Deliverable 5.1

State of the Art of the systems at the beginning of the project

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Executive Summary

This report presents the state of the art of the existent systems (ADAS, ARAS, V2X), driven in the work package 5 (WP5) “Study of the possible technical solutions” of the Motorcycle Users Safety Enhancement (MUSE) project. As this last one focuses on improving safety of rider in order to reduce the amount of mortality on road, the existence of the systems on the market need to be study.
That is why, at the beginning of the project, in parallel of the development of the work package 1 “Accident data study”, this state of the art had to be done to draw a general picture of the existent systems on the market or upcoming. It includes ADAS (Advanced Driver Assistance Systems), ARAS (Advanced Rider Assistance Systems) or V2X communications (Vehicle-to-Vehicle and Vehicle-to-infrastructure)., but also different projects that has been led, or still driven, about the development or possible ARAS and V2X.

The goal of this state of this art is to be link to the main accident scenarios resulting of the work package 1 to underline the suitability of the different systems in the resolution of the possible accidents. Indeed, the following step is to cross every main accident which stem from the work package 1 to find which system can have an impact on the accident to mitigate or even avoid it. This will allow the definition of a test and assessment protocol within the 4th work package (WP4) “Test and assessment protocols definition” of the MUSE project.
A first step of a previous selection of the ADAS, ARAS and V2X communications which can mitigate an accident has been done in this report.

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Table of Acronyms

ABS : Antilock Braking Systems

ACC : Adaptive Cruise Control

ADAS : Advanced Driver Assistance Sysems, : Advanced Driver Assistance Systems

ARAS : Advanced Rider Assistance System

ESP : Electronic Stability Program

EU : European Union

GPS : Global Positioning System

HMI : Human-Machine Interface

ITS : Intelligent Transport Systems

IVIS : In-Vehicle Information Systems

LDW : Lane Departure Warning

LED : Light-Emitting Diode

LIDAR : Light Detection and Ranging

MUSE : Motorcycle Users Safety Enhancement

OBIS : On-Bike Information Systems

OEM : Original Equipment Manufacturer

PTW : Powered Two-Wheelers

V2I : Vehicle-to-infrastructure

V2V : Vehicle to Vehicle, : Vehicle-to-Vehicle

V2X : V2V & V2I

VRU : Vulnerable Road User

WP : Work Package

1 Introduction

Despite representing a small part of the road users (e.g. a 2% of the traffic in France) the percentage of Motorcyclist in the total deaths is the highest for the VRUs (World road deaths in 2010: 23% PTWs, 22% pedestrian and 5% Cyclist). A motorcyclist is between 9 to 30 times more likely to be killed in a traffic crash than a driver. (OECD, 2015)

In recent years, wea have observed a decrease in the number of deaths on the roads. But this reduction is not equal for all the different road users. If we take a look at the evolution of the mortality depending of the type of road user we can see that, while in the case of cars it has been reduced by 50%, in the case of the motorcyclist this reduction it has been only of the 30%. (European Comission, Directorate General for Transport, 2016)

Concerned by this problematic the French Government decide in 2015 to perform a study in collaboration with UTAC to evaluate the accidentology of the motorcyclist and the possibility of avoid them or mitigate the consequences using the new ADAS systems. Knowing the importance of EuroNCAP in motivating the OEMs to invest in security, in May 2016 the Interior Minister Mr Bernard Cazeneuve and the Transport Minister Ms Ségolène Royal write a letter to EuroNCAP claiming for a safety rating. At the beginning of 2017 EuroNCAP includes the scenarios with motorcycles in their Roadmap 2020/2025 and the possibility of start to assess the presence of security systems in motorcycles.

But, how will it be possible to evaluate the systems without the necessary tools to do so? At this moment it doesn't exists the testing equipment who will allow us to evaluate the systems, not even a protocol in which the main scenarios and their characteristics are defined.

In addition, which will be the best systems to avoid the accidents? Will it origin new accidents? What about ADAS systems in the motorcycle? Is feasible to perform real test to assess the systems in motorbikes?

The aim of this project is to answer these questions and to provide the OEMs and TIERs1with the tools that will allow them to develop their systems and evaluate them.

The main objective in MUSE is to improve safety of motorcyclist.

By studying in a first stage the main accident scenarios and possible systems that could help to avoid them or, at least, reduce their consequences. And, at the same time, by developing the tools that will allow as to improve these systems and to evaluate their performances.

In addition the improvement of the detection and interaction with motorist is an indispensable stage for the arrival of autonomous vehicles.

To achieve the aforementioned strategic objective, the following specific objectives are identified:

WP1.Compile in-depth accident data from Europe and identify the main scenarios and parameters.

In Europe there exists a variety of in-depth databases but not all of them has the same degree of detail and take into account the same parameters. One of the first objectives of this project is to study the different European in-depth databases and to come across with the best way of combining them to draw conclusions that can be attributed to the EU as whole.

Once we have defined a common structure to apply to the different databases we will compile them to find the main scenarios and variables for the accidents with deaths and seriously injured.

WP2.Study of the existent solutions, their suitability to address the main accident scenarios and the possible solutions that we can imagine.

In a first step we will perform a state of the art of the existent ADAS solutions in cars and motorcycles and the current intercommunication solutions between vehicles and between vehicles and the infrastructure. That will allow us to evaluate its effectiveness in avoiding or mitigating the accident scenarios obtained in WP1 and their possible influence in generating new accident scenarios.

In a second part we will study if the current systems cover the accident scenarios that we have obtained and we will give a thought to the possible new technologies and their efficacy.

WP3.Development of a Motorcyclist Dummy

In order to be able to evaluate the performances of the different sensors and systems, it is necessary to develop the test equipment to perform it. That is why we will develop a Target that complies with the visual and radar signature requirements and, at the same time, is able to be impacted repeatedly without damaging the Car.

WP4.Development of a propulsion system to drive the Motorcyclist Dummy

From previous studies we know that the speed of the motorcycle is an important variable in their accidents. It will be necessary to study if the solutions in the market are able to accomplish the requirements coming from the WP1. We will work with the test equipment providers to improve the propulsion system to be able to simulate our scenarios in real tracks.

At the end the platform and the dummy have to be physically similar to a real motorcycle in terms of perception and able to be conducted in the specifics characteristics of the accident scenarios.

WP5.Definition of a test and assessment protocols.

Taking into account the main scenarios obtained in WP1 and the most suitable systems obtained in WP2 we will define a test protocol and an assessment protocol that will allow us to evaluate them.

WP6. Paving the way for the autonomous vehicle arrival:

The improvement of the detection and interaction with motorist is an indispensable stage for the arrival of autonomous vehicles. We cannot introduce the autonomous vehicle in the roads without considering before all the users that we can cross.

2 Advanced Driver Assistance System (ADAS) in cars

During the last decades, ADAS (Advanced Driver Assistance Systems) and IVIS (In-Vehicle Information Systems) development has been some of the main research areas of the automotive industries in order to increase safety and comfort of cars.

They take advantage of a variety of sensors installed in the car to detect and recognize the static and dynamic objects. They can alert the driver in the shortest time when a dangerous situation occurs, and then improve the safety of driving.

2.1 Existent ADAS in cars (non-exhaustive list)

2.1.1 ADAS involved in comfort

As said previously, there are two major categories of ADAS: comfort and security. In the first one, we can find the following ADAS:

2.1.1.1 *Parking*

Parking sensor

It is a proximity sensor for road vehicles designed to alert the driver to obstacles while parking. This system use either electromagnetic or ultrasonic sensors.

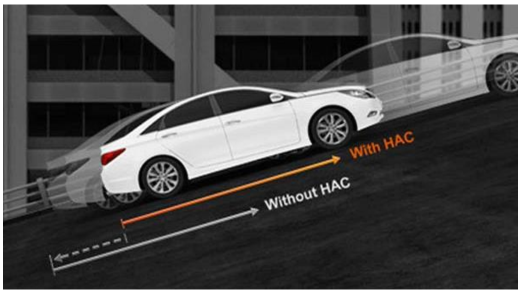
Automatic Parking

This function is an autonomous car-manoeuvring system that moves a vehicle from a traffic lane into a parking spot to perform parallel, perpendicular or angle parking. The automatic parking system aims to enhance the comfort and safety of driving in constrained environments where much attention and experience is required to steer the car. The parking manoeuvre is achieved by means of coordinated control of the steering angle and speed which takes into account the actual situation in the environment to ensure collision-free motion within the available space.

2.1.1.2 *Driving*

Hill-start Assist Control (HAC)

The system prevent the car from rolling away when trying to pull away on an up or down gradient, simulating a "handbrake hill start" manual drivers will be familiar with. The pilot assist system engages automatically when a gradient of 3% or more is detected; it then acts to hold the car stationary for two seconds after the brake is released giving the driver time to apply the throttle.



Cruise Control

Cruise Control is a system which is capable of maintaining the speed of a car at a desired level. The conventional systems are capable of taking over the throttle once the driver activates Cruise Control and sets the desired speed.

Platooning

Grouping vehicles into platoons is a method of increasing the capacity of roads. An automated highway system is a proposed technology for doing this.

Platoons decrease the distance between vehicles using electronic, and possibly mechanical, coupling. This capability would allow many cars or trucks to accelerate or brake simultaneously. This system also allows for a closer headway between vehicles by eliminating reacting distance needed for human reaction.

Automotive navigation system

An automotive navigation system is part of the automobile controls or a third party add-on used to find direction in an automobile. It typically uses a satellite navigation device to get its position data which is then correlated to a position on a road. When directions are needed routing can be calculated.

2.1.2 ADAS involved in the security

On the other side, the list of ADAS involved in the security is exposed below.

2.1.2.1 *Lighting and visibility*

Glare-free High Beam

Glare-free high beam is a camera driven dynamic lighting control strategy that selectively shades spots and slices out of the high beam pattern to protect other road users from glare, while always providing the driver with maximum seeing range. The area surrounding other road users is constantly illuminated at high beam intensity, but without the glare that would result from using uncontrolled high beams in traffic. This constantly changing beam pattern requires complex sensors, microprocessors and actuators, because the vehicles which must be shadowed out of the beam are constantly moving. The dynamic shadowing can be achieved with movable shadow masks shifted within the light path inside the headlamp. Or, the effect can be achieved by selectively darkening addressable LED emitters or reflector elements, a technique known as “Pixel light”.

Adaptive Front-Lighting System (AFS)

The Adaptive Front-lighting System (AFS) optimizes distribution of light from the headlights according to driving circumstances. Depending on vehicle speed and steering input, the system points the low-beams headlights in the direction the driver intends to travel.

In combination with discharge headlights, the system illuminates a greater distance and more brightly compared to halogen headlights, improving the driver's field of vision and visibility around curves and at intersections during night driving. Mated with the auto-levelling function, the system offers a stable distribution of light unaffected by the vehicle's position. Maintaining the illumination axis, the system helps to prevent drivers of oncoming vehicles from getting blinded when many people or a lot of luggage weighs down the back of the car, or when the vehicle position changes going over a bump or driving up a slope.

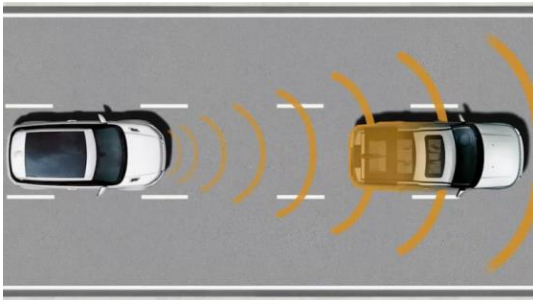
Automotive Night Vision

An automotive night vision system uses a thermographic camera to increase a driver's perception and seeing distance in darkness or poor weather beyond the reach of the vehicle's headlights.

2.1.2.2 *Driving*

Adaptive Cruise Control (ACC)

The ACC is an advanced type of cruise control system and it is the most widely used one. The system is capable of adjusting the speed of the vehicle depending on various factors influencing it, including the speed of the vehicle ahead and safe distance.



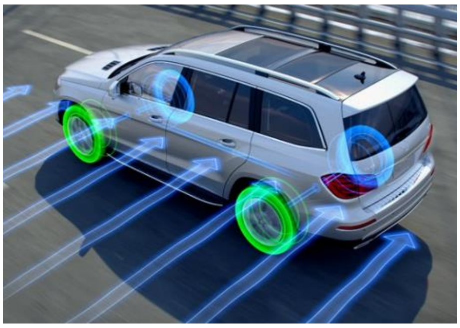
Such systems may use a radar or laser sensor, or a dual video camera set up allowing the vehicle to brake when it detects the car is approaching another vehicle ahead, and then accelerates when traffic allows.

Intelligent Speed Adaptation (ISA)

ISA is any system that ensures vehicle speed does not exceed a safe or legally enforced speed. In case of potential speeding, a human driver can be alerted, or the speed reduced automatically. Intelligent Speed Adaptation uses information about the road to determine the required speed. Information can be obtained from knowledge of the vehicle position, taking into account speed limits known for the position, and by interpreting road features such as signs.

Crosswind Stabilization

Crosswind stabilization compensates for strong crosswinds. It uses sensors to detect forces acting on the vehicle through side wind gusts be it on a bridge or when overtaking a truck. The system's response also takes account of vehicle speed, vehicle load and steering characteristics of the driver. Brakes are applied on the wheels on the side of the vehicle facing the wind, depending on the situation, and counteract the side wind interference.



Hill Descent Control (HDC)

HDC allows a smooth and controlled hill descent in rough terrain without the driver needing to touch the brake pedal. Indeed, the vehicle will descend using the ABS brake system to control each wheel’s speed. If the vehicle accelerates without driver input, the system will automatically apply the brakes to slow down to desired vehicle speed.

Applying pressure to the accelerator or brake pedal will override the HDC system when the driver requires.

Surround View System

Surround View System provides the driver a 360-degree view of the area surrounding the vehicle. Surround View System normally consists of four to six fish-eye cameras mounted around the vehicle (front and rear bumper, under each side mirror).

Looking Glass

The main aim of the i8 Mirrorless concept is to improve the driver's view of the road behind. It relies on three cameras, one on the upper edge of the rear windshield, and two replacing the conventional exterior mirrors. The three camera streams are combined into one panoramic image, which is shown on a central 300 x 75 mm display where the rear-view mirror would normally be.

Rain Sensor

A Rain Sensor is a switching device activated by rainfall. It adjusts speed of wiper automatically according to the amount of water on the windshield and allows detection of moisture inside the car while raining. The system activates the wiper to operate in full automatic mode.

Traffic Jam Assist

Traffic Jam Assist uses proven functions such as ACC adaptive cruise control and LDW lane departure warning to allow easy slow driving in traffic jams. The car will follow the vehicle ahead and automatically operate the accelerator and brakes within the limits of the system so the vehicle is kept in lane.

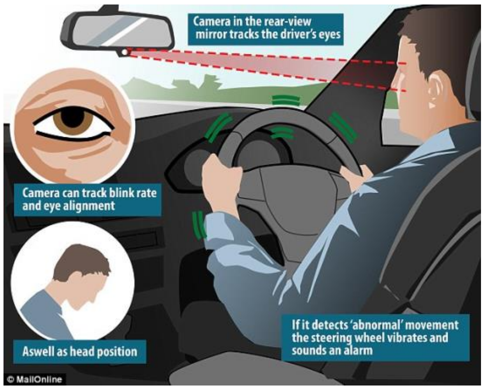
2.1.2.3 *Warning*

Driver Drowsiness Detection

Driver drowsiness detection is a car safety technology which helps prevent accidents caused by the driver getting drowsy.

Various studies have suggested that around 20% of all road accidents are fatigue-related, up to 50% on certain roads.

Some of the current systems learn driver patterns and can detect when a driver is becoming drowsy.



Electric Vehicle Warning Sounds

Electric vehicle warning sounds are a series of sounds designed to alert pedestrians to the presence of electric drive vehicles such as hybrid electric vehicles (HEVs), plug-in hybrid electric vehicles (PHEVs), and all-electric vehicles (EVs) travelling at low speeds. Warning sound devices were deemed necessary because vehicles operating in all-electric mode produce less noise than traditional combustion engine vehicles and can make it more difficult for pedestrians, the blind, cyclists, and others, to be aware of their presence.

Emergency Driver Assistance

Emergency Driver Assistance monitors driver behaviour. In case of a medical emergency, if the system concludes that the driver is no longer able to safely drive the vehicle, the car takes the control of the brakes and the steering until a complete stop.

Some devices are even able to make an automatic call to the emergency services (e.g.: Ford's SYNC Emergency Assistance).

Forward Collision Warning (FCW)

Forward Collision Warning helps the driver to avoid accidents or reduce their consequences by detecting vehicles or other obstacles in front of them on the road, and by informing them of an imminent risk of collision. The system uses the information from the sensors to emit visual, audio and haptic signals.

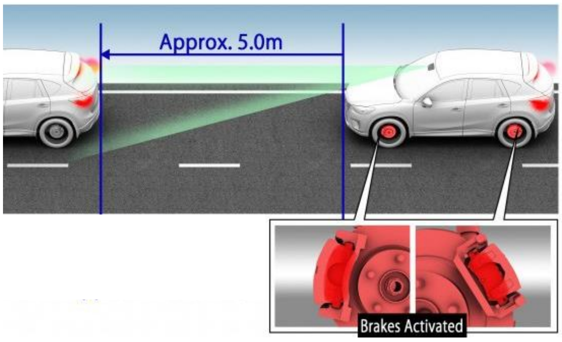
Wrong-way Driving Warning

In the case of imposing access restrictions, through the wrong-way driving warning function an acoustic warning is emitted together with a visual warning in the instrument cluster, making an effective contribution towards helping to prevent serious accidents caused by wrong-way drivers.

2.1.2.4 *Braking*

Autonomous Emergency Braking (AEB)

AEB systems detect an impending forward crash with another vehicle or VRU in time to avoid or mitigate the crash. This system first alert the driver to take corrective action to avoid the crash. If the driver's response is not sufficient to avoid the crash, the AEB system may automatically apply the brakes to assist in preventing or reducing the severity of a crash.



We can include Dynamic Brake System and Crash Imminent Braking as functions of the AEB system.

Dynamic Brake System (DBS)

If the driver brakes but not hard enough to avoid the crash, DBS automatically supplements the driver's braking in an effort to avoid crash.

Crash Imminent Braking (CIB)

If the driver does not take any action to avoid the crash, CIB automatically applies the vehicle's brakes to slow or stop the car, avoiding the crash or reducing severity.

Automatic Post-Collision Braking

The Automatic Post-Collision Braking system is a passive safety feature that will automatically apply the brakes after airbag sensors pickup that a collision is occurring during the initial impact of a crash. By applying the brakes right away, the system prevents further damage and injury which could occur through the continuing motion of the vehicle due to the crash momentum.

Electronic Stability Control (ESC)

This technology helps drivers maintain control of their vehicle during extreme steering manoeuvres by keeping the vehicle headed in the driver's intended direction, even when the vehicle nears or exceeds the limits of road traction.

When drivers attempt an extreme manoeuver (for example, to avoid a crash or because a curve's severity has been misjudged), they may experience unfamiliar vehicle handling characteristics as the vehicle nears the limits of road traction. The result is a loss of control. This loss usually results in either the rear of the vehicle "spinning out - oversteering," or the front of the vehicle "plowing out - understeering".

2.1.2.5 *Information*

Tire Pressure Monitoring System (TPMS)

A Tire Pressure Monitoring system is an electronic system designed to monitor the air pressure inside the pneumatic tires on various types of vehicles. TPMS report real-time tire-pressure information to the driver of the vehicle, either via a gauge, a pictogram display, or a simple low-pressure warning light. The target of a TPMS is avoiding traffic accidents, poor fuel economy, and increased tire wear due to under-inflated tires through early recognition of a hazardous state of the tires.

Traffic Sign Recognition

Traffic Sign Recognition is a technology by which a vehicle is able to recognise the traffic signs put on the road e.g. "speed limit" or "children" or "turn ahead".

Speed Limit Information Function (SLIF)

The Speed Limit Information Function uses the front camera and information from the navigation system to identify road speed signs and display the speed limit in real time. The information is displayed both in the navigation system display as well as in the TFT (Thin-Film Transistor) cluster.

2.1.2.6 *Other focus on collision*

Left Turn Assist (LTA)

When turning left involves crossing the other side of the road it is easy to overlook oncoming traffic or to estimate the speed incorrectly. The left turn assist function can issue a warning to the driver or can automatically apply the brakes in order to avoid a collision.

Intersection assistant

Whereas humans often react too slowly in city junctions when they are subject to distraction or misjudgement, assistance systems are immune to that brief moment of shock. The system monitors cross traffic in an intersection/road junction. If this anticipatory system detects a hazardous situation of this type, it prompts the driver to start emergency braking by activating visual and acoustic warnings and automatically engaging brakes.

Collision Avoidance System

A collision avoidance system is an automobile safety system designed to reduce the severity of a collision. It uses radar and sometimes laser (LIDAR) and camera (employing image recognition) to detect an imminent crash. GPS sensors can detect fixed dangers such as approaching stop signs through a location database. Once the detection is done, these systems either provide a warning to the driver when there is an imminent collision or take action autonomously without any driver input (by braking, steering or both).

Driver Monitoring System

The system's functions co-operate with the Collision Avoidance System. The system uses infrared sensors to monitor driver attentiveness. Specifically, the Driver Monitoring System includes a CCD (Charge-Coupled Device) camera placed on the steering column which is capable of eye tracking, via infrared LED detectors. If the driver is not paying attention to the road ahead and a dangerous situation is detected, the system will warn the driver by flashing lights, warning sounds. If no action is taken, the vehicle will apply the brakes (a warning alarm will sound followed by a brief automatic application of the braking system).

Proactive Occupant Protection System

The proactive occupant protection system uses the sensors from the ESP and the Front Assist ambient traffic monitoring system to detect critical situations with elevated accident potential.
If the system detects such a situation, the vehicle occupants and the vehicle are prepared for a possible accident:

- The front seat belts in use are tensioned to securely hold both the driver and the passenger.
- Open windows and the sunroof are closed to just a crack.

If a safe condition is restored and the vehicle has been stabilised, the front seat belts are relaxed. The side windows and the sunroof can be returned to their original positions.

Finally, we can highlight that Cruise Control and Platooning can be included in security ADAS, as well as Traffic Jam Assist can be a comfort ADAS.

2.2 ADAS which takes into account motorcycles (Officially)

Other vehicles are involved in about half of Powered Two-Wheelers serious casualty crashes. Many of the high risk traffic situations between other vehicles and PTWs could be prevented if the drivers anticipated the presence of a PTW. There are a number of new technologies which can prevent collisions, in general including those with PTW riders, pedestrians and cyclists.

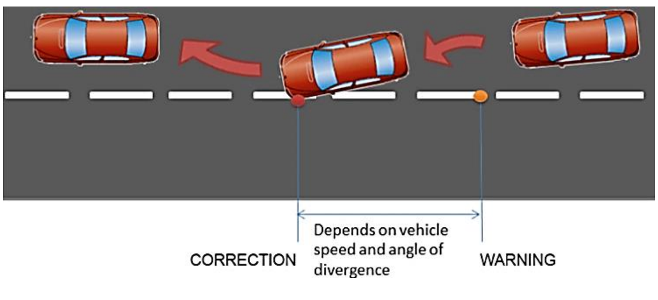
2.2.1 Safety devices on other vehicles impacting PTW safety

Blind Spot Information Systems (BLIS)

The BLIS detect vehicles and possible-colliding objects in the blind-spot area, on both right and left sides, by computer vision techniques. Once possible-collision objects enter the blind-spot area, the system raises a pre-collision alert, which consists of a LED light and buzzer. The system has been adopted by both car manufacturers and heavy vehicle industry.
Examples of range for the BLIS:
The Ford system can pick up a vehicle moving at least 5 mph within a 45-foot range (or five parking spaces) from either the left or right side of the vehicle.
The Mercedes system's range is 3 meters to the rear and to both sides of the vehicle at a speed range of greater than 30km/h.

Lane Departure Warning (LDW)

Certain lane-changing crashes could be prevented if drivers are warned of vehicles in their blind spot. LDW is a mechanism designed to warn the driver when the vehicle begins to move out of its lane (unless a turn signal is on in that direction) on freeways and arterial roads.
As a number of crashes involving a car and a PTW involve a wrong decision by the driver



on lane changing manoeuvre, it is anticipated that this technology will also contribute to reducing PTW crashes.

Lane Keeping Assist (LKA)

In addition, a Lane Keeping Assist system (LKA) contributes to active safety by inducing a corrective steer force to guide the driver after LDW warnings.

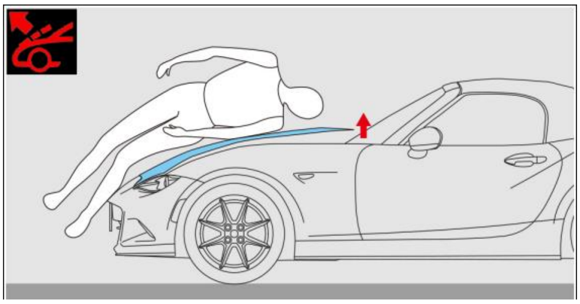
VRU Detection Systems

The sensor systems (often a combination of several sensor types) monitor the area in front of the vehicle, detect vulnerable road users and distinguish them from other obstacles. The systems use different actuators which help avoid collisions or significantly mitigate their impact by reducing the speed of the vehicle before the collision. The systems can combine visual and acoustic alerts and even actively take actions by means of autonomous braking systems. They commonly use forward-looking sensors to predict emergency situations. If this is a case, they inform the driver of the potential danger (if there is enough time for the required evasive action) and in case of limited time or no driver response, the systems activate the brakes of the vehicle shortly before the predicted impact. In the case where the crash cannot be avoided, the reduction in the impact speed will mitigate the VRU injury severity.

Night Vision Warning (NVW)

Another example of VRU detection is the Night Vision Warning (NVW) system. Its aim is to extend the visible range for a driver in darkness, including obstacle detection and warning. This is achieved by using an infra-red camera, looking forward, and displaying its view on a screen in the vehicle. The display shows the area in front of the vehicle with a longer range of visibility than with the normal headlights beam. It detects and warns for obstacles and vulnerable road users if a critical driving situation is identified.

Post-impact Safety Systems



If a collision cannot be avoided, protective structural actuators can be triggered which reduce the chance of serious injuries or even save the lives of vulnerable road users. The pop-up bonnet was designed for pedestrians but this innovation in vehicle design could protect all VRUs who are hit by the front of the vehicle. Pop-up bonnets are designed to rise in a crash involving VRUs to soften the crush, absorb the head impact energy, and reduce the severity of the injury. Several manufacturers are developing these systems, which are often combined with external airbags.

2.2.2 Specific bike detection features

Tesla’s sensors

Tesla’s cars use a combination of three different types of sensors: camera (forward and backward), radar (forward) and ultrasonic sensors of 5 meters range (forward, backward and lateral). Those sensors detect the other users, and can make a difference between a passenger car, a truck and a motorcycle or scooter. But the car shows the other vehicle on the HMI once the car is in front it, not when it is on its side. The Tesla can only warn the driver if there is another user around it but cannot differentiate until it has overtaken it.

Jaguar Land Rover “Bike Sense”

Bike Sense is powered by sensors placed on the vehicles, and will make drivers aware of potential hazards before they have even seen it using colours, sound and touch. Reaction time is decreased further by not using on a generic warning icon or beep, with danger being highlighted by lights and sounds that the driver will instinctively associate with the potential danger.

To help the driver understand where the bike or the motorcycle is in relation to their car, the audio system will make it sounds as if a bicycle bell or motorbike horn is coming through the speaker nearest the bike, so the driver immediately understands the direction the cyclist is coming from.

As the cyclist gets closer to the car, a matrix of LED lights on the window sills, dashboard and windscreen pillars will glow amber and then red as the bike approaches. The movement of these red and amber lights across these surfaces will also highlight the direction the bike is taking.

If they are approaching from the rear, Bike Sense will detect if it is overtaking or coming past the vehicle on the inside, and an air cushion inside the top of the car seat will extend to ‘tap’ the driver on the left or right shoulder.

Bike Sense will also help prevent vehicle doors being opened into the path of bikes when the vehicle is parked, causing door handles to light up, vibrate and buzz to alert them to the danger.

If the driver ignores the warnings and presses the accelerator, Bike Sense will make the accelerator pedal vibrate or feel stiff, so the driver instinctively knows not to move the car forwards until the hazard has been avoided.

2.3 Selected ADAS which can address accident and safety of riders:

Finally, over all those existent ADAS on car, some of them are already developed in order to detect motorcycles. However, we can suggest that other ADAS can also have an impact on bike's detection, even if they are not made for it at the beginning. That is how, as part of the MUSE (Motorcycle Users Safety Enhancement) project, we can pick up ADAS which are susceptible to be used:

Adaptive Cruise Control (ACC)
Glare-free High Beam
Adaptive Front-Lighting System (AFS)
Automotive Night Vision
Collision Avoidance System
Driver Monitoring System
Forward Collision Warning (FCW)
Intersection Assistant
Autonomous Emergency Braking (AEB)
Dynamic Brake Support (DBS)
Crash Imminent Braking (CIB)
Left Turn Assist (LTA)
Intelligent Speed Adaptation (ISA)
Blind Spot Information Systems (BLIS)
Lane Departure Warning (LDW)
Lane Keeping Assist (LKA)
VRU Detection Systems
Night Vision Warning (NVW)
Post-impact Safety Systems.

As said above, some of those ADAS are not focused on rider detection but can have an impact on their security. As example, we can highlight an accident which occurred in Arizona (USA): a Tesla Model X driven on autopilot, with the cruise control function on and it struck a police motorcycle because the car did not see the rider.

2.4 Information about ranges of sensor, camera or Lidar

When evaluating the possibility of ADAS systems to avoid an accident it is important to know the limits of the sensors used by these systems. In the table here below we wanted to show, in a general way, the limitations of these sensors:

Manufacturer	Type	Range	Opening angle	Frequency
Daimler	Multi-mode **Radar**	80m	30°	
		40m	140°	
	Long range **Radar**	250m	20°	
		70m	90°	
	Stereo multi-purpose **Camera**	90-500m	50°	
	Ultrasonic **Sensors**	1.5m		
		4.5m		
Bosch	LRR2 **Radar** (2nd generation)	2-200m	4°	76-77 Hz
	LRR3 **Radar** (3rd generation)	0.5-250m	5° (inner) 8° (outer)	
Continental	ARS200 **Radar** (2nd generation)	1-7m (detection) 7-150m (measurement)	3.4°	76-77 Hz
	ARS300 **Radar** (3rd generation)	1-200m Far range scan 1-60m Near range scan 0.25-50m at low speed	2.5° Far range scan 8° Near range scan	
Common devices	**Lidar**	1-150,180,200m		
	Mono **Camera**	140m*		
SUBARU (EyeSight)	Dual colour **Cameras**	110m		

Table 1: Limits of sensors

*: This range depends on the object: a pedestrian could only be detected by 60m, and is classified by 30m.

3 Advanced Rider Assistance System (ARAS) in Powered Two-Wheelers

ADAS technologies have already been explored for passenger cars, whereas the application of such devices on PTWs (so-called ARAS Advanced Rider Assistance Systems, and OBIS On-Bike Information Systems) in order to increase the safety and comfort of riders, is still at the early stages of development. Indeed, Human Machine Interfaces (HMI) are hugely different for a motorbike: difficulty to warn with the background noise, hardware need to resist to vibration, water…

3.1 Existent ARAS and OBIS in PTW (non-exhaustive list)

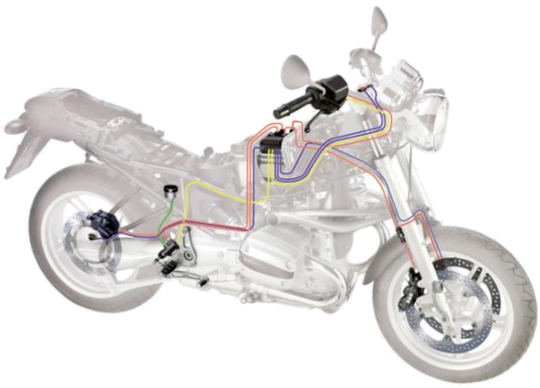
The term "Advanced Rider Assistance Systems for Powered Two-Wheelers (abbr. ARAS-PTW)" denotes equipment which supports and assists the operator of a powered two-wheeler and / or reduces the stress and strain for the rider. It is a means of active safety (accident avoidance) but also influences accident results during a pre-crash phase in a positive way.

3.1.1 ARAS

Some of these technologies are already available, have been assessed and proposed as an option when purchasing the bike, while others are still at the development stage.

3.1.1.1 *Braking*

Antilock Braking System (ABS)



ABS allows safer, mainly straight-line, braking by optimising braking distance and helping riders keep stability when braking hard (especially in wet conditions). It has therefore the potential to reduce the occurrence of PTW crashes and to attenuate their consequences. The system prevents the wheels from locking up by automatically modulating the brake pressure when the rider brakes hard. By preventing the wheels from locking, the system aids riders to maintain steering control which may reduce stopping distances in certain emergency conditions. ABS is technically suitable for most types of motorised two-wheelers, but in practice it is currently mainly available on the more powerful motorcycles.

ABS cannot prevent or mitigate all crashes, and neither can one expect the same level of benefits from ABS on crash risk for PTWs and passenger cars, especially when braking in a curve.

Combined Braking Systems (CBS)

International and EU regulations require PTWs to be fitted with independent controls for front and rear brakes. For motorcycle, this is usually in the form of a foot pedal for the rear brake and a front brake lever both on the right-hand side. Most automatic PTWs (which do not require a clutch control) have the rear brake operated by a lever on the left-hand side of the handlebars. In a CBS system, the application of one brake control actuates both front and rear brakes.

CBS could be promoted as a less expensive braking technology (compared to ABS) for smaller powered two-wheelers.

Amplified Braking Systems

This system amplifies the activation input made by the rider, resulting in a more rapid deceleration. It enables a stronger braking pressure from the start of the braking procedure. This can be compared to the emergency brake assistance system in cars.

Advanced Braking Systems

Advanced Braking Systems encompass several braking technologies including anti-lock braking system, combined braking system and amplified braking system. This variety of “advanced braking systems” can make a positive contribution to motorcycle road safety. In the event of emergency stops the primary objective is to ensure that the vehicle remains stable or, in the case of combined braking system, to increase braking power in case of inadequate braking operation.

Rear wheel Lift-off Protection (RLP)

Certain PTW architectures can benefit from RLP, which detects if the rear wheel lifts during braking operation. This initiates a momentary reduction of the pressure in the front braking circuit.

Brake by Wire

The system consists of an electronically controlled combined brake by wire system with an innovative stroke simulator. Direct motor control ensures precise operation of the ABS, resulting in reduced pitching and smooth modulated ABS intervention.

3.1.1.2 *Stability*

Electronic Traction Control System

Electronic Traction Control is a technology now largely adopted for the passenger car market. A Traction Control System (TCS) has the potential to prevent the rear wheel from spinning uncontrolled when accelerating all-out and thus avoids any loss of side forces and stability which otherwise would make the rear wheel swerve out of control. Lift-off detection and intervention serves furthermore to prevent the front wheel from moving up when accelerating under full power (Anti Wheelie Control).

In reality, the principles of the systems cannot be the same for 2-wheeled and 4-wheeled vehicles: on a PTW, it acts more as an anti-skidding system; therefore one cannot expect the same benefits as from Electronic Stability Control (ESC) installed on cars which uses the same technology but which has the possibility to stabilise the vehicle by acting differentially on the left/right wheels on the same axle. Nevertheless TCS provides useful assistance, particularly on powerful motorcycles and when riding under conditions with slippery surfaces. TCS is a logical complement to ABS insofar as these two functions together enhance riding stability and control.

Electronic Traction Control System (TCS) can potentially reduce motorcycle crashes, notably single PTW ones.

Motorcycle Stability Control

This highly advanced system is designed to allow a braking manoeuvre while cornering. It works on the basis of a combination of ABS, electronic CBS, a lean angle dependent traction control and lean angle dependent brake control. Motorcycle Stability Control detects critical situations, and instantly computes the best possible values for acceleration and braking.

Anti-hop (slipper) Clutch System

This system is designed to partially disengage or “slip” when the rear wheel tries to drive the engine faster than it would run under its own power. The engine braking forces in conventional clutches will normally be transmitted back along the drive chain causing the rear wheel to hop, chatter or lose traction. This is especially noted on larger displacement four-stroke engines, which have greater engine braking than their two-stroke or smaller displacement counterparts. Slipper clutches eliminate this extra loading on the rear suspension giving riders a more predictable ride and minimise the risk of over-revving the engine during downshifts. Slipper clutches can also prevent a rear wheel lockup in case of engine seizure.

Active and Semi-Active Suspension

Active suspension replaces the spring and damper with a hydraulic or electromagnetic actuator to control the wheel. In a conventional suspension setup, the ground pushes the wheel up and the spring pushes it down; in an active system, the actuator controls the wheel movement by literally lifting the wheel over bumps or pushing it down into dips, which keeps the chassis at a smooth, steady attitude.

3.1.1.3 *Lighting and visibility*

Automatic Headlamp On (AHO)

This is a switch that ensures the (main or dipped beam) headlight (or the Daytime Running Lamp if the vehicle is equipped with such lights) is always on when the engine is running.

Daytime Running Lamps (or Lights) (DRL)

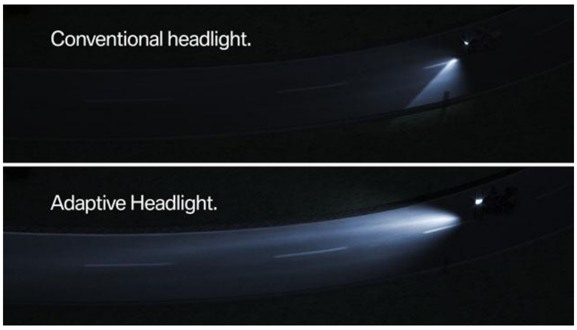
DRLs for motorcycles are bright white forward-facing lights designed to optimise the conspicuity of PTWs during daytime, while reducing the energy consumption in comparison to the use of regular headlamps. There is, today, little research on the relative effectiveness – in terms of safety or energy savings of daytime running lights for motorcycle compared to riding with the dipped beam headlight on during daytime.

Alternative Front Light Patterns

Alternative Front Light Patterns aim to provide a unique visual signature (signal pattern) that clearly differentiates them from other vehicles and may facilitate their perception by other road users. Such visual configurations as distinctive features can be implemented by varying the colour of the headlights (e.g. yellow) or by dedicated positioning and lay-out of PTWs’ frontal headlights (e.g. T-light configuration, Long-Light-system by Honda, triangular configuration). The T-configuration uses vertical linear lights at the fork and horizontal ones at the rear of the mirrors. The headlight is positioned at the intersection of the two. The T-design (consisting of five dedicated daytime running lights) was found to be the easiest to recognise because the design reflects the silhouette as well as the size of the motorcycle.

Adaptive Front Headlights

Those headlights improve the illumination of the motorcycles path on curves. They ensure that the illumination from the headlight is projected on the intended path of the motorcycle when cornering by adjusting it in accordance with the speed and position of the PTW. Improving the illumination of the path of motorcycles improves the sight of motorcyclists and can therefore lead to a reduction of PTW crashes.



Motorrad laser light

It is an adaptation of a BMW car component, and generates a bright and pure-white light with a high-beam range of 600m, which BMW Motorrad says is double that of conventional headlights.

3.1.1.4 *Warning*

Speed Alert

As the Intelligent Speed Adaptation (ISA) in car, the Speed Alert uses information on the position of the vehicle in a network in relation to the speed limit in force at that particular location to warn the rider (visibly and/or audibly) that the speed limit is being exceeded. The rider then decides whether or not to slow down.

There is also different researches on active ISA that would automatically increase the required pressure on the accelerator when the speed limit is exceeded (the active accelerator). Apart from the technical challenges, the introduction of active ISA may not be well accepted by riders because intervention on brakes/throttle during cornering or other manoeuvres can perturb the rider’s control.

Curve Warning

The Curve Warning function provides the rider with a warning signal when the motorcycle speed is too high in relation to a curve ahead. The safe speed is estimated in real time by comparing the PTW speed and acceleration to the road profile and map based information, such as the presence of critical locations (e.g. intersections, pedestrian crossings, etc.).

The Curve Warning function provides continuous feedback about possible acceleration, i.e. the system intervenes when the rider accelerates in a way that makes it impossible to hold the optimal and safest riding line. In order to work efficiently the system requires the rider’s acceptance and immediate reaction that would lead to safe deceleration and curve negotiation.

Front Collision Warning

The Frontal Collision function aims to warn the rider when an obstacle has been detected in the headway of the PTW and a collision is likely to occur. The Frontal Collision Warning function will not only detect obstacles, but also evaluate the severity of the encounter.

This function is made of two functions: the Safe Distance and the Safe Relative Speed/Path. The former warns the rider if the distance is too close compared to the calculated reaction time, while the latter alerts when a prompt correction is suddenly needed but the rider seems not to react to an imminent collision. By producing the alert, the riders’ attention is refocused on the headway and they have time to react adequately by braking or an evasive manoeuvre.

Lane Change Support (LCS)

Lane Change Support (LCS) aims to alert the rider in case of an imminent lane change that may cause a collision with another vehicle. PTWs have large blind spots due to their small mirrors and small gap. Thus, dangerous situations are quite likely to occur when motorcyclists miss another vehicle while changing the lane.

Blind Spot Monitoring

In blind spot monitoring systems, the rear/lateral surroundings of the motorcycle are monitored by a radar sensor that provides information about the speed and position of oncoming vehicles. This information is used to assess how critical could be the lane change. In the event that the rider activates the indicator to perform a lane change, if another vehicle is approaching and it is in the blind spot, the rider is informed about the potential risks by an appropriate HMI (usually by different colour lights on the top of the left mirror).

Tyre Pressure Monitoring Systems

Tyre Pressure Monitors give indication and assurance to the driver that tyres will perform according to manufacturer's standards. There are a number of tyre pressure monitors on the market which provide either a visual or an acoustic warning of falling tyre pressures.

Intersection Safety (INS)

Intersection safety (INS) assists the driver in avoiding common mistakes which may lead to typical intersection crashes. It covers the following functions:

- *Traffic light assistance*: preventing red light ignoring. The system emits an urgent acoustic warning if the situation becomes critical.
- *Right-of-way assistance*: The right-of way assistance pays special attention to lateral traffic. The system warns the driver if violating a right-of-way, but also if somebody else is expected not to give the right-of-way to the case vehicle.
- *Left-turn (right-turn) assistance*: The left-turn (right-turn in left-hand-side countries) assistance warns the drivers about potential collision with other vehicles with crossing path.

Side View Assist (SVA)

Designed to improve safety when riders change lanes, it is composed of four ultrasonic sensors, with a range of 5m, installed in pairs at the front and rear. The rear sensors monitor the blind spot in neighbouring lanes and the two front sensors provide a plausibility check. If a rear ultrasonic sensor registers an object before the front sensors, the system issues an optical warning, displayed near to the mirror on the relevant side. It works at speeds from 25-80 kph.

3.1.1.5 *Other*

PTW Airbags

Airbags for motorcycles requires special design as they need to take into account that the position of the rider is not always upright such that there may be smaller distances between the rider's face and the airbag than that typical for car drivers, and that the presence of pillion passengers will affect the forward force of the rider. It has a V-shape on the panel facing the rider, and deploys in 60ms and absorbs the rider's kinetic energy in 0.15 seconds.

3.1.2 OBIS

e-Call

This function is activated when an accident occurs. Inertial sensors placed both on the vehicle and in the helmet detect the accident in order to activate a remote link with the infrastructure. The e-Call function provides information about location of the crash/fall to the emergency centre, which call back the rider in order to check its conditions. Once the call is established, the emergency centre can be ensured about the conditions or, in alternative, send the emergency rescue team. The e-Call modules receive inputs from on-board vehicle sensors and data, as head impact, from the helmet. In this way, more information is available to the rescue team in order to give the right medical treatments. Finally, the implementation of a GPS based navigation system includes the information of the location of the crashed vehicle.

Telediagnostic Module

Telediagnostics services provide added value related to safety and security concerns, performance, maintenance and upgrading. It allows the rider to monitor constantly the use and functioning conditions of the vehicle and it offers early warnings about next vehicle services or imminent failure of some vehicle subsystem

Navigation and Route Guidance (N&RG)

Most of the Navigation and Route Guidance developed so far are addressed to the car occupants. This OBIS function consists of a navigation unit which is dedicated to the rider, especially for novice riders and tourists. It is integrated with several options in order to be more motorcycle-oriented, starting from the *7" display* (see point 2.2), lane assistance system, and a dedicated interface which include the warnings/information of the overall SAFERIDER (see point 2.4) functionalities.

Weather Traffic & Black spot info (WTB)

The Navigation unit is integrated with traffic, weather and black spot functionalities able to inform the rider about potential traffic jam or critical weather conditions that the rider could encounters during the planned route. Traffic and weather information are downloaded from the server via 3G connection. On Black spot side, the Navigation Unit is able to warn the rider about statistically dangerous place: relying on accurate understanding of accidents causation by accident analyses, the system could effectively inform the rider about a potential risk.

3.2 HMI concept based on haptic devices

In order to properly warn the rider, engineers had to develop new ideas adapted to motorbikes because of the background noise, the dashboard, the wind, the water … The HMI concept explored is mainly based on haptic devices able to provide information by the touch sensory channel to the riders. The main advantage is to leave visual attention to the road while warning is produced.

Haptic Glove

It is a special motorcycle glove capable of transmitting warnings to the user through vibro-tactile cues. On the left hand, the rider wears a traditional motorcycle glove while the right hand glove is equipped with an electronic and vibration motors. The glove is equipped with 4-haptic motors placed on upper, bottom, left and right side of the wrist. The communication between the glove and the system is done via Bluetooth.

Smart Helmet

This HMI is able to provide audio, visual and vibration warning to the rider. All the information for the different types of warning is exchanged with the system via Bluetooth communication. The acoustic information is transmitted through loudspeakers located in each side of the helmet cheek pads while the visual is produced by a head-up display and overlapped to the global visual field. Finally, the Smart Helmet can give vibration feedback by means of two vibration motors located one inside the left cheek pad and the other inside the right cheek pad.

7” Display

The 7” display with touch functionality can be used for output as well as for input by the rider. The standard screen of the display is split out into three main parts: at the top the ARAS alarms are represented, below is the place for OBIS and the middle is dedicated to the navigation function.

Haptic Handle

It is a device able to warn the rider by changing its shape and providing pressure feedback to the rider. The feedback provided to the rider consists in a shape variation of the surface of the handle, generating pressure variations in specific points of the palm of rider’s hand. The intensity of the feedback is fixed, but it is possible to change frequency and duration of the pressure stimulus.

Vibrating Seat

This HMI provide haptic warning to the rider by means of controlled pulsed vibration under the PTW seat. The vibration is obtained through an electrical motor and a rotating eccentric mass controlled by a microcontroller connected through serial connection to the SAFERIDER system. The intensity of the vibrations is fixed and constant, but the frequency of activation, the relative phase, the duty cycle and the duration time of each motor can be programmed by controlling the activation of the electrical motor.

Visual Attractor on rear mirror

This is a specific HMI dedicated to the LCS, providing warnings by means of two LED’s placed on the left side rear view mirror. When a car is driving in the Blind Spot Zone or is approaching to PTW a yellow LED is informing the driver that it isn’t safe to do a lane change. If the driver starts the Lane Change Support by activating the left side blinker, another LED is flashing red to alert the driver not to change the lane.

Haptic Throttle

It warns the rider by applying force feedback on the gas throttle handle. Such system allows modifying the torque that calls back the throttle. It thereby implicitly suggests the rider to react by releasing the gas throttle and thus to decelerate or not further accelerate.

3.3 Selected ARAS which can address accident and safety of riders

As part of the MUSE project, we can imagine to take into account the following ARAS:

Amplified Braking System
Electronic Traction Control System (for single crash especially)
Motorcycle Stability Control
Front Collision Warning
Lane Change Support (LCS)
Blind Spot Monitoring
Intersection Safety
Side View Assist (SVA).

3.4 Projects about active safety for PTW

European statistics show that Powered Two-Wheelers road accidents are extremely high. That is why reducing the amount of PTW accidents is a major concern for the European community. Therefore, several projects focusing on this issue have emerged.

SafeRider

Actors/Partners: AvMap, Bast, Hellenic Institute of Transport, Centro para la Inverstigacion y Desarrollo en Trasnporte y Energia, CONNCEP SWISS, Europe Recherche Transport, FMEA, Fraunhofer Institut für Arbeitswirtschraft und Organisation, Ibeo Automobile Sensor GmbH, French National Institutes for Transport and Safety Research, Meta System S.p.a., MIRA Ltd, NZI Helmets, PERCRO, PIAGGIO, Prsche Engineering, Universita degli Studi di Firenze, University of Modena and Reggio Emilia, University of Padova, University of Trento, YAMAHA Motor Europe.

Website

Dates: 2008-2010

Description: SAFERIDER aimed to study the potential of ADAS/IVIS integration on motorcycles for the most crucial functionalities and develop efficient and rider-friendly interfaces and interaction elements for riders comfort and safety.
Specifically, SAFERIDER targeted the following objectives:

- To develop priority Use Cases for ARAS/OBIS implementation on PTWs.
- To define the functionalities of the prioritised ARAS/OBIS for PTWs of different levels based on accident analysis data and naturalistic driving studies.
- To design and develop ARAS/OBIS prototypes for the selected functionalities.
- To design an optimal HMI concept and develop warning/ information provision elements for the prototypes, as well as for potential combinations of their output.
- To technically verify the developed ARAS/OBIS and integrate them to different motorcycles and motorcycle simulators.
- To estimate the safety impact and user acceptance of the prototypes in a series of pilot applications.
- To develop a Design Guidelines handbook for ARAS/OBIS integration and HMI design for motorcycles.
- To develop riders training tools for optimal ARAS/OBIS usage.

Safe2Wheelers (COST)

Actors/Partners: Università degli Studi Firenze, Siemens, University of West Bohemia, The Csech Technical Unvisersity in Prague, Imperial College London, Universidade de Vigo, Universitatea Babes-Bolyai, Aristole University of Thessaloniki, Ludwig-Maximilians-Universitat München, Technische Universität Darmstadt, University of Southampton, Chalmers Unvisersity of Technology, Applus Idiada, University of Zaragoza, Universidade de Coimbra, Institute of Transport Economics of Norway, SWOV, Politecnico Milano, Israel National Road Safety

Authority, University of Limerick, Henry Dunant Hospital Center of Greece, CERTH Hellenic Institute of Transport of Greece, Hochschule Furtwangen University of Germany, WIVW Germany, University of Strasbourg, University of Zagreb, University of Mons, University of Ruse, TU Graz Austria, Joahnnes Keppler University Linze Austria and Medizinische Hochschule Hannover Germany.

Website

Dates: 2016-Ongoing

Description: The main objective of the Action is to develop a holistic and integrated approach towards PTW safety across Europe by bringing together PTW safety experts from academia and industry to a) acquire, unify and coordinate PTW safety research, and b) ensure broad dissemination towards PTW users, industry and public authorities. The COST Action aims to create a wide network of scientists and experts, to work jointly on new solutions and policy recommendations for PTW safety.

SaferWheels (SWOV)

Website

Description: Within the European project *SaferWheels* SWOV carries out an in-depth study into crashes involving two wheelers. The study investigates crashes in which:

- an e-bike, (light) moped, or motorcycle was involved
- a cyclist collided with a motor vehicle (powered two wheeler, car, bus or truck)

The project SaferWheels is carried out by SWOV and teams from Great Britain, Italy, France, Greece and Poland. Each of the countries collects information about 85 crashes. The purpose is to learn more about how these crashes occur of these and which factors play a role. This information is used to propose measures to prevent similar crashes.

WATCH-OVER *(Vehicle-Vulnerable roAd user cooperaTive communication and sensing teCHnologies to imprOVE transpoRt safety)*

Actors/Partners: Centro Ricerche Fiat, Daimler AG, Piaggio & C. S.p.A., Robert Bosch GmbH, MIRA Limited, Technische Universität Chemnitz, Austrian Research Centers GmbH - ARC, Centre for Research and Technology Hellas, University of Stuttgart - Institute for Human Factors and Technology Management, Steinbeis Research Institute Wireless Communication, Faber Software S.r.L, Logica CMG Nederland B.V., Università di Modena e Reggio Emilia.

Website

Dates: 2006-2008

Description: WATCH-OVER intended to examine the detection of vulnerable road users in the complexity of traffic scenarios in which pedestrians, cyclists and motorcyclists are walking or moving together with cars and other vehicles.

The technical challenge is the development of a cooperative system for real time detection and relative localisation of vulnerable users that includes innovative short range communication and video sensing technologies. The implementation challenge is the deployment of a reliable system that is versatile for different vehicles and vulnerable road users.

2BeSafe

Actors/Partners:

Vehicle Manufacturer: Piaggio ITALY

Users: Federation of European Motorcyclists' Associations (FEMA)BELGIUM

Universities: Technical University Dresden (TUD)GERMANY; University of Firenze (UNIFI)ITALY; University of Modena & Reggio Emilia (UNIMORE) ITALY; University of Padova (UNIPD)ITALY; University Vienna (UNIVIE)AUSTRIA; National Technical University of Athens (NTUA) GREECE; Aristotle University of Thessaloniki (UoT)GREECE; Faculty of Human Kinetics/ Technical University of Lisbon (FMH/UTL) PORTUGAL; Ben Gurion University of the Negev (BGU)ISRAEL; Monash University Accident Research centre (MUARC)AUSTRALIA; University of Nottingham (UoN)UK

Research Institutes: European Research Transport (ERT)FRANCE; The French National Institute for Transport and Safety Research (INRETS) FRANCE; Centre Européen d'Etudes de Sécurité et d'Analyse des Risques (CEESAR)FRANCE; Bundesanstalt für Straßenwesen (BAST) GERMANY; Transportation Research Laboratory (TRL) UK; FACTUM Chaloupka & Risser OHG (FACTUM); Österreichiches Forschungs- und Prüfzentrum Arsenal Ges.m.b.H (AIT)AUSTRIA; Center for Research & Technology Hellas/ Hellenic Institute of Transport (CERTH/HIT) GREECE; Institute for Communication and Computer Systems (ICCS)GREECE; Fundación CIDAUT (CIDAUT)SPAIN; Technical Research Centre of Finland (VTT)FINLAND; Transport Research Centre of Brno (CDV)CZECH; Api R&D FRANCE

Others: Austrian Road Safety Board (KFV) AUSTRIA (private non-profit association).

Website #1
Website #2

Dates: 2008-2011

Description: 2-BE-SAFE main objective was to undertake behavioural and ergonomics research and, based on the findings, to propose new and refined injury countermeasures for enhancing Powered Two Wheeler (PTW) rider safety. WP1 (Power-two wheelers Critical risk factors) identified the influence of the rider or driver and the road environment characteristics (road infrastructure and weather conditions) that constitute risk factors for PTW's.

MOTORIST *(MOTOrcycle Rider Integrated SafeTy)*

Actors/Partners:. Universita Degli Studi Di Firenze, Delft University Of Technology, Universita Degli Studi Di Padova, Zapadoceska Univerzita V Plzni, Universite De Strasbourg, Ludwig-Maximilians-Universitaet Muenchen, Siemens Industry Software Nv, Technische Universiteit Eindhoven, Dainese Spa.

Website #1
Website #2

Dates: 2014-2018, Ongoing.

Description: The aim of the research activities within the project is to make the use of PTWs safer and reduce consequently the number of accidents. If an accident is unavoidable make the consequences for the rider minimal. The project is divided in three work packages (WPs) with three separate but related goals. The first work package aims to improve the rider's skills with training strategies that are derived from in-depth accident data and from a quantification of rider behaviour in critical situations. The second work package aims at developing advanced safety systems that improve the interaction between the rider and the PTW by modelling the rider, also based on the in WP1 quantified rider behaviour. The third work package considers the cases where the crash is unavoidable and will develop personal protective equipment to protect the riders, given the input conditions from WP2 at the moment right before impact. The end result of this project will be a set of rider training guidelines that are proven to be effective, safety system concepts implemented on PTWs and improved personal protective equipment and accompanying standards.

PISa

Actors/Partners:. Carver Engineering, Ibeo Automobile Sensor GmbH, Ludwig-Maximilians-Universität, MALAGUTI Spa, Paioli Meccanica, TNO - The Netherlands Organisation for Applied Scientific Research, Science and Industry & Security and Safety, Transport Research Lab, TVS MOTOR Company Ltd., Uniresearch, University of Firenze, Vehicle Safety Research Centre of Loughborough University, EC - European Commission Research DG.

Website

Dates: 2007-2009

Description: The aim of the PISa project was to develop and implement "reliable and fail-safe" integrated safety systems for a range of Powered Two Wheelers (PTWs), which will greatly improve the performance and primary safety (handling and stability) and can link to secondary safety devices. PTWs are single track vehicles, which means that the rider has a more difficult vehicle to control in relation to a car, in particular when cornering or braking, and even more so in emergency situations. Only a few (high-end) motorcycle brands are fitted with ABS and (partly) combined braking systems. Optimization of the PTW brake performance will reduce the impact speed in case an accident cannot be avoided and this will directly reduce the fatality rate and injury level.

Riderscan

Actors/Partners:

Project Partners: European Commission, European Parliament, AMDM (Assurance Mutuelle des Motards), ACEM (The Motorcycle Industry in Europe), GDV (German Insurance Association).

Expert Group Members: IFSTTAR (France), CIECA (Europe), FEHRL (Europe), NTUA (Greece), Local Transport Project (United Kingdom), RAMBOLL (Finland), Assurance Mutuelle des Motards (France), Ministry of infrastructure and the Environment (the Netherlands).

Activities Partners: NMCU (Norway), AMM (Spain), AMDM (France), Motothesis (Greece), MOTOE (Greece), Slovenian Traffic Safety Agency (Slovenia), MAG NL (The Netherlands), SMC (Sweden), GSM (Italy), FFMC (France), MCTC (Denmark), Smoto (Finland), FMP (Portugal), NTUA (Greece), UNIFI (Italy).

Media Partners: Motociclismo.es (Spain), MC-Folket (Sweden), Moto Magazine (France), Motorrad (Germany), IFZ (Germany), Ride Magazine (United Kingdom), MotoTriti (Greece), Motorrijder (Belgium), Bike (Finland), Touring NYT (Denmark), Motociclismo.pt (Portugal), Motovoyager.net (Poland).

Website #1
Riderscan report

Dates: 2011-2015

Description: The main objectives of the Riderscan project were the following:

- To gather existing knowledge in all relevant areas of motorcycle safety: on transport authorities' initiatives towards motorcycling; on motorcycling use and safety characteristics (infrastructure, training, accident reporting and statistics, awareness campaigns, research, traffic management, emergency response, etc.) and on the motorcycling population and means to reach it.
- To identify and report on needs for European action (legislation, standardization, research and specific actions) in the field of motorcycle safety.
- To disseminate the collected information and best practices to relevant stakeholders throughout Europe (press, motorcycling community, transport stakeholders, national governments and parliaments, research community, etc.) at national and EU level.
- To foster a new dynamic among road safety stakeholders by improving knowledge and enhancing communication and cooperation between the various areas related to motorcycle safety.

4 Intelligent Transport Systems (ITS) [Vehicle-to-Vehicle (V2V) and Vehicle-to-Infrastructure (V2I)][1]

Intelligent Transport Systems (ITS) technologies have the potential to improve the safety, security and efficiency of surface transport systems, in particular at high risk locations for PTWs such as intersections. Safety researches addressing the development and application of ITS technologies has focused primarily on passenger vehicles and has not been vigorously developed or applied to motorcycles. Nevertheless, existing and emerging ITS research results have the potential to be adapted to PTWs.

4.1 Existent ITS (Non-exhaustive list)

There are two main categories of ITS:

Vehicle-to-Vehicle (V2V) communication system consists in the dynamic wireless exchange of data by radio signals between nearby vehicles that offer the opportunity for significant safety improvements. The vision for V2V is that eventually, each motor vehicle on the roadway (including automobiles, trucks, buses, motor coaches, and motorcycles) will be able to communicate with other vehicles and that this rich set of data and communications will support a new generation of safety applications that will enable crashes on the roadway to be prevented.

Vehicle-to-infrastructure (V2I) communications system is the wireless exchange of data between vehicles and highway infrastructure, intended primarily to avoid or mitigate motor vehicle crashes but also to enable a wide range of other mobility, and environmental benefits. V2I communications apply to all vehicle types and all roads, and transform infrastructure equipment into "smart infrastructure". One particularly important advance is the ability for traffic signal systems to communicate the signal phase and timing information to the vehicle in support of delivering active safety advisories and warnings to drivers.

4.1.1 V2V possible applications

Below are quoted some safety applications of V2V:

Intersection Movement Assist

IMA warns the driver of a vehicle when it is not safe to enter an intersection due to a high probability of colliding with one or more vehicles at intersections both where a signal is present (a "controlled" intersection) and those where only a stop or yield-signal is present (an "uncontrolled" intersection").

Left Turn Assist

LTA warns the driver of a vehicle, when they are entering an intersection, not to turn left in front of another vehicle traveling in the opposite direction.

Emergency Electronic Brake Light

Emergency Electronic Brake Light enables a vehicle to warn its driver to brake in a situation where another V2V-equipped vehicle decelerates quickly but may not be directly in front of the vehicle. The

[1] Sources: *Vehicle-to-vehicle communications: Readiness of V2V technology for application.* (Report No. DOT HS 812 014), Harding, J., Powell, G., R., Yoon, R., Fikentscher, J., Doyle, C., Sade, D., Lukuc, M., Simons, J., & Wang, J. (2014, August). Washington, DC: National Highway Traffic Safety Administration.

EEBL warning is particularly useful when the driver's line of sight is obstructed by other vehicles or bad weather condition, such as heavy rain.

Forward Collision Warning

FCW warns the driver of the host vehicle in case of an impending rear-end collision with a remote vehicle ahead in traffic in the same lane and direction of travel.

It is thought that FCW system using radar or cameras cannot provide a warning fast enough for very high speed rear end crashes. V2V, in contrast, has that capability based on its longer range (300 meters).

Radar and camera FCW systems also have a problem detecting stopped vehicles if the vehicle is stopped before coming into range of the radar and camera. Recently, dual radar and dual camera systems have been developed to provide detection of stopped vehicles. A V2V system could act as the redundant system and allow a single radar or single camera FCW system to detect stopped vehicles, thus reducing system cost as compared to dual radar or dual camera.

Blind Sport Warning + Lane Change Warning

Both warns the driver of the host vehicle during a lane change attempt if the blind spot zone into which the host vehicle intends to switch is, or will soon be, occupied by another vehicle traveling in the same direction. The application also provides the driver of the host vehicle with advisory information that a vehicle in an adjacent lane is positioned in a vehicle's "blind spot" zone when a lane change is not being attempted.

Do Not Pass Warning (DNPW)

This system gives alerts to the drivers to help avoid a head-on-crash resulting from passing manoeuvres.

Vehicle Turning Right in Front of Bus Warning

This application warns transit bus operation of the presence of vehicles attempting to go around the bus to make a right turn as the bus departs from a bus stop.

Car Breakdown Warning

This function enhances the safety of vehicles by detecting an upcoming disabled vehicle or by warning other/following cars that the own car is about to break down or disabled. Cars receiving this information will relay it to other following traffic-participants.

Approaching Emergency Vehicle

Wireless communication is used to distribute messages about approaching emergency vehicles which claim the right of way. If a received message is relevant in the current situation the driver will be informed at an early stage. Depending on the OEM's strategy the information is displayed on the head unit or another display device and may also be augmented by audio or haptic signals.

Slow Vehicle Warning

The slow vehicle warning system is designed to aid the driver in avoiding or mitigating rear-end collisions with vehicles in front of the own car. The driver will be alarmed through driver notification or warning of the impending collision on slow vehicles. The system does not attempt to control the vehicle in order to avoid an impending collision; instead it warns the following vehicles on the potential danger of the slow vehicle.

Post-Crash Warning

The objective of this function is to provide information about one or more crashed vehicles on the driver's route. The most relevant factor is to provide the information about the location of the crashed vehicle as soon as possible after the event. It must be taken into account that the crashed vehicles might not be able to send out any messages. Therefore, the challenge consists in the capacity to detect the crashed vehicle(s) by recognizing its/their situation from the outside.

Obstacle Warning

The driver will receive a warning to be prepared for an upcoming danger. For example the driver receives a warning about an obstacle blocking the driver's route, such as lost cargo on the road. This allows the driver to slow down the vehicle early. Obstacle locations will be provided:

- from another vehicle, entered manually by the driver,
- from another vehicle automatically detected by performed driving manoeuvres,
- from a roadside unit, generated by the road administration.

Motorcycle Warning

The motorcycle continuously provides movement and position information to vehicles nearby. The surrounding vehicles receive the information and can automatically compare their own movement data with the motorcycle data. If a possible crossing with the motorcycle is detected or the relative distance between the two vehicles decreases below a given safety margin, a warning is issued to the driver.

Traffic Information and Recommended Itinerary

In this function the overall traffic flow in monitored areas is improved by suggesting an optimized route for the driver manoeuvring through areas with dense traffic.

Transparent Leasing

This function collects information about driving behaviour and number of kilometres driven, and how this impacts the resale value of the vehicle. This may ensure that the driver keeps within agreed leasing parameters (number of km per month, maximum speed, gentle accelerating and braking patterns). This might also help drivers to adapt their driving to a safe, deterioration-minimizing style in order to ensure low leasing costs and maximize resale value of the vehicle later on.

4.1.2 V2V devices

OEM devices

An OEM device is an electronic device built or integrated into a vehicle during its production. An integrated V2V system is connected to proprietary data busses and can provide highly accurate information using in-vehicle information to generate the Basic Safety Message (BSM). The integrated system both broadcasts and receives BSMs. In addition, it can process the content of received messages to provide advisories and/or warnings to the driver of the vehicle in which it is installed. Because the device is fully integrated into the vehicle at the time of manufacture, vehicles with Integrated Safety Systems could potentially provide haptic warnings to alert the driver (such as tightening the seat belt or vibrating the driver's seat) in addition to audio and visual warnings provided by the aftermarket safety devices. It is expected that the equipment required for an integrated OEM V2V system would consist of a general purpose processor and associated memory, a radio transmitter and transceiver, antennas, interfaces to the vehicle's sensors, and a GPS receiver. Such integrated systems are capable of being reasonably combined with other vehicle-resident crash avoidance systems to exploit the functionality of both types of systems.

Aftermarket Safety Device (ASD)

An "aftermarket" device is defined as any product with one or more functions in the areas of comfort, convenience, performance, or safety, which are added to a motor vehicle after its original assembly. An aftermarket V2V device provides advisories and warnings to the driver of a vehicle similar to those provided by an OEM-installed V2V device. However, these devices may not be as fully integrated into the vehicle as an OEM device, and the level of connection to the vehicle can vary based on the type of aftermarket device itself. Aftermarket V2V devices can be added to a vehicle at a vehicle dealership, as well as by authorized dealers or installers of automotive equipment. Some of these devices (cell phones with apps for example) are portable and can be standalone units carried by the operator, the passenger or pedestrian.

Retrofit Safety Device (RSD)

The RSD is more fully integrated than the ASD: it connects to the vehicle and receives information from the vehicle's data bus to support operation of various applications on the device. The advantage to RSDs, as compared to the other types of aftermarket devices, is that they can potentially perform different or enhanced safety applications or execute more sophisticated applications because they can access a richer set of data (i.e., data from the data bus). Therefore, the RSD is considered to be the closest of all of the aftermarket devices to a V2V device integrated into a new vehicle.

The following table sums up the three different types of aftermarket V2V safety devices:

Device Type	Definition	Method of Installation	Functionality
Vehicle Awareness Device	Device is able to be connected to the vehicle for power source. Device provides Basic Safety Message for surrounding vehicles.	Device would need to be installed by a certified installer on vehicles not equipped with V2V technology to ensure correct antenna placement and security. In the future, VADs might be mobile devices or stand-alone key fobs.	• Transmits BSM
Aftermarket Safety Devices (i.e., Self-contained)	Device is connected to the vehicle for power source, Device transmits BSM and receives BSMs to support safety applications for the driver of the vehicle in which it is installed.	This device only receives power from the vehicle; however, a certified installer would need to ensure correct antenna placement and security.	• V2V Safety applications • Receives and Transmits BSM • Driver-Vehicle Interface
Retrofit Safety Devices	Device is connected to the vehicle's data bus that provides BSM and safety applications for the driver of the vehicle in which it is installed.	This device needs to be connected to the vehicle's data bus, therefore would require an installer that can access this for the particular make of vehicle. Also, a certified installer would need to ensure correct antenna placement and security.	• V2V Safety applications • Receives and Transmits BSM • Driver Vehicle Interface • Integration into the vehicle data bus

Table 2: Aftermarket Safety Device Types

4.1.3 V2I possible applications

V2I communications involve the wireless exchange of critical safety and operational data between vehicles (including brought-in devices) and roadway infrastructures. V2I communications are intended primarily to avoid motor vehicle crashes while enabling a wide range of mobility and environmental benefits.

The following is a list of contemplated, but may not yet be developed, V2I safety applications:

4.1.3.1 *Traffic regulation warning*

Red Light Violation Warning

This technology will provide in-vehicle alerts to drivers about potential violations of upcoming red lights, based on vehicle speeds and distances to intersections.

Curve Speed Warning

If a driver's current speed is unsafe for traveling through an upcoming road curve, this technology will alert the motorist to slow down.

Stop Sign Gap Assist

This technology will assist drivers at STOP-sign-controlled intersections via vehicle gap detections, alerting motorists when it is unsafe to enter intersections.

Stop Sign Violation Warning

Based on vehicle speeds and distances to intersections, this technology will provide in-vehicle alerts to drivers about potential violations of upcoming stop signs.

Railroad Crossing Violation Warning

This technology will assist drivers at controlled railroad crossings via RSE connections with existing train detection equipment, alerting motorists when it is unsafe to cross the railroad tracks.

Green Light Optimized Speed Advisory (GLOSA)

This function reduces stop times and unnecessary acceleration in urban traffic situations to save fuel and reduce emissions. The provided speed advice helps to find the optimal speed to pass the next traffic lights during a green phase. In case it is not possible to provide a speed advice, the remaining time to green is displayed.

4.1.3.2 *Setback warning*

Reduced Speed Zone Warning

This technology will assist drivers in work zones, by issuing alerts to drivers to reduce speed, change lanes, and/or prepare to stop.

Oversize Vehicle Warning

Drivers of oversized vehicles will receive an in-vehicle alert to take an alternate route or a warning to stop, based upon information from RSE connections to infrastructure at bridges/tunnels.

In-vehicle Signage

Roadside units mounted on traffic signs and key points along the roadway send messages to approaching vehicles, increasing the likelihood of drivers being aware of potentially dangerous conditions in case a roadside traffic sign is not noticed.

Road Works Warning

Roadside units mounted on road works send messages to approaching vehicles, making drivers aware of potentially dangerous conditions at road works.

4.1.3.3 *Information*

Spot Weather Information Warning

This technology will provide in-vehicle alerts or warning to drivers about real-time weather events and locations, based upon information from Roadside Equipment connections with Transportation Management Center and other weather data collection sites/services.

4.1.3.4 *Other*

Insurance and Financial Services

The central objective is to provide on-site and real-time access to insurance and financial service providers in order to interact according to current and local context. This function aims at facilitating and accelerating claim management, related financial services and business processes. One benefit lies in automatically providing information to insurance companies directly after an accident occurred.

Dealer Management

Based on the collected data the OEM identifies potential customer needs and proposes additional services to fulfil those needs (e.g. driving on icy road without winter tires). Consequently the driver gets tailored services/offerings (e.g. winter tires) and detailed information about how to benefit from the offered services (e.g. schedule an appointment at repair shop).

Point of Interest Notification

This function informs drivers and passengers about points of interest in close the surrounding area or along the road. This might include sights, parking areas or fuel stations.

Fleet Management

The efficiency of fleet management can be considerably enhanced, if fleet operational data can be collected, processed and made available to different actors in real-time. This can be achieved by a distributed architecture connecting business processes in a service-oriented design. The overall goal is to allow collaboration along the fleet management workflow across departments, organisations and companies.

4.2 Selected ITS which can address accident and safety of riders

V2V and V2I safety applications including traffic regulation and setback warnings could play a role to address accident and safety of riders, but only if cars and motorcycles are equipped with ITS devices in order to communicate together. At this moment, relaying all the responsibility of detection in this kind of technology is not something planned due to the security risk. Nowadays we consider the communication systems as a redundant system to compliment physical sensors.

4.3 Projects and Programs about ITS

With the upcoming delegation of conduct functions and the autonomous cars, many project are focused on the development of the ITS.

Car 2 Car Communication Consortium

Actors/Partners: Audi, BMW Group, Daimler, Ford, Honda, Hyundai, Jaguar Land Rover, Kawasaki, KTM, Man, Opel, PSA Peugeot Citroën, Groupe Renault, Toyota, Volkswagen, Volvo Cars, Volvo Trucks and Yamaha.

Website

Dates: Since 2007

Description: The mission and objectives of the Car 2 Car Communication Consortium are:

- **to develop**
  ...an open European standard for C-ITS

...an associated validation process focusing on V2V Systems
...realistic deployment strategies and business models to speed-up the market penetration
...a roadmap for deployment of C-ITS (for V2V and V2I)

- **to contribute**
  ...to the development of European standards for V2I Communication being interoperable with the specified V2V standard
  ...to an associated validation process
  ...its specifications to the standardisation organisations, in particular ETSI TC ITS, in order to achieve common European standards for ITS
- **to push**
  ...the harmonisation of C2C Communication Standards world-wide
- **to promote**
  ...the allocation of a royalty free European wide frequency band for V2V applications
  ...joint deployment of C-ITS by all stakeholders
- **to demonstrate**
  ...the C2C-System as proof of technical and commercial feasibility

Drive-C2X

Actors/Partners:
Automotive OEMs: Adam Opel, Audi, BMW Forschung und Technik, Centro Ricerche Fiat, Daimler AG, Ford Forschungszentrum Aachen, Honda Research Institute Europe, Peugeot Citroen Automobiles, Renault, Volvo Personenvagnar, Yamaha Motor.
Electronics and supplier industry: Continental, Delphi Deutschland, Denso Automotive Deutschland, Hitachi Europe SAS, Neavia Technologies, NEC Europe, Renesas Electronics Europe, Robert Bosch.
Software developers: Testing Technologies, Vector Informatik , YGOMI.
Traffic engineers: PTV Planung Transport Verkehr
Research institutes: Bundesanstalt für Straßenwesen, Centro Tecnológico de Automoción de Galicia, Chalmers University, Deutsches Zentrum für Luft- und Raumfahrt, Facit Research, Fraunhofer Institute FOKUS, Hochschule für Technik und Wirtschaft Saarland, Institut français des sciences et technologies des transports, de l'aménagement et des réseaux, Institut Nationale de Recherche en Informatique et en Automatique, Interuniversity Microelectronics Centre, Karlsruhe Institute of Technology, Lindholmen Science Park, Technische Universität Graz, Nederlandse Organisatie voor Toegepast Natuurwetenschappelijk Onderzoek, Universitatea Tehnica Cluj-Napoca, University of Surrey, Technical Research Centre of Finland.
Road operators: Autostrada del Brennero, City of Tampere, Hessen Mobil – Road and Traffic Management, Rijkswaterstaat, Trafikverket.
Others: EICT, ERTICO - ITS Europe, ETSI Centre for Testing and Interoperability, Nokian Renkaat.

Website

Dates: 2011-2014

Description: With 34 partners, 13 support partners and 18.6 million Euro budget, DRIVE C2X will lay the foundation for rolling out cooperative systems in Europe**.** Hence, lead to a safer, more economical and more ecological driving.

Funded with 12.4 million Euro by the European Commission, DRIVE C2X will carry out a comprehensive assessment of cooperative systems through Field Operational Tests. Building up on the results of the predecessor PRE-DRIVE C2X, the project will deploy cooperative technologies in several European test sites. ly, the test deployment will include seven test sites in Finland, France, Germany, Italy, Netherlands, Spain and Sweden. This effort will create a harmonized Europe-wide testing environment for C2X technologies. The results of this large-scale environment will be used to raise awareness in the general public, provide feedback for standard organizations and for initiating public-private ventures. These steps will lead to a successful road to market**.**

CVIS-Cooperative Vehicle-Infrastructure Systems

Actors/Partners:
Austria: Efkon.
Belgium: Ertico - ITS Europe (Project Coordinator); FEHRL; Navteq; POLIS; Vlaams Gewest (Flemish Community) - Departement Mobiliteit en Openbare Werken; Ygomi.
France: ASF - Autoroutes du Sud de la France; CNRS (HDS/UTC); Grand Lyon; INRIA; Intempora; Lacroix Trafic; IFSTTAR; Télécom Bretagne; Renault; Trialog; Thales-Alenia Space.
Germany: Daimler; DLR; Hessisches Landsamt für Strassen und Verkehrswesen; HTW des Saarlandes - University of Applied Sciences, Saarbrücken; MAT.TRAFFIC; MM-Lab; PTV; Siemens; Tele-Atlas; Bosch; Vodafone Group Services.
Hungary: Advanced Vehicles and Vehicle Control Knowledge Center; Ramsys.
Ireland: Cork Institute of Technology; Mapflow.
Italy: 5T; ATC Bologna; CRF - Centro Ricerche FIAT; Infoblu; Istituto Superiore Mario Boella; Mizar Automazione; Thetis; Telecom Italia.
Norway: Technolution; Q-Free; SINTEF.
Spain: Fundación RACC.
Sweden: Kapsch TrafficCom; Lindholmen Science Park; Trafikverket; Makewave; Volvo.
The Netherlands: Logica; Peek Traffic; Provincie Noord Brabant; Rijkswaterstaat; Vialis Traffic; TNO.
United Kingdom: DfT - Department for Transport; BAe Systems (Operations); Imperial College, London; TfL -Transport for London; Highways Agency; Thomas Miller.

Website #1
Website #2

Dates: 2006-2010

Description: The EU-co-funded CVIS Integrated Project had the aim to bring major benefits for drivers as well as road authorities and managers, by allowing vehicles to communicate – and cooperate – directly with each other and with roadside infrastructure.

The CVIS objectives were:

- to create a unified technical solution allowing all vehicles and infrastructure elements to communicate with each other in a continuous and transparent way using a variety of media and with enhanced localisation; to enable a wide range of potential cooperative services to run on an open application framework in the vehicle and roadside equipment;
- to define and validate an open architecture and system concept for a number of cooperative system applications, and develop common core components to support cooperation models in real-life applications and services for drivers, operators, industry and other key stakeholders;
- to address issues such as user acceptance, data privacy and security, system openness and interoperability, risk and liability, public policy needs, cost/benefit and business models, and roll-out plans for implementation.

SAFESPOT

Actors/Partners: Centro Ricerche Fiat ScpA (CRF), Daimler, Renault FRANCE, REGIENOV (REGIENOV), Volvo Technology Corporation (VOLVO), Robert BOSCH GmbH (BOSCH), ANAS SpA (ANAS), Compagnie Financière et Industrielle des Autoroutes (COFIROUTE), Netherlands Organisation for Applied Scientific Research (TNO), MIZAR Automazione S.p.A. (MIZAR), Piaggio & C. SPA (PIAGGIO), IBEO Automobile Sensor GmbH (IBEO), Kapsch TrafficCom AB (KAPSCH), Lacroix Trafic (LAC), NAVTEQ Europe B.V. (NAVTEQ), Planung Transport Verkehr AG (PTV AG), Q-Free ASA (QFREE), Tele Atlas NV (TA), PEEK traffic solutions (NL), VTT Technical research Centre of Finland (VTT), Autostrada Brescia Verona Vicenza Padova S.p.A. (BSPD), CG Côtes d'Armor (CG22), Swedish Road Administration (SRA), CIDAUT: Fundación para la Investigación y Desarrollo en Automoción (CIDAUT), Centro Studi sui Sistemi di Trasporto (CSST), Dipartimento di Ingegneria Biofisica ed Elettronica - Università degli Studi di Genova (DIBE), Centre for Research and Technology - HELLAS (CERTH), Institute of Communication and Computer Systems (ICCS), Laboratoire Central des Ponts et Chaussées (LCPC), Istituto Superiore Mario Boella (ISMB), MIRA Limited (MIRA), Société pour le Développement de l'Innovation dans les Transports (SODIT), 3: Rijkswaterstaat (RWS), Technische Universität Chemnitz (TUC), Technische Universität München (TUM), University of Stuttgart (USTUTT), German aerospace center (DLR), European Road Transport Telematics Implementation coordination Organization Scrl (ERTICO), Center for Research And Telecommunication Experimentation for NETworked Communities (CREATE-NET),Politechnika Warszawska (IRE PW), Budapest University of Technology and Economics (BME), Centre National de la Recherche Scientifique (CNRS), Bundesanstalt für Straßenwesen (BASt), Thomas Miller & CO. LTD (MILLER), Provincie Noord-Brabant (PNB), RENAULT SPAIN (RNS), Universidad Politécnica de Madrid (UPM), Telefónica Investigación y Desarrollo Sociedad Anónima Unipersonal (TEL), AT4 wireless (AT4 wireless), Magneti Marelli Electronic Systems (MMSE), Continental (CA), TRANSVER GmbH (TRV).

Website

Dates: 2006-2010

Description: SAFESPOT aims to:

- Use the infrastructure and the vehicles as sources and destinations of safety-related information and develop an open, flexible and modular architecture and communication platform.

- Develop the key enabling technologies: ad-hoc dynamic network, accurate relative localisation, dynamic local traffic maps.
- Develop and test scenario-based applications to evaluate the impacts on road safety.
- Define a sustainable deployment strategy for cooperative systems for road safety, evaluating also related liability, regulations and standardisation aspects
- The SAFESPOT co-operative system is composed by the following communicating elements
- Intelligent vehicles equipped with on board co-operative systems.
- Intelligent infrastructure including road side units
- Safety centre(s) and/or Traffic centre(s) that are able to centralize or forward safety information coming from the intelligent vehicle and/or the intelligent infrastructure.

Connected Motorcycle Consortium

Actors/Partners:
Core members: BMW Motorrad, Honda and Yamaha
Other CMC members: Kawasaki, KTM, ACEM and Technische Universität Dresden.

Website

Dates: Since 2015

Description: The Connected Motorcycle Consortium (CMC) is a non-profit organisation established by key OEM's with the unilateral goal to promote and develop Cooperative Intelligent Transport Systems (C-ITS) to benefit all stakeholders and enhance rider safety.
Future mobility will be defined by C-ITS. It is important that the Powered Two-Wheeler (PTW) OEM's embrace connectivity technology and work towards the development of systems specific to PTW to enable motorcycles to be a part of the future 'traffic society'.
The CMC is unified in its approach to develop C-ITS for the PTW community and is able to draw on the expertise offered by various OEM's from around the world.

The strategic objectives of the Connected Motorcycle Consortium are:

- Integrating PTW as an accepted and recognized partner into global ITS development
- Joining forces amongst the Consortium members to create an amalgamated approach on ITS for PTW
- Achieving a successful implementation and deployment of PTW ITS functions.

EasyWay I + II

Participating countries: Austria, Belgium, Cyprus, Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Lithuania, Luxembourg, Netherlands, Portugal, Romania, Slovakia, Slovenia, Spain, Sweden, UK. In addition, non-EU countries Andorra, Norway and Switzerland participate without EU funding. Bulgaria and Poland currently have observer status but are expected to be full partners in future phases

Website #1
Website #2

Dates: 2007-2009 and 2010-2012

Description: The EasyWay Projects phase I (2007-2009) and phase II (2010-2012) have been co-funded by the European Commission and are part of the *EasyWay Global Programme 2007-2020*.

EasyWay I and II are projects for deployment of Europe-wide ITS systems and services on TEN-T road network and its interfaces with urban areas and other modes of transport.

Both EasyWay I and II Projects were driven by the national road authorities of the majority of the EU Member States (EWI 21 and EWII 22, plus 3 other European Countries), along with public and private road operators and associated partners working in close cooperation with other key stakeholders.

EasyWay I and II's main strength was the provision of an "unique" European Platform bringing together Ministries, Road Authorities and Road Operators (Public and Private) across Europe and fosters close cooperation among key stakeholders, allowing them to exchange "know how" (including best practices) and to elaborate on common "deployment guidelines" ensuring harmonized ITS deployment whilst directly supporting the European Transport policies.

The main objectives of EasyWay I and II were to improve safety, to reduce congestion and to reduce environmental impacts through the coordinated deployment of real-time information and traffic management services, supporting the creation of a seamless European transport system through coordinated ITS deployment. The core objective of EasyWay phases I and II were to deploy Europe-wide ITS Core Services for the benefit of the road users. By doing so, the Projects supported the transport policy goals concerning road safety, environmental impact from transport and mobility.

European ITS Platform (+)

Website

Dates: 2013-2015 and 2014-2015

Description: The "EU ITS Platform" (EU EIP) is the follow up of projects already supported by the European Commission TEN-T programme d: "*European ITS Platform" (2013-2015)* and "*European ITS Platform+"* (2014-2015).
To increase the efficiency of the TEN-T Core Network Corridors, it is mandatory to encourage the development of an integrated trans-European network and a better use of the existing infrastructures by employing intelligent transport systems as well as uniform technical standards. Interoperability must be discussed, designed, tested and finally deployed on the basis of the evolution of technology, standards, specifications and open interfaces.
Ensuring continuity of high quality services for European end-users requires the creation of a proper environment for the harmonization of existing and future ITS Services.

The "EU ITS Platform" brings together the majority of the European key players, cooperating to establish an open "forum", aiming at providing valid contribution for the future strategy and policy recommendation for better development of ITS service along European road Corridors.
By monitoring, processing, evaluating and disseminating results delivered by the 5 ITS Road

Corridor projects: Arc Atlantique2, Crocodile2, NEXT-ITS2, MedTIS2, and URSA MAJOR2 (the Works projects that are co-founded by EC within the CEF MAP ITS Call 2014), the EU ITS Platform can be considered as the technical European ITS ***"Knowledge Management Centre",*** contributing significantly to the most effective use of ITS standards and specifications.

euroFOT

Actors/Partners: **Vehicle manufacturers:** Ford, BMW Group, DAIMLER, Centro Ricerche Fiat (CRF), MAN, Vovlo, VolksWagen, Audi.
Automotive suppliers: Bosch, Continental, Delphi, Harman International
Universities and Research Centres: Chalmers, ICCS, Institut für Kraftfahrzeuge (IKA), IZVW, Politecnico di Torino, ITS University of Leeds, Bast, Ceesar, Centro Tecnologico de Automocion de Gallicia (CTAG), Iffstar, TNO, Allianz
Other organisations: ADAS Management consulting (Advanced Drvier Assistance and Safety), Alcor, EICC, ERTICO ITS Europe.

Website

Dates: 2008-2012

Description: euroFOT establishes a comprehensive, technical, and socio/economic assessment programme for evaluating the impact of intelligent vehicle systems on safety, environment, and driver efficiency. The project assesses several technically mature systems using vehicles that include both passenger cars and trucks across Europe.
A variety of intelligent vehicle systems (IVS) are being tested on a large scale in real driving conditions. About 1000 IVS-equipped vehicles will be driven over the course of one year, tested on roads across Europe.

The objectives of the testing were to:

- Assess various aspects of in-vehicle systems, such as their capabilities and performance, and the driver's behaviour and interactions with those systems
- Gain a better understanding of the short- and long-term socio-economic impact of such systems on safety, efficiency and driver comfort
- Provide early publicity of the systems to the consumer and create wider acceptance of them

PRESERVE

Actors/Partners: University of Twente, escrypt GmBH – Embedded Security, Fraunhofer Institute for Secur Information Technology – SIT & AISEC, Kungliga Tekniska högskolan, Renault and Trialog.

Website #1
Website #2

Dates: 2011-2015

Description: The mission of PRESERVE is, to design, implement, and test a secure and scalable V2X Security Subsystem for realistic deployment scenarios.

The goal of PRESERVE (Preparing Secure Vehicle-to-X Communication Systems) is to bring secure and privacy-protected V2X communication closer to reality by providing and field testing a security and privacy subsystem for V2X systems. PRESERVE will combine and extend results from earlier research projects, integrating and developing them to a pre-deployment stage by enhancing scalability, reducing the cost level, and addressing open deployment issues. It aims at providing comprehensive protection ranging from the vehicle sensors, through the on-board network and V2V/V2I communication, to the receiving application. As a result, PRESERVE will present a complete, scalable, and cost-efficient V2X security subsystem that is close-to-market

Preserve Objectives:

- Create an integrated V2X Security Architecture (VSA) and design, implement, and test a close-to-market implementation termed V2X Security Subsystem (VSS).
- Prove that the performance and cost requirements for the VSS arising in current FOTs and future product deployments can be met by the VSS, especially by building a security ASIC for V2X.
- Provide a ready-to-use VSS implementation and support to FOTs and interested parties so that a close-to-market security solution can be deployed as part of such activities.
- Solve open deployment and technical issues hindering standardization and product pre-development.

FOTsis

Actors/Partners:
Highway operator: OHL Concesiones, Iridium, Planestrada, Marestrada, Nea Odos
Technology integrator: Sice, Indra, ACB Systems, GMVIS Skysoft, Trasnver, Terna Energy, GMV Sistemas
Telecommunications operator: France telecom, Optimus
University: Universidad Politécnica de Madrid, Aalto University Foundation, Universidad de Murcia
Users association: Federation International de l'Automobile
Industry association: European Union Road Federation, Association Européenne des concessionnaires d'autoroutes et d'ouvrages à péage
Socio-economic research association : ASM Market Research and Analysis Centre

Website

Dates: 2011-2016

Description: FOTsis (European Field Operational Test on Safe, Intelligent and Sustainable Road Operation) was a largescale field testing of the road infrastructure management systems needed for the operation of seven close-to-market cooperative I2V, V2I & I2I technologies (the FOTsis Services), in order to assess in detail both 1) their effectiveness and 2) their potential for a full-scale deployment in European roads.

Specifically, FOtsis tested the road infrastructure's capability to incorporate the latest cooperative systems technology at 9 Test-Sites in four European Test-Communities (Spain, Portugal, Germany and Greece), providing the following services:

- S1: Emergency Management
- S2: Safety Incident Management
- S3: Intelligent Congestion Control
- S4: Dynamic Route Planning
- S5: Special Vehicle Tracking
- S6: Advanced Enforcement
- S7: Infrastructure Safety Assessment

Using an integral and comprehensive approach, FOTsis reviewed the road infrastructure and communication networks required to secure a proper connectivity from the traffic control centres (and all the information they already have available, enhanced with the V2I data) with the users/vehicles.

COOPERS

Website

Dates: 2006-2011

Description: COOPERS provides vehicles and drivers with real time local situation based, safety related status and infrastructure status information distributed via dedicated Infrastructure to Vehicle Communication link (I2V).

This approach extends the concepts of in-vehicle autonomous systems and vehicle to vehicle communication (V2V) with tactical and strategic traffic information which can only be provided by the infrastructure operator in real time. I2V in this respect will significantly improve traffic control and safety via effective and reliable transmission of data fully adapted to the local situation of the vehicle (ensemble of vehicles). I2V will extend massively the responsibility and liability of the infrastructure operator compared with today in terms of reliability and accuracy of information to advice drivers/vehicles. The highest effect of I2V communications will be achieved in areas of dense traffic also known as areas where risk of accidents and traffic jams is extremely high. The real time communication link between infrastructure and vehicle can also be used vice versa for V2I communication utilizing vehicles as floating sensors to verify infrastructure sensor data as primary source for traffic control measures: traffic jam warning and guidance, in-car display and alert of area-specific speed limits, lane specific, selective ban of lorries, estimated time of arrival, based on current traffic situation on the network, car breakdown/emergency services.

And for network operators: enhanced traffic management based on floating car data, safety related information for drivers, speed and distance proposal, data exchange between operators for international seamless service handover, monitoring of transport flows and information exchange for changing demands of transport.

5 Conclusion

In a nutshell, ADAS and IVIS play an important role in the comfort of the driver on road. But it especially allows enhancing safety and security for drivers and VRUs, which include bicyclists, pedestrians and motorcyclists.

On the other hand, a number of specific challenges face the development of ARAS and ITS for motorcycles:

The Human Machine Interface (HMI) requirements of the motorcycle are hugely different from passenger cars. The driving task requires more instantaneous attention and the possibilities to provide visual or audio information in a safe manner are limited due to the position of the dashboard, the helmet and the background noise experienced by the motorcyclist. Compared to car technologies, the specifications of the hardware need to be more resistant to vibration, have lower levels of electric consumption and be water resistant. In addition, the system must adapt to much-reduced fitment space.

A system that removes or interferes with the longitudinal or lateral control of the vehicle, such as automatic braking, could destabilise the rider and his machine, potentially causing, rather than preventing, a crash.

The impact of systems that intervene in the riding task is quite different from passenger cars and requires specific Research & Development. Stability is critical on a motorcycle and imposes very different constraints compared to four-wheeled vehicles. The process of deployment of ARAS is extremely complicated, notably due to the leaning behaviour of motorcycles.

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