CHARACTERISTICS OF POWERED TWO WHEELERS ACCIDENTS SUSCEPTIBLE TO BE AVOIDED AND MINIMIZED THROUGH ADAS AND IVIS IMPLEMENTATIONS

Aquilino Molinero
Oscar Martín
José Miguel Perandones
David Pedrero
CIDAUT
Spain

Dimitris Margaritis
CERTH
Greece

Christhard Gelau
BASt
Germany

Paper Number 09-0543

ABSTRACT

Powered Two Wheelers (PTWs) accidents constitute one of the road safety problems in Europe. PTWs fatalities represent 22% at EU level in 2006 [1], having increased during last years, representing an opposite trend compared to other road users' figures.

In order to reduce these figures it is necessary to investigate the accident causation mechanisms from different points of view (e.g.: human factor, vehicle characteristics, influence of the environment, type of accident). SAFERIDER project [2] ('Advanced telematics for enhancing the SAFEty and comfort of motorcycle RIDERs', under the European Commission '7th Framework Program') has investigated PTW accident mechanisms through literature review and statistical analyses of National and In-depth accident databases; detecting and describing all the possible PTW´s accident configurations where the implementation of ADAS (Advanced Driver Assistance Systems) and IVIS (In-Vehicle Information Systems) could contribute to avoid an accident or mitigate its severity.

DIANA, the Spanish in-depth database developed by CIDAUT, has been analyzed for that purpose. DIANA comprises of accident investigation teams, in close cooperation with police forces, medical services, forensic surgeons, garages and scrap yards. An important innovation is the fact that before injured people arrive to hospitals, photographs and explanations about the possible accident injury mechanisms are sent to the respective hospitals (via 3G GPRS technology). By this, additional information to medical staff can be provided in order to predict in advance possible internal injuries and select the best medical treatment. This methodology is presented in this paper.

On the other hand, the main results (corresponding to road, rider and PTW characteristics; pre and post-accident manoeuvres; road layout; rider behaviour; impact points; accident causations;…) from the analyses of the PTW accidents used for SAFERIDER are shown. Only accident types relevant to ADAS and IVIS devices have been considered

INTRODUCTION

European statistics show that the number of Powered-Two-Wheelers (PTW) road accidents is high. Motorcycle and moped fatalities account for 22% of the total number of road accident fatalities in 2006, in EU-14 member countries. It is therefore evident that the reduction of PTW accidents is of major concern for the European community. The adaptation and implementation of appropriate Advanced Driver Assistance Systems (ADAS) and In-Vehicle Information Systems (IVIS) technologies in PTWs might contribute to the significant enhancement of riders' safety.

SAFERIDER project

During the last decade, ADAS and IVIS development has been one of the main research areas of the automotive industry, in order to increase safety and comfort of passenger cars. These new technologies have been already introduced in the automotive market and their evolution is definitely fast and efficient. However, such technologies in motorcycles and even clean motorbikes (electric), in order to increase the safety and comfort of riders, an extremely susceptible road user group, is currently lacking behind and should be undoubtedly studied further. Thereby it needs to be stressed that such technologies should be designed and developed in a way that will not interfere with driving and/or annoy the rider.

SAFERIDER project ('Advanced telematics for enhancing the SAFEty and comfort of motorcycle RIDERs', under the European Commission '7th Framework Program') has started in January 2008 with the aim of enhancing PTW riders' safety by applying ADAS/IVIS on PTWs of all types for the most crucial functionalities and develop efficient and rider-friendly interfaces and interaction elements for riders' comfort and safety.

Characterization of PTW accident scenarios - One of the first steps carried out in the SAFERIDER project has been the characterization of the PTW accident scenarios susceptible to be avoided or minimized through ADAS and IVIS implementations. For obtaining this purpose, the following tasks have been done:

- ✓ 1. Review of existing European motorcyclists' accident reports [3].
- ✓ 2. Analysis of national accident statistics:
  -*Spain*: DGT (Spanish national database).
  -*Germany*: Official German Road Accident Database.
  -*Italy*: SISS (Italian national database).
  -*France*: Assurance Mutuelle des Motards (French insurance company database).
- ✓ 3. Analysis of in-depth accident databases:
  -*Spain*: DIANA (Spanish in-depth accident database).
  -*Germany*: GIDAS (Germany in-depth accident database).
  -*Europe*: MAIDS (under permission by ACEM), which is an ad-hoc motorcyclists' accidents database developed, with more than 900 motorcyclists' accidents analysed in detail.

This paper will firstly present a description of DIANA database (one of the in-depth accident databases used in the characterization of the PTW accidents scenarios). In the second part, the most relevant accident scenarios concerning to PTWs are described together with the parameters that should be considered in the next SAFERIDER steps (ADAS and IVIS implementations). This identification has resulted in 17 pre-crash scenarios, so called SAFERIDER 'Use cases'.

DIANA: THE SPANISH IN-DEPTH ACCIDENT DATABASE

DIANA is the Spanish in-depth accident database developed by CIDAUT. It has been one of the three in-depth databases used during the analyses of SAFERIDER to obtain the main characteristics of PTW accidents where ADAS and IVIS could avoid them or mitigate the consequences.

CIDAUT counts with accident investigation teams (composed of engineers and psychologists) that travel immediately ('prospective investigations') to the accident scene to perform an 'in-depth investigation', in close cooperation with police forces, medical services, forensic surgeons, garages and scrap yards. When it is not possible to travel immediately to the accident spot, a 'retrospective investigation' is made if sufficient information can be gathered. A complete scene and vehicle analysis equipment and reconstruction software are used. All information gathered is stored in an own database for further exploitation jointly with access to other accident databases, as for example the national one coming from the DGT (Dirección General de Tráfico) which provides information on every injury accident.

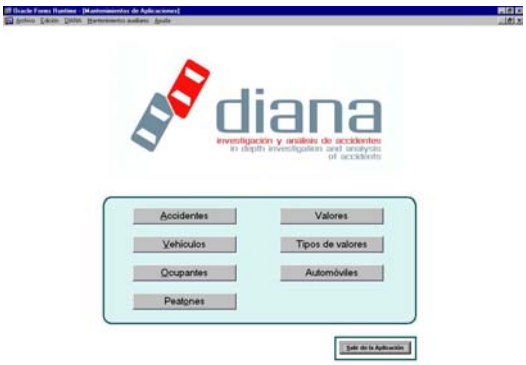

Figure 1. DIANA 'Spanish in-depth database'

Sampling plan

The sampling area is located within the Valladolid province (8,202 km^2), covering both urban and non-urban roads. Nevertheless this sampling area can be wider depending of the type of accidents to be researched.

Figure 2. Sampling area (in red)

Accident selection is based on random notification from police control rooms, as the responsibility for accidents within urban areas rely on Urban Police (Policía Municipal del Ayuntamiento de Valladolid) and accidents occurred within non-urban areas rely on other kind of police (Guardia Civil de Tráfico).

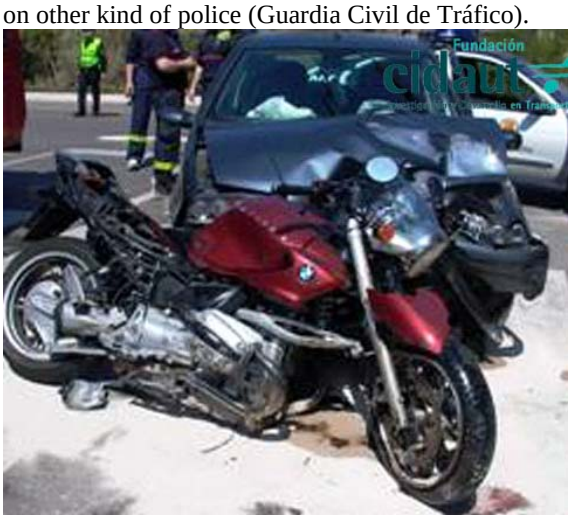

Figure 3. Prospective in-depth investigation of a PTW accident

Data coding and quality control

After data collection, an accident reconstruction is carried out with the aim of finding out what happened and assessing the causes that led to the accident. Accident reconstruction allows to discover the collision severity and to obtain a detailed simulation of the accident dynamics. It is carried out based on vehicle deformations, vehicle marks and remains, etc. The reconstruction is performed using PC Crash obtaining the estimation of delta-V and EES. In some cases, analytical calculations are also performed (conservation of linear/angular momentum and conservation of energy).

Furthermore, interviews to the people involved in the accident and witnesses (if any) are performed in order to collate both sources also together with police information. When it is not possible to interview these people, different sources are asked for, such as police forces or medical services.

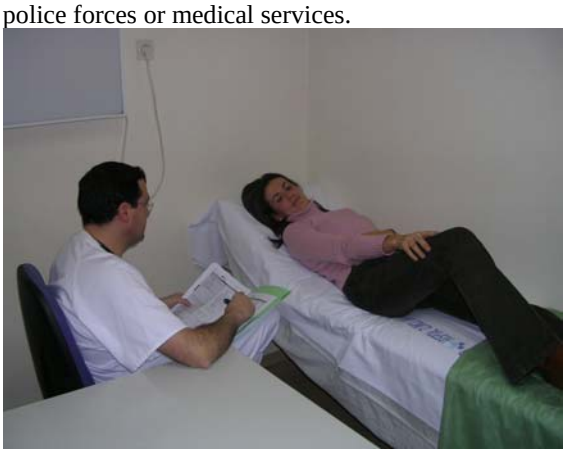

Figure 4. Interview by hospital staff

Police reports are always obtained by accident investigation teams, and later are contrasted with the in-depth information gathered on the spot by themselves.

Finally, information about injuries is collected by the medical staff belonging to the DIANA consortium ('Río Hortega' hospital in the cases of injured people or 'Legal Anatomic Institute of Valladolid' in the cases of fatalities) in order to obtain both the injured people statements and the injury report with the AIS codifications.

Information gathered

More than one thousand of different variables are defined in DIANA database (this figure increases when there is more than one vehicle, occupant or pedestrian involved). These variables are classified into three modules: 'Accident', 'Vehicle' and 'Occupant/Pedestrian'.

In the case of the accidents used for SAFERIDER project, specific information about PTW´s was gathered:

- Motorcyclist dynamic: It was collected specially in cases in which motorcyclist impacted against a safety barrier, even when a motorcyclist protective device is present.
- Motorcyclist clothing: Type and thickness.
- Helmet: Use, type, screen existence, subjection, ejection, damage localization and cause of this damage.

On-line photosafety

In the cases of 'prospective investigations', the technical members of CIDAUT, just after arriving to the scene, send photographs of the accident to the respective hospitals where the injured people are going to or are being taken. This process is called 'On-line photosafety'.

The objective of this process is that medical staff receives these photographs (via 3G GPRS technology) before the injured people arrive and they can diagnose/predict possible internal injuries. Obviously, it is necessary that CIDAUT´s team arrives to the scene before the EMS (Emergency Medical Service) takes the injured people to the hospital. The information sent to the hospital concerns photographs and explanations (also by mobile phone) about the possible accident injury mechanisms.

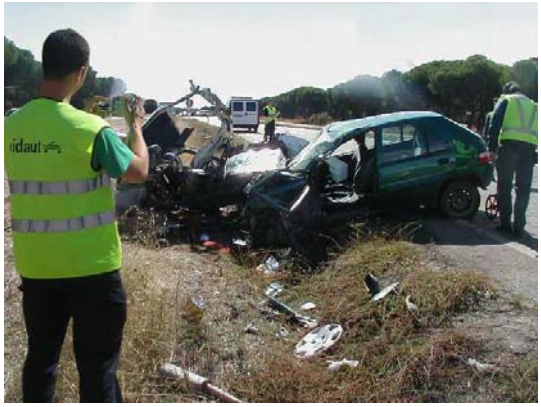

Figure 5. Member of CIDAUT taking photographs at the accident scene

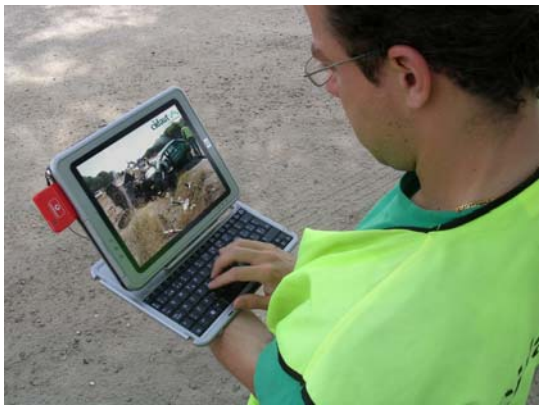

Figure 6. Member of CIDAUT sending the photographs before injured people arrive at respective hospitals

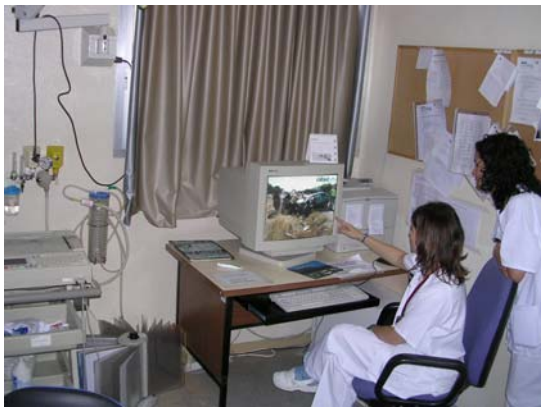

Figure 7. Hospital members analysing the photographs before injured people arrive

PTWS ACCIDENTS SUSCEPTIBLE TO BE AVOIDED OR MINIMIZED THROUGH ADAS AND IVIS

Once SAFERIDER carried out the first steps of the project (literature review about PTW accidents, analyses over National PTW accident databases and analyses over in-depth PTW accident databases), it has been possible to characterize the PTW accident scenarios susceptible to be avoided and minimized through ADAS and IVIS implementations.

It should be underscored the importance of matching the information derived from National and In-depth databases. While the general figures from National databases have allowed obtaining the scope of each problem over the whole PTW accidents, the in-depth databases have given very detailed and deep information.

Following, the description of the seventeen accident scenarios selected is given. For each one of these scenarios, the structure of the information is:

-Characterization: Variables and respective values describing each scenario, for instance, 'Accident causes', 'Accident characteristics', 'Type of vehicles involved', 'Relative trajectories', 'Vehicle speed'. 'Road conditions', 'Rider type', 'Rider experience'…and any possible variables needed for reproducing (via tests or via simulations) the same conditions in which the accident happened. Furthermore, specific variables have been chosen as 'Priority variables' with the aim of having a general use case description.

- List of possible ADAS/IVIS: A list of the 'Main variables to be studied in this accident' as well as

'Possible ADAS/IVIS detected which can be avoid or minimize this accident scenario'. The reason of listing these ADAS/IVIS is because, at the end, the result of this study is to detail ('Characterization') the main scenarios where the accidents happen as well as the possible ADAS/IVIS that could avoid these accident.

- Example of ADAS/IVIS working: Finally, an example of a possible ADAS/IVIS working in that scenario is given.

Urban Single Motorcycle Accident On Straight Road.

Characterization:

CASE NAME	Urban single motorcycle accident on straight road
GOAL	27% of all crashes (literature), 4.5 % (national), 7.5% (in-depth)
TYPE OF EGO-VEHICLE (MOPED, MOTORCYCLE)	Motorcycle (L3), 32.9% (scooter style), 30% (sport style)
TYPE OF OTHER INVOLVED VEHICLE	None
ACCIDENT CAUSES	Loss of control (70%) **Priority High** Travelling too fast [10.2% (national) - 55% (in-depth)] **Priority High** Lack of attention (28%) Distraction (26%) Road environment (23.8%) Driver behaviour or experience (90%) **Priority High**
ACCIDENT CHARACTERISTICS	Running off the roadway (23% of all single vehicle accidents) **Priority High** Breaking side-outs (15%) Motorcycle capsize (10%)
EGO NO OF OCCUPANTS	-
TYPE OF ROAD	Urban, Flat road (79%) **Priority High**
RELATIVE TRAJECTORIES	Straight road: 67% of relevant accidents **Priority High**
EGO-VEHICLE SPEED	<40 km/h (10%) 40-59 km/h (51.4%) **Priority High** 60-99 km/h (14.3%)
OTHER VEHICLE SPEED	N/A
TIME TO COLLISION	-
TIME OF THE DAY/ WEATHER	Day/ Clear: 16.9% (in-depth) - 51.4% (national) **Priority High** Day/ Slight Rain: 15.5% Dawn Clear: 13.4% Night/ Clear: 22.6% **Priority High**
ROAD CONDITIONS	Dry: 64%-96% **Priority High** Wet: 4%-19% Bad weather [10% (GIDAS) - 70% (MAIDS)]
VISIBILITY	Visibility problems on 40% of relevant accidents
RIDER TYPE	18-25 years (13-14.7%) 26-35 years (27-34.4%) **Priority High** 36-45 years (26.9-29%) **Priority High** 46-55 years (11-12.7%)
RIDER EXPERIENCE	1-4 years (23-30%) **Priority High** 5-10 years (17%) >10 years (31-36%) **Priority High**

List of possible ADAS/IVIS:

Variables to be studied in each type of accident	Possible ADAS/IVIS related with the factor detected (which can help to minimize or avoid the accident)
Impaired visibility	ADAS - Intersection support ADAS - Visibility improvement system (infrared)
Driver physical status	ADAS - Hypovigilance system
Age of driver	ADAS - Hypovigilance system
Driver experience	ADAS - Hypovigilance system
Driver inhaction	ADAS - Frontal collision warning (Obstacle detection)
Inappropiate speed	ADAS - Speed alert functionality ADAS - Adaptative cruise control
Loss of control to the left or to the right	ADAS - Warning of a dangerous curve ADAS - Speed alert functionality
Bend negotiation	ADAS - Warning of a dangerous curve
Environmental factors: weather	ADAS - Warning of low temperature (frost)
Vehicle status	ADAS - Warning of mechanical failure, low tyre pressure

Example of ADAS/IVIS working: If the support system is on: A motorcycle is driving straight on an urban road in its own lane. The speed is too high for the circumstances. The "Speed Alert" system effectively warns the rider to reduce speed. There is a sudden event (i.e. pedestrian suddenly crossing, car leaving parking place), which might cause an accident, if the rider does not decrease speed.

Urban single motorcycle accident on bends.

Characterization:

CASE NAME	Urban single motorcycle accident on bends
GOAL	15% of all crashes (literature), 1.9 % (national), 3.7% (in-depth)
TYPE OF EGO-VEHICLE (MOPED, MOTORCYCLE)	Motorcycle L3, 18.8% (scooter style), 20.8% (sport style), 18.8% (conventional street style)
TYPE OF OTHER INVOLVED VEHICLE	None
ACCIDENT CAUSES	Loss of control (95%) **Priority High** Travelling too fast [20.4% (national) - 70-100% (in-depth)] Lack of attention (28%) Distraction (25.4%) Road environment (25.6%) Driver behaviour or experience (70%) **Priority High**
ACCIDENT CHARACTERISTICS	Running off the roadway (23% of all single vehicle accidents) **Priority High** Breaking side-outs (15%) Motorcycle capsize (10%)
EGO NO OF OCCUPANTS	-
TYPE OF ROAD	Urban Safety Barrier (6%) Lane width 6-7m (19%) Flat road (68.8%) **Priority High** Uphill (16.7%) Downhill (12.5%)
RELATIVE TRAJECTORIES	Left Curve: Curve radius <90m (15.8%) Curve radius 90, 450 (20.6%) **Priority High** Right Curve Curve radius <90m (10.8%) Curve radius 90, 450 (21.6%) **Priority High**
EGO-VEHICLE SPEED	<40 km/h (16.7%) 40-59 km/h (29.2%) 60-99 km/h (43.8%) **Priority High**
OTHER VEHICLE SPEED	N/A
TIME TO COLLISION	-
TIME OF THE DAY/ WEATHER	Day/ Clear: 24.1% (in-depth) - 50.3% (national) **Priority High** Dawn Clear: 5.6-13.1% Night/ Clear: 25.7% **Priority High**
ROAD CONDITIONS	Dry: 71.8%-96% **Priority High** Wet: 4%-13%
VISIBILITY	Visibility problems on 40% of relevant accidents
RIDER TYPE	>18 years (5.9-12.5%) 18-25 years (16.4-18.8%) 26-35 years (29.2-35.7%) **Priority High** 36-45 years (12.5-24.3%) 46-55 years old (11.5%)
RIDER EXPERIENCE	1-4 years (22.9-31.1%) **Priority High** 5-10 years (17.2-27.1%) >10 years (12.5-28.6%)

List of possible ADAS/IVIS:

Variables to be studied in each type of accident	Possible ADAS/IVIS related with the factor detected (which can help to minimize or avoid the accident)
Impaired visibility	ADAS - Intersection support ADAS - Visibility improvement system (infrared)
Driver physical status	ADAS - Hypovigilance system
Age of driver	ADAS - Hypovigilance system
Driver experience	ADAS - Hypovigilance system
Driver inhaction	ADAS - Frontal collision warning (Obstacle detection)
Inappropiate speed	ADAS - Speed alert functionality ADAS - Adaptative cruise control
Loss of control to the left or to the right	ADAS - Warning of a dangerous curve ADAS - Speed alert functionality
Bend negotiation	ADAS - Warning of a dangerous curve
Environmental factors: weather	ADAS - Warning of low temperature (frost)
Vehicle status	ADAS - Warning of mechanical failure, low tyre pressure

Example of ADAS/IVIS working:

If the support system is on: A motorcycle is approaching a bend on an urban road. The riding conditions are not appropriate for the bend. The "Curve Warning" system effectively warns the rider about the appropriateness of the current riding conditions in order to ride safely through the curve. If the rider reduces speed, it is likely that he/she keeps the motorcycle under control and no accident occurs.

Rural single motorcycle accident on straight road (motorways and two carriageways roads excluded).

Characterization:

CASE NAME	Rural single motorcycle accident on straight road (motorways and two carriage roads excluded)
GOAL	2.7 - 2.8% of all crashes
TYPE OF EGO-VEHICLE (MOPED, MOTORCYCLE)	12.1% (scooter style) 30.3% (sport style) 18.8% (enduro motorcycle style)
TYPE OF OTHER INVOLVED VEHICLE	None
ACCIDENT CAUSES	Loss of control (30%) Travelling too fast [21.5% (national) - 45-100% (in-depth)] **Priority High** Distraction (30%) Animal or object on carriageway (25%) Driver behavior or experience [13%(national)-45%(in-depth)]
ACCIDENT CHARACTERISTICS	-
EGO NO OF OCCUPANTS	-
TYPE OF ROAD	Rural Safety Barrier (6%) Lane width 6-7m (15%) Lanes separation and verges (27%) Flat road (67%) **Priority High**
RELATIVE TRAJECTORIES	-
EGO-VEHICLE SPEED	> 100 km/h 21% (literature) 40-59 km/h (21.2%) 60-99 km/h (54.5%) **Priority High**
OTHER VEHICLE SPEED	N/A
TIME TO COLLISION	-
TIME OF THE DAY/ WEATHER	Day/ Other: 38.9% (in-depth) - 59% (national) **Priority High** Day/ Clear: 13.9% Dawn Clear: 10.6% Night with artificial luminosity/Other: 13.9% Night/ Clear: 19%
ROAD CONDITIONS	Dry: 83-96% **Priority High** Wet: 3.5-11%
VISIBILITY	Visibility problems on 40% of relevant accidents
RIDER TYPE	<18 years (12.5%) 18-25 years (14.4-18.2%) 26-35 years [9.1% (national) & 35.1% (in-depth)] 36-45 years (24.5-27.3%) **Priority High** 46-55 years (12-13.5%)
RIDER EXPERIENCE	<1 year (15-24.9%) 1-4 years (16-18%) 5-10 years (12-28%) >10 years (36%) **Priority High**

List of possible ADAS/IVIS:

Variables to be studied in each type of accident	Possible ADAS/IVIS related with the factor detected (which can help to minimize or avoid the accident)
Impaired visibility	ADAS - Intersection support ADAS - Visibility improvement system (Infrared)
Driver physical status	ADAS - Hypovigilance system
Age of driver	ADAS - Hypovigilance system
Driver experience	ADAS - Hypovigilance system
Driver infraction	ADAS - Frontal collision warning (Obstacle detection)
Inappropriate speed	ADAS - Speed alert functionality ADAS - Adaptative cruise control
Loss of control to the left or to the right	ADAS - Warning of a dangerous curve ADAS - Speed alert functionality
Bend negotiation	ADAS - Warning of a dangerous curve
Environmental factors: weather	ADAS - Warning of low temperature (frost)
Vehicle status	ADAS - Warning of mechanical failure, low tyre pressure

Example of ADAS/IVIS working:

If the support system is on: A motorcycle is driving straight on a rural road (which is not a motorway or a two carriageway road) in its own lane. The speed is too high for the circumstances. The "Speed Alert" system effectively warns the rider to reduce speed. There is a sudden event (i.e. animal suddenly crossing, car crossing road), which might cause an accident, if the rider does not decrease speed.

Rural single motorcycle accident on straight road (only motorways and two carriageways roads).

Characterization:

CASE NAME	Rural single motorcycle accident on straight road (only motorways and two carriage roads)
GOAL	0.3 - 2.7% of all crashes
TYPE OF EGO-VEHICLE (MOPED, MOTORCYCLE)	44.4% (Cruiser motorcycle style) **Priority High** 22.2% (sport style) 11.1% (Sport touring motorcycle style)
TYPE OF OTHER INVOLVED VEHICLE	None
ACCIDENT CAUSES	Loss of control (80%) **Priority High** Travelling too fast [13.9% (national) - 70-100% (in-depth)] Distraction (38%) Disobeyed traffic rules (18.1%) Changing lane (40%)
ACCIDENT CHARACTERISTICS	-
EGO NO OF OCCUPANTS	-
TYPE OF ROAD	Motorways or two carriageways roads Safety Barrier (67%) Lane width 6-7m (33%) Lanes separation and verges (67%) Flat road (78%) **Priority High**
RELATIVE TRAJECTORIES	-
EGO-VEHICLE SPEED	> 100 km/h 21% 40-59 km/h (11.1%) 60-99 km/h (55.6%) **Priority High** 120-150 km/h (22.2%) >150 km/h (11.1%) (in -depth)
OTHER VEHICLE SPEED	N/A
TIME TO COLLISION	-
TIME OF THE DAY/ WEATHER	Day/ Clear: 55.2% **Priority High** Day/ Other 37.5% **Priority High** Day/ Slight rain: 37.5% **Priority High** Dusk/ Dawn Clear: 11.4% Dusk/ Dawn Other: 12.5% Night without artificial luminosity/ fog: 12.5% Night/ Clear: 19.7%
ROAD CONDITIONS	Dry: 67-84% **Priority High** Wet: 12-33% Bad weather (60%)
VISIBILITY	Visibility problems on 40% of relevant accidents
RIDER TYPE	18-25 years [13%] 26-35 years (33 - 37.3%) **Priority High** 36-45 years (28.8-56%) 46-55 years (13.5%)
RIDER EXPERIENCE	1-4 years [28.9%] 5-10 years (18.6-22%) >10 years [32.9% (national) 67% (in-depth)] **Priority High**

List of possible ADAS/IVIS:

Variables to be studied in each type of accident	Possible ADAS/IVIS related with the factor detected (which can help to minimize or avoid the accident)
Impaired visibility	ADAS - Intersection support ADAS - Visibility improvement system (Infrared)
Driver physical status	ADAS - Hypovigilance system
Age of driver	ADAS - Hypovigilance system
Driver experience	ADAS - Hypovigilance system
Driver infraction	ADAS - Frontal collision warning (Obstacle detection)
Inappropriate speed	ADAS - Speed alert functionality ADAS - Adaptative cruise control
Loss of control to the left or to the right	ADAS - Warning of a dangerous curve ADAS - Speed alert functionality
Bend negotiation	ADAS - Warning of a dangerous curve
Environmental factors: weather	ADAS - Warning of low temperature (frost)
Vehicle status	ADAS - Warning of mechanical failure, low tyre pressure

Example of ADAS/IVIS working:

If the support system is on: A motorcycle is driving straight on a rural road (motorway or two carriage road) in its own lane. The speed is high for the circumstances. The "Speed Alert" system effectively warns the rider to reduce speed. An animal (for example) suddenly crosses the road. The accident may be averted if the rider reduces speed and thus has more time to react. The "Frontal Collision" system may also warn the rider to brake, thus avoiding the accident.

Rural single motorcycle accident on bends (motorways and two carriageways roads excluded).

Characterization:

CASE NAME	Rural single motorcycle accident on bends (motorways and two carriage roads excluded)
GOAL	5.7% (national) and 35.9% (in-depth) of all crashes
TYPE OF EGO-VEHICLE (MOPED, MOTORCYCLE)	49.1% (sport style) **Priority High** 11.8% (Conventional Street Style)
TYPE OF OTHER INVOLVED VEHICLE	None
ACCIDENT CAUSES	Loss of control (100%) **Priority High** Travelling too fast for the conditions [65.4% (national) - 100% (in-depth)] **Priority High** Distraction (24.3%) Disobeyed traffic rules (8.9%) Driver behaviour or experience (7.1%)
ACCIDENT CHARACTERISTICS	-
EGO NO OF OCCUPANTS	-
TYPE OF ROAD	Rural Safety Barrier (35%) Lane width 6-7m (35%) Lane separation and verges (56%) Edge marks (55%) Flat road (44%) **Priority High** Uphill (15%) Downhill (20%)
RELATIVE TRAJECTORIES	Left Curve: Curve radius <90m (40.3%) **Priority High** Curve radius 90, 450 (17.9%) Right Curve: Curve radius <90m (18.2%) **Priority High** Curve radius 90, 450 (9.1%),
EGO-VEHICLE SPEED	40-59 km/h (14.5%) 60-99 km/h (40%) **Priority High** 100-119 km/h (19.1%)
OTHER VEHICLE SPEED	N/A
TIME TO COLLISION	-
TIME OF THE DAY/ WEATHER	Day/ Other: 38% Day/ Clear: 68.6%(National), 33.1%(In-depth) **Priority High** Night/Clear: 12.7% **Priority High**
ROAD CONDITIONS	Dry: 87-88%
VISIBILITY	Visibility problems on 40% of relevant accidents
RIDER TYPE	18-25 years (14.8 - 16.3%) 26-35 years [44.6 %(national), 23 %(in-depth)] **Priority High** 36-45 years (23- 23.2%) 46-55 years (10.5%)
RIDER EXPERIENCE	<1 year (13%) 1-4 years (20-28.1%) 5-10 years (19.9%) >10 years (27-32.2%) **Priority High**

List of possible ADAS/IVIS:

Variables to be studied in each type of accident	Possible ADAS/IVIS related with the factor detected (which can help to minimize or avoid the accident)
Impaired visibility	ADAS – Intersection support ADAS – Visibility Improvement system (Infrared)
Driver physical status	ADAS – Hypovigilance system
Age of driver	ADAS – Hypovigilance system
Driver experience	ADAS – Hypovigilance system
Driver distraction	ADAS – Frontal collision warning (Obstacle detection)
Inappropriate speed	ADAS – Speed alert functionality ADAS – Adaptative cruise control
Loss of control to the left or to the right	ADAS – Warning of a dangerous curve ADAS – Speed alert functionality
Bend negotiation	ADAS – Warning of a dangerous curve
Environmental factors: weather	ADAS – Warning of low temperature (Frost)
Vehicle status	ADAS – Warning of mechanical failure, low tyre pressure

Example of ADAS/IVIS working:

If the support system is on: A motorcycle is approaching a bend on a rural road (not motorway or two carriageways road). The riding conditions are not appropriate for the bend. The "Curve Warning" system effectively warns the rider about the appropriateness of the current riding conditions in order to ride safely through the curve. If the rider reacts according to the system warning, it is likely that the rider does not lose control and no accident occurs.

Rural single motorcycle accident on bends (only motorways and two carriageways roads).

Characterization:

CASE NAME	Rural single motorcycle accident on bends (only motorways and two carriage roads)
GOAL	0.5-3.1% of all crashes
TYPE OF EGO-VEHICLE (MOPED, MOTORCYCLE)	71.4% (sport style) **Priority High** 28.6% (Conventional Street Style)
TYPE OF OTHER INVOLVED VEHICLE	None
ACCIDENT CAUSES	Loss of control (100%) **Priority High** Travelling too fast for the conditions [58.3% (national) - 100% (in-depth)] **Priority High** Distraction (22.9%) Driver behaviour or experience (75%)
ACCIDENT CHARACTERISTICS	-
EGO NO OF OCCUPANTS	-
TYPE OF ROAD	Rural Safety Barrier (43%) Lane width >7m (57%) Lanes separation and verges (71%) Edge marks (29%) Flat road (57%) **Priority High** Uphill (14%) Downhill (14%)
RELATIVE TRAJECTORIES	Left Curve: Curve radius <90m (33.7) **Priority High**
EGO-VEHICLE SPEED	60-99km/h (42.9%) **Priority High** 100-119km/h (28.6%) 120-150 km/h (14.3%)
OTHER VEHICLE SPEED	N/A
TIME TO COLLISION	-
TIME OF THE DAY/ WEATHER	Day/ Other :22.2% **Priority High** Day/ Clear: 60.1%(national), 33.3% (in-depth) **Priority High** Day/ Heavy rain: 22% **Priority High** Day /Slight and heavy wind: 22.2% Night/Clear: 17.5% **Priority High**
ROAD CONDITIONS	Dry: 71-83% **Priority High** Wet: 14-29% **Priority High**
VISIBILITY	Visibility problems on 40% of relevant accidents
RIDER TYPE	18-25 years (15.5-29%) 26-35 years [42.5 %(national), 14 %(in-depth)] **Priority High** 36-45 years (26.5%) 46-55 years (10.5-14%)
RIDER EXPERIENCE	1-4 years (29-30.9%) **Priority High** 5-10 years (19.6%) >10 years (14-33.8%)

List of possible ADAS/IVIS:

Variables to be studied in each type of accident	Possible ADAS/IVIS related with the factor detected (which can help to minimize or avoid the accident)
Impaired visibility	ADAS – Intersection support ADAS – Visibility Improvement system (Infrared)
Driver physical status	ADAS – Hypovigilance system
Age of driver	ADAS – Hypovigilance system
Driver experience	ADAS – Hypovigilance system
Driver distraction	ADAS – Frontal collision warning (Obstacle detection)
Inappropriate speed	ADAS – Speed alert functionality ADAS – Adaptative cruise control
Loss of control to the left or to the right	ADAS – Warning of a dangerous curve ADAS – Speed alert functionality
Bend negotiation	ADAS – Warning of a dangerous curve
Environmental factors: weather	ADAS – Warning of low temperature (Frost)
Vehicle status	ADAS – Warning of mechanical failure, low tyre pressure

Example of ADAS/IVIS working:

If the support system is on: A motorcycle is approaching a bend on a rural road (motorway or two carriageways road). The riding conditions are not appropriate for the bend. The "Curve Warning" system effectively warns the rider about the appropriateness of the current riding conditions in order to ride safely through the curve. If the rider reacts according to the system warning, it is likely that the rider keeps the motorcycle under control and no accident occurs.

For the night lighting condition, a motorcycle is approaching a bend on a rural road (motorway or two carriageways road). The lighting conditions are not appropriate. The radius of the curve is smaller than expected. The speed is high for the bend. The "Adaptive Light" system effectively informs the rider about the real radius of the bend. If the rider reduces speed to the one appropriate for the bend, it is possible that the rider does not lose control and no accident occurs.

Front-side urban junction accident with car.

Characterization:

CASE NAME	Front-side urban junction accident with car.
GOAL	22% (literature), 11.4% (national), 1.6% (in-depth) of all accidents
TYPE OF EGO-VEHICLE (MOPED, MOTORCYCLE)	Motorcycle L3 27.9% (sport style) 15.3% (Conventional Street Style) 17.1 (Scooter Motorcycle Type) 7.2 (Cruiser Motorcycle Type)
TYPE OF OTHER INVOLVED VEHICLE	Passenger car (in the majority)
ACCIDENT CAUSES	Perception failure OV (56%) Decision failure OV (26.6%) MC traffic scan error (25.3%) OV traffic scan error (50%) MC loss of control (25.3%) OV disobeyed give-way or stop-sign or markings (37.1%) **Priority High** MC disobeyed traffic rules (62.5%) **Priority High** Poor turn or maneuver (40%) **Priority High** MC mistakes during overtaking (20%) MC distraction (23.9%)
ACCIDENT CHARACTERISTICS	*First PTW contact point with the passenger car:* Centre front: 25.2% Right front (9.9%) Right centre (9%) Left centre (9%)
EGO NO OF OCCUPANTS	-
TYPE OF ROAD	T or Y-junction [4.3 %(national), 26.8% (in-depth)] X or +junction [9.4 %(national), 33.3 %(in-depth)] **Priority High** Traffic Light (18%) Flat road (84.5%) **Priority High** Downhill (10%)
RELATIVE TRAJECTORIES	Perpendicular, *Motorcycle:* Moving in a straight line with constant speed (60%) **Priority High** Moving in a straight line accelerating (13.3%) Moving in a straight line- throttle off (8%) *Passenger car:* Stopped in traffic with zero speed (26.7%) **Priority High** Moving in a straight line with constant speed (25.3%) **Priority High** Moving in a straight line braking (10.7%) Moving in a straight line accelerating (9.3%) *Angles of trajectories:* 76º-90º (19.8%) **Priority High** 91º-105º (9%) 121º-135º (9%) 226º-240º (9%) 256º-270º (11.7%)
EGO-VEHICLE SPEED	<40km/h (22.5%) 40-59 km/h (48.9%) **Priority High** 60-99 km/h (25.2%)
OTHER VEHICLE SPEED	Up to 50 km/h (literature)
TIME TO COLLISION	-
TIME OF THE DAY/ WEATHER	Day/clear (57.5-80.7%) **Priority High** Day/fog (15.8%) Day/slight rain (15.8%) Day/slight wind (29.8%) Dusk-Dawn/clear (14.6%) Night with artificial luminosity/Clear (10.5%) Night/clear (18.7%)
ROAD CONDITIONS	Dry: 83-93% **Priority High** Wet: 7-14%
VISIBILITY	28% visibility obstruction
RIDER TYPE	18-25 years (17.4-21 %) 26-35 years (22-34.3%) **Priority High** 36-45 years (21-24.2%) 46-55 years (11-11.4%)
RIDER EXPERIENCE	1-4 years (32%-39%) **Priority High** 5-10 years (16.8-22%) >10 years (29.8-32%)

Example of ADAS/IVIS working:

Variables to be studied in each type of accident	Possible ADAS/IVIS related with the factor detected (which can help to minimize or avoid the accident)
Light conditions (night/day/light)	ADAS - Night vision ADAS - Adaptative light control
Rider maneuvers	ADAS - Blind Spot detection
Inappropriate speed	ADAS - Speed alert functionality ADAS - Adaptative cruise control
Type of intersection (crossroad, T or Y junction)	ADAS - Intersection support IVIS - Navigational and route guidance IVIS - Weather, traffic and black spot warning
Intersection regulated by	ADAS - Intersection support IVIS - Navigational and route guidance
Right of way violation	ADAS - Intersection support IVIS - Navigational and route guidance
Visibility impaired	ADAS - Intersection support
Poor or incorrect avoidance collision strategy/action	ADAS - Frontal collision warning (Obstacle detection)

Example of ADAS/IVIS working:

If the support system is on: A motorcycle is approaching an urban '+' junction type. The motorcycle is on a priority road. A passenger car is approaching the same junction at 90º relevant to the motorcycle. The passenger car does not obey the give priority sign and does not brake. The "Intersection Support" system warns the rider to pay attention to the next intersection. The possible accident may be averted, if the rider does reduce speed in the proper time.

Front-side rural junction accident with car (motorways and two carriageways roads excluded).

Characterization:

CASE NAME	Front-side rural junction accident with passenger car (motorways and two carriage roads excluded).
GOAL	22% (literature), 0.9-4.7% of all accidents
TYPE OF EGO-VEHICLE (MOPED, MOTORCYCLE)	10.3% (sport style) 15.3% (Conventional Street Style) 17.3% (Cruiser Motorcycle Type) 17.2% (Sport touring motorcycle type)
TYPE OF OTHER INVOLVED VEHICLE	Passenger car
ACCIDENT CAUSES	Perception failure OV (90%) OV traffic scan error (90%) Loss of control (15%) OV disobeyed give-way or stop-sign or markings (33-50%) MC disobeyed traffic rules (86.8%) **Priority High** Poor turn or maneuver (50%) MC risk action/ behaviour (1UUS) **Priority High** MC distraction (20.4%) Motorcycle is travelling too fast for the conditions (20%)
ACCIDENT CHARACTERISTICS	*First PTW contact point with the passenger car:* Centre front (51.7%) Right centre (6.9%) Left centre (13.8%)
EGO NO OF OCCUPANTS	-
TYPE OF ROAD	Rural junctions T or Y-junction [61.4 %(national), 27.6% (in-depth)] **Priority High** X or +junction [24.2 %(national), 48.3 %(in-depth)] Roundabout (8.8%) Traffic Light (13.8%) Yield sign (3.4-8.2%) Stop sign (44.6%) **Priority High** Flat road (75.9%) **Priority High** Downhill (10.3%)
RELATIVE TRAJECTORIES	*Motorcycle:* Moving in a straight line with constant speed (80%) **Priority High** Moving in a straight line accelerating (5%) Moving in a straight line-braking (5%) Passing maneuver-passing on right (5%) Negotiation a bend-constant speed (5%) *Passenger car:* Stopped in traffic with zero speed (35%) Moving in a straight line with constant speed (10%) Moving in a straight line-throttle off (10%) Moving in a straight line-accelerating (10%) Turning left-accelerating *Angles of trajectories:* 60º-75º (10.3%) 91º-105º (20.7%) 106º-120º (24.1%) 121º-135º (13.8%) 226º-240º (10.3%)
EGO-VEHICLE SPEED	40-59 Km/h (17.2%) 60-99 km/h (65.5%) **Priority High**
OTHER VEHICLE SPEED	-
TIME TO COLLISION	-
TIME OF THE DAY/ WEATHER	Day/clear (56.8-56.9%) **Priority High** Day/other (14.7%) Day/fog (15.8%) Day/slight wind (11.8%) Dusk-Dawn/clear (15.9%) Night/clear (15.1%)
ROAD CONDITIONS	Dry: 90-95% **Priority High** Wet: 4-10%
VISIBILITY	
RIDER TYPE	<18 (9%) 18-25 years (14.8-32 %) 26-35 years (18-38.9%) **Priority High** 36-45 years (23.9-27%) 46-55 years (12.2-14%)
RIDER EXPERIENCE	<4 years (18%) 1-4 years (30.9-32%) 5-10 years (9-17.9%) >10 years (32-32.4%) **Priority High**

List of possible ADAS/IVIS:

Variables to be studied in each type of accident	Possible ADAS/IVIS related with the factor detected (which can help to minimize or avoid the accident)
Light conditions (night/day/light)	ADAS - Night vision
Rider maneuvers	ADAS - Adaptative light control ADAS - Blind Spot detection
Inappropriate speed	ADAS - Speed alert functionality ADAS - Adaptative cruise control
Type of intersection (crossroad, T or Y junction)	ADAS - Intersection support IVIS - Navigational and route guidance IVIS - Weather, traffic and black spot warning
Intersection regulated by	ADAS - Intersection support IVIS - Navigational and route guidance
Right of way violation	ADAS - Intersection support IVIS - Navigational and route guidance
Visibility impaired	ADAS - Intersection support
Poor or incorrect avoidance collision strategy/action	ADAS - Frontal collision warning (Obstacle detection)

Example of ADAS/IVIS working:

If the support system is on: A motorcycle is approaching a rural T-junction. The motorcycle is on a give way road. A passenger car is approaching the same junction at 90º relatively to the motorcycle. The rider does not obey the give priority sign and does not brake. The "Intersection Support" system warns the rider. The possible accident may be averted, if the rider does reduce

speed and obeys the priority rules, as a result of the warning.

Rear-end accidents in urban non-junctions with cars.

Characterization:

CASE NAME	Rear-end accidents in urban non-junctions with cars
GOAL	10% (along with 4b) (literature) 2-2.6% of all motorcycle accidents
TYPE OF EGO-VEHICLE (MOPED, MOTORCYCLE)	9.7% (sport style) 41.9% (Scooter/Motorcycle Type) **Priority High** 6.5% (Touring Motorcycle Type)
TYPE OF OTHER INVOLVED VEHICLE	Passenger car
ACCIDENT CAUSES	Illegal overtaking of the rider (8%) Too-short distance from vehicle ahead (17%) MC driving too close (50%) **Priority High** MC perception failure (50%) **Priority High** MC traffic scan error (60%) **Priority High** MC unsafe act (70%) **Priority High** OV perception failure (40%) Poor turn or maneuver (30%) MC distraction (45%) MC disobeyed traffic rules (35.6%)
ACCIDENT CHARACTERISTICS	-
EGO NO OF OCCUPANTS	-
TYPE OF ROAD	Urban non junction Flat road (84%) **Priority High** Downhill (9.7%) Uphill (6.5%)
RELATIVE TRAJECTORIES	*Motorcycle:* Moving in a straight line (29%) *Passenger car:* Moving in a straight line (16.1%)
EGO-VEHICLE SPEED	<40 km/h (25.8%) 40-59 km/h (29%) **Priority High** 60-99 km/h (25.8%)
OTHER VEHICLE SPEED	-
TIME TO COLLISION	-
TIME OF THE DAY/ WEATHER	Day/clear [62%(national), 25% (in-depth)] **Priority High** Day/other (36.1%) Dusk-Dawn/clear (13%) Dusk-Dawn/other (5.6%) Night/clear (16%)
ROAD CONDITIONS	Wet: 10-16% Dry: 84-89% **Priority High**
VISIBILITY	Restricted visibility in 5% of the cases.
RIDER TYPE	<18 years (19.4%) 18-25 years (17-19.4%) 26-35 years (19.4-34%) 36-45 years (24%) **Priority High** 46-55 years (11%) 56-65 years (12.9%)
RIDER EXPERIENCE	<1year (12.9%) 1-4 years (29-29.2%) **Priority High** 5-10 years (17.2-22.6%) >10 years (12.9-29%)

List of possible ADAS/IVIS:

Variables to be studied in each type of accident	Possible ADAS/IVIS related with the factor detected (which can help to minimize or avoid the accident)
Visibility impaired (melee)	ADAS - Visibility improvement system (Infrared) IVIS - Weather, traffic and black spot warning
Distraction	ADAS - Frontal collision warning (Obstacle detection) ADAS - Adaptative cruise control
Inappropriate speed	ADAS - Speed alert functionality ADAS - Adaptative cruise control
Surface condition	IVIS - Weather, traffic and black spot warning IVIS - Navigational and route guidance ADAS - Warning of low temperature (frost)
Poor or incorrect evoidance collision strategy/action	ADAS - Frontal collision warning (Obstacle detection)

Example of ADAS/IVIS working:

If the support system is on: A motorcycle is driving straight on an urban road (non junction). There is a passenger car moving in front of the motorcycle. The motorcycle drives very close to the passenger car. The "Frontal Collision" system warns the rider about the dangerously low distance from the passenger car. The passenger car suddenly breaks abruptly. The possible accident may be averted, if the rider obeys the warning of the system.

Rear-end accidents in rural non-junctions with cars (motorways and two carriageways roads excluded).

Characterization:

CASE NAME	Rear-end accidents in rural non-junctions with cars (motorways and two carriage roads excluded)
GOAL	10% (along with 4a) (literature), 0.8-1.6% of all motorcycle accidents
TYPE OF EGO-VEHICLE (MOPED, MOTORCYCLE)	Motorcycle (L3) 57.1% (sport style) **Priority High** 14.3% (Enduro Motorcycle Type)
TYPE OF OTHER INVOLVED VEHICLE	Passenger car
ACCIDENT CAUSES	Illegal overtaking of the rider (8%) Too-short distance from vehicle ahead (17%)
ACCIDENT CHARACTERISTICS	MC driving too close (66%) **Priority High** MC error during overtaking maneuver (50%) Motorcycle is travelling too fast for the conditions [10.2% (national), 50% (in-depth)] Slippery road surface (50%) MC distraction (46.1%) MC disobeyed traffic rules (46.7%)
EGO NO OF OCCUPANTS	-
TYPE OF ROAD	Rural non junction (motorways and two carriageways roads excluded) Flat road (43%) **Priority High** Downhill (28.6%) Uphill (14.3%)
RELATIVE TRAJECTORIES	*Motorcycle:* Moving in a straight line (14.3%)
EGO-VEHICLE SPEED	40-59 km/h (14.3%) 60-99 km/h (28.6%) **Priority High** 100-119 km/h (14.3%) 120-150 km/h (14.3%)
OTHER VEHICLE SPEED	-
TIME TO COLLISION	-
TIME OF THE DAY/ WEATHER	Day/clear [57-64%] **Priority High** Day/other (14%) Day/fog (14%) Dusk-Dawn/clear (14%) Dusk-Dawn/other (14%) Night/clear (15%)
ROAD CONDITIONS	Dry: 86-93% **Priority High** Wet: 6-14%
VISIBILITY	Restricted visibility in 5% (literature) and 50% of the cases
RIDER TYPE	18-25 years (14.1-29%) 26-35 years (29-36.5%) **Priority High** 36-45 years (23.1-29%) 46-55 years (13.2%)
RIDER EXPERIENCE	1-4 years (14.3-25.9%) 5-10 years (14.3-19.4%) >10 years (28.5-30.9%) **Priority High**

List of possible ADAS/IVIS:

Variables to be studied in each type of accident	Possible ADAS/IVIS related with the factor detected (which can help to minimize or avoid the accident)
Visibility impaired (melee)	ADAS - Visibility improvement system (Infrared) IVIS - Weather, traffic and black spot warning
Distraction	ADAS - Frontal collision warning (Obstacle detection) ADAS - Adaptative cruise control
Inappropriate speed	ADAS - Speed alert functionality ADAS - Adaptative cruise control
Surface condition	IVIS - Weather, traffic and black spot warning IVIS - Navigational and route guidance ADAS - Warning of low temperature (frost)
Poor or incorrect evoidance collision strategy/action	ADAS - Frontal collision warning (Obstacle detection)

Example of ADAS/IVIS working:

If the support system is on: A motorcycle is driving straight on a rural road (not motorway and two carriage way road). There is a passenger car moving in front of the motorcycle. The motorcycle drives very close to the passenger car. The "Frontal Collision" system warns the rider about the dangerously low distance from the passenger car. The passenger car suddenly breaks abruptly. The possible accident may be averted, if the rider obeys the warning of the system.

Rear-end accidents in rural non-junctions with cars (only motorways and two carriageways roads).

Characterization:

CASE NAME	Rear-end accidents in rural non-junctions with cars (only motorways and two carriage roads)
GOAL	10%, 0.2-04% of all motorcycle accidents (along with 48)
TYPE OF EGO-VEHICLE (MOPED, MOTORCYCLE)	33.3% (Sport style) 33.3% (Scooter/Motorcycle Type)
TYPE OF OTHER INVOLVED VEHICLE	Passenger car
ACCIDENT CAUSES	Illegal overtaking of the rider (8%) Too-short distance from vehicle ahead (17%) OV traffic scan error (33%) MC error during overtaking maneuver (33%) OV error during overtaking maneuver (33%) Motorcycle is travelling too fast for the conditions [8%(national), 66% (in-depth)] **Priority High** MC distraction (45%) MC disobeyed traffic rules (47.8%)
ACCIDENT CHARACTERISTICS	-
EGO NO OF OCCUPANTS	-
TYPE OF ROAD	Motorways or two carriageways roads, Flat (100%)
RELATIVE TRAJECTORIES	-
EGO-VEHICLE SPEED	40-59 km/h (33.3%) 60-99 km/h (33.3%) 120-150 km/h (33.3%)
OTHER VEHICLE SPEED	-
TIME TO COLLISION	-
TIME OF THE DAY/ WEATHER	Day/clear (33.3-59.1%) **Priority High** Dusk-Dawn/clear (14.3%) Night/clear (17.2%)
ROAD CONDITIONS	Dry:67-94% **Priority High** Submerge-flooded: 33%
VISIBILITY	Restricted visibility in 5% of the cases.
RIDER TYPE	<18 years (33.3%) 18-25 years (13.1%) 26-35 years (39%) **Priority High** 36-45 years (30.1-33.3%) 46-55 years (12.2-33.3%)
RIDER EXPERIENCE	<1 year (33.3%) 1-4 years (32.2-33.3%) **Priority High** 5-10 years (16.9%) >10 years (33.3-33.7%) **Priority High**

List of possible ADAS/IVIS:

Variables to be studied in each type of accident	Possible ADAS/IVIS related with the factor detected (which can help to minimize or avoid the accident)
Visibility impaired (motor)	ADAS - Visibility improvement system (Infrared)
	IVIS - Weather, traffic and black spot warning
Distraction	ADAS - Frontal collision warning (Obstacle detection)
	ADAS - Adaptative cruise control
Inappropriate speed	ADAS - Speed alert funotionality
	ADAS - Adaptative cruise control
Surface condition	IVIS - Weather, traffic and black spot warning
	IVIS - Navigational and route guidance
	ADAS - Warning of low temperature (frost)
Poor or incorrect avoidance collision strategy/action	ADAS - Frontal collision warning (Obstacle detection)

Example of ADAS/IVIS working:

If the support system is on: A motorcycle is driving straight on a rural road (motorway or two carriageway road). There is a passenger car moving in front of the motorcycle. The motorcycle drives very close to the passenger car. The “Frontal Collision” system warns the rider about the dangerously low distance from the passenger car. The passenger car suddenly breaks abruptly. The possible accident may be averted, if the rider obeys the warning of the system.

Mopeds single urban accident.

Characterization:

CASE NAME	Mopeds single urban accident (including run-offs, rollover on the carriageway and collisions with road restraint systems).
GOAL	4.1-6.5% of all accidents
TYPE OF EGO-VEHICLE (MOPED, MOTORCYCLE)	Moped (LT) 55.4% (Scooter style) **Priority High** 7.1% (Step-through style moped)
TYPE OF OTHER INVOLVED VEHICLE	-
ACCIDENT CAUSES	Inadequate speed in 80% as a contributing factor **Priority High** Rider behaviour or experience (45%) Rider's lack of attention (35%) MC travelling too fast for the conditions (38%) MC loss of control (65%) **Priority High** MC distraction (32%) Road environment (18.7%) Vehicle defect (1.7%) MC disobeyed traffic rules (8.2%)
ACCIDENT CHARACTERISTICS	-
EGO NO OF OCCUPANTS	-
TYPE OF ROAD	Urban Flat (62.5%) **Priority High** Uphill (17.9%) Downhill (14.3%)
RELATIVE TRAJECTORIES	-
EGO-VEHICLE SPEED	<40 km/h (28.6%) 40-59 km/h (67.9%) **Priority High**
OTHER VEHICLE SPEED	-
TIME TO COLLISION	-
TIME OF THE DAY/ WEATHER	Day/clear [46.5 %(national), 20% (in-depth)] **Priority High** Day/other (32.3%) Day/slight wind (4.6%) Dusk-Dawn/clear (10.5%) Night/clear (16%) Night without artificial luminosity/Other (10.8%) Night/Clear (28.7%)
ROAD CONDITIONS	Dry:73-76.8% **Priority High** Wet: 8.9-17%
VISIBILITY	Visibility was a problem in 20% of relevant accidents, most related to terrain profile (15%).
RIDER TYPE	<18 years (14.3-25%) 18-25 years (25-27%) **Priority High** 26-35 years (8.9-23%) 36-45 years (12-12.5%) 46-55 years (5.4-6%)
RIDER EXPERIENCE	<1 year (14.3-25%) 1-4 years (24-32.1%) **Priority High** 5-10 years (5.4-8%) >10 years (8-17.9%)

List of possible ADAS/IVIS:

Variables to be studied in each type of accident	Possible ADAS/IVIS related with the factor detected (which can help to minimize or avoid the accident)
Visibility impaired (terrain profile)	ADAS - Warning of a dangerous curve
	IVIS - Weather, traffic and black spot warning
Driver inexperience	ADAS - Road departure warning system
Inappropriate speed	ADAS - Speed alert functionality
	ADAS - Adaptative cruise control

Example of ADAS/IVIS working:

If the support system is on: A moped is driving straight on an urban road in its own lane. The speed is too high for the circumstances. The "Speed Alert" system effectively warns the rider to reduce speed. There is a sudden event (i.e. pedestrian suddenly crossing, car leaving parking place), which might cause an accident, if the rider does not decrease speed.

Mopeds single rural accident (motorways and two carriageways roads excluded).

Characterization:

CASE NAME	Mopeds single rural accident (including run-offs, rollover on the carriageway and collisions with road restraint systems) (motorways and two carriage roads excluded).
GOAL	3.1-3.1% of all crashes
TYPE OF EGO-VEHICLE (MOPED, MOTORCYCLE)	Moped (L1) 46.2 % (Scooter motorcycle style moped) **Priority High** 30.8% (Step-through style moped)
TYPE OF OTHER INVOLVED VEHICLE	-
ACCIDENT CAUSES	Problem related to bad road condition (50-67%) **Priority High** Travelling too fast for the conditions (19.8-50%) **Priority High** MC distraction (57.3%) Road environment (6.3%) MC disobeyed traffic rules (7.7%)
ACCIDENT CHARACTERISTICS	-
EGO NO OF OCCUPANTS	-
TYPE OF ROAD	Rural Flat (38.5%) **Priority High** Uphill (23.1%) Downhill (23.1%)
RELATIVE TRAJECTORIES	-
EGO-VEHICLE SPEED	<40km/h (38.5%) 40-59 km/h (46.2%) **Priority High**
OTHER VEHICLE SPEED	-
TIME TO COLLISION	-
TIME OF THE DAY/ WEATHER	Day/clear (47%) **Priority High** Day/other (13.3%) Dusk-Dawn/clear (7.6%) Dusk-Dawn/other (13.3%) Night/clear (33.2%) Night without artificial luminosity/Clear (13.3%) Night without artificial luminosity/Other (20%) Night/Clear (28.7%)
ROAD CONDITIONS	Dry: 76.9-81% **Priority High** Wet: 12% Ice:7.7% Mud: 7.7% Oil:7.7%
VISIBILITY	Restricted visibility in 20% of the cases.
RIDER TYPE	<18 years (25%) **Priority High** 18-25 years (23.1%) **Priority High** 26-35 years (17.4-23.1%) 36-45 years (7.7-13.9%) 46-55 years (7.9-15.4%)
RIDER EXPERIENCE	1-4 years (23.1-24.7%) **Priority High** 5-10 years (7.7-9.6%) >10 years (17.8-23.1%)

List of possible ADAS/IVIS:

Variables to be studied in each type of accident	Possible ADAS/IVIS related with the factor detected (which can help to minimize or avoid the accident)
Visibility impaired (terrain profile)	ADAS - Warning of a dangerous curve IVIS - Weather, traffic and black spot warning
Driver inexperience	ADAS - Road departure warning system
Inappropriate speed	ADAS - Speed alert functionality ADAS - Adaptative cruise control

Example of ADAS/IVIS working:

If the support system is on: A moped is driving on a rural road (which is not a motorway or two carriageway roads) in its own lane. The speed is too high for the circumstances. The "Speed Alert" system effectively warns the rider to reduce speed. There is a sudden event (i.e. animal suddenly crossing, car crossing road), which might cause an accident, if the rider does not decrease speed.

Urban front-side accidents in junctions of mopes with cars.

Characterization:

CASE NAME	Urban front-side accidents of mopeds with cars.
GOAL	12.7-13.2% of all accidents
TYPE OF EGO-VEHICLE (MOPED, MOTORCYCLE)	Moped (L1) 67.6 % (Scooter motorcycle style moped) **Priority High** 19.4% (Step-through style moped)
TYPE OF OTHER INVOLVED VEHICLE	Passenger car
ACCIDENT CAUSES	MC traffic scan error (28.6%) OV traffic scan error (33.3-66%) **Priority High** MC view obstruction (27.8%) OV view obstruction (36%) MC careless, reckless or in a hurry (45.9%) OV careless, reckless or in a hurry (40.1%) MC disobeyed traffic rules (65.6%) OV disobeyed give-way or stop-sign or markings (33.3-62.5%) **Priority High** Poor turn or maneuver (18.7%) MC distraction (21.4%) Motorcycle is travelling too fast for the conditions [3.8(national),16.3%(in-depth)]
ACCIDENT CHARACTERISTICS	Priority violation of traffic lights (26%) **Priority High** Violation of stop sign (24%) **Priority High** Violation of yield sign (19%) no sign (22%). *First PTW contact point with the passenger car:* Centre front: 30.2% Right front 10.1% Right centre 9.4% Top centre 14.4% Undercarriage front 19.4%
EGO NO OF OCCUPANTS	-
TYPE OF ROAD	T or Y-junction [8.4 %(national), 25.9% (in-depth)] X or +junction [17.3 %(national), 46.8 %(in-depth) **Priority High** Traffic Light [6.1%(national), 29.5% (in0depth) Yield sign (6.3%) Stop sign (4.2%) Warning junction sign (47.5%) **Priority High** None (application of general priority norm) (34.5%) Flat road (84.2%)
RELATIVE TRAJECTORIES	Perpendicular or converging. *Motorcycle:* Normal driving (on a straight section or on a curve section) (80.6%) **Priority High** *Passenger Car:* Normal driving (on a straight section or on a curve section) (49.6%) **Priority High** Turning left at an intersection (25.9%) Turning right at an intersection (7.9%) *Angles of trajectories:* 60º-75º (25.9%) **Priority High** 75º-90º (7.2%) 91º-105º (11.5%) 106º-120º (5.8%) 226º-240º (5.8%) 256º-250º (12.9%) 271º-285º (10.8%)
EGO-VEHICLE SPEED	<40km/h (56.8%) **Priority High** 40-59km/h (40.3%)
OTHER VEHICLE SPEED	-
TIME TO COLLISION	-
TIME OF THE DAY/ WEATHER	Day/clear (26.7-51.4%) **Priority High** Day/other (23.1%) Day/Slight wind (11.3%) Day/Heavy wind (13.3%) Dusk-Dawn/Clear (13.4%) Night/clear (23.1%)
ROAD CONDITIONS	Dry: 89-90% **Priority High** Wet: 5-95
VISIBILITY	
RIDER TYPE	<18 years [9.4% (national), 35.5% (in-depth)] 18-25 years (18-27%) **Priority High** 26-35 years (5-18%) 36-45 years (5-8%)
RIDER EXPERIENCE	<1year (7.2%) 1-4 years (20.1-27.9%) **Priority High** 5-10 years (6.7%) >10 years (6-6.5%)

List of possible ADAS/IVIS:

Variables to be studied in each type of accident	Possible ADAS/IVIS related with the factor detected (which can help to minimize or avoid the accident)
Light condition	ADAS - Adaptative light control
Visibility impaired	ADAS - Intersection support
Type of intersection	ADAS - Intersection support IVIS - Navigational and route guidance
Priority regulated by	ADAS - Intersection support IVIS - Navigational and route guidance
Right of way violation	ADAS - Intersection support
Other infraction	ADAS - Frontal collision warning (Obstacle detection)
Poor or incorrect evidence collision simulation	ADAS - Frontal collision warning (Obstacle detection)

Example of ADAS/IVIS working:

If the support system is on: A moped is approaching an urban 'X' or '+' junction type. The moped is moving on an inferior road. A passenger car is approaching the same junction at 90º relatively to the moped. The moped does not obey the give priority sign and does not brake. The "Intersection Support" system warns the rider to reduce speed. The possible accident may be averted, if the rider does reduce speed and obeys the priority rules.

Rural front-side accidents in junctions of mopes with cars (motorways and two carriageways roads excluded).

Characterization:

CASE NAME	Rural front-side accidents of mopeds with cars (motorways and two carriage roads excluded).
GOAL	1.7-4.7% of all crashes
TYPE OF EGO-VEHICLE (MOPED, MOTORCYCLE)	Moped (L1) 50 % (Scooter motorcycle style moped) **Priority High** 35.7% (Step-through style moped)
TYPE OF OTHER INVOLVED VEHICLE	Passenger car
ACCIDENT CAUSES	OV traffic scan error (54.5%) MC view obstruction(27.2-33.3%) OV view obstruction (36.6%) MC careless, reckless or in a hurry (36.3%) OV careless, reckless or in a hurry (45.5%) MC disobeyed traffic rules [83.9% (national), 33.3% (in-depth)] **Priority High** OV disobeyed give-way or stop-sign or markings (33.3%) MC lack of attention (6%) MC distraction (20%)
ACCIDENT CHARACTERISTICS	Not obeying traffic signs indications (8%) Absent-minded driving (6%) Overtaking illegally (5%) *First PTW contact point with the passenger car:* Centre front: 35.7% Right front 14.3% Left centre 14.3% Top centre 14.3%
EGO NO OF OCCUPANTS	-
TYPE OF ROAD	T or Y-junction [25.7 %(national), 50% (in-depth)] **Priority High** X or +junction (12.9-28.6%) Roundabout (5.8-7.1%) Traffic Light [28%(national) 7.1% (in-depth) Yield sign (5.8%) Stop sign (19.9-28.6%) None (application of general priority norm) [14.9 %(national), 57.1% (in-depth)] Warning junction signs (42.9%) Flat road (71.4%) Uphill (7.1%)
RELATIVE TRAJECTORIES	Perpendicular or converging. *Motorcycle:* Normal driving (on a straight section or on a curve section) (71.4%) **Priority High** Crossing the intersection straight ahead (14.3%) *Passenger Car:* Normal driving (on a straight section or on a curve section) (71.4%) **Priority High** Turning left at an intersection (28.6%) Turning right at an intersection (14.3%) *Angles of trajectories:* 45º-60º (7.1%) 60º-75º (7.1%) 75º-90º (14.3%) 91º-105º (14.3%) 106º-120º (7.1%) 226º-240º (7.1%) 241-255º (7.1%) 256º-250º (21.4%) 286º-300º (7.1%)
EGO-VEHICLE SPEED	<40km/h (42.9%) 40-59km/h (57.1%) **Priority High**
OTHER VEHICLE SPEED	-
TIME TO COLLISION	-
TIME OF THE DAY/ WEATHER	Day/clear [53.7% (national), 18.8% (in-depth)] **Priority High** Day/other (25%) Dusk-Dawn/Clear (11.9%) Dawn/Other (12.5%) Night/clear (21.2%) Night with artificial luminosity/Clear (12.5%) Night without artificial luminosity/Clear (12.5%)
ROAD CONDITIONS	Dry: 90-92% **Priority High** Wet: 9% Mud: 7.1%
VISIBILITY	
RIDER TYPE	<18 years [14.3% (national), 31.7% (in-depth)] 18-25 years [22.3% (national), 7.1% (in-depth)] **Priority High** 26-35 years (15.4%), 36-45 years (9.9%) 46-55 years (5.6%) >65 years (9.4%)
RIDER EXPERIENCE	1-4 years (21.4-27.3%) **Priority High** >10 years (7.1-13.2%)

List of possible ADAS/IVIS:

Variables to be studied in each type of accident	Possible ADAS/IVIS related with the factor detected (which can help to minimize or avoid the accident)
Light condition	ADAS - Adaptative light control
Visibility impaired	ADAS - Intersection support
Type of intersection	ADAS - Intersection support IVIS - Navigational and route guidance
Priority regulated by	ADAS - Intersection support IVIS - Navigational and route guidance
Right of way violation	ADAS - Intersection support
Driver infraction	ADAS - Frontal collision warning (Obstacle detection)
Poor or incorrect avoidance collision strategy/action	ADAS - Frontal collision warning (Obstacle detection)

Example of ADAS/IVIS working:

If the support system is on: A moped is approaching a rural T-junction. The moped is moving on a give way road. A passenger car is approaching the same junction at 90º relatively to the moped. The rider does not obey the give priority sign and does not brake. The "Intersection Support" system warns the rider to reduce speed. The likely accident can be averted, if the rider does reduce speed, as a result of the warning of the system.

Head-on accidents in urban areas, between mopeds and cars.

Characterization:

CASE NAME	Head-on accidents in urban areas, between mopeds and passenger cars.
GOAL	21% of the moped accidents (along with /b). 2.3-2.5% of all accidents
TYPE OF EGO-VEHICLE (MOPED, MOTORCYCLE)	45.5 % (Scooter motorcycle style moped) **Priority High** 33.3% (Step-through style moped)
TYPE OF OTHER INVOLVED VEHICLE	Passenger car
ACCIDENT CAUSES	OV traffic scan error (15-38%) MC view obstruction (69%) MC careless, reckless or in a hurry (76%) **Priority High** MC disobeyed give-way or stop-sign or markings (15%) MC disobeyed traffic rules (54.1%) OV poor turn or maneuver (30%) MC wrong choice of lane (61%) OV wrong choice of lane (61%) MC distraction (23.7%) Motorcycle is travelling too fast for the conditions (10.7%)
ACCIDENT CHARACTERISTICS	Rider entering the opposite lane (18%) **Priority High** Absent-minded driving (9%) Driving in a forbidden direction (6%) Overtaking illegally (4%)
EGO NO OF OCCUPANTS	-
TYPE OF ROAD	No junction (21.2-47.9%) **Priority High** T or Y-junction (9.1%) X or +junction (6%) Traffic Light (3-9.8%) Yield sign (7.4%) Stop sign (8.1%) None (application of general priority norm) (12.1-21.2%) Flat road (60.6%) **Priority High** Uphill (12.1%) Downhill (27.3%)
RELATIVE TRAJECTORIES	*Motorcycle:* Normal driving (on a straight section or on a curve section) (21.2%) *Passenger Car:* Normal driving (on a straight section or on a curve section) (21.2%)
EGO-VEHICLE SPEED	<40km/h (57.6%) **Priority High** 40-59km/h (33.3%)
OTHER VEHICLE SPEED	-
TIME TO COLLISION	-
TIME OF THE DAY/ WEATHER	Day/clear [47.7% (national), 14% (in-depth)] **Priority High** Day/other (35%) **Priority High** Day/Slight rain (11%) Dusk-Dawn/Clear (14.8%) Night/clear (22.9%) Night with artificial luminosity (15%)
ROAD CONDITIONS	Dry: 78.8-86% **Priority High** Wet: 9.1-13% Submerged-flooded: 12.1%
VISIBILITY	Visibility problems in 40%.
RIDER TYPE	<18 years (32-41%) **Priority High** 18-25 years (24-32%) **Priority High** 26-35 years (8-16%) 36-45 years (8-12%)
RIDER EXPERIENCE	<1year (20%) 1-4 years (27-36%) **Priority High** 5-10 years (5-12%) >10 years (5-20%)

List of possible ADAS/IVIS:

Variables to be studied in each type of accident	Possible ADAS/IVIS related with the factor detected (which can help to minimize or avoid the accident)
Type of intersection	ADAS - Intersection support IVIS - Navigational and route guidance
Bend negotiation	ADAS - Warning of a dangerous curve IVIS - Navigational and route guidance
Inappropriate speed	ADAS - Speed alert functionality
Light condition	ADAS - Adaptative light control
Visibility impaired	ADAS - Intersection support
Driver infraction	ADAS - Frontal collision warning (Obstacle detection) ADAS - Lane departure warning system
Poor or incorrect avoidance collision strategy/action	ADAS - Frontal collision warning (Obstacle detection)
Driver's age	ADAS - Speed alert functionality IVIS - Weather, traffic and black spot warning

Example of ADAS/IVIS working:

If the support system is on: A moped is driving straight on an urban road. There is a slow passenger car moving in front of the moped. The moped wants to overtake and enters in the opposite lane. There is an oncoming car. The "Frontal Collision" system warns the rider that the distance to the oncoming car is reducing. The possible accident can be averted, if the rider obeys the warning of the system.

Head-on accidents in rural areas, between mopeds and cars (motorways and two carriageways roads excluded).

Characterization:

CASE NAME	Head-on accidents in rural areas, between mopeds and passenger cars (motorways and two carriage roads excluded).
GOAL	21% (literature), 0.4-0.7% of the moped accidents (along with 7a).
TYPE OF EGO-VEHICLE (MOPED, MOTORCYCLE)	40 % (Scooter motorcycle style moped) **Priority High** 20% (Step-through style moped)
TYPE OF OTHER INVOLVED VEHICLE	Passenger car
ACCIDENT CAUSES	OV perception failure (100%) MC view obstruction (50%) OV view obstruction (50%) OV not driving on the right side of the road (100%) OV disobeyed give-away or stop-sign or marks (50%) MC disobeyed traffic rules (66.2%) **Priority High** MC distraction (23%) Motorcycle is travelling too fast for the conditions (10.7%)
ACCIDENT CHARACTERISTICS	Rider entering the opposite lane (18%) **Priority High** Absent-minded driving (9%) Driving in a forbidden direction (6%) Overtaking illegally (4%)
EGO NO OF OCCUPANTS	-
TYPE OF ROAD	No junction [70.9% (national), 40% (in-depth)] **Priority High** Yield sign (2%) Stop sign (10.9%) None (application of general priority norm) (11.4%) Flat road (50%) Downhill (25%)
RELATIVE TRAJECTORIES	*Motorcycle:* Normal driving (on a straight section or on a curve section) (20%), Overtaking on the left prior to the intersection (20%) *Passenger Car:* Normal driving (on a straight section or on a curve section) (40%)
EGO-VEHICLE SPEED	<40 km/h (40%) 40-59 km/h (40%) **Priority High** 60-99 km/h (20%)
OTHER VEHICLE SPEED	-
TIME TO COLLISION	-
TIME OF THE DAY/ WEATHER	Day/Clear [49.3% (national), 16.7% (in-depth)] Dusk, Dawn/Clear (9.7%) Night (without artificial luminosity)/Heavy wind (16.7%) Night (without artificial luminosity)/Clear (16.7%) Night (without artificial luminosity)/Other (50%) **Priority High** Night/Clear (27.2%)
ROAD CONDITIONS	Dry:80-86% **Priority High** Wet: 11-20%
VISIBILITY	Visibility problems in 40%.
RIDER TYPE	<18 years (25-41.5%) 26-35 years (23.3-25%) **Priority High** 36-45 years (12.5-25%) 46-55 years (7.7-25%)
RIDER EXPERIENCE	1-4 years (32.1-50%) **Priority High** >10 years (8.9-25%)

List of possible ADAS/IVIS:

Variables to be studied in each type of accident	Possible ADAS/IVIS related with the factor detected (which can help to minimize or avoid the accident)
Type of intersection	**ADAS - Intersection support** **IVIS - Navigational and route guidance**
Road negotiation	**ADAS - Warning of a dangerous curve** **IVIS - Navigational and route guidance**
Inappropriate speed	**ADAS - Speed alert functionality**
Light condition	**ADAS - Adaptative light control**
Visibility impaired	**ADAS - Intersection support**
Driver infraction	**ADAS - Frontal collision warning (Obstacle detection)** **ADAS - Lane departure warning system**
Poor or incorrect avoidance collision strategy/action	**ADAS - Frontal collision warning (Obstacle detection)**
Driver's age	**ADAS - Speed alert functionality** **IVIS - Weather, traffic and black spot warning**

Example of ADAS/IVIS working:

If the support system is on: A moped is driving straight on a rural road (no motorway or two carriageway road). There is a slow passenger car moving in front of the moped. The moped wants to overtake and enters in the opposite lane. There is an oncoming car. The "Frontal Collision" system warns the rider that the distance to the oncoming car gets too close. The possible accident may be averted, if the rider obeys the warning of the system.

CONCLUSIONS

The main characteristics of PTW accidents susceptible to be avoided or minimized through ADAS and IVIS implementations have been obtained through 'Literature review' and analyses over 'National' and 'In-depth' PTW accident databases, which have been carried out in the first steps of SAFERIDER project (FP7 European funded project).

One of the in-depth accident databases available to SAFERIDER project has been DIANA. During this paper, a brief explanation has been given about how an important and innovative working methodology developed in DIANA is helping to hospital members to diagnostic possible injuries before people involved in accidents arrive to hospitals.

The use of DIANA accident database, as well as other in-depth and National databases has allowed to obtain the characterization (e.g.: road, rider and PTW characteristics; pre- and post-accident manoeuvres; road layout; rider behaviour; impact points, accident situations) of 17 PTWs accident scenarios 'susceptible' to be avoided or minimized its effect through the implementation of ADAS-IVIS on the PTWs.

The next step of SAFERIDER project will be the use of this information, as well as the information from 'User forums' carried out and 'User needs' analysed, with the only objective of selecting the four ADAS and the four IVIS most important with respect to safety and therefore with highest priority. Then, the systems will be implemented to PTWs and tests either through simulation scenarios on a driving simulator or real test will be developed. Finally, cost-benefit analyses will be performed to identify the social impact of the implementation of the selected ADAS-IVIS systems.

ACKNOWLEDGMENT

The authors would like to acknowledge the following SAFERIDER partners: FEMA, METASYSTEM and MIRA, for their contribution to this study.

REFERENCES

[1] European Road Safety Observatory. "Traffic Safety Basic Facts 2008. Motorcycles and Mopeds".

[2] SAFERIDER project: www.saferider-eu.org/

[3] References used in task 'Literature review':

-Molinero et al. 2008. "TRACE project: Preliminary accident road users".

-Happon H. 2006. "APROSYS project: Report on Accidentology analyses for motorcycles/riders impacts against vehicles. State-of-the-art of motorcycle protective devices. Future research guidelines. AP-SP41-0002".

-Peldschus S.. 2006. "APROSYS project: Report on accident scenarios for motorcycles-motorcyclist-infrastructure interaction. State-of-the-art. Future research guidelines. AP-SP41-0003".

-Manzardo D. 2006. "APROSYS project: Report on the Performance of Riders Protective Devices. AP-SP4-0004".

-Molinero et al. 2007. "APROSYS project: Accident reconstruction. Methodology and scenario. AP-SP4-0005".

-König J. et al. 2007. "SIM project: D2.1-Report on analyses of motorcycles accidents databases".

-ACEM. 2004. "MAIDS project: Final report".

-Clarke et al. 2004. "An in-depth case study of motorcycle accidents using police road accident files".

-Assing, K. 2002. "Schwerpunkte des Unfallgeschehens von Motorradfahrern".

-PISa consortium. 2007. "PISa project: D8-Final-General-Flyer".

-Bos N et al. 2006. "Traffic Safety Basic Facts 2006. Motorcycles and Mopeds".

-Andreone L. et al. 2006. "Watch-Over project: D2.1 Requirements and use cases".