EURO NCAP'S FIRST STEP TOWARD RIDER SAFETY WITH NEW CAR-TO-MOTORCYCLIST SCENARIOS

Pierre-Marie Damon, Aurélien Garcia
UTAC
France

Adriano Palao
Euro NCAP
Belgium

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ABSTRACT

Embedded collision avoidance systems such as Autonomous Emergency Braking Systems, Forward Collision Warnings or Emergency Lane Keeping Systems have largely contributed to reducing the number of car collisions over the past decade. Although those systems have demonstrated ever-increasing performance in case of imminent risk of collision against pedestrian, bicyclist, or car in recent years, most of them were not capable of intervening in the case of a motorcyclist. Since motorcycle crashes remain a major concern across Europe and for most of them are the result of collisions between cars and motorcycles, those systems were identified as relevant technologies to address this issue. In that context, UTAC led the MUSE European project between 2017 and 2019 with the ambition to promote motorcyclist safety through car consumer information programs such as Euro NCAP. As this topic was well identified in the Euro NCAP 2020-2025 roadmap, the organization showed interest in the outcomes of the project and their integration into the new generation of car active safety testing protocols. This paper presents the background established during the MUSE project, its outcomes, and their integration into the so-called Euro NCAP safety rating, as well as the outlook for motorcyclist safety as part of Euro NCAP Vision 2030.

INTRODUCTION

For several years now, more and more Advanced Driver Assistance Systems (ADAS) have been fitted into modern cars improving comfort and providing assistance to the driver into the driving task. Thanks to some exteroceptive sensors like cameras, radars, lidars, etc., ADAS helps the driver to perceive the surrounding environment and, for some of them, they may even intervene when safety is at stake. Whereas the regulations define the minimal set of performance that these systems shall fulfill, other consumer organizations, such as Euro New Car Assessment Program (NCAP), rate the level of safety of the car regarding well established testing protocols. These NCAP programmes are constantly pushing to improve system performance before and beyond regulation requirements. Until 2023, neither the ADAS regulations nor the Euro NCAP requirements for Powered-Two Wheelers (PTW) in emergency situations have been adopted, whilst pedestrians and bicyclists' safety have been widely addressed in Euro NCAP ratings for years.

Several studies of PTW accidentology highlighted that collisions with passenger cars occurred in a large proportion of crashes and often resulted in severe consequences (road deaths and/or serious injuries) for the motorcyclist. In most cases, the visibility of the PTW by the driver of the opponent vehicle was identified as the crash causation [1]. Moreover, PTW riders are very endangered in case of collision with other vehicles because they lack protective equipment and the risk of exposure. For that reason, PTW riders have been classified as Vulnerable Road Users (VRU) in addition to pedestrians and bicyclists.

In that context, UTAC led the Motorbike Users Safety Enhancement (MUSE) project, which started in 2017 and lasted 2 years. All major European vehicle manufacturers and system suppliers were involved in the project with the ambition to improve car collision avoidance systems regarding their capabilities of perceiving PTW and then to intervene accordingly. The project was divided into 5 work packages. In the first one, crash analysis was performed across European databases. The objective was to identify the most frequent conflict situation resulting in a collision between passenger cars and PTW and their parameters. In the second and third work packages, the members developed relevant testing equipment. First, a soft target representing an average adult motorcyclist on a motorbike. Secondly, a propulsion system was designed to move the target according to the dynamic parameters which were identified during the crash analysis. A fourth work package was dedicated to the selection of the test scenario to be performed on the test track. During the fifth and last work package, a state-of-play has been conducted to highlight existing technologies which may have a safety benefit in these crash scenarios. MUSE was one of the first European common initiatives, involving industry, with the ambition to improve ADAS for the detection of PTW. It rapidly raised interest for Euro NCAP since motorcyclist protection was clearly identified in the car active safety roadmap [2].

This paper is structured around the main work packages of MUSE project such as the accidentology review, the development of the testing equipment and the definition of the test cases. Those 3 sections explain the background behind the inclusion of the new Car-to-Motorcyclist scenarios into the next Euro NCAP active safety testing protocols which is detailed in section 4. It is then completed with a section dedicated to general discussions, limitations and future works preceding a conclusion.

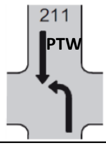
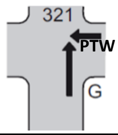
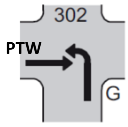
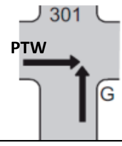
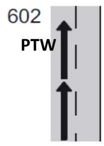
ACCIDENTOLOGY

In a world where the decarbonization of mobility is one of the main challenges of the century, the PTW has an important role to play. Although the total number of road deaths significantly decreased over the past decades, the number of motorcyclists who died or were severely injured in road crashes are still overrepresented. In 2018, according to the World Health Organization (WHO), around 28% of all road deaths all over the world were PTW riders [3]. In South-East Asia, where PTW is well democratized, they counted for almost half of the deaths, whereas in Europe, they represented 11% of the road deaths. Even across Europe, there are notable differences. In France, for several years now, motorcyclists represent around 25% of global traffic fatalities and more than 30% of global severe injuries while the proportion of motorcycles in the vehicle population does not exceed 2% [4]. Moreover, several crash databases have shown that most of the crashes involving PTW also involved another vehicle and mainly a car. In the UK during 2019, for more than 60% of all the crashes involving PTW, there were collisions with cars according to STATS19. Whereas single PTW crashes counted only for 25% of the total.

In that context, the first work package of MUSE was dedicated to a European accidentology analysis in a three step approach [5]. First, a review of the existing literature was conducted. Indeed, crashes involving PTW have been a major concern for decades and addressed by various European initiatives and projects such as SAFERIDER or MAIDS where some crash data were already collected. To complement these first figures, the next step consisted in gathering the most up-to-date Car-to-Motorcyclist crash data in Europe. In 2016, CARE, which is a European community database on road crashes resulting in death or injury, highlighted that Italy, France, Germany, Spain, United Kingdom, Poland and Greece concentrated 80.5% of motorcyclist fatalities at 30 days in Europe. Nevertheless, because of accessibility, only Italian ACI-STATS, French BAAC ONSIR, German Destatis (represented within the GIDAS weighted analysis), Spanish DGT, UK STATS19, Greek ELSTAT and The Netherlands SWOV/BRON national datasets were considered in this second step decreasing the coverage to 75% of fatal crashes involving motorcyclists in Europe. The analysis included data from the last 3 years preceding the project (2014-2016) in order to capture only the most-up-to data crash data. Finally, thorough investigations in the 7 national crash datasets allowed us to derive a group of distinct scenarios incorporating key information, where available, such as vehicle maneuvers, impact locations, road type and speed limits. These scenarios were assigned a GDV (German Insurance Association) code, a pictogram-based illustration of the conflict scenario, and then grouped in crash clusters based on common vehicle maneuvers and conflict situations. Furthermore, analysis of weather and lighting conditions at the time of the crash have shown that there is no significant effect on crash propensity, the main influence being the road infrastructure (e.g., junctions) and injudicious actions from the car driver.

Once crash scenario clusters were identified and quantified for each country of the study, they were weighted according to CARE to be as representative as possible from the overall European accidentology. Regarding the 62% of identified car to motorcycle crash scenarios, half of them occurred at junctions while rear-end collisions represented only 5.77% of them (Table 1). Remaining crash scenarios were mainly head-on conflicts either while both vehicles were traveling straight or cornering, lane change conflicts in the same or opposite directions of travel. A notable crash group, that although not as frequent as others but worthy of consideration as it potentially has similar sensing requirements as lane change maneuvers, was left turn across path in same direction.

Table 1.
Overview of Car-to-Motorcyclist crash scenario clusters in Italy, France, Germany, Spain, Greece, and the Netherlands

Road infrastructure	Conflict situation	Coverage	Main pictogram
Junctions	Left Turn Across Path – Opposite Direction	16.03%	
	Straight Crossing Path – Right Direction	12.84%	
	Left Turn Across Path – Left Direction	11.29%	
	Straight Crossing Path – Left Direction	5.83%	
Others	Rear-end – Parallel driving	5.77%	

Usually, national datasets are based on police recordings of road crashes. Although they are very useful for macro-analysis, they are lacking information when it comes to in-depth characterization of crashes (impact speed, impact location, etc.). This characterization is essential to understand the scene and to guarantee that the parameters used on the test track are representative of the reality. For that reason, in-depth crash datasets from the UK, Italy, Spain, France and Germany were analyzed to return the initial travel and impact speeds for both vehicles and by crash scenario.

TESTING EQUIPMENT DEVELOPMENT

This section summarizes the second [6] and third [7] work packages of MUSE which were dedicated to the development of appropriate testing equipment. The aim was to develop a 3D-dimensional target made of soft crash-resistant material representing an average European rider on his PTW with its self-propelling system. The whole target has been designed to work with all kinds of sensors used in ADAS perception such as radar (24 and 76-81 GHz), lidar, camera or ultrasonic sensor. In order to allow interoperability between target and self-propelling systems, their characterizations have been addressed independently.

Motorcyclist target specification

In 2014, the European Association of Motorcycle Manufacturers (ACEM) published a report on the PTW market in Europe. During this year, there were 1 099 000 two-wheeled vehicles sold in Europe including 30% of light PTW's also called mopeds. Amongst the motorcycles, the BMW R1200GS occupied the first place in Europe in terms of sales volume followed by the Yamaha MT-07 sold at 18013 and 13125 units respectively. As the European best seller with about 2% of the overall PTW vehicle registration in 2014, the BMW R1200GS was unanimously selected as the reference vehicle to design the PTW target.

Whereas the characterization of the average PTW was new, the definition of human being dimensions has largely been addressed in various studies and activities (anthropology studies, ISO activities, etc.). Since male riders are largely overrepresented into the PTW accidents, the definition of the motorcyclist was based on the description of the adult male pedestrian target in [8]. It represents an average (50th %-ile) male with a body height of 180 cm according to EN ISO 7250-1: 2016-05. For the definition of the pedestrian dummy, a similar dress code with a black long-sleeved t-shirt, blue trousers and black shoes was defined. Obviously, a soft helmet was designed for better representativity of the dummy. Then, all its body parts were positioned in a way to be close to a naturalistic PTW riding posture.

Figure 1. 4activeMC motorcycle target with the 4activeFB-small platform

After establishing the visual attributes of the overall dummy including the PTW and the rider, the next step consisted of making sure the non-visible properties, such that infrared and radar properties, were realistic. Infrared reflectivity ranges of the dummy clothes and the motorcycle parts were characterized from 850 to 950 nm wavelength according to the methodology presented in appendix 1 in [6]. Since radars were becoming more and more common in the ADAS perception systems, it was essential to define the radar reflectivity characteristics of the target and especially its Radar Cross Section (RCS). To do so, RCS measurements were performed on 8 static motorcycles (including the BMW R1200GS) from different angles of approach and from different distances. Two 77 GHz radars from Bosch and Continental, the MRR-SGU and the ARS 400 Series respectively, were placed in car to do the characterization. Assuming symmetrical properties of the target, the approach angles were incremented by 30 degrees starting from approaching the PTW from the front up to an approach of the PTW from the rear. For each angle, the RCS was measured from 100 to 4 m between the target and the radar positions. A second method consisted in measuring the RCS while the car was at a standstill whereas the target was on a turntable in order to capture the overall angles for a given distance which was 30 m. These measurements were finally used to define the upper and lower RCS boundaries in which the target should be to be considered, from the radar point of view, close to a real vehicle.

For design reasons, target suppliers decided to have non-rotating wheels on the target which may significantly affect the RCS when the PTW is moving. Indeed, rotating wheels generate a micro-doppler effect which can be an important identification characteristic for the radar. Nevertheless, it remained a proposal of improvement during MUSE until 2022 when target suppliers finally developed an additional device imitating the micro-doppler effect of the non-rotating wheels of the target. It considers the speed of the target to adapt the signal. Indeed, when the PTW target is at a standstill, the device does not emit any signal.

Propulsion system specification

Whereas self-propelling platforms were already available for car, pedestrian, and bicyclist targets, such a solution did not exist for a PTW target. These platforms allow accurate control of the target dynamic in order to ensure testing repeatability. They should reflect the real vehicle dynamic behavior in addition to not affecting the detection characteristics of the target itself. Because of the limited dynamic of the existing self-propelling systems for pedestrian or bicyclist and the large dimensions of the platform for the car target leading to a “flying carpet” effect, the development of a dedicated solution was needed for the PTW.

In addition to a robust design allowing car to driver over, the vertical position of target, the color and the RCS of the platform were identified as the most important static properties. In other words, the target carrier shall be colored grey to reduce as maximum their optical impact on asphalt and allow a positioning of the target such that the gap between the ground and the lowest point of the target wheels is not more than 1 cm. Although, maximum RCS of the car target platform was already defined according to ISO 19206-3, during MUSE, it was decided to not define specific values. Instead, it shall be ensured that the combination of target plus propulsion system is inside the boundaries defined for the target itself. As the carrier was supposed to move the target like a real motorcycle, definitions of the dynamic properties were needed. Four variables were considered as relevant in that context and a maximum deviation was associated to each of them based on real-world data recordings. These four variables were the speed, the lateral deviation from the theoretical path and the yaw rate. This last becomes even more important for PTW since the platforms are compact and more prone to yaw instability while the test speed increases. Acceleration capability was also discussed to make sure the carrier can reach the desired speed in a reasonable time on the test track.

Over the course of 2022, several combinations of motorcycle target and propulsion systems (EMT – Euro NCAP Motorcycle Target) were approved to be used from 2023 in the Euro NCAP Car-to-Motorcyclist tests. These combinations are available for reference in the Euro NCAP Technical Bulletin 029 [9]. Normally, the accreditation process of a new target and propulsion system includes compliance with the ISO 19206-X standards, plus a back-to-back verification where the performance of a given vehicle with a previously accredited target is similar to the new target. Since motorcycle targets are introduced for the first time (i.e., no prior experience on track), back-to-back tests could not be conducted. To provide industry and test laboratories with the necessary confidence of the intended target functionality, a workshop was held in ADAC Test Centrum (Penzig, Germany) in July 2022, where equipment manufacturers applying for accreditation displayed their combinations through a set of 2023 Car-to-Motorcyclist scenarios.

DEFINITION OF TEST CASES

This section describes the background behind the selection of the test cases and their integration into the Euro NCAP active safety test protocols. The selection was a compromise between accidentology coverage, addressability, technology maturity and testing limitations.

Selection of the testing scenarios

For a consumer information programme, such as Euro NCAP, introductions of new ADAS requirements into the protocols are almost always the result of a data-driven approach. In other words, the estimated safety benefit regarding the accidentology data is guiding the priorities and the selection of the test cases. This approach was naturally used in MUSE to identify areas of interest. In order to have the best accidentology coverage with a limited number of test scenarios, the most frequent Car-to-Motorcyclist conflict situations were grouped considering ADAS technologies and sensing requirements. 6 scenarios of collision between car and PTW were then identified as the most frequent conflict situations and addressable with existing ADAS ([10] and [11]) such as the well-known Autonomous Emergency Braking (AEB) system, the Forward Collision Warning (FCW) or the Lane Support System (LSS) which have existed for several years now.

The Car-to-Motorcyclist Crossing straight crossing path (CMCscp) was identified as the most relevant scenario to address Straight Crossing Path – Left and Right Direction and Left Turn Across Path – Left Direction conflicts at the same time with the AEB system. In CMCscp, both vehicles travel towards an intersection with the PTW coming perpendicularly either from the right or the left side of the car. Among the 62% of identified Car-to-Motorcyclist crash scenarios in the accidentology study, CMCscp scenarios should cover about 30% of them. The second scenario which was directly derived from the crash study is the Car-to-Motorcyclist Front turn across path (CMFtap) where the car is turning and crossing the PTW trajectory while both vehicles are travelling in opposite directions. A similar crash scenario is already part of the AEB Car-to-Car test protocol. CMFtap is supposed to increase the crash coverage from 16%. The third, and last AEB relevant identified scenario, is Car-to-Motorcyclist Rear-end (CMR). Two sub-scenarios were then identified as the most recurrent conflicts in CMR cluster which are Car-to-Motorcyclist Rear stationary (CMRs) and Car-to-Motorcyclist Rear braking (CMRb) where the car is approaching the PTW from the rear whereas it is at a standstill or braking respectively. CMRb and CMRs cover a maximum of 6% of the overall accidentology. With very optimistic assumptions, about half of all the Car-to-Motorcyclist crashes identified in the European countries in the scope of the study could have been avoided with appropriate AEB systems.

While AEB was identified as one the most promising technology to prevent the recurrent Car-to-Motorcyclist crashes, the LSS was also a good candidate to address the remaining conflict situations which were mainly head-on and lane change conflicts in the same or opposite directions of travel. Car-to-Motorcyclist oncoming (CMoncoming) or Car-to-Motorcyclist overtaking (CMovertaking) scenarios were then defined. In both cases, the car is drifting toward the PTW's path while both vehicles are travelling in the same or opposite direction. With very optimistic assumptions, LSS could have avoided about 10% of all the Car-to-Motorcyclist crashes previously identified.

After the selection of the test cases, the next step consisted of defining the necessary parameters to reproduce those scenarios on test tracks, to maximize the accident coverage and to ensure they are as close as possible to real crash conflict situations. The most important parameters being the impact location, the initial speed and relative position for both vehicles. Those parameters were characterized due to statistical analysis of the in-depth crash databases. They were then refined according to the state-of-art testing equipment and test tracks. At the time of MUSE project, the self-propelling platforms could travel at a maximum of 50 km/h which was the main testing limitation. However, in 2022, a new generation of platforms came to life, and they are now capable of travelling at 80 km/h. Hence, some outcomes from MUSE were recently reconsidered regarding new testing capabilities. All the testing parameters are described in Table 2.

Table 2.
Selected PTW test scenarios with the testing parameters

Scenarios	CMRs		CMRb	CMFtap	CMoncoming	CMovertaking	BSM
Type of test	AEB	FCW	AEB/FCW	AEB	LSS	LSS	LSS
VUT speed [km/h]	10-60	30-60	50	10, 15, 20	72	50, 72	72
Target speed [km/h]	0		50*	30, 45, 60	72	60, 80	80
VUT direction	Forward		Forward	Farside turn	Forward	Forward	Forward
Impact location [%]	50		25	50	10**	Rear Axle***	No contact

* *Target deceleration: 4 m/s2 at 12 and 40 m headway*

** *Impact point assuming no system reaction: outermost front left impact point of the EMT's virtual box vs. 10% of the VUT front bumper width*

*** *Impact point assuming no system reaction: outermost front right impact point of the EMT's virtual box vs. rear axle of the VUT*

Integration into the Euro NCAP test protocols

The MUSE project was rapidly identified as a major contribution to the Euro NCAP 2020-2025 roadmap [2] which was one of the first consumer information programmes showing interest in considering PTW protection into its passenger car safety rating. Considering the outcomes from MUSE, Euro NCAP decided on a two-step approach for the 6 scenarios previously cited completed by one additional scenario.

In 2023, the Euro NCAP AEB/LSS VRU test protocol [12] will introduce 5 new dedicated scenarios promoting PTW safety: CMRs, CMRb, CMFtap, CMoncoming and CMovertaking (Figure 2). The 3 first ones are AEB/FCW relevant testing scenarios and will be eligible to attract 6 points into the VRU box, whereas the LSS, and especially the Emergency Lane Keeping (ELK) system, is a more appropriate solution to address CMoncoming and CMovertaking and can attract 3 additional points. Finally, these 5 new scenarios combined will count for almost 15% of all the points attributed to the VRU box (Table 3) and about 1.5% in the overall safety rating after the final weighting.

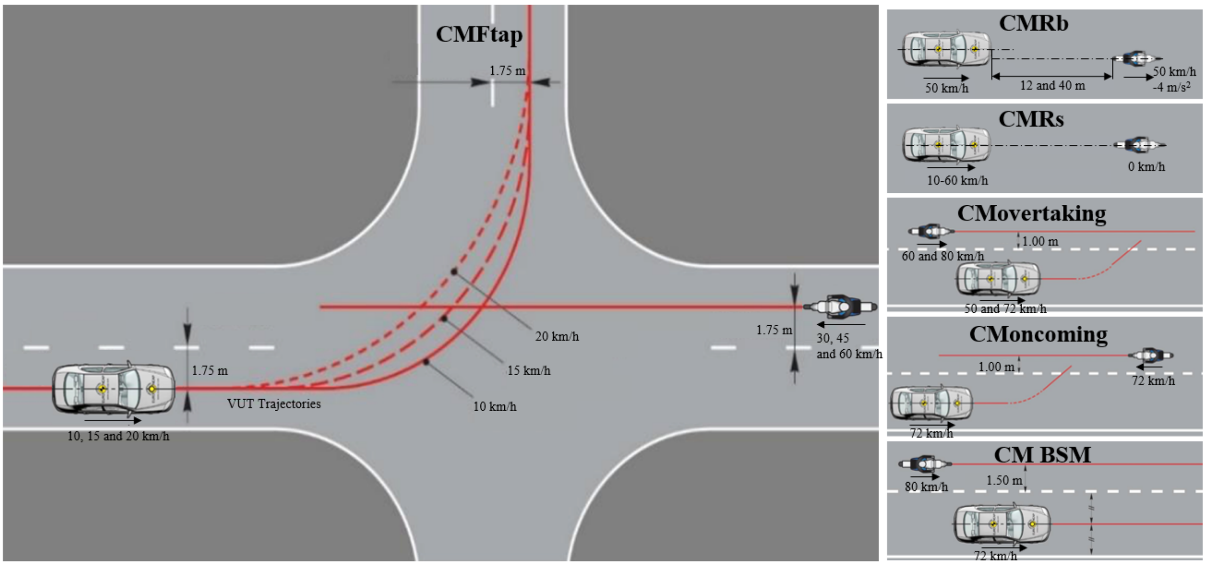


Figure 2. Car-to-Motorcyclist scenarios part of the 2023 Euro NCAP safety rating

Furthermore, the 2023 Car-to-Car LSS test protocol will also integrate new requirements for the Blind Spot Monitoring (BSM) system regarding the detection of PTW [13]. The intention is to promote systems capable of alerting the driver when a PTW is in his blind spot.

For the second step, the Car-to-Motorcyclist Crossing straight crossing path (CMCscp) will be integrated into the protocol in 2026. Indeed, this scenario has been delayed as it requires specific sensing technologies which are not widely available yet.

Table 3.
Point distribution across the boxes for the 2023 Euro NCAP safety rating

2023	AOP (total 40 pts)	COP (total 49 pts)	VRU (total 63 pts)	SA (total 18 pts)
	Front MPDB (8)	Dynamic front (16)	Adult head form (6)	Occupant State (3)
	Front FW (8)	Dynamic side (8)	Child head form (6)	SAS (3)
	Side AMDB (6)	CRS installation (12)	Cyclist head form (6)	AEB/AES C2C Head-on (1)
	Side pole (6)	Vehicle based (13)	Leg form(s) (18)	LSS C2C (3)
	Far side (4)		*LSS PTW (3)	AEB/AES C2C Crossing (4)
	Whiplash F/R (4)		*AEB PTW (6)	AEB/AES C2C Rear (4)
	Rescue (4)		*AEB/AES Pe (7)	
			*AEB Reverse Pe (2)	
			*AEB/AES Cy (9)	
★★★★★	≥32 pts (80%)	≥39.2 pts (80%)	≥44.1 (70%)	≥12.6 pts (70%)
★★★☆☆	≥24 pts (60%)	≥23.4 pts (60%)	≥31.5 (50%)	≥9 pts (50%)

** Minimum 18 pts required in subsystem tests for scoring active safety (VRU box)*

DISCUSSIONS, LIMITATIONS AND FUTURE WORKS

Additional Car-to-Motorcyclist scenarios in the passenger car safety rating

The test campaign ranging from 2023 to 2026 includes the aforementioned Car-to-Motorcyclist test scenarios. The missing CMCscp scenario is set to be added in 2026, which together with the 2023 scenarios, is expected to cover the broad majority of Car-to-Motorcyclist conflict situations. Other scenarios listed in the MUSE accidentology deliverable but not included or foreseen to be included in the Euro NCAP Car-to-Motorcyclist scheme (e.g., Left turn across path – same direction, Left turn across path – left direction) might be considered for future incorporation. To that end, a sensible approach to be taken on short term would be to assess whether well performing vehicles in the existing scenarios can as well perform in the missing ones.

Although MUSE highlighted typical Car-to-Motorcyclist conflict situations in Europe, there are specific local traffic rules or tolerated riding practices which may need to be further investigated. For instance, several European countries such as France, allow motorcyclists to filter between lanes of slow moving or stopped traffic. These crashes were of course considered in the process of test cases selection but in the way they were declined in testable scenario on the proving ground, they partially reflect these specific accident scenes. In the next generation of protocols, Euro NCAP may continue to close the gap between test scenarios and real crash scenes. For example, obstructive vehicles, reflecting dense traffic conditions, may be integrated into CMovertaking or other scenarios. Furthermore, the recent inclusion of Car-to-Bicyclist Dooring scenario into the 2023 Euro NCAP AEB/LSS VRU test protocol [12] rewards alert and/or door retention systems capable of preventing a crash when a car occupant is about to open a door into the trajectory of an approaching bicyclist. Euro NCAP may extend this scenario to PTW after a careful review of the crash data.

Recent connectivity technologies, also called Vehicle-to-X (V2X), may take vehicle safety to the next step in the coming years. These are identified as relevant technologies either for increasing robustness of the embedded sensing system into the vehicle or for addressing new conflict situations where conventional sensors are blind (e.g., junction with obstruction, etc.). UTAC is currently leading a consortium, called SECUR, which is expected to support Euro NCAP in the introduction of connectivity into its passenger car safety rating. First new scenarios assessing PTW protection using V2X technologies are expected to be introduced in 2026 before being largely extended in 2029.

Robustness

Evidence suggests that current ADAS can help reducing in crashes [14], although it is acknowledged that its coverage in corner cases is still to be improved. Euro NCAP acknowledges this and aims to encourage the development of robust external perception that accounts for a large number of situations, closing the gap between current ADAS performance on track tests and real-world performance. To that end, existing Car-to-Car and Car-to-VRU scenarios are expected to be populated with adjustments related to scenery (e.g., road infrastructure, urban furniture), target appearance (e.g., moped, chopper, sport bike), vehicle behavior prior to crash (e.g., steering and/or accelerator inputs – within system overriding tolerances), and environmental occlusion (e.g., night-time, glare from oncoming vehicles, adverse weather) among others. The first changes, expected in 2026, are supposed to be simple to include into the test programme, yet impactful. The feasibility of such implementations will be linked to keeping the tests repeatable and reproducible across test laboratories.

Target and propulsion systems

The current Car-to-Motorcyclist scenarios are entirely executed in a proving ground, and hence limited to physically testable cases. Such limitations include the impact speed between the vehicle under test and the target without resulting in personal or material damage, but as well to the dynamic properties of the target, especially the maximum longitudinal speed at which platforms are able to travel (80 km/h) while keeping other parameters within tolerance levels (e.g., yaw rate). In addition, state-of-the-art testing equipment is limited when it comes to testing scenarios with multiple targets. This leaves some of the crashes seen in the real world uncovered. It is foreseen that the assessment of physically untestable cases in the future could be done by means of virtual validation methods, or a combination of virtual plus physical.

Extension to commercial vehicles active safety progammes

Although Euro NCAP established its reputation thanks to its car safety rating, it started to address commercial vehicle active safety in 2020. Activities began with the assessment of the ADAS fitted in Light Commercial Vehicles (LCV) before being more recently extended to Heavy Commercial Vehicle (HCV) which correspond to vehicles of categories N2 and N3. Considering the lack of active safety systems fitted into LCV, their ADAS are currently assessed according to the previous generation of passenger car test protocols which do not address PTW protection until now. Nevertheless, Euro NCAP is planning to close the gap between passenger car and LCV active safety requirements in 2026. In other words, from 2026 and beyond, LCV and passenger car test protocols will be aligned including PTW scenarios. After the recent adoption of the HCV safe and clean label, Euro NCAP is now working on the development of the HCV testing scenario for a first official test campaign in the near future. Although the roadmap for the introduction of LCV-to-Motorcyclist scenarios is well established, introduction of HCV-to-Motorcyclist scenarios is still under discussion based on some accidentology findings. One thing is for certain, Euro NCAP will encourage HCV manufacturers to fit their vehicles with ADAS capable of alerting and/or intervening in case of emergency situations with PTWs.

Introduction of PTW scenario into the assisted driving system grading

From 2018, Euro NCAP is conducting, in parallel to its safety rating, a complementary grading of the passenger car Assisted Driving (AD) systems (SAE level 2) which leans on 3 pillars: the driver engagement, the safety backup, and the vehicle assistance. Whereas the driver engagement assessment evaluates the capabilities of the AD system to keep the driver engaged into the driving task, the two last pillars reward ADAS and AD systems capable of assisting the driver in regular or emergency highway driving situations (e.g., cut-in, cut-out, etc.). Since Car-to-Car are the most recurrent conflict situations on highway, the first generation of protocol is focused on these scenarios. As part of its Vision 2030, Euro NCAP recently affirmed its intention to extend the scope of AD assessment in 2024 by including other off-highway scenarios. This will obviously include new VRU scenarios such as Car-to-Motorcyclist cut-in, cut-out and longitudinal scenarios. Whereas the safety rating will encourage OEM to develop emergency ADAS capable of preventing crashes with PTW, the AD grading will ensure that comfort ADAS like the Active Cruise Control (ACC) is also able to cooperate with surrounding motorcyclists.

Single vehicle crashes and PTW test campaign

In the 25 years of its existence, Euro NCAP has been devoted to encourage passenger car manufacturers to fit safety equipment as standard, with ever-increasing requirements above and beyond type approval. Ultimately, Euro NCAP's goal is to maximize the safety of the European passenger car fleet, helping to reduce crashes involving customer's own cars, other cars and VRUs. To that end, the first step in the reduction of crashes involving motorcycles has been the introduction of Car-to-Motorcyclist scenarios so that ADAS can identify and react to motorcycles. In the near future, the introduction of LCV and HCV-to-Motorcyclist scenarios will also help to prevent or mitigate crashes involving PTW and commercial vehicles. However, as the crash data analysis of MUSE suggests, a large number of severe PTW crashes are single vehicle, where the motorcyclist loses control of the motorcycle without any other road actor involved and ends up crashing. According to the UK dataset STATS19, single PTW crashes represented 25% of all the accidents involving PTW whereas, in France, 38% of all the fatal accidents for the motorcyclists were single vehicle accidents in 2021 [4]. In that context, motorcycle safety technology can help prevent single vehicle crashes to a large extent, for instance 6-axis ABS and traction control, and other Advanced Rider Assistance Systems (ARAS) such as blind spot monitoring and connected vehicle technologies. In the coming period, Euro NCAP is planning to go beyond its traditional scope and will be initiating, together with the industry support, the first-ever 'Test Campaign on PTW Safety', which is intended to evaluate existing motorcycle safety technologies (e.g., ARAS, Connected Vehicle, Personal Protective Gear), understanding the infrastructure needs, and outlining the first results of Car-to-Motorcyclist tests. The main purpose of this campaign is facilitating consumers (drivers and riders) with objective and comprehensive information about the latest technologies, as well as educating them by creating awareness of the risks and how these technologies can help avoiding or mitigate these.

CONCLUSIONS

For decades now, car manufacturers never stopped improving vehicle safety. First, with passive safety systems and, more recently, with ADAS which have widely become part of consumer organization testing such as Euro NCAP. Although the well-known Euro NCAP passenger car star rating rewards VRU active protection for several years (from 2016 for AEB Car-to-Pedestrian and 2018 for AEB Car-to-Bicyclist), motorcyclist protection remains unaddressed until now.

Road crashes involving PTW have been a major concern across Europe for years and, for most of them, they are the result of a conflict with passenger cars. Euro NCAP rapidly identified ADAS as relevant technologies to address these crashes and adopted PTW protection into its 2020-2025 active safety roadmap. In that context, UTAC led the European consortium called MUSE which lasted 2 years (2017-2019) and involved major car manufactures, system suppliers and testing laboratories with the ambition to develop testing scenarios to promote ADAS capable of detecting, alerting and/or intervening in case of emergency situations with motorcyclists. The project was divided into 3 main workstreams which are detailed into this paper. It started with crash data analysis to identify the most recurrent Car-to-Motorcyclist conflict situations and their characteristics. The second step consisted of developing appropriate testing equipment such as an average European rider dummy and its PTW both propelled by means of a small platform. The last workstream was dedicated to the test scenario selection and their parametrization to maximize crash representativity and coverage while keeping the test workload acceptable. Finally, CMRs, CMRb, CMFtap, CMCscp, CMovertaking and CMoncoming were identified as the most recurrent conflict situations in addition to be ADAS relevant.

These 6 scenarios were rapidly adopted by Euro NCAP and the working group in charge of the AEB/LSS protocol elaboration. Nevertheless, considering ADAS maturity, CMCscp is delayed to the next generation of protocols in 2026. Hence, 2023 Euro NCAP AEB/LSS VRU test protocol [12] includes 5 dedicated Car-to-Motorcyclist scenarios (CMRs, CMRb, CMFtap, CMovertaking and CMoncoming) which count for almost 15% of all the points attributed to the VRU box. These 5 testing scenarios are completed with a blind spot scenario tested either with a car or a motorcyclist into the blind spot area of the vehicle under test [13]. 2023 will definitely be a first milestone for motorcyclist safety thanks to Euro NCAP with the introduction of new PTW scenarios into its passenger car safety rating.

Nevertheless, Euro NCAP won't stop there. The 2026 passenger car protocols are already expected to include complementary Car-to-Motorcyclist scenarios such as CMCscp while addressing ADAS robustness in general (target appearance, scenery diversity, etc.). Euro NCAP will also promote PTW safety when it comes to commercial vehicle active safety assessments. LCV-to-Motorcyclist scenarios will be part of the assessment from 2026 whereas introduction dates of HCV-to-Motorcyclist scenarios are still under discussion. In parallel to the safety rating, Euro NCAP has also the intention to integrate new PTW scenarios into the AD grading from 2024 while extending the scope of the AD assessment to other driving domains. V2X was also identified as a relevant technology to prevent Car-to-Motorcyclist crashes. UTAC is currently leading the consortium SECUR which is expected to support Euro NCAP in the introduction of connectivity into its car safety rating in the coming years. New scenarios assessing PTW protection using connectivity technologies will be part of the next generation of passenger car testing protocols starting from 2026 before being extended in 2029. Moreover, introduction of virtual testing and the improvement of the testing equipment are about to bring new testing possibilities allowing to cover more and more Car-to-Motorcyclist conflict situations while addressing system robustness at the same time.

ADAS such as AEB, LSS or even V2X technologies have an important role to play in the reduction of PTW crashes. Nevertheless, such systems are not relevant in case of a single vehicle crash which still represents a large number of all the riders killed or seriously injured in road crashes. Although PTW manufactures and systems suppliers are working hard on developing ARAS, the market penetration of these systems is very limited for the moment. In its Vision for 2030, Euro NCAP announced its ambition to addressee PTW safety assessment in the future [15].

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