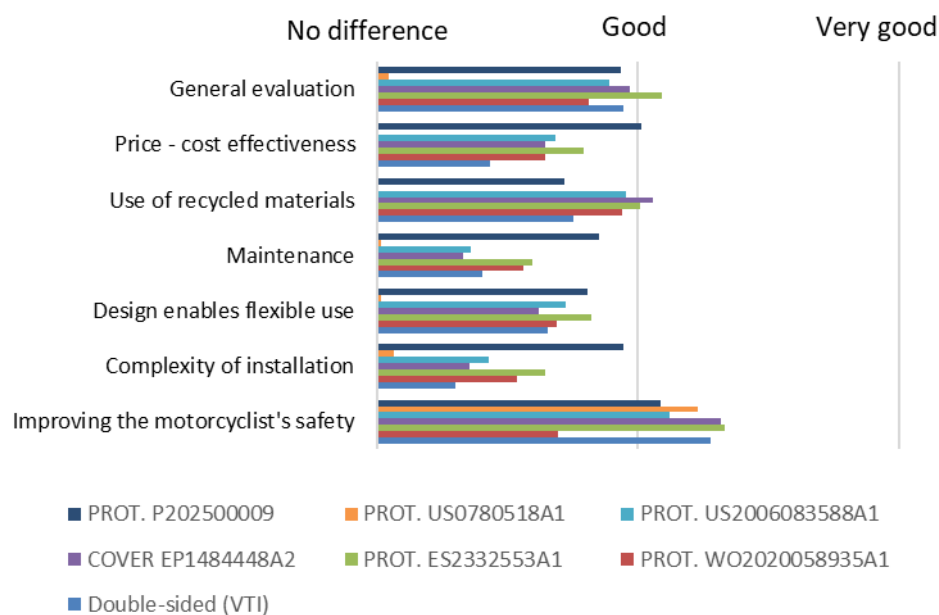


Figure 4.12 : Comprehensive evaluation of the upper guiderail protection

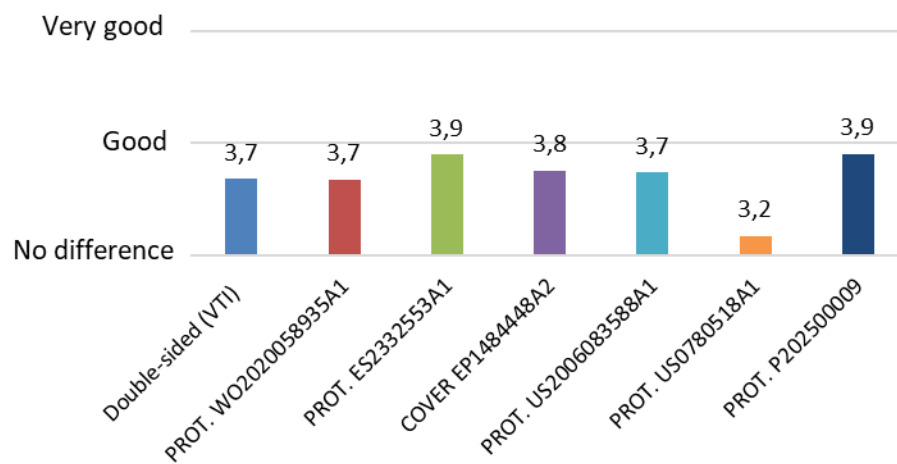
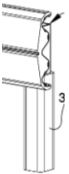
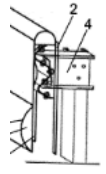
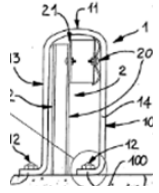
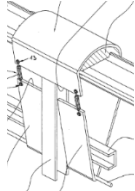
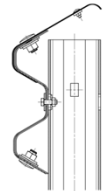


Figure 4.13 : Overall assessment of the upper guiderail protection

Table 1 : Comprehensive evaluation of upper guiderail protection systems

	Double-sided (VTI) 	PROTECTION WO2020058935A1 	PROTECTION ES2332553A1 	COVER EP1484448A2 	PROT. DEVICE US2006083588A1 	PROT. ELEM. EP0780518A1 	PROT. ELEM. P202500009 
Improving the motorcyclist's safety	4.28	4.01	4.33	4.32	4.12	4.23	4.09
Complexity of installation	3.30	3.40	3.65	3.35	3.43	3.06	3.94
Design enables flexible use	3.65	3.61	3.82	3.62	3.72	3.02	3.81
Maintenance	3.40	3.45	3.60	3.33	3.36	3.02	3.85
Use of recycled materials	3.75	3.91	4.01	4.06	3.95	2.95	3.72
Price - cost effectiveness	3.43	3.57	3.79	3.65	3.68	2.93	4.01
General evaluation	3.95	3.81	4.09	3.97	3.89	3.04	3.94
S	3.7	3.7	3.9	3.8	3.7	3.2	3.9

4.2. TRAFFIC MANAGEMENT FOR MOTORCYCLES

Regarding Traffic Management for Motorcycles — i.e.:

- Dedicated Motorcycle Lanes,
- Lane Splitting,
- Filtering,
- Advanced Stop Lines and
- Lane Sharing

an expert opinion was given in relation to the following aspects:

- Traffic safety,
- Traffic flow,
- Compliance with traffic rules by motorcyclists and
- Compliance with traffic rules by other road users.

The survey was conducted in a way that allows the results to be compared based on (Table 2):

- Gross National Income (GNI) per capita (Low-Income Countries – LIC, Middle-Income Countries – MIC, and High-Income Countries – HIC),
- Whether the respondent is a member of the PIARC association,
- Whether the respondent has professional experience with motorcycle protection systems and safety aspects of traffic management for motorcyclists,
- Whether the respondent is a motorcyclist or not and
- Continent origin.

In general, none of the evaluated measures Traffic Management for Motorcycles received a high rating (Table 2, Figure 4.14). The highest overall score was given to Dedicated Motorcycle Lanes, with a rating of 3.7 out of a maximum of 5, which places it just below the 'Good' category. The lowest-rated measure was Lane Splitting, which received a score of 2.8, indicating that this measure is not recommended, as its implementation is expected to have a negative impact on traffic safety.

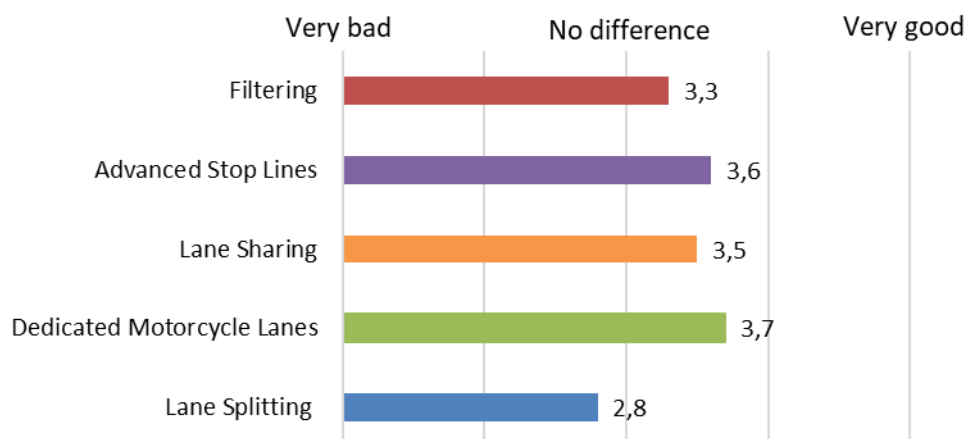


Figure 4.14 : Overall assessment of the measure of Traffic Management for Motorcycles

In the following section, we will take a closer look at the individual evaluation of each measure from the category Traffic Management for Motorcycles.

Table 2 : Comprehensive evaluation of Traffic Management for Motorcycles

		LANE SPLITTING	DEDICATED MOTORCYCLE LANES	LANE SHARING	ADVANCED STOP LINES	FILTERING
Traffic safety	General	2.6	4.0	3.6	3.7	3.2
	Regulated Yes / No / ?	2.7 / 2.8 / 2.4	3.9 / 4.0 / 4.0	3.9 / 3.3 / 3.5	3.9 / 4.0 / 3.7	3.1 / 3.5 / 3.2
	HIC / MIC / LIC	2.7 / 2.4 / 2.4	3.8 / 4.2 / 4.1	3.6 / 3.4 / 3.4	3.7 / 3.8 / 4.0	3.1 / 3.3 / 3.4
	Motorcyclists Yes/No	2.6 / 2.4	4.0 / 3.9	3.7 / 3.6	3.8 / 3.8	3.3 / 3.0
Traffic flow	General	3.2	3.7	3.7	3.8	3.5
	Regulated Yes / No / ?	3.3 / 3.4 / 3.1	4.1 / 4.3 / 3.7	3.9 / 3.7 / 3.6	3.7 / 4.0 / 3.8	3.7 / 3.6 / 3.4
	HIC / MIC / LIC	3.5 / 2.9 / 2.5	3.6 / 4.1 / 4.1	3.3 / 3.3 / 3.2	3.7 / 3.8 / 3.9	3.6 / 3.3 / 3.5
	Motorcyclists Yes/No	3.3 / 3.1	3.8 / 3.7	3.7 / 3.7	3.8 / 3.8	3.6 / 3.5
Compliance with traffic rules by motorcyclists	General	2.6	3.7	3.4	3.6	3.3
	Regulated Yes/No/?	2.6 / 2.7 / 2.7	3.5 / 3.0 / 3.7	3.5 / 3.0 / 3.4	3.5 / 3.5 / 3.6	3.2 / 3.4 / 3.2
	HIC / MIC / LIC	3.0 / 2.0 / 2.2	3.7 / 3.7 / 3.8	3.0 / 3.02 / 2.8	3.6 / 3.5 / 3.6	3.3 / 3.2 / 3.1
	Motorcyclists Yes/No	2.7 / 2.5	3.7 / 3.7	3.5 / 3.5	3.6 / 3.5	3.3 / 3.2
Compliance with traffic rules by other road users	General	2.6	3.4	3.3	3.4	3.1
	Regulated Yes / No / ?	2.8 / 2.5 / 2.6	3.3 / 3.3 / 3.4	3.4 / 3.3 / 3.2	3.4 / 3.5 / 3.4	3.2 / 3.2 / 3.0
	HIC / MIC / LIC	2.7 / 2.5 / 2.5	3.3 / 3.7 / 3.7	2.8 / 3.2 / 3.0	3.3 / 3.5 / 3.5	3.1 / 3.2 / 3.4
	Motorcyclists Yes/No	2.7 / 2.6	3.5 / 3.5	3.3 / 3.3	3.4 / 3.4	3.2 / 3.1
S	General	2.8	3.7	3.5	3.6	3.3
	Regulated Yes / No / ?	2.9 / 2.8 / 2.7	3.7 / 3.7 / 3.7	3.7 / 3.3 / 3.4	3.6 / 3.8 / 3.6	3.3 / 3.4 / 3.2
	HIC / MIC / LIC	3.0 / 2.4 / 2.4	3.6 / 3.9 / 3.9	3.1 / 3.3 / 3.1	3.6 / 3.7 / 3.8	3.3 / 3.3 / 3.4
	Motorcyclists Yes/No	2.8 / 2.6	3.8 / 3.7	3.6 / 3.5	3.6 / 3.6	3.3 / 3.2

Table 3 : Comprehensive evaluation of Traffic Management for Motorcycles

		LANE SPLITTING	DML	LANE SHARING	ASL	FILTERING
Traffic safety	Europe	2.7	3.9	3.7	3.7	3.1
	Asia	2.3	4.3	3.7	3.6	3.4
	Africa	2.5	4.1	3.3	3.8	3.3
	North America	2.4	4.2	4.2	3.8	3.3
	Latin America	2.6	4.1	3.0	4.3	2.9
	Oceania	2.3	3.6	3.6	3.4	3.2
Traffic flow	Europe	3.5	3.6	3.9	3.8	3.3
	Asia	2.6	4.0	3.5	3.6	3.3
	Africa	2.8	4.0	3.0	3.8	3.1
	North America	3.4	4.2	4.2	3.8	3.5
	Latin America	3.3	4.3	3.5	4.2	2.8
	Oceania	3.4	3.3	3.8	3.2	3.3
Compliance with traffic rules by motorcyclists	Europe	2.9	3.7	3.5	3.7	3.6
	Asia	2.1	4.0	3.3	3.5	3.2
	Africa	2.1	3.6	2.8	3.5	3.4
	North America	2.6	4.2	4.2	4.0	4.0
	Latin America	2.3	3.6	3.3	3.5	3.2
	Oceania	3.2	3.6	3.7	3.4	3.6
Compliance with traffic rules by other road users	Europe	2.7	3.4	3.4	3.4	3.1
	Asia	2.5	3.8	3.3	3.5	3.2
	Africa	2.4	3.6	3.0	3.4	3.2
	North America	3.0	3.7	3.6	3.0	3.0
	Latin America	2.6	3.4	2.9	3.4	2.6
	Oceania	2.5	2.9	3.2	3.2	3.1
S	Europe	2.9	3.6	3.6	3.6	3.3
	Asia	2.4	4.0	3.4	3.6	3.3
	Africa	2.5	3.8	3.0	3.6	3.3
	North America	2.9	4.0	4.1	3.6	3.4
	Latin America	2.7	3.9	3.2	3.8	2.9
	Oceania	2.8	3.3	3.6	3.3	3.3

4.2.1. Lane Splitting

Lane splitting is a measure where motorcyclists can ride between two lanes furthest to the left (in Europe - right side driving) of slowly moving vehicles.

This measure is relatively well known globally, as only 12% of respondents indicated they were unfamiliar with it. Nearly 50% of respondents reported that the measure is implemented in their country. Among these (Figure 4.15, Figure 4.16):

- 73% stated it is legally regulated, with 59% saying it is permitted by law and 14% stating it is prohibited by law,
- and 27% reported that it is not regulated, yet still implemented in practice.

Is this practice in use in your country?

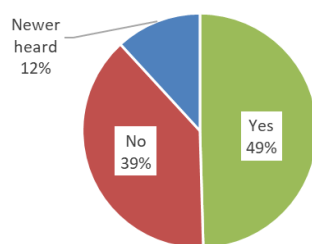


Figure 4.15 : Use of lane splitting

Has this practice been legally regulated in your country?

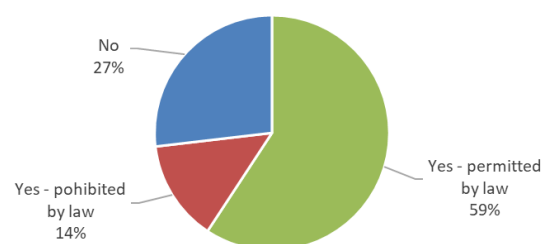


Figure 4.16 : Legally regulated lane splitting

Regardless of whether the measure is regulated, unregulated or unknown to respondents, the overall evaluation indicates that lane splitting is not recommended (Figure 4.14). This is particularly evident in the traffic safety category, which received an average score of only 2.7 out of 5, suggesting that its implementation is expected to have a negative impact on traffic safety (Figure 4.17). There is no significant difference in the evaluation between countries where the measure is regulated and those where it is not. The only slightly positive evaluation was in the area of traffic flow, with an average score of 3.3 out of 5.

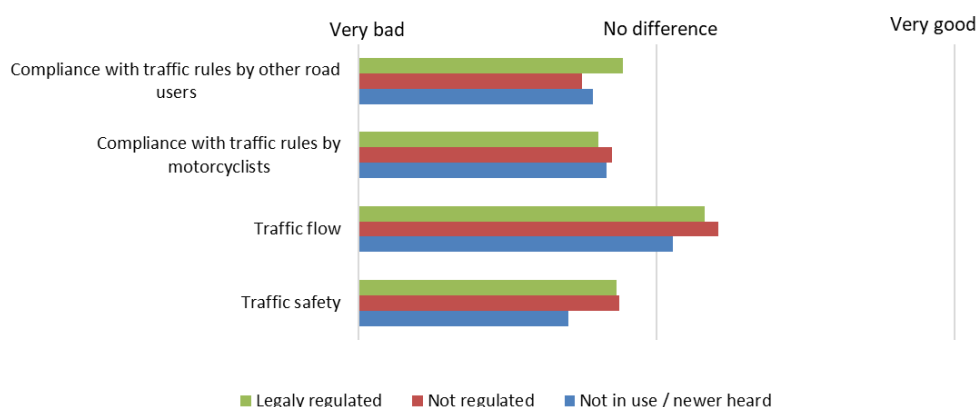


Figure 4.17 : Detailed evaluation of lane splitting

These findings are consistent with responses to the question: "Would you recommend this practice be implemented in your country?" (Figure 4.18):

- In countries where the measure is not regulated, not used, or it is unknown, the majority of respondents would not recommend its implementation.
- In countries where it is regulated, 41% of respondents would recommend it, while approximately 30% would not recommend it or had no opinion.

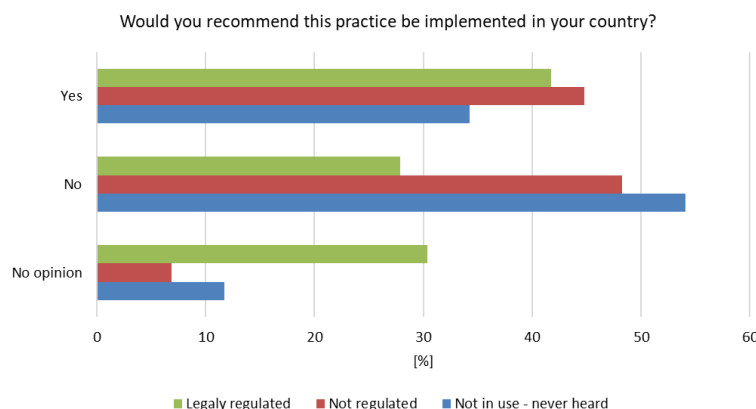


Figure 4.18 : Recommendation of lane splitting

When analyzing responses based on whether the respondent is a motorcyclist or not, motorcyclists rated the measure approximately 0.2 points higher across all categories. Only in the category 'Traffic Flow' did both motorcyclists and non-motorcyclists rate this measure as slightly positive. However, the overall evaluation remained negative (Figure 4.19). Despite this, 47% of motorcyclists would recommend the measure, compared to 40% who would not (Figure 4.20).

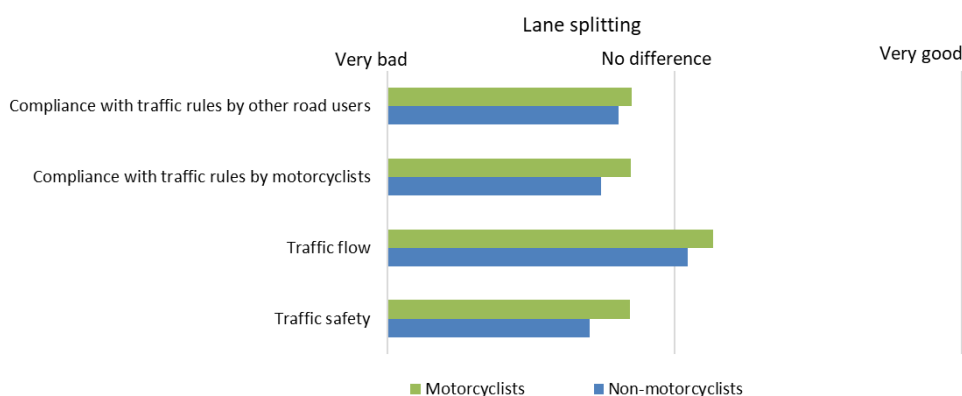


Figure 4.19 : Detailed evaluation of lane splitting - motorcyclists

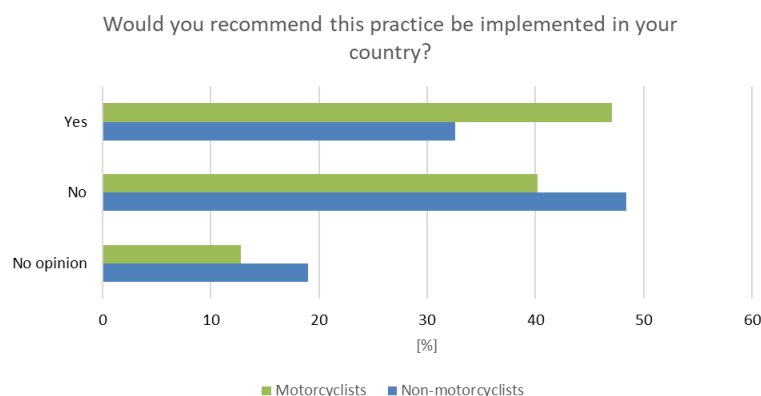


Figure 4.20 : Recommendation of lane splitting - motorcyclists

When comparing responses by the country's income level (LIC – Low-Income Countries, MIC – Middle-Income Countries, HIC – High-Income Countries), the measure received the highest ratings in HICs and the lowest in LICs (Figure 4.21). The most significant difference was observed in the 'Traffic Flow' category, where respondents from LICs believed that implementation would have a strong negative impact, while respondents from HICs perceived the measure as having a positive impact on traffic flow.

As a result, lane splitting is generally not recommended for implementation in LICs and MICs, while opinions are more divided in HICs (Figure 4.22).

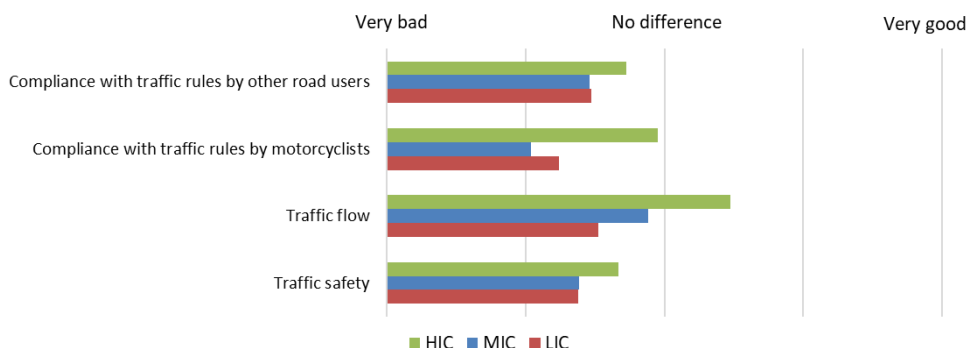


Figure 4.21 : Detailed evaluation of lane splitting – HIC/MIC/LIC

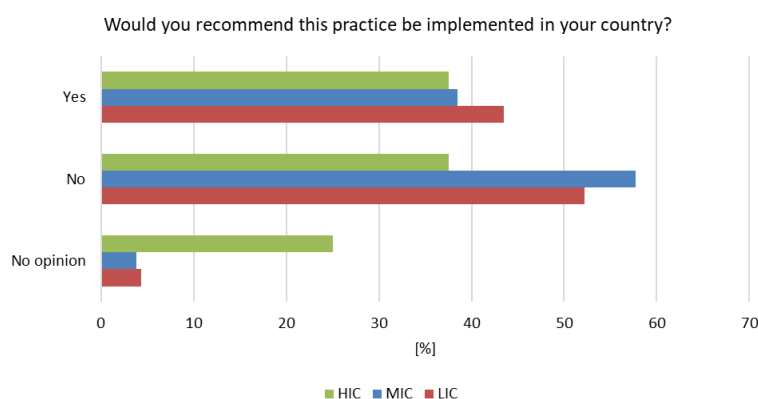


Figure 4.22 : Recommendation of lane splitting - HIC/MIC/LIC

Finally, when comparing responses by continent, the measure Lane Splitting received the highest ratings in North America and Europe (although still negative), and the lowest in Asia (Table 2). The most significant difference was observed in the Traffic Flow category, where respondents from Asia and Africa believed that implementation would have a negative impact on traffic flow. A similar pattern was seen in the Compliance with Traffic Rules by Motorcyclists category, where only respondents from Oceania believed the implementation would have a positive impact, while respondents from all other continents believed the measure would have a negative impact (Figure 4.23).

As a result, lane splitting is generally recommended for implementation only in Latin America. In all other continents, the prevailing opinion is that lane splitting is not recommended for implementation (Figure 4.24).

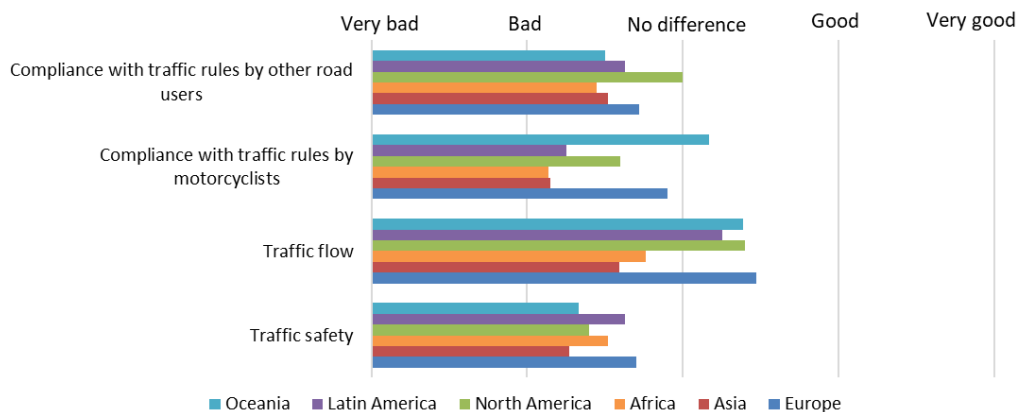


Figure 4.23 : Detailed evaluation of lane splitting – continent origin

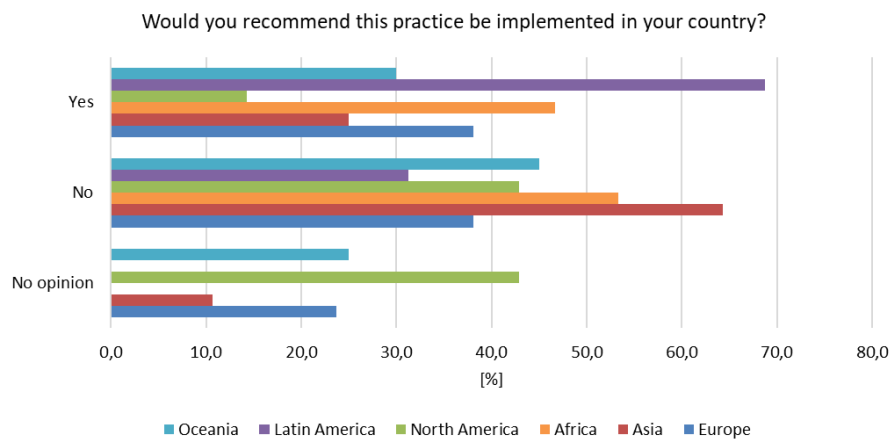


Figure 4.24 : Recommendation of lane splitting – continent origin

4.2.2. Dedicated Motorcycle Lanes

Dedicated Motorcycle Lanes (DML) are traffic lanes on which only Powered Two-Wheelers (PTWs) are permitted. - Inclusive - located on the outside of the main carriageway for each direction of traffic flow. - Exclusive - completely separated.

The measure Dedicated Motorcycle Lanes (DML) is rarely implemented, as only 6% of respondents indicated that it is used in their country. Among these respondents, additional insights are presented in Figure 4.25 and Figure 4.26.

- 77% stated it is legally regulated,
- and 23% reported that it is not regulated, yet still practiced.

Is this practice in use in your country?

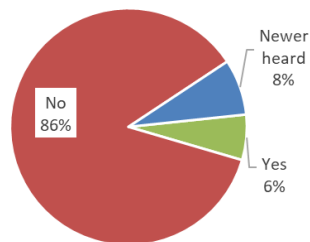


Figure 4.25 : Use of DML

Has this practice been legally regulated in your country?

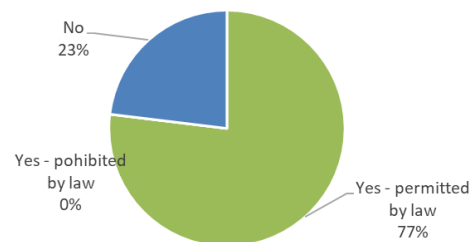


Figure 4.26 : Legally regulated DML

Regardless of whether the measure DML is regulated, unregulated, or unknown to respondents, the overall evaluation indicates that the measure DML received the highest score of 3.7 out of 5, suggesting that its implementation is expected to have a positive impact on overall traffic (Figure 4.14). This is particularly evident in the traffic safety and traffic flow categories, which received an average score of approximately 4 out of 5 (Figure 4.27). There is no significant difference in the evaluation between countries where the measure is regulated and those where it is not.

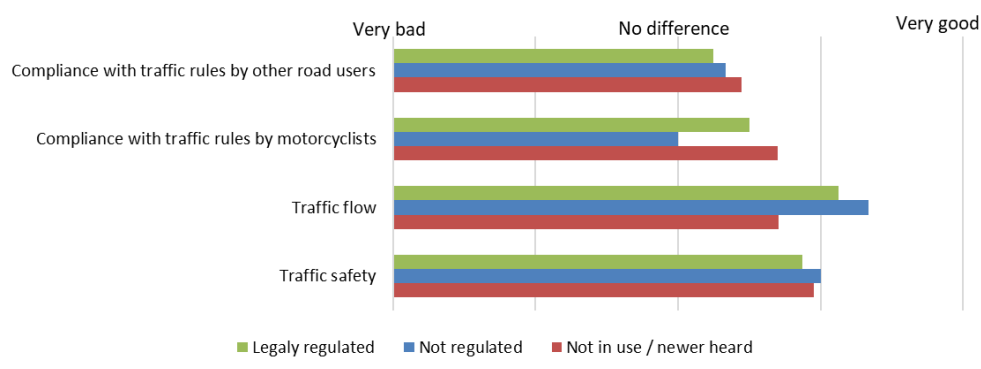


Figure 4.27 : Detailed evaluation of DML

These findings are consistent with responses to the question: “Would you recommend this practice be implemented in your country?” (Figure 4.28):

- In countries where the measure is legally regulated or not regulated, the majority of respondents would recommend its implementation.
- In countries where it is not used, or it is unknown, 48% of respondents would recommend it, while approximately 36% would not recommend it.

When analyzing the responses based on whether the respondent is a motorcyclist or not, motorcyclists rated the measure approximately 0.1 points higher across all categories. The overall evaluation is positive, especially in Traffic safety with an average score of approximately 4.0 out of 5 (Figure 4.29). More than 54% of motorcyclists would recommend the measure. The share of non-motorcyclists who would recommend the measure DML is slightly lower, at 49% (Figure 4.30).

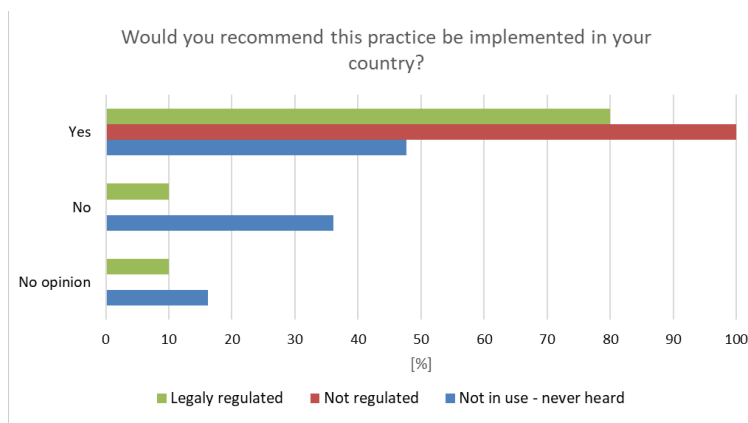


Figure 4.28 : Recommendation of DML

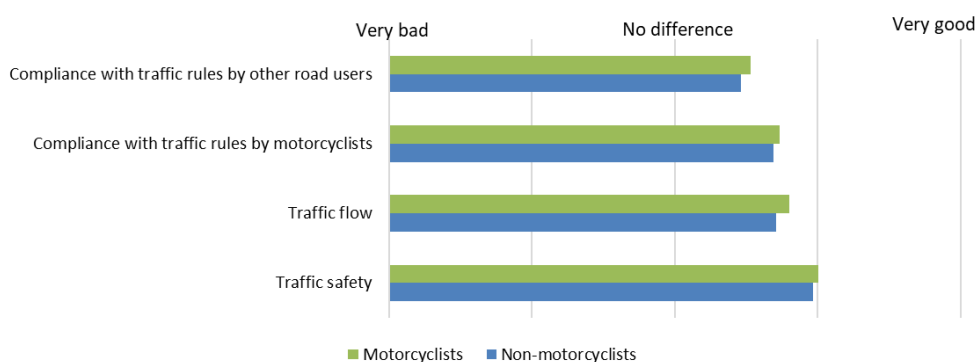


Figure 4.29 : Detailed evaluation of DML - motorcyclists

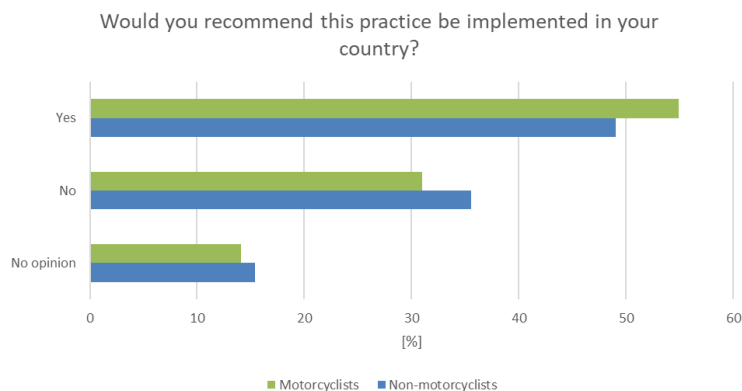


Figure 4.30 : Recommendation of DML - motorcyclists

Comparing the responses by the country's income level (LIC – Low-Income Countries, MIC – Middle-Income Countries, HIC – High-Income Countries), this measure received the highest ratings in MICs and LICs, while the lowest in HICs (Figure 4.31). The most significant difference was observed in the traffic flow category, where respondents from HICs believed that implementation would have on average the lowest positive impact across all evaluated aspects, especially in the traffic flow category.

As a result, DML is generally highly recommended for implementation in LICs and MICs, while in HICs the majority is against its implementation (Figure 4.32).

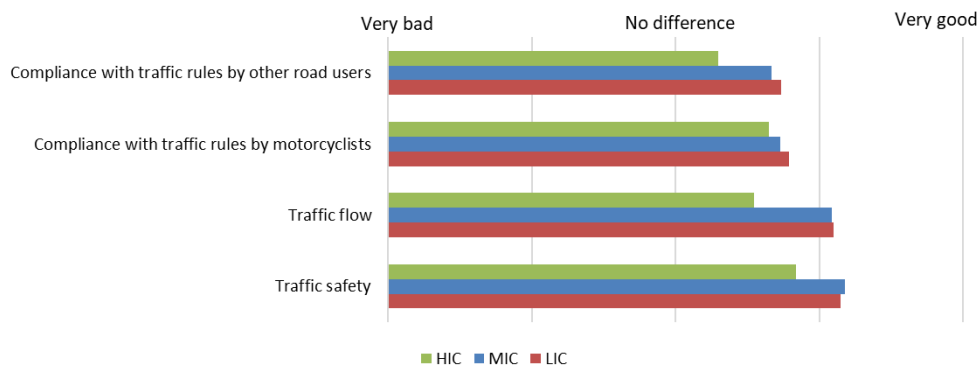


Figure 4.31 : Detailed evaluation of DML – HIC/MIC/LIC

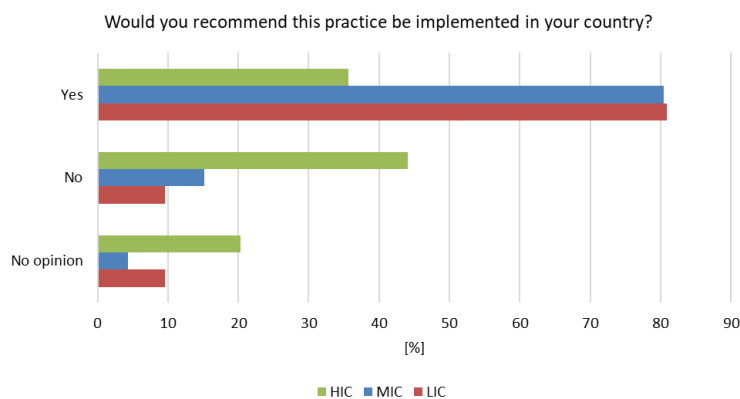


Figure 4.32 : Recommendation of DML - HIC/MIC/LIC

Finally, when comparing responses by continent, the measure DMC received the highest ratings in Asia and North America (4.0 out of a maximum of 5), and the lowest in Oceania (3.3 out of 5) (Table 3). The most significant difference was observed in the category Compliance with Traffic Rules by Other Road Users, where respondents from Oceania believed that implementation would have a negative impact on other road users' compliance with the DML regulation. However, across all continents, respondents believed that the implementation of DML would have a positive impact—particularly on traffic flow and safety (Figure 4.33).

As a result, DML is generally recommended for implementation in Europe, Asia, Africa, North America and Latin America. Only in Oceania is the prevailing opinion that DML would not be recommended for implementation (Figure 4.34).

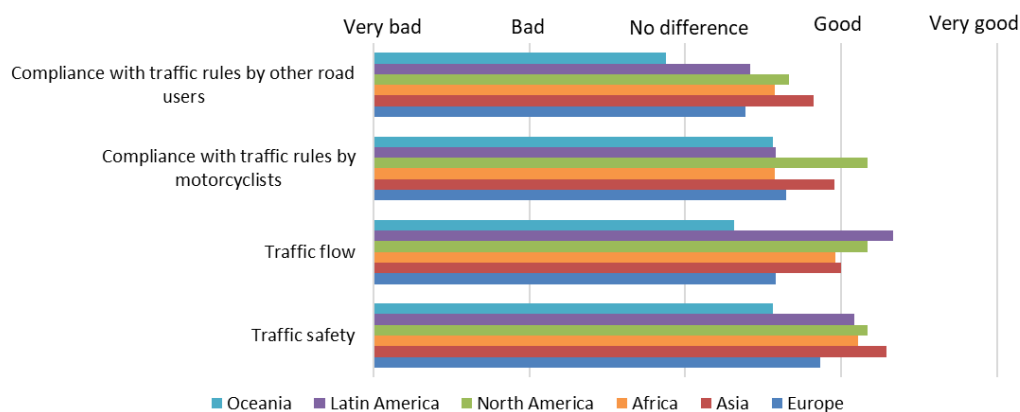


Figure 4.33 : Detailed evaluation of DML – continent origin

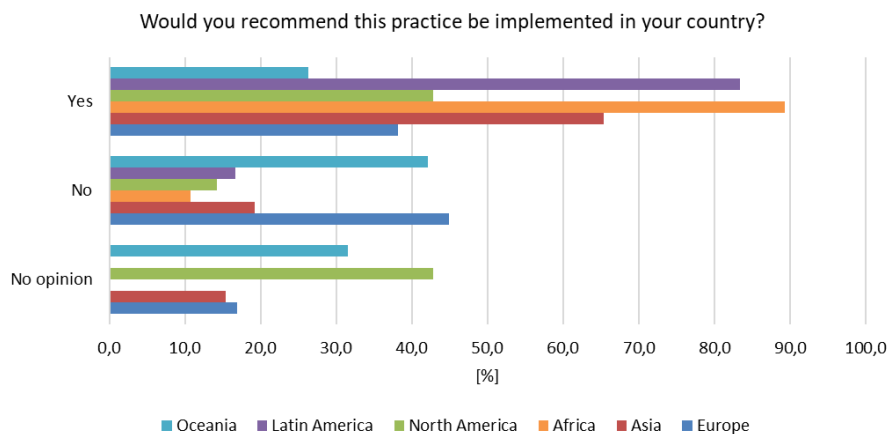


Figure 4.34 : Recommendation of DML – continent origin

4.2.3. Lane sharing

Lane sharing with public (passenger) transport is a traffic regulation where other road users (usually taxis, but also cyclists and powered two-wheelers) are allowed to drive on lanes designated for public passenger transport. In this case, separate lanes for public passenger transport are an integral part of the carriageway.

The measure Lane Sharing is not a global practice, as only 28% of respondents indicated that lane sharing is in practice in their country. Among these (Figure 4.35, Figure 4.36):

- 95% stated it is legally regulated, with 93% saying it is permitted by law and only 2% stating it is prohibited by law,
- and 5% reported that it is not regulated, yet still practiced.

Is this practice in use in your country?

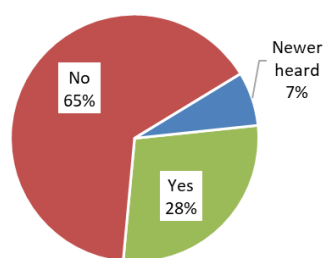


Figure 4.35 : Use of lane sharing

Has this practice been legally regulated in your country?

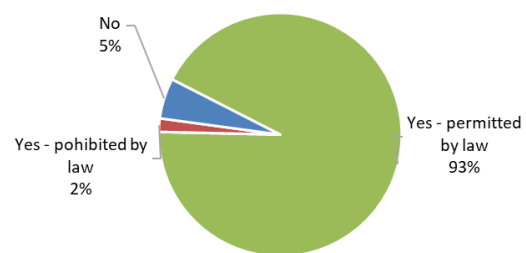


Figure 4.36 : Legally regulated lane sharing

Regardless of whether the measure is regulated, unregulated, or unknown to respondents, the overall evaluation indicates that lane sharing is recommended (Figure 4.14). This is particularly evident in the traffic safety and traffic flow category, which received an average score of 3.7 out of 5, suggesting that its implementation is expected to positively impact overall traffic (Figure 4.37). Where the measure is not regulated there is significant drop in the evaluation score especially in the category Compliance with traffic rules by motorcyclists. The score drops to 3.0, which corresponds to the rating 'No difference'.

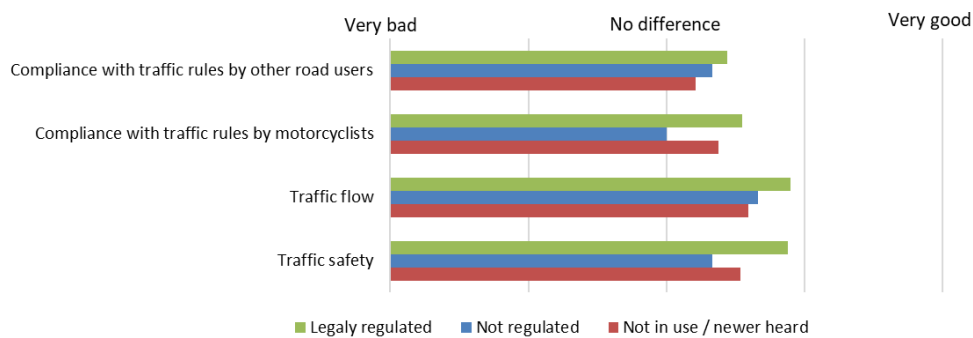


Figure 4.37 : Detailed evaluation of lane sharing

Responses to the question: “Would you recommend this practice be implemented in your country?” (Figure 4.38):

- In all countries where the measure is regulated, not regulated, not used, or unknown, the majority of respondents would recommend its implementation.
- Only 7% of respondents from countries where it is regulated would not recommend it, while approximately 33% of respondents from countries where the measure is not regulated, not used, or unknown would not recommend it.

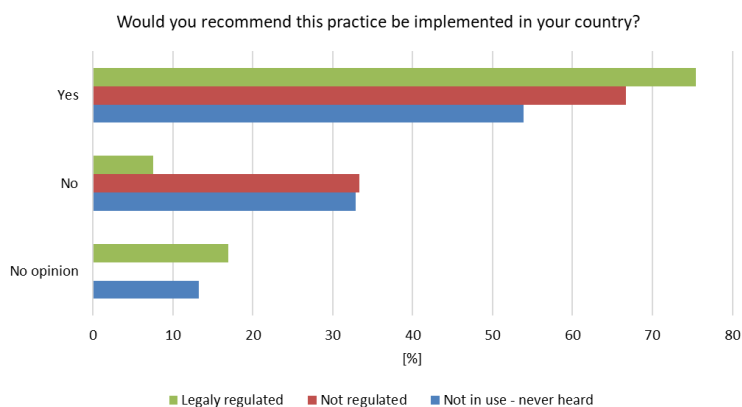


Figure 4.38 : Recommendation of lane sharing

The responses for the criterion 'Lane sharing' are almost identical regardless of whether the respondent is a motorcyclist or not. The highest ratings for this measure were given in the categories of 'Traffic Flow' and 'Traffic Safety'. The overall evaluation remained positive. Despite this, 75% of motorcyclists and also 67% of non- motorcyclists would recommend the measure (Figure 4.40).

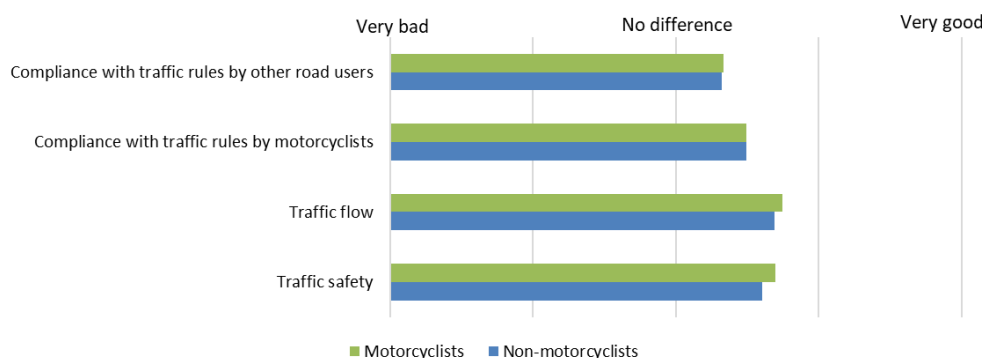


Figure 4.39 : Detailed evaluation of lane sharing - motorcyclists

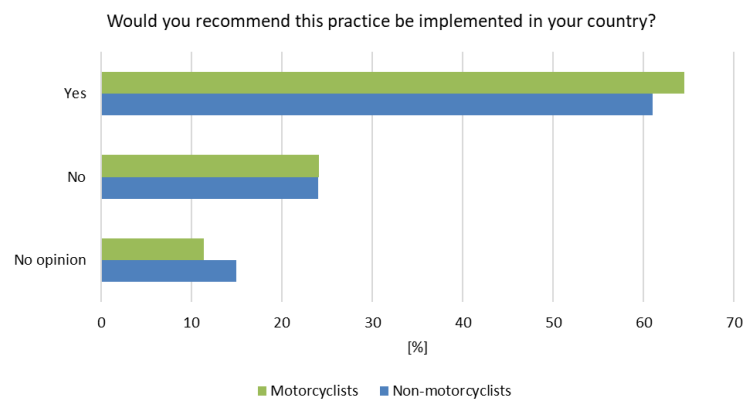


Figure 4.40 : Recommendation of lane sharing - motorcyclists

Finally, when comparing responses by country income level (LIC – Low-Income Countries, MIC – Middle-Income Countries, HIC – High-Income Countries), special attention should be given to the evaluation of Compliance with traffic rules by other road users and by motorcyclists. In both LICs and HICs, the scores in these categories were negative, indicating that respondents believe drivers do not comply with the lane sharing measure (Figure 4.41). However, across all income groups, respondents agreed that the implementation of the measure would have a positive impact on traffic flow.

More than 60% of respondents believe that the implementation of the lane sharing measure is generally highly recommended across all country income groups (LICs, MICs, and HICs) (Figure 4.42).

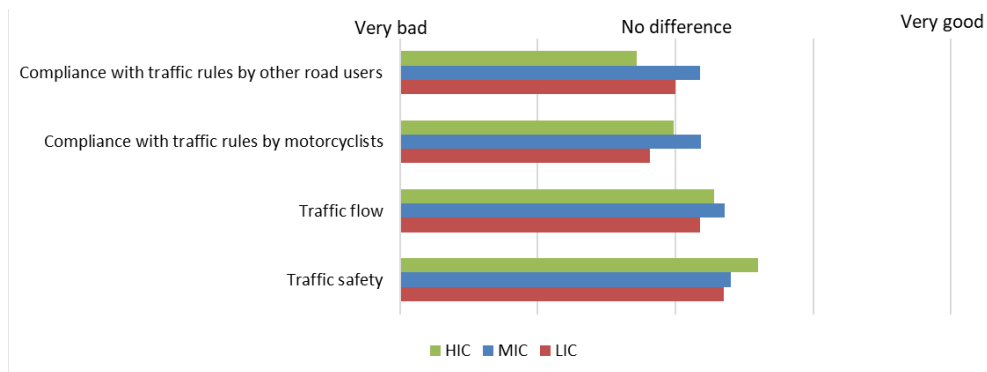


Figure 4.41 : Detailed evaluation of lane sharing – HIC/MIC/LIC

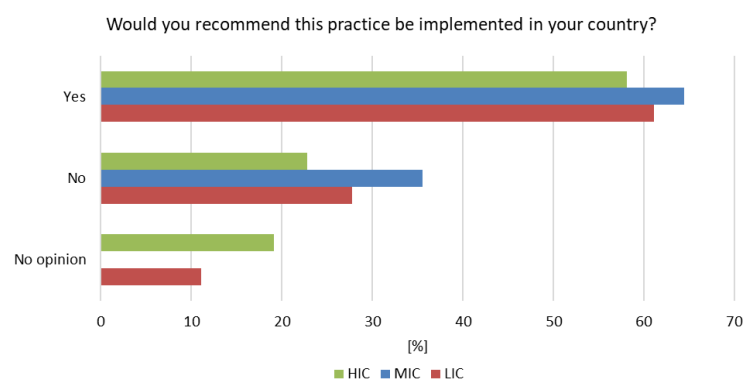


Figure 4.42 : Recommendation of lane sharing - HIC/MIC/LIC

Finally, when comparing responses by continent, the measure Lane Sharing received the highest ratings in North America (4.1 out of 5) and the lowest in Africa (3.0 out of 5) (Table 3). The most

significant difference was observed in perceptions of Traffic Flow, where respondents from Africa believed that implementation would negatively affect traffic flow. In contrast, respondents from all other continents generally believed that lane sharing would have a positive impact—particularly on traffic flow and safety (Figure 4.43).

As a result, lane sharing is generally recommended for implementation in Europe, Asia, Africa, and Oceania. In Latin America, opinions remain undecided. In North America and Oceania, a notably large proportion of respondents were also undecided (Figure 4.44).

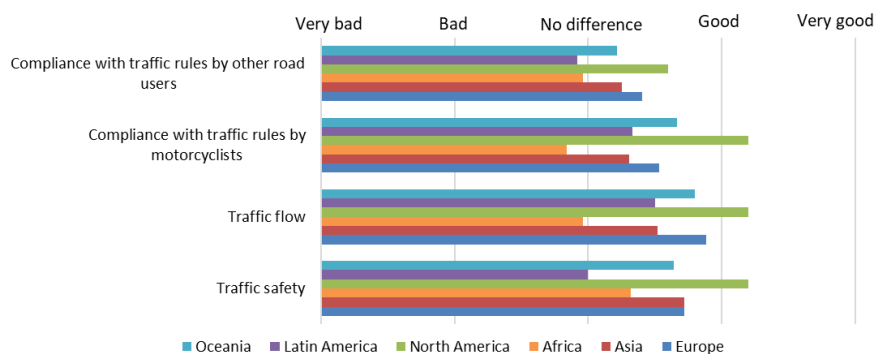


Figure 4.43 : Detailed evaluation of lane sharing – continent origin

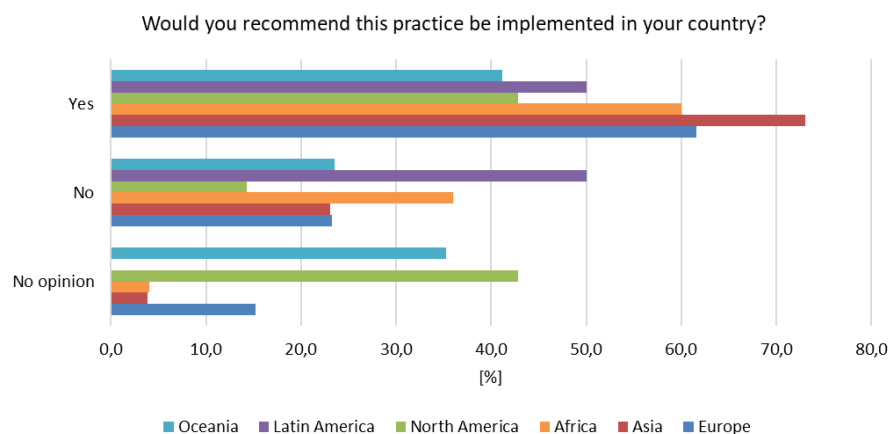


Figure 4.44 : Recommendation of lane sharing – continent origin

4.2.4. Advanced Stop Lines

Advanced Stop Lines (ASLs), also called "advanced stop box" or "bike box", are a type of road markings at signalised road intersection, allowing certain types of vehicles a head start when the traffic signal changes from red to green. Most commonly associated with bicycles, they may also be provided for motorcycles.

The measure Advanced Stop Lines is not a global practice, as only 26% of respondents indicated that they are in practice in their country. Among these (Figure 4.45, Figure 4.46):

- 92% stated this measure is legally regulated, with 90% saying it is permitted by law and only 2% stating it is prohibited by law,
- and 8% reported that it is not regulated, yet still practiced.

Is this practice in use in your country?

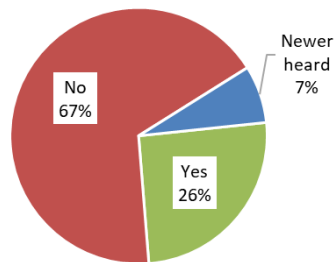


Figure 4.45 : Use of advanced stop lines

Has this practice been legally regulated in your country?

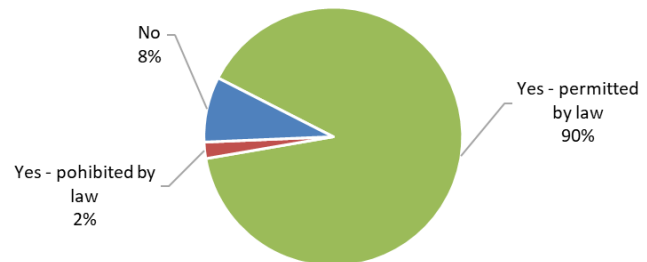


Figure 4.46 : Legally regulated advanced stop lines

Regardless of whether the measure is regulated, unregulated, or unknown to respondents, the overall evaluation indicates that lane sharing is recommended (Figure 4.14). This is particularly evident in the traffic safety and traffic flow categories, which received an average score of 3.8 out of 5, suggesting that its implementation is expected to positively impact overall traffic (Figure 4.47). Interestingly, respondents from countries where the measure is not regulated rated the measure Advanced Stop Lanes more positively, especially in the categories of traffic flow and traffic safety.

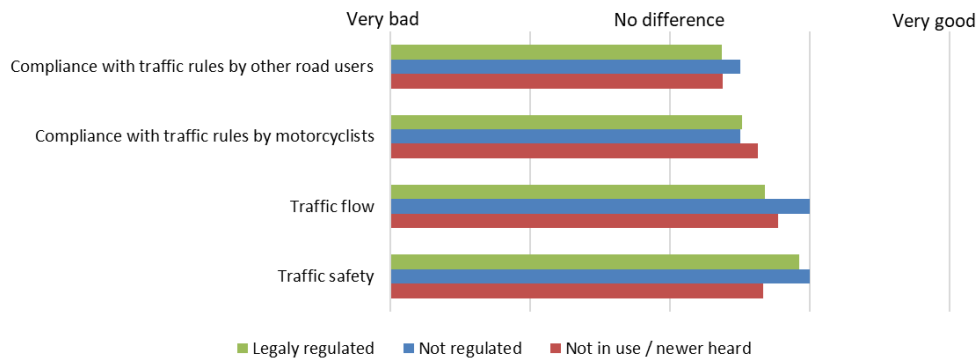


Figure 4.47 : Detailed evaluation of advanced stop lines

Responses to the question: "Would you recommend this practice be implemented in your country?" (Figure 4.48):

- In all countries where the measure is regulated, not regulated, not used, or unknown, the majority of respondents would recommend its implementation.
- Only 9% of respondents from countries where it is regulated would not recommend it and non from of respondents from countries where the measure is not regulated.

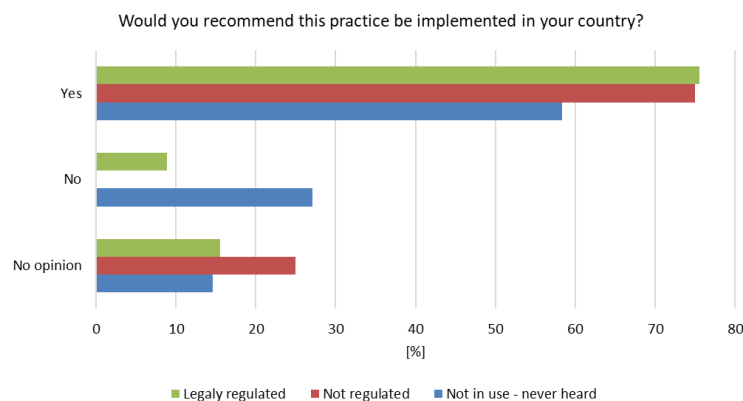


Figure 4.48 : Recommendation of advanced stop lines

When analyzing responses based on whether the respondent is a motorcyclist or not, the results do not differ significantly. However, it is noticeable that both groups similarly evaluate the measure as having bigger positive impact on traffic flow and safety (Figure 4.49). The overall evaluation of the measure remains slightly positive. Despite this, 70% of motorcyclists and 62% of non-motorcyclists would recommend the measure (Figure 4.50).

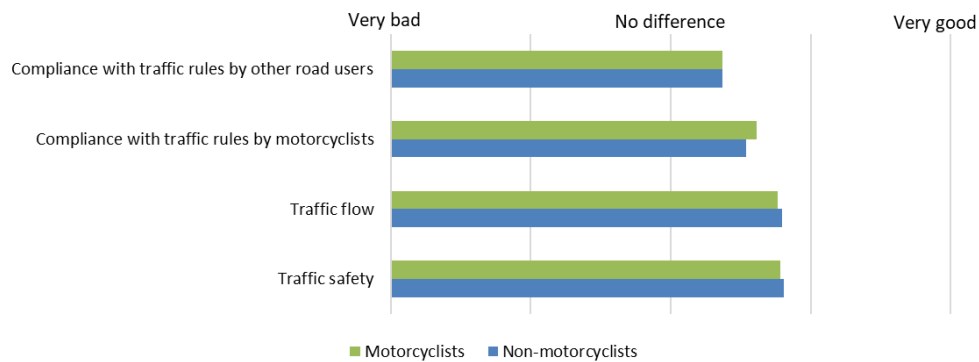


Figure 4.49 : Detailed evaluation of advanced stop lines - motorcyclists

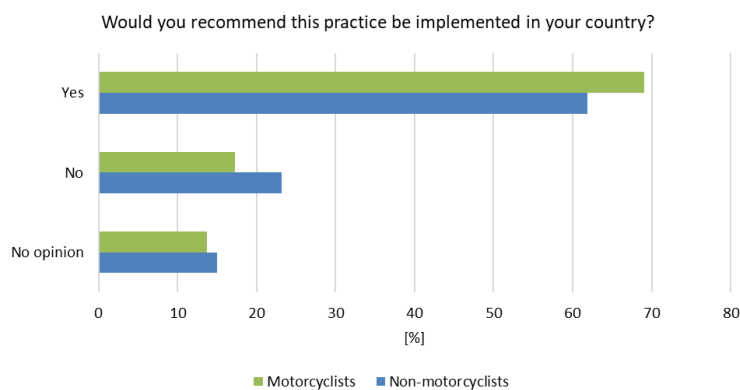


Figure 4.50 : Recommendation of advanced stop lines - motorcyclists

Finally, when comparing responses by country income level (LIC – Low-Income Countries, MIC – Middle-Income Countries, HIC – High-Income Countries), special attention should be given to the evaluation of 'Compliance with traffic rules by other road users' and 'Compliance by motorcyclists'. In HICs, the scores in these categories were the lowest among the positive ratings, indicating that respondents believe drivers may face challenges with the Advanced Stop Lines measure (Figure 4.51). Additionally, respondents in HICs rated the measure lower in terms of its positive impact on traffic flow and safety. However, across all income groups, respondents agreed that the implementation of the measure would have a positive impact on traffic flow.

The majority of respondents believe that the implementation of the lane sharing measure is generally highly recommended across all country income groups (LICs, MICs, and HICs) (Figure 4.52). The lowest level of support was observed in HICs, where only 55% of respondents recommended the measure, compared to 89% in LICs.

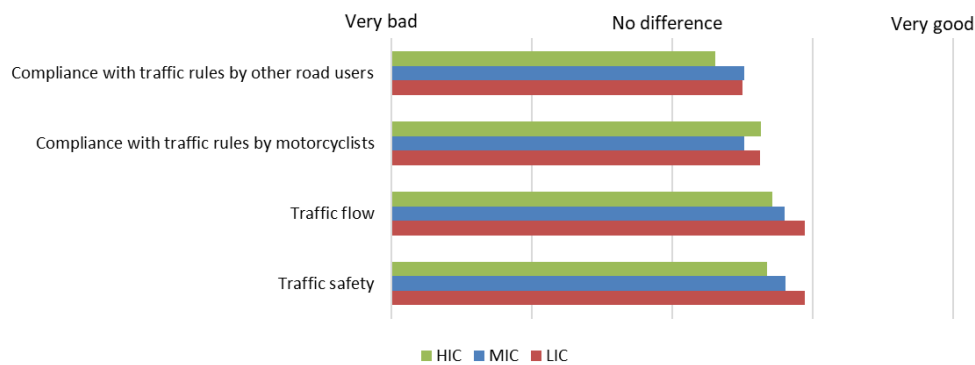


Figure 4.51 : Detailed evaluation of advanced stop lines – HIC/MIC/LIC

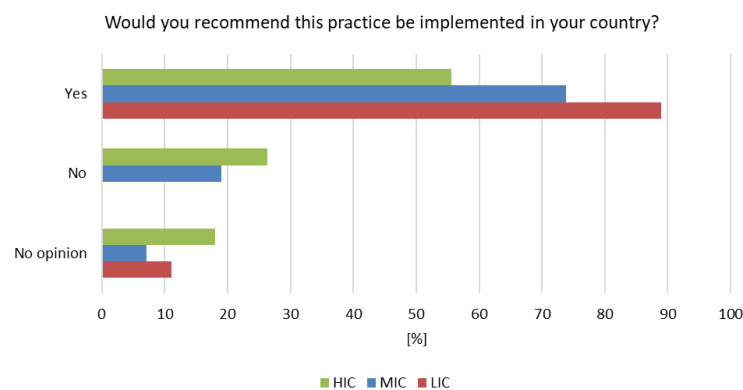


Figure 4.52 : Recommendation of advanced stop lines - HIC/MIC/LIC

When comparing responses by continent, the measure ASLs received the almost the same ratings in all continents. The highest ratings were in Latin America (3.8 out of a maximum of 5), especially higher than others in the field Traffic safety and flow, and the lowest ratings in North America in the Compliance with Traffic Rules by Other Road Users category, (3.0 out of 5) (Table 3 and Figure 4.53).

As a result, lane splitting is generally recommended for implementation across all continents. However, in North America, a notably large proportion of respondents (almost equal to those in favor of implementation) remained undecided (Figure 4.54).

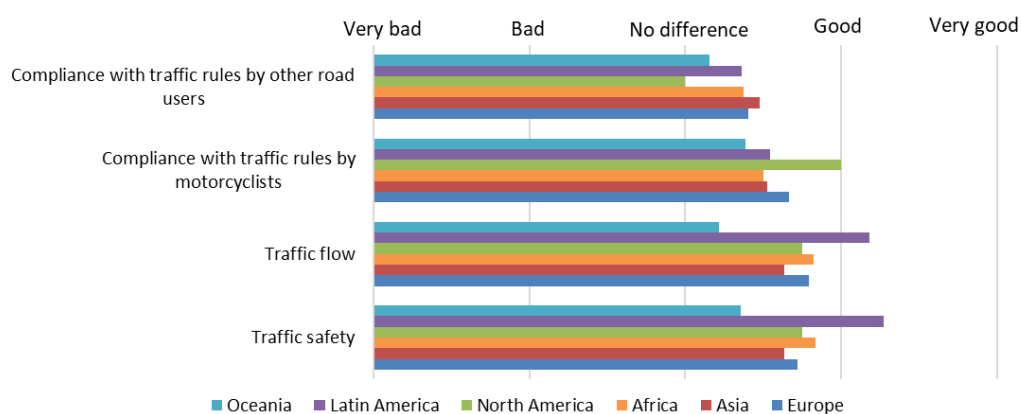


Figure 4.53 : Detailed evaluation of advanced stop lines – continent origin

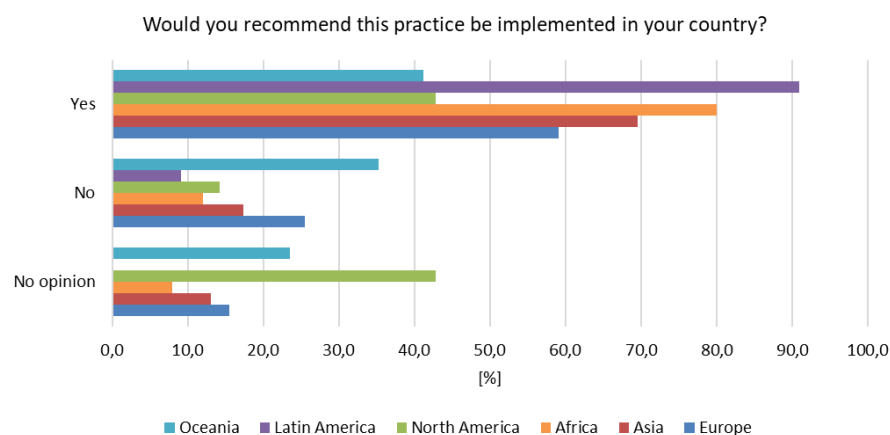


Figure 4.54 : Recommendation of advanced stop lines – continent origin

4.2.5. Filtering

Filtering refers to riding a Powered Two-Wheeler (PTW) between two columns of stationary vehicles (on two-lane roads, in front of a traffic light intersection, road construction site, at a traffic light level crossing of a road with a railway/tram, or something similar).

The measure Lane Filtering is a global practice, as 48% of respondents indicated that lane filtering is in practice in their country. Among these (Figure 4.55, Figure 4.56):

- 65% stated it is legally regulated, with 55% saying it is permitted by law and 10% stating it is prohibited by law,
- and 35% reported that it is not regulated, yet still practiced.

Is this practice in use in your country?

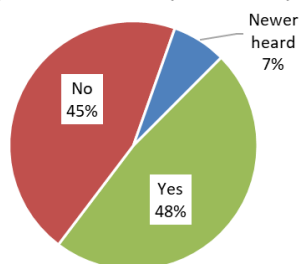


Figure 4.55 : Use of filtering

Has this practice been legally regulated in your country?

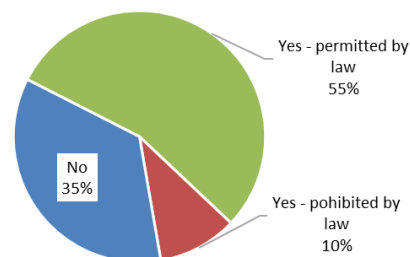


Figure 4.56 : Legally regulated of filtering

Regardless of whether the measure is regulated, unregulated, or unknown to respondents, the overall evaluation indicates that lane sharing is recommended; it received an average score of 3.3 out of 5 (Figure 4.14). This is particularly evident in traffic flow categories, which received an average score of 3.5 out of 5, in all other categories receives average score of 3.2 out of 5, suggesting that its implementation is expected to positively impact overall traffic (Figure 4.57).

Responses to the question: “Would you recommend this practice be implemented in your country?” (Figure 4.58):

- In all countries where the measure is regulated, not regulated, not used, or unknown, the majority of respondents would recommend its implementation.
- In countries where measure is not used, or unknown almost 38% of respondents would not recommend it.

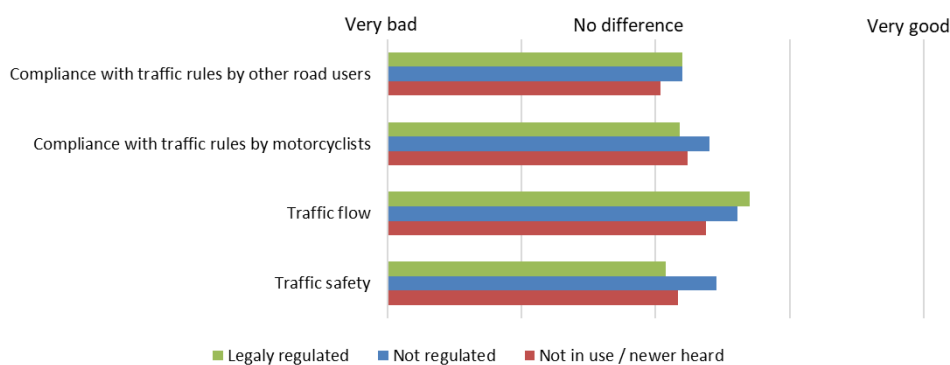


Figure 4.57 : Detailed evaluation of filtering

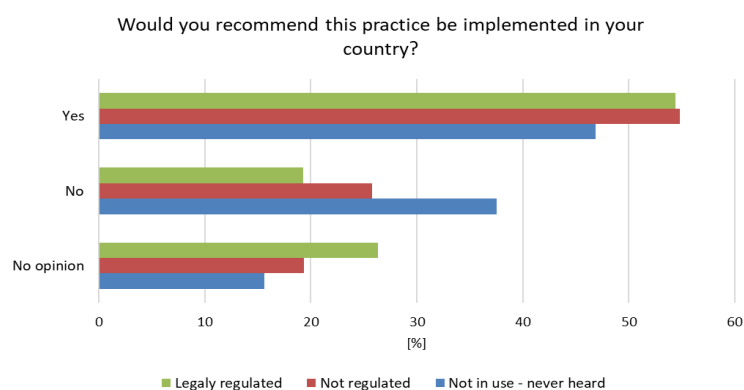


Figure 4.58 : Recommendation of filtering

When analyzing responses based on whether the respondent is a motorcyclist or not, the results do not differ significantly. However, it is noticeable that both groups similarly evaluate the measure as having a positive impact on traffic flow and safety, while having the lowest positive impact on the category “Compliance with traffic rules by other road users (Figure 4.59). The overall evaluation of the measure remains slightly positive. Despite this, 58% of motorcyclists and 45% of non-motorcyclists would recommend the measure (Figure 4.60).

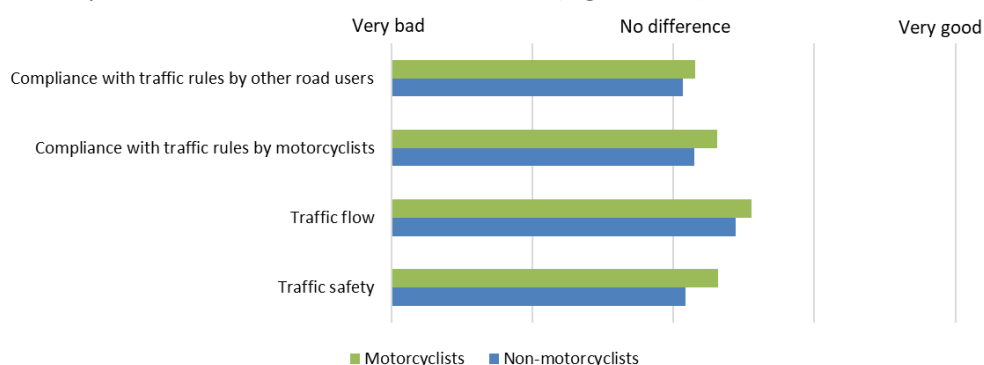


Figure 4.59 : Detailed evaluation of filtering - motorcyclists

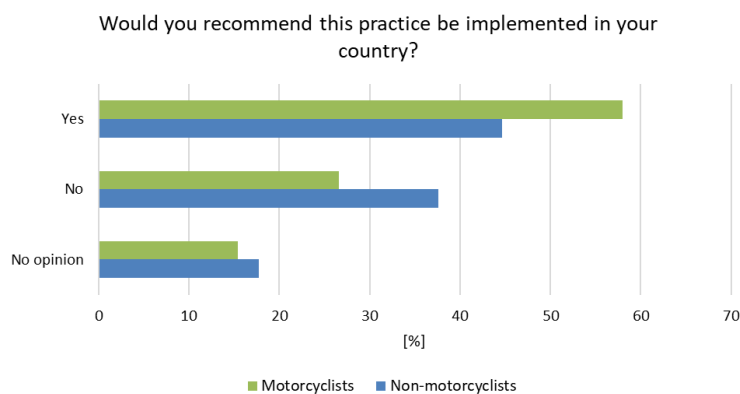


Figure 4.60 : Recommendation of filtering - motorcyclists

Finally, when comparing responses by country income level (LIC – Low-Income Countries, MIC – Middle-Income Countries, HIC – High-Income Countries), no significant differences were observed. Special attention should be given to the evaluation of 'Compliance with traffic rules by other road users' and 'Compliance by motorcyclists', as the use of this measure does not have a positive impact (Figure 4.61). Additionally, respondents in HICs rated the measure lower in terms of its positive impact on traffic safety. However, across all income groups, respondents agreed that the implementation of the measure would have the highest positive impact on traffic flow.

The majority of respondents believe that the implementation of the Lane Filtering measure is generally highly recommended across all country income groups (LICs, MICs, and HICs) (Figure 4.62). The lowest level of support was observed in HICs, where only 45% of respondents recommended the measure, compared to 71% in LICs.

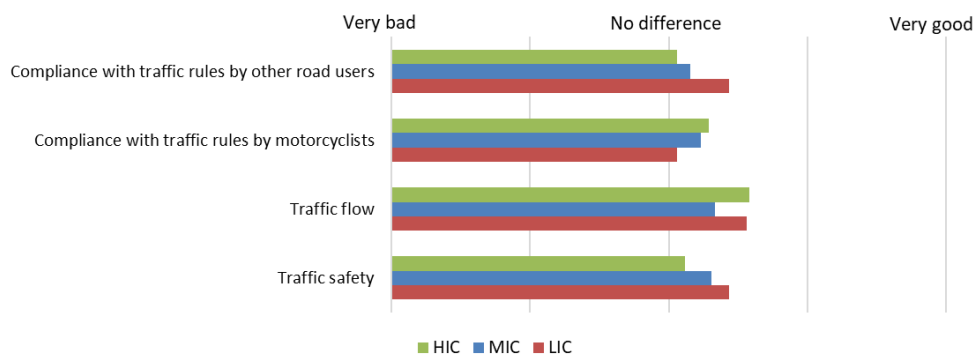


Figure 4.61 : Detailed evaluation of filtering – HIC/MIC/LIC

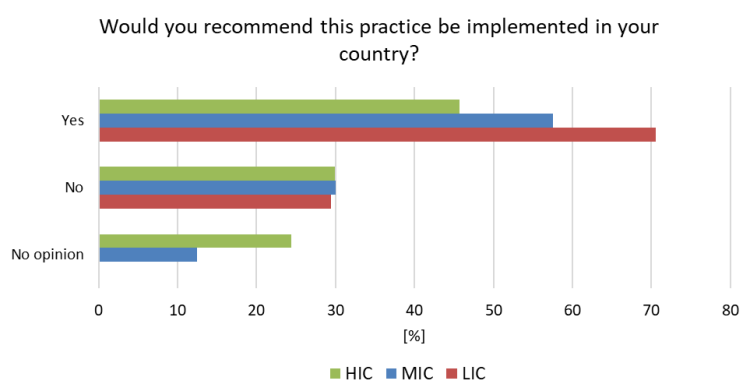


Figure 4.62 : Recommendation of filtering - HIC/MIC/LIC

When comparing responses by continent, the measure Lane Filtering received the highest ratings in North America (3.4 out of 5) and the lowest negative in Latin America (2.9 out of 5) (Table 3). The most significant difference was observed in perceptions of Compliance of traffic rules by motorcyclists and other road users and as well as in Traffic safety, where respondents from Latin America believed that implementation would negatively affect. In contrast, respondents from North America generally believed that lane filtering would have a positive impact—particularly on traffic flow (Figure 4.63).

As a result, lane filtering is generally recommended for implementation in Europe, Asia, Africa, and Oceania. In contrast, respondents in North and Latin America were generally against its implementation. Notably, in both North America and Oceania, a large proportion of respondents remained undecided (Figure 4.64).

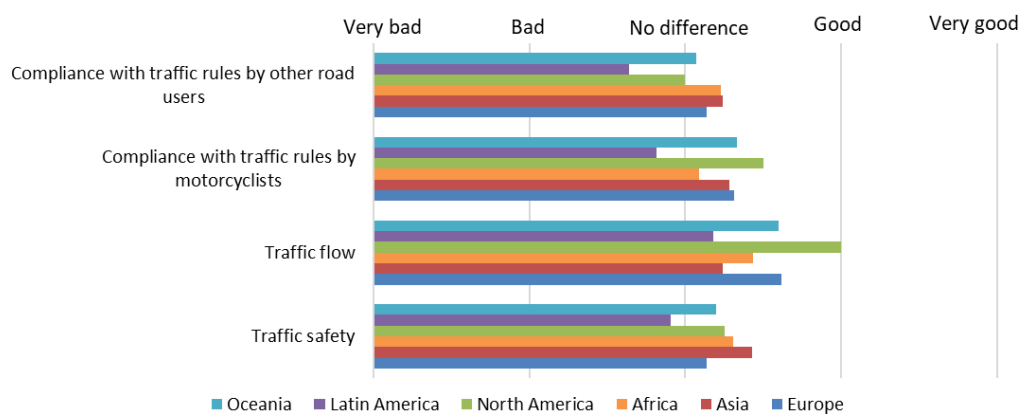


Figure 4.63 : Detailed evaluation of filtering – continent origin

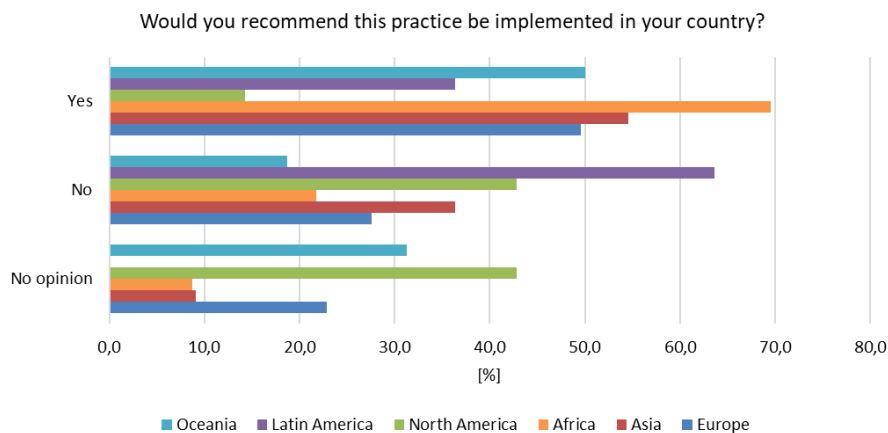


Figure 4.64 : Recommendation of filtering - continent origin

5. DISCUSSIONS

In the analysis and review of the survey results for both Motorcycle Protection Systems and Safety Aspects of Traffic Management for Motorcycles, we obtained a sufficient number of responses. Moreover, the distribution of the respondents across continents, countries, GNI levels, and between motorcyclists and non-motorcyclists was adequately balanced, allowing for meaningful cross-analysis and comparison.

5.1. MOTORCYCLE PROTECTION SYSTEMS

Regardless of the respondent groups, the greatest difficulty was observed in the evaluation of individual Motorcycle Protection Systems, as there are currently no standards, criteria, or guidelines available that would allow for a structured assessment of such systems. Consequently, more than 31% of the respondents did not provide an answer (responded with “No opinion”) when asked to evaluate systems or criteria related to traffic management for motorcycles.

Within the scope of this research, we did not identify any protection systems designed specifically for motorcyclists in the event of a collision with point obstacles, nor did we find any motorcycle-friendly crash cushions or end terminals. Although there are some systems that offer protection in the case of a motorcyclist impacting the upper edge of a steel guardrail, such solutions are rarely implemented in practice.

We believe that the main reason for the underdeveloped state of motorcycle-specific protection systems—whether for crash cushions, guardrails, or upper-edge protection of steel barriers—is the absence of appropriate standards, evaluation criteria, or even basic guidelines. These are essential to provide researchers with boundary conditions for system development and to support designers in making informed decisions about the installation of suitable protective measures.

5.1.1. Motorcyclists’ crash cushions

As part of the research, we identified only two crash cushions that, at first glance, appear suitable for protecting motorcyclists in the event of a collision:

- ARMADILO; designed for the protection of motorcyclists and
- RAPTOR® – COMPACT, which, in our opinion, can also effectively protect motorcyclists in the event of a point impact.

Of the two crash cushions, only the ARMADILO crash cushion is reported to have been tested according to the CEN/TS 17342:2019 standard. However, this standard is intended solely for assessing the suitability of longitudinal protection systems (SSB) that prevent motorcyclists from colliding with support posts, and does not address frontal impacts.

Despite the manufacturers’ claims, we were unable to obtain technical documentation for either crash cushion (ARMADILO or RAPTOR® – COMPACT) that would allow us to perform numerical simulations or assess the loads on a motorcyclist or a HYBRID III crash test dummy under various impact angles.

Both the survey results and the expert design team agree that the use of crash cushions such as ARMADILO or RAPTOR® – COMPACT significantly improves motorcyclist safety by contributing to the reduction of severe injuries in the event of a collision with a hazardous obstacle.

5.1.2. End terminals

As part of the research, we have identified two types of end terminal that, at first glance, appear suitable for protecting motorcyclists in the event of a collision:

- PolyBuffer and
- MAX-Tension®.

Both terminals exhibit significant safety shortcomings in the event of a motorcycle collision (sharp edges, lack of integration with the SSB, rigid structure, etc.), particularly the MAX-Tension® terminal. The PolyBuffer terminal received the highest rating in the category "Improving motorcyclists' safety", with a score of 4.2 out of 5, classified as slightly above "Good".

5.1.3. Upper guardrail protection for motorcyclists

In the fields of upper guardrail protection for motorcyclists, a considerable number of protective systems have already been documented. Based on our analysis, we highlight two systems that received the highest rating of 3.9 (GOOD) from both the survey respondents and the expert project team:

- ES2332553A1 (Figure 5.1) offers dual protection—both for the upper edge of the guardrail and against collisions with SSB posts (commonly referred to as a motorcycle rail). However, it has some limitations as stated below.
 - It does not adequately protect the motorcyclist from impact with the upper edge of the guardrail.
 - The upper edge protection is narrow and rigid, which may be unsuitable in the event of a collision.

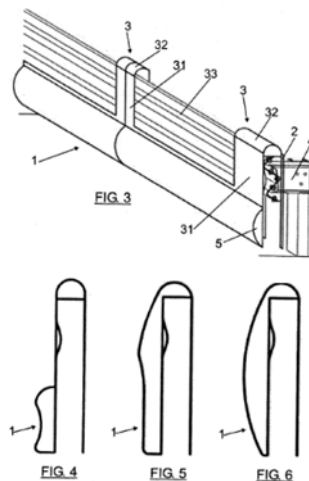


Figure 5.1: Protection device on road safety barriers - ES2332553A1

- P-202500009 (Figure 5.2) is focused solely on upper edge protection. Its slim design and cantilever mounting on the top of the SSB guardrail effectively prevent contact between the motorcyclist and both the upper edge and the top of the support post. Its slender structure also helps absorb impact forces during a collision. Furthermore, analysis has shown that extending the upper edge of the guardrail can help prevent motorcyclists from falling over to the opposite side of the barrier during an impact.

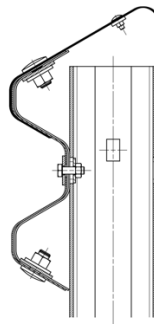


Figure 5.2 : Protection element for motorcyclists on SSB - P-202500009

Both protective elements are recommended, as they significantly improve motorcyclist safety by contributing to the reduction of severe injuries in the event of a collision with SSB barriers.

5.2. SAFETY ASPECTS OF MANAGEMENT OF TRAFFIC FOR MOTORCYCLES

After analysing the topic of Traffic Management for Motorcycles, the measures can be divided into two main groups.

- Separation of motorcyclists from other traffic, including:
 - Dedicated Motorcycle Lanes (DML) and
 - Lane Sharing.
- Granting privileges to motorcyclists, allowing them to ride between lanes, including:
 - Lane Splitting,
 - Filtering and
 - Advanced Stop Lines (ASLs).

The survey results also show that the respondents from different countries provided varying answers regarding whether each specific criterion is applied in their country and whether it is legally regulated.

5.2.1. Dedicated Motorcycle Lanes (DML) and Lane Sharing

The measure Dedicated Motorcycle Lanes (DML) has a very positive impact on traffic safety, as it relocates vulnerable road users—namely Powered Two-Wheelers (PTWs)—into a safer zone: lanes on which only PTWs are permitted. These lanes can be: inclusive: located on the outer edge of the main carriageway for each direction of traffic flow, or exclusive: completely separated from the main traffic lanes. By reducing interactions between PTWs and other traffic participants, DMLs enhance safety. However, their positive effect on traffic flow becomes noticeable only when the AADT (Annual Average Daily Traffic) of PTWs is relatively high.

In the case of lane sharing—where PTWs shared a lane with buses and/or taxis - the safety benefits for PTW riders are also positive. Moreover, this measure improves both safety and traffic flow even at lower PTW AADT (Annual Average Daily Traffic).

Road safety gains can only be obtained if PTW users strictly respect speed limits in the bus lanes and if all road users are well aware of the possibility of meeting a PTW at an intersection when crossing the bus lanes. But reports highlight that the main issue with both Dedicated Motorcycle Lanes and Lane Sharing is non-compliance with traffic rules by motorcyclists, who often ride across the entire roadway instead of staying within the designated lanes.

Nevertheless, the use of dedicated motorcycle lanes and lane sharing is strongly recommended by the respondents and experts across continents, countries, GNI levels, and among both motorcyclists and non-motorcyclists.

5.2.2. Lane splitting

The measure Lane Splitting allows motorcyclists to ride between the two lanes furthest to the left (in countries with right-side driving, such as in most European countries) of slowly moving vehicles. This means that a greater number of vehicles can occupy the same road surface area, which leads to an increase in traffic flow, particularly for Powered Two-Wheelers (PTWs).

However, it is important to note that this measure also increases the potential for interaction between vehicles, which can negatively affect traffic safety (Figure 5.3), even though lane splitting is intended to be used only in conditions of slow-moving traffic.

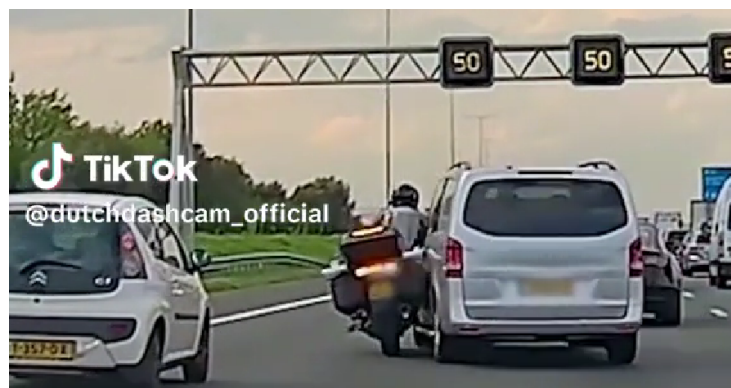


Figure 5.3: While changing line, vehicle crashes into PTW, which is practicing lane splitting [48]

Survey results support these findings, with the respondents generally advising against the implementation of Lane Splitting due to safety concerns.

5.2.3. Filtering

The measure Lane Filtering is widely practiced globally, as confirmed by survey results showing that it is both commonly used and legally permitted in most countries. Filtering refers to riding a Powered Two-Wheeler (PTW) between two columns of stationary vehicles—for example, on two-lane roads in front of traffic lights, at road construction sites, or at level crossings with rail or tram lines.

This measure allows a greater number of vehicles to occupy the same road surface area, which leads to an increase in traffic flow, particularly for PTWs. However, it may slightly reduce the flow efficiency for other vehicles. It is important to note that filtering also increases the potential for interaction between vehicles, which can negatively affect traffic safety, even though it is intended to be used only in stationary traffic conditions.

Once traffic begins to move, filtering often transitions into lane splitting, a practice that is not recommended due to its higher safety risks.

Nevertheless, the use of filtering is recommended by the respondents and experts across continents, countries, GNI levels – especially by LICs, and among both motorcyclists and non-motorcyclists.

5.2.4. Advanced Stop Lines (ASLs)

The measure Advanced Stop Lanes (ASLs)—also known as advanced stop boxes or bike boxes—is not widely practiced globally. These are road markings at signalised intersections that allow certain types of vehicles a head start when the traffic signal changes from red to green.

According to survey results, ASLs are among the most recommended measures for improving traffic safety. However, to implement them effectively, it is advisable to combine them with Dedicated Motorcycle Lanes (DML) or at least Lane Sharing, so that PTWs can safely reach the advanced stop box.

Without such supporting infrastructure, PTWs can only access the ASL by riding between vehicles—through filtering or lane splitting—which negatively affects traffic safety.

Additionally, in cases of increased PTW traffic volume, situations may arise—such as the one illustrated in the cover image—where the effectiveness of ASLs is compromised due to congestion and limited space.

6. CONCLUSIONS

As part of the PIARC Special Project: “Motorcycle Protection Systems & Safety Aspects of Traffic Management for Motorcycles,” we conducted an extensive study of the issues outlined in the project brief. The workflow and conclusions of the study can be summarized in the following key points.

1. At the beginning of the project, we conducted a global scan and extensive data collection, which included three main approaches: scientific and professional expertise of the research group in the field of traffic safety, a comprehensive review of publicly available literature and a multilingual online survey.
2. Based on the expertise of the project team, as well as insights from the comprehensive review of publicly available literature, completed project proposals, and market research, we expanded the scope of the study within the project to include the areas listed below.
 - Within the topic of Motorcycle Protection Systems (MPS), we expanded the study to include the following areas:
 - Motorcyclists’ Crash Cushions,
 - End Terminals and
 - Upper Guardrail Protections
 - Within the topic of Traffic Management for Motorcycles, we expanded the study to include the following areas:
 - Dedicated Motorcycle Lanes,
 - Lane Splitting,
 - Filtering,
 - Advanced Stop Lines and
 - Lane Sharing.
3. In the area of Motorcycle Safety and Protection Systems, we emphasized that a credible analysis and further development of these systems is currently not possible due to the absence of a dedicated standard, guideline, or recommendation. Such a framework should define the minimum safety requirements for motorcyclists in the event of a collision with these systems, and also provide clear criteria for when and how to install such safety systems. Specifically, it is necessary to define specifications for motorcyclist-friendly Crash Cushions, End Terminals, and Safety Barrier Systems (SSB), especially for rural and high-speed roads, to prevent injuries in the case of a sliding crash and upright-posture crash. These measures should promote forgiving infrastructure that accommodates human error and reduces crash consequences.
4. Guardrail End terminals are especially critical: poorly designed terminals can cause severe injuries to motorcyclists. Safer alternatives need to be developed, including rounded, energy-absorbing, or shielded ends. Additionally, certain hazards can be avoided already during the road design phase, and they can also be corrected later, even after the road has been built. Therefore, with minor adjustments to the alignment of road safety barriers, the need for installing end terminals can sometimes be eliminated altogether.
5. For Upper Guardrail Protection in the event of a motorcyclist collision, several systems have already been developed that successfully prevent any contact between the rider and the sharp edge of the barrier or the upper part of the Safety Barrier System (SSB) post.

However, to ensure credible evaluation of these systems, an appropriate standard is needed—one that defines specifications for motorcyclist-friendly SSBs designed to prevent injuries in the case of a sliding crash and upright-posture crash.

6. In the field of Motorcycle Traffic Management Practices, in addition to Dedicated Motorcycle Lanes and Lane Splitting, we expanded the study to include Filtering, Advanced Stop Lines (ASLs), and Lane Sharing.
7. The measures in the category Traffic Management for Motorcycles can be divided into two main groups.
 - Separation of motorcyclists from other traffic which generally increase Traffic safety and flow of motorcyclists:
 - Dedicated Motorcycle Lanes (DML) and
 - Lane Sharing
 - Granting privileges to motorcyclists, allowing them to ride between lanes, which generally increases Traffic flow and decrease Traffic safety of motorcyclists:
 - Lane Splitting,
 - Filtering and
 - Advanced Stop Lines (ASLs).
8. In the field of Motorcycle Traffic Management Practices, a major issue is the inconsistency in both practical application and legal regulations regarding whether certain measures are permitted or not. These differences vary across continents and even between individual countries. To improve safety, it is recommended that both practices and legal frameworks related to Motorcycle Traffic Management be coordinated as much as possible.
9. A multilingual online survey was conducted, through which we gathered information regarding the evaluation of Motorcycle Protection Systems—specifically Motorcyclists' Crash Cushions, End Terminals, and Upper Guardrail Protections. The evaluation focused on the following aspects: improving motorcyclists' safety, complexity of installation, design flexibility, maintenance requirements, use of recycled materials, cost-effectiveness, and general performance. Additionally, the survey included an evaluation of Motorcycle Traffic Management practices—such as Dedicated Motorcycle Lanes, Lane Splitting, Filtering, Advanced Stop Lines, and Lane Sharing—based on expert opinions regarding traffic safety, traffic flow, compliance with traffic rules by motorcyclists, and compliance with traffic rules by other road users.
10. The survey was conducted in a way that allows the results to be compared based on several criteria: Gross National Income (GNI) per capita—distinguishing between Low-Income Countries (LIC), Middle-Income Countries (MIC), and High-Income Countries (HIC); whether the respondent is a member of the PIARC association; whether the respondent has professional experience with motorcycle protection systems and safety aspects of traffic management for motorcyclists; and whether the respondent is a motorcyclist or not.
11. The data collected from the survey was analyzed using both qualitative and quantitative methods. Key success factors were identified, and the effectiveness of various protective measures and traffic management systems was assessed.

12. Based on the results, we proposed general recommendations as well as targeted suggestions for improving road safety related to each Motorcycle Protection System and Motorcycle Traffic Management practice. These recommendations are adaptable to local environmental conditions, especially for Low- and Middle-Income Countries (LMICs).
13. The survey results also reveal a lack of expertise among professionals in the field of Traffic Management for Motorcycles across different countries, as they provided contradictory answers regarding whether each specific criterion is applied in their country and whether it is legally regulated.

7. RECOMMENDATIONS

Recommendations from the PIARC Special Project regarding Motorcycle Protection Systems and Safety Aspects of Traffic Management for Motorcycles include:

- Standardization Requirements for Motorcycle Crash Protection Systems,
- Guidelines for the Selection and Implementation of Motorcycle Protection Systems,
- Guidelines for Traffic Management for Motorcycles Measures,
- Conducting Pilot Tests and Evaluating Informal Practices Prior to Implementation,
- Integrate motorcycle-specific rules into driver training programs.

The project group is aware that the unification of traffic rules is a basic condition for safe traffic. This is especially true for transit and tourist countries where foreigners are not familiar with these rules. The same applies to road signs and road markings. If a foreigner understands them, it is easier for them to follow the rules.

On the other hand, each country has its own traffic regulations (rules and also traffic signs), which are adapted to the greatest extent possible to the real conditions in that country (general culture, traffic culture, weather conditions, the length of the motorcycle season, speed limits, road widths, the number of PTWs, percentage of PTWs in the traffic flow structure, etc.) and are therefore the most appropriate for these countries.

Although there is an umbrella document Vienna Convention on Road Signs and Signals, a key international document that standardizes traffic signage worldwide) [46], it is not possible to expect that all countries will have the same road signs. If, for an example, a country already has a road sign indicating lane splitting and the sign is then changed, this could have a completely opposite effect than expected (drivers not understanding the new road sign). In fact, changes to traffic signs and road markings might lead to reduced road safety due to a lack of understanding.

Therefore, the project group does not propose traffic rules and traffic signs be unified worldwide.

However, the project group does propose the unification of traffic rules and traffic signs, while leaving the final decision to the respective decision makers in each country.

The following sections provide a detailed description of each recommendation, as well as specific guidelines related to individual traffic management measures.

7.1. RECOMMENDATIONS FOR DECISIONS MAKERS - MOTORCYCLE PROTECTION SYSTEMS

7.1.1. Standardization requirements for motorcycle crash protection systems

To eliminate motorcyclist injury and fatality in crashes with single obstacles, end terminals of safety barriers, or steel guardrails themselves, a set of standards need to be defined:

- impact test criteria for motorcyclists,
- testing methods for evaluating safety performance for motorcyclists,
- and design restrictions for protective systems to prevent contact with sharp or rigid structural elements.

Only through such standardization will it be possible to validate motorcycle protection systems and provide clear development guidelines for manufacturers.

7.1.2. Guidelines for the selection and implementation of motorcycle protection systems

Until a standard or formal criterion is established, it is recommended that decision-makers first develop clear guidelines for a selection of Motorcycle Protection Systems, which can be consistently followed. The recommendations listed below should be considered.

- The system should have at least the CEN/TS 17342:2019 certification.
- Preference should be given to systems that have undergone successful real-world crash tests or simulations involving motorcyclists, with results demonstrating improved safety outcomes.
- The system should be made of motorcyclist-friendly materials and designed with a structure that absorbs the rider's kinetic energy gradually (slowing them down gently rather than abruptly), while also allowing for safe redirection.
- The protection system must not contain sharp edges or rigid protruding elements that could come into contact with a motorcyclist during a crash.

Additionally, certain hazards can be avoided even during the road design phase, and they can also be corrected later, even after the road has been built. Therefore, with minor adjustments to the alignment of road safety barriers, the need for installing end terminals can sometimes be eliminated altogether.

7.2. RECOMMENDATIONS FOR DECISIONS MAKERS - MEASURES OF TRAFFIC MANAGEMENT FOR MOTORCYCLES

7.2.1. Conduct pilot tests and assess informal practices before implementation

As the safety impact of traffic management measures for motorcycles appears to depend on numerous individual factors such as PTW traffic volume, general and traffic culture, human behaviour, the amount of fines for traffic violations, the percentage of fines collected, climatic conditions, and the mass of different types of motorized road users — it is recommended that pilot tests of such measures be conducted and the results of traffic safety, traffic flow, compliance with traffic rules by motorcyclists and by other road users be carefully analysed prior to implementation. Each specific case must be thoroughly assessed.

It is also very important to take into account the current practices by motorcyclists, especially those that are not yet officially permitted, regulated, or prohibited. In such cases, the actual state of road safety must be considered when evaluating the effectiveness or necessity of specific criteria. Understanding how motorcyclists interact with the existing infrastructure and informal practices can provide valuable insights for developing realistic and effective safety measures.

7.2.2. Integrate motorcycle-specific rules into driver training programs

A very important recommendation, regardless of whether a specific measure of traffic management for motorcycles is implemented in a country or not, is that the characteristics and rules of such a measure should be included at least in the theoretical part of driver training for all categories. In countries where such measures are not yet permitted or are prohibited, it is also recommended for the safety of both motorcyclists and other road users to include practical training (exercises) for drivers of all categories, but only on dedicated training grounds. This is the only way drivers can acquire the necessary practical skills for driving in situations where such measures are implemented (e.g., when driving in countries where these measures are implemented).

7.2.3. Compliance with traffic rules

Road safety improvements can only be achieved if powered two-wheeler (PTW) users, as well as other road users, strictly adhere to speed limits and the specific rules associated with each implemented traffic management measure for motorcycles.

7.2.4. Recommendation for specific traffic management measure

Listed below are the conditions that must be met for a measure to perform its function effectively (from traffic safety and traffic flow point of view).

Dedicated Motorcycle Lanes:

- This measure requires clear rules (such as minimum lane width, permitted driving speed, the position of DMV on the carriageway, junction arrangements, prohibition of use by other vehicles, etc.) be set out in legislation.
- The introduction of this measure only makes sense in the case of a large percentage of PTWs in the overall traffic flow structure ($\geq 30\%$).
- Exclusive motorcycle lanes are a better (safer and more "fluid") solution than inclusive motorcycle lanes.

- It is safer if inclusive motorcycle lanes are separated from other traffic by physical barriers, rather than by painted lines.
- It is safer if inclusive motorcycle lanes are located on the outside of the main carriageway, rather than in the middle.
- The biggest shortcoming of the inclusive motorcycle lane occurs before the intersection area (where drivers make different manoeuvres).
- Regardless of whether it is an exclusive or inclusive dedicated motorcycle lane, the width of a lane for one-way direction must be at least 1.5 m.
- For the purposes of an inclusive dedicated motorcycle lane, one lane of the main carriageway can also be used (lane withdrawal).

Lane Splitting:

- This measure requires clear rules set out in legislation.
- Lane splitting may only be permitted on open road sections.
- Sections of motorways where lane splitting is permitted must be marked with an appropriate traffic sign.
- The condition for introducing lane splitting is traffic lanes of appropriate width (on motorways ≥ 3.75 m).
- Motorcyclists must ride between the two lanes furthest to the left.
- When riding between two rows of cars, motorcycles must not exceed 50 km/h.
- The difference between their speed and that of the cars they are passing must not exceed 20 km/h.
- It is necessary to decide whether riding a PTW with all four turn signals activated is permitted or recommended — a clear yes or no should be defined. Reaserch group recommends that all four turn signals activated be permitted for safety reasons.
- To improve motorcyclists' visibility, we recommend the harmonization of regulations across countries regarding such practices. Unified rules would help ensure that visibility-enhancing measures are both legally supported and consistently applied, contributing to greater safety for motorcyclists in traffic.
- The introduction of this measure makes sense especially in countries with extreme heat during the summer season and frequent traffic jams.

Lane Sharing:

- This measure requires clear rules set out in legislation.
- Road sections where lane sharing is permitted must be marked with appropriate traffic signs and road markings (letters or pictograms).
- It is desirable that the use of the bus lanes is time-limited by PTW (allowed during peak hours).
- The biggest shortcoming of the lane sharing occurs before the intersection area (where drivers make different manouvres) so road designer needs to pay attention when designing intersections between a bus lane and a regular lane in order to avoid unexpected conflicts by both car drivers and PTW riders.

Filtering:

- This traffic measure is safer than lane splitting, as surrounding traffic is at a standstill.
- Two methods of lane filtering can be used: on four-lane roads or on two-lane roads (before the traffic light intersection area, at a road construction site, at a traffic light level crossing of a road with a railway/tram, or something similar- e.g., border crossing).
- The main condition for implementing lane filtering is traffic lanes of appropriate width (on motorways ≥ 3.50 m, on two-lane roads (in front of the traffic light intersection or similar ≥ 3.25 m).
- When riding between two rows of cars, motorcycles must not exceed 30 km/h.

Advanced stop lines:

- A decision needs to be made: Either ASL for cyclists or for PTW, but certainly not both.
- This measure requires sufficiently wide lanes for access to the ASL (≥ 3.25 m).
- The advanced stop box must be of adequate length (at least 3.0 m) so that the PTW can be positioned correctly in it (in the direction of travel).

7.3. RECOMMENDATIONS FOR PIARC

This task was limited in both time and financial resources. As a result, the project team did not have the opportunity to visit countries that have already implemented certain protection systems or measures, nor to personally verify their effectiveness or obtain data from relevant institutions (e.g., police authorities).

Therefore, we strongly recommend that the PIARC Association continue research in this area, especially because several issues remain unclear or lack coordination.

- Inconsistencies in survey responses: Respondents from the same country sometimes assessed the effectiveness of a particular measure differently.
- Lack of accessible legislation: For most measures implemented outside Europe, it was not possible to obtain the legal documents defining these measures.

7.3.1. Motorcycle protection systems

A major shortcoming in the evaluation and, even more importantly, in the development of Motorcycle Protection Systems is the lack of applicable standards. It was found that no European or American standards currently exist for motorcyclists' crash cushions, end terminals, or upper guardrail protection. The only available standard is CEN/TS 17342:2019, which defines criteria and testing methods for motorcyclist impacts with the lower part of safety barriers.

There is no standard or regulation that defines:

- injury thresholds for the motorcyclist's torso,
- the testing methods for impacts with point protection systems (e.g., crash cushions, end terminals), and
- design limitations to prevent contact with sharp or rigid elements.

For effective implementation, it is essential that PIARC connects developers and manufacturers of Motorcycle Protection Systems and, possibly with the support of an external expert group, develops

guidelines for their validation. Based on these results, PIARC should engage with standardization bodies to propose either an update to CEN/TS 17342:2019 or the development of a new standard. PIARC should also contact relevant institutions (e.g., FEMA, AMA, DG MOVE, EPO) and encourage them to initiate the development of standards for:

- motorcyclists' crash cushions,
- end terminals for motorcyclists,
- and upper guardrail protection systems.

Through its network of members, PIARC can advocate for the adoption of these standards in individual countries, which would greatly assist decision-makers in establishing criteria for the use of Motorcycle Protection Systems.

In the meantime, PIARC could leverage its influence to gather technical data on the best-rated Motorcycle Protection Systems. These systems could then undergo numerical validation, such as dynamic simulations of motorcyclist impacts using the HYBRID III dummy model, to assess injury criteria and evaluate the safety performance of each system.

7.3.2. Traffic management for motorcycles

First and foremost, PIARC should, through its members and connections, advocate for the dissemination of knowledge about all Traffic Management Measures for Motorcycles, regardless of whether a specific measure is currently implemented in a given country or not. This should be done in cooperation with motorcyclist associations and official safe driving schools, ensuring that motorcyclists are informed about the characteristics and rules of each measure.

Only in this way can riders acquire the necessary practical skills to safely navigate situations where such measures are in place. For example, when riding in countries where these measures are already implemented.

The survey results also revealed a lack of expertise among professionals in the field of Traffic Management for Motorcycles across different countries. Respondents provided contradictory answers regarding whether specific criteria are applied or legally regulated in their country. This suggests that some responses were subjective, and not necessarily based on official positions from relevant institutions.

In light of these findings, we propose that PIARC continue this Special Project on the Safety Aspects of Traffic Management for Motorcycles, with the following objectives.

- Establish additional contact with relevant institutions in countries where specific measures have been implemented, and obtain data on their effectiveness (e.g., comparing road sections with and without the measure, in terms of traffic flow and safety).
- Additional data collection on the severity and frequency of motorcycle accidents involving steel safety barriers, upper guardrail edges, and end terminals.
- Acquire legislation from national institutions that prescribes the implementation of specific measures (What, When, How).
- Explore the possibility of coordinating regulations for certain measures between countries at least within the EU and North America, if global harmonization is not feasible.

If the same mopeds and motorcycles are sold worldwide, then the regulations for traffic management measures could also be unified globally. If full regulation is not possible, then at least common guidelines should be developed.

Regardless of all the above, the authors of the task believe that it would be very challenging (practically impossible) to unify measures across the entire world.

After all, the unwritten safety rule followed by motorcyclists who drive long distances says:

Ride like the locals!

8. GLOSSARY

Term	Definition
AMA	American Motorcyclist Association
AADT	Annual Average Daily Traffic
ASL	Advanced Stop Lines
ATD	Anthropomorphic Test Device
BSM	Black Spot Management
CEN	Comité Européen de Normalisation (European Committee for Standardization)
DML	Dedicated Motorcycle Lane
EC	European Commission
EU	European Union
EPO	European Patent Office
ETSC	European Transport Safety Council
EVU	European Association for Accident Research and Analysis
FEMA	The Federation of European Motorcyclists' Associations
FHWA	Federal Highway Administration
FIM	Fédération Internationale de Motocyclisme
GNI	Gross National Income
HDPE	High-Density Polyethylene
HIC	High-Income Country
IMMA	International Motorcycle Manufacturers' Association
ISO	International Organization for Standardization
ITF	International Transport Forum
LIC	Low-Income Country
MASH	Manual for Assessing Safety Hardware
MIC	Middle-Income Country
MPS	Motorcycle Protection Systems
NCHRP	National Cooperative Highway Research Program

OECD	Organisation for Economic Co-operation and Development
PIARC	World Road Association
PTW	Powered Two-Wheelers
RSA	Road Safety Audit
RSI	Road Safety Inspection
RSIA	Road Safety Impact Assessment
SSB	Steel Safety Barrier
TERN	Trans-European Road Network
TRL	Transport Research Laboratory
TTI	Texas A&M Transportation Institute
WHO	World Health Organization

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