J. P. Dias
IDMEC – Department of Mechanical Engineering,
Instituto Superior Técnico,
Technical University of Lisbon, Portugal

Notation

TWMV   Two wheels motor vehicle
OV   Other vehicle

Accidents Involving Motorcycles and Pedestrians in Portugal

Introduction

Abstract

Portugal has the highest rate of road fatalities in Europe (2002 and for Eur-15 - CARE database). For this highest rate, the accidents involving pedestrians and motorcycle occupants have a higher contribution than the European average.

In the last years, especially accidents involving motorcycles have been investigated and currently two different projects are being carried out, one related with motorcycles accidents and the other with pedestrian accidents. In these projects, countermeasures among others to reduce the fatalities between these two types of road users are being studied.

These accidents are investigated with the commercial accident reconstruction software PC-CRASH but also new methodologies based on multibody dynamics are in development in order to more accurately study these two types of accidents. In this paper, the methodologies in use for accident reconstruction and new methodologies in development are presented.

Speeding his found to be one of the major causes of road fatalities for pedestrians and motorcycle occupants. In the case of motorcycle accidents, these involve mainly young drivers. Aspects as social behavior are also important to understand the causes of some of these accidents. Some examples of accidents occurring in Portugal, involving especially motorcycles and pedestrians are presented and discussed.

In 2003, according to the Portuguese accident data, 41495 accidents with injuries occurred, 1498 persons died (within 30 days: correction factor = 1.14), 4659 severe and 50599 slight injuries occurred. Portugal is one of the European countries with higher rates of road fatalities and accidents. This numbers are unacceptable in a social viewpoint, and the socio-economical cost for the country is estimated between 1498 and 5385 million Euros. The reduction of the Portuguese road fatalities involves among others countermeasures the in-depth study of the road accidents. The development of methodologies for the study of road accidents is very relevant for a wide group of entities, from the legislators, the traffic police, the courts, the insurance companies and for all the victims and relatives involved in road accidents. The accidents involving motorcycles and pedestrians represent, in Portugal, about 40% of all injuries. The statistical data for the year 2003 is presented in table 1, where the motorcycles have been separated in two groups; moped or scoter vehicles with engine size lower than 50 cm^3 and motorcycles having an engine size greater than 50 cm^3. The conditions namely driver license and qualifications required for these two types of motorcycles are quite different.

In the Portuguese statistics only three levels of injuries are recorded (fatal, serious and slight). A more accurate classification of injuries such as AIS is necessary. European harmonization requires homogenous definitions to establish meaningful comparisons.

	Injuries					
	Fatal(*)	% of Total	Serious	% of Total	Slight	% of Total
Moped (<50cm^3)	138	10.2	628	13.5	5482	10.8
Motorcycles (>50cm^3)	187	13.8	585	12.5	4086	8.1
Pedestrians	274	20.2	902	19.4	6326	12.5
TWMV + Pedestrians	599	44.2	2115	45.4	15894	31.4
Total (For all vehicle types)	1356		4659		50599	
(*) Fatalities on accident scene according the Portuguese statistics						

Tab. 1: Injuries involving pedestrians and motorcyclists in Portugal 2003 [1]

When comparisons are made between Portugal and other European countries [2], Portugal has 11.2 deaths per 10000 two wheels vehicles (2001 data), when other south Europe countries have rates as Spain 2.5, France 2.2 and Italy 1.7. Unfortunately there are no more accurate statistics for the two wheel vehicle such as rider deaths by motor vehicle kilometers.

Another interesting fact form the statistics is that Portugal has the highest share of frontal collisions in EU-15 (data from 1992-1995 [3]) of 21.5% when in Spain the frontal collisions only represent 5.4% and in Italy 7.6%. In the data presented in [3], Portugal presents the second highest fraction of injured motorcyclists per total injuries. This fact has to be deeply investigated and one of the causes that can lead to this situation can be, in addition a to large quantity of frontal impacts, related with the speed.

The in-depth study of the accidents involvs motorcyclists in a current issue in Europe that is illustrated by the European Project, MAIDS [4]. Unfortunately in this project Portugal has not been involved but all the detailed methodologies and knowledge from this project are to be considered in the in-depth study undergoing. Other in-depth research reports concerning motorcycle accidents have been conducted, namely the work of HURT [5] who founds for instance and increasing risk of motorcycle injuries related with speed.

The in-depth analysis of accidents involving pedestrians is another issue of concern, because they represent about 20% of the road fatalities in Portugal. Education efforts on education and the change of the behavior of pedestrians [6] and measures to modify the social environment are some of the measures that have been analyzed to reduce the number of pedestrians injured. The characteristics of the persons involved in accidents and the circumstances of the accidents have proved [7] to be very important to the understanding of these phenomena. Speed and crash severity for pedestrian accidents are found to have a strong connection by GARDER [8].

The work presented hereunder in just the preliminary approach of two in-depth research projects of accidents involving motorcycles and pedestrians will be carried out with the financial support of the Allianz Portugal, DGV (Portuguese Directorate-General for Traffic) and PRP (Road Safety Prevention Institute).

Methodologies

The methodologies for the study of accidents involving motorcycles and pedestrians, presented hereunder, are based on the following steps. The starting point is the information from the police reports that include the more relevant data including diagrams and other information required for the reconstruction. The information contained in the police reports is sometimes incomplete, and one of the aims of this undergoing work is also to collaborate with the police and traffic authorities in order to improve the quality and the quantity of the data collected at the crash scene. Next, when some information is missing or some questions arise, the vehicle (if still available) has been mechanically inspected in order to detect mechanical failures or malfunctions and also evidences related with the contact between vehicles or vehicle and road users. From these data, a 3D accident reconstruction has been performed, as in the cases presented hereunder using the software PC-Crash [9]. All the data resulting from the reports and accident reconstruction is included in a Microsoft Access database. Of course a detailed 3D accident reconstruction is almost impracticable to do for all the accidents occurring. In the future also non-accident population is to be included. Regarding motorcycles, the on-scene in-depth motorcycle accident investigations methodology by the OECD [10] will be adopted.

Accident Reconstruction

In opposition to automotive vehicles where the pre and post-crash movement is in the majority of the cases planar, motorcycles have frequently three-dimensional motions and sliding/skidding during fall down. Due to these three-dimensional motions the classical accident reconstruction techniques based on deformation or speed from skid and sliding marks can lead to erroneous results. Also the estimation of speed from skid marks should be used carefully because a significant number of the drivers in an emergency situation only use the rear brake. One example is presented in figure 1. Based on the deformations presented by the vehicle (left side showing evidence of an impact), one expert concluded that the moped vehicle was doing a U-turn. However the reconstruction of the motion shows that the moped was traveling in the same

direction as the car that hit it. Two frames of the accident showing the rotation of the moped are presented in figure 2.

The accurate reconstruction of accidents involving motorcyclists and pedestrians requires the use of three-dimensional models. These models are necessary to reproduce the motion of the vehicles as also to estimate the injuries in pedestrians and to correlate them with the medical reports in order to allow the determination of the vehicles' speeds.

Multibody dynamics models are used in many fields, from vehicle dynamics, human body models to crashworthiness. Theses models are to be adapted to accident reconstruction of motorcycle accidents, giving a more reliable description of the vehicles' pre- and post-crash dynamics, and will include also models for occupants such as the Madymo models [11].

Fig. 1: Moped damage

Motorcycle Accidents: Case Study

In table 2 some relevant data for eleven accidents involving motorcycles having occurred in Portugal are presented. The results are yet preliminary and are not fully detailed. These examples are mainly cases where the reconstruction has been required by courts in litigation processes, because the rider die or because conflicting statements supplied by the witnesses or persons involved in the accident are observed.

The accident reconstruction has been carried out using three-dimensional reconstruction techniques that have been briefly described in the previous section. The determination of the impact speed and the pre-impact direction of the vehicles is a crucial point that is requested by courts. In the data presented, it can be observed that only in one case no helmet use is observed. This agrees with the Portuguese statistics that reveal that the helmet use is greater than 90%. Alcohol use is considered one of the major causes of accidents in Portugal. However in this sample only one case has been detected, in which curiously both drivers were drunk. In the cases presented, accidents involve motorcycles and several types of other collision partners, from trucks to forklifts. The most surprising accident in this sample is the collision off-road between a moped and a motorcycle. The two occupants of the moped vehicle die and the occupant of the motorcycle has been severely injured. No vehicle has insurance and the motorcycle does not have even a license plate and registration.
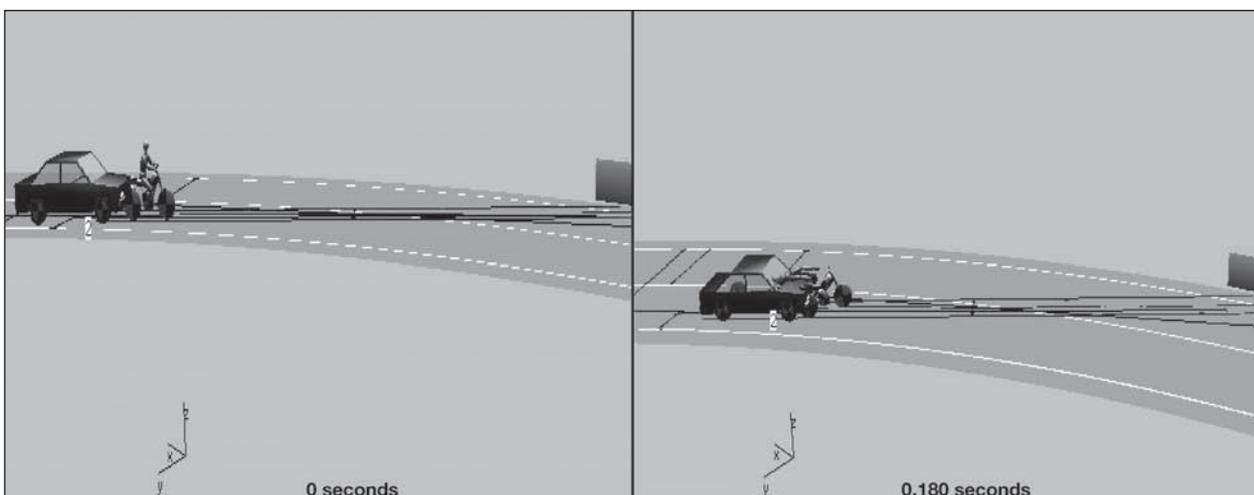
Fig. 2: Reconstruction of an accident involving a moped vehicle

CASE N.	Helmet Usage	Alcohol Use	Vehicle Type	Collision Partner	Motor-cyclist Injuries	Motor-cycle Speed	Speed Limit	Primary Contrib.	Day-time	Weather
1	Yes	NA	Moped	Truck	Severe	30	50	Motor.	Day	Dry
2	Yes	Yes	Motor.	Truck	Fatal	110	50	OV	Night	Dry
3	Yes	No	Motor.	Car	Fatal	75	50	OV	Night	Dry
4	Yes	No	Moped	Car	Fatal	15	90	OV	Day	Dry
5	No	No	Moped/Motor.	S/M	Fatal (2)	40/25	NA	Motor.	Day	Dry
6	Yes	No	Motor.	Car	Fatal	145	50	Motor.	Day	Dry
7	Yes	No	Motor.	Forklift truck	Fatal	150	90	Motor.	Day	Dry
8	Yes	NA	Motor.	Car	Minor	30	50	OV	Night	Dry
9	Yes	No	Motor.	Car	Minor	45	50	OV	Night	Dry
10	Yes	No	Motor.	Guard rail	Fatal	115	90	Motor.	Day	Dry
11	Yes	No	Motor.	Truck	Fatal	127	50	Motor.	Day	Dry

Tab. 2: Motorcycles accidents in Portugal: case studies

Fig. 3: Motorcycle license plates in some European countries the (Portuguese one is on the left side)

Even if the primary contribution for the accident is the other vehicle driver, speed plays a crucial role in the severity of the accident. For the nine fatalities presented, speed above the limits was observed in six cases. The typical profile of the drivers of the moped vehicles involved in the accidents presented are very young boys or older men. The license qualifications to drive a moped vehicle in Portugal are very easy to obtain because only the basic notions of the road laws are required. In addition concerning motorcycles the typical driver is a 20-30 year old male.

One of the aspects related with speed enforcement is the dimension of license plates. In Portugal they are quite small, and are sometimes hidden or intentionally deteriorated or presenting small sizes that are legally specified. Because of this the enforcement of speed and impaired driving laws becomes difficult. The behavior which breaks the traffic rules is an element of risk causing road traffic accidents [12].

For the data presented all accidents occurred at good weather conditions and some of them at night.

The in-depth mechanical inspection of the vehicles is very important. Some details are not registered in

Fig. 4: Mechanical failure of motorcycle components

the police reports but sometimes they play a crucial role for the determination of the accidents causes. Traffic police reports usually do not contain detailed information to fully understand the causes of the motorcycles accidents. Detailed photographs are in the majority of the cases absent and also a mechanical inspection of the vehicles is not performed. As an example in figure 4 the photographs of a frontal damper failure are presented. Initial suggestions are that this fatal accident has been caused by a mechanical failure. A more detailed inspection of the vehicle and guard rails and the 3D reconstruction of the accident have shown that the mechanical failure has been caused by a violent impact against the vertical beams of the guard rail. The scratch presented in
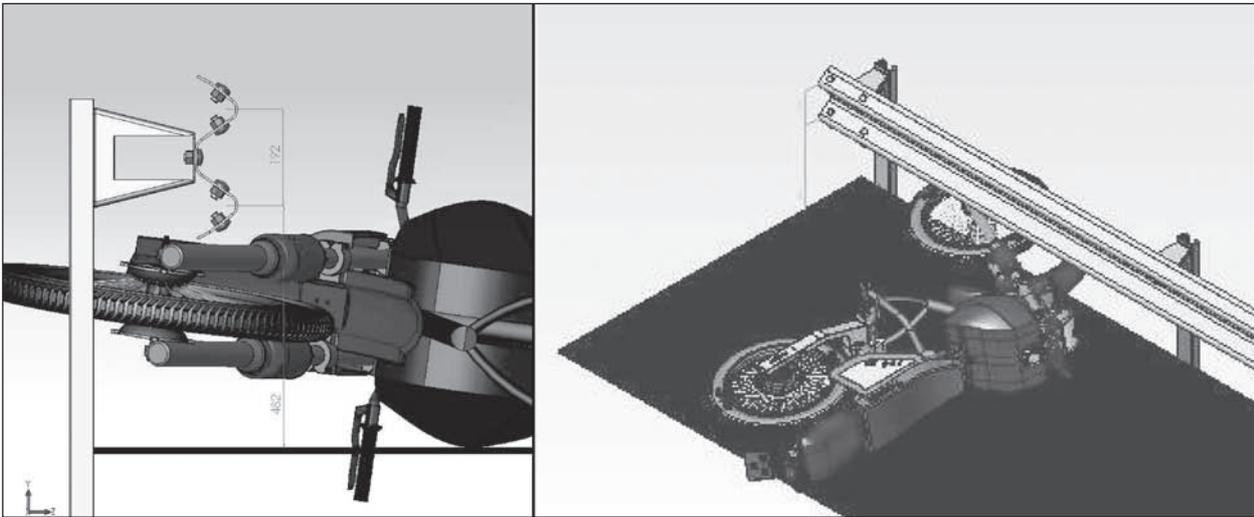
Fig. 5: CAD 3D models for accident visualization
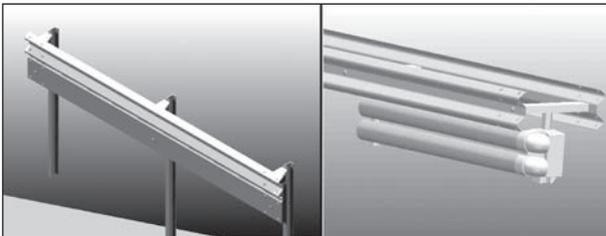
Fig. 6: Guard rail models for motorcyclist protection

the mechanical component has been caused by the sliding of the structural parts of the motorcycle into the lower part of the W beam of the guard rail. Scientific visualization tools or even CAD 3D models can be used to illustrate these aspects of the accident, as indicated in figure 5.

The reconstruction of motorcycle accidents is a difficult task. The information about crash-tests is limited and the commercial accident reconstructions available sometimes have some difficulties dealing with some accident scenarios. In addition to the necessary crash data, multibody dynamics models can give an important contribution providing a more accurate modeling of the pre- and post-crash dynamics of the vehicle as also to include crashworthiness description. We are currently developing these types of models. The protection of motorcycles in the impact with guard rails is under investigation, in order to provide guidelines for the design of the road and necessary location of these motorcyclist protections. Also with regard to the limits of survivability (speed and angle) in collisions motorcyclist guard rails are to be found.

Pedestrian Accidents: Case Study

The rate of accidents involving pedestrians, in Portugal, is comparatively higher than in the other European countries. In figure 7 the pedestrian deaths in Europe are presented. As can be observed Portugal has the highest fatality rate per population in Europe-15 when the data is normalized using the population.

In opposition to Europe where the majority of the pedestrian fatalities are in the age group of children and younger, in Portugal the most important group of risk are the older persons as can be observed in figure 8.

A very large portion (about 90%) of the pedestrian fatalities occurred in urban areas.

In table 3 two cases of pedestrian accidents analyzed with the described methodologies are presented.

The accidents already analyzed concerning pedestrians are for now very limited. However in the two cases presented, because no witnesses saw the accident, it was necessary to compare the medical reports with the injuries values calculated from the simulations. Case 2 presents a case where the car hit an older pedestrian at a cross-road at night in an urban area. The excess speed was only 5km/h but the impact speed was large enough to cause the death of the older person due to the violent impact on the ground. Visibility of pedestrians is one of the concerning issues as also the traveling speed of the vehicles in urban areas. Another aspect that is to be analyzed is car's age that is, in Portugal, one of the highest in Europe.
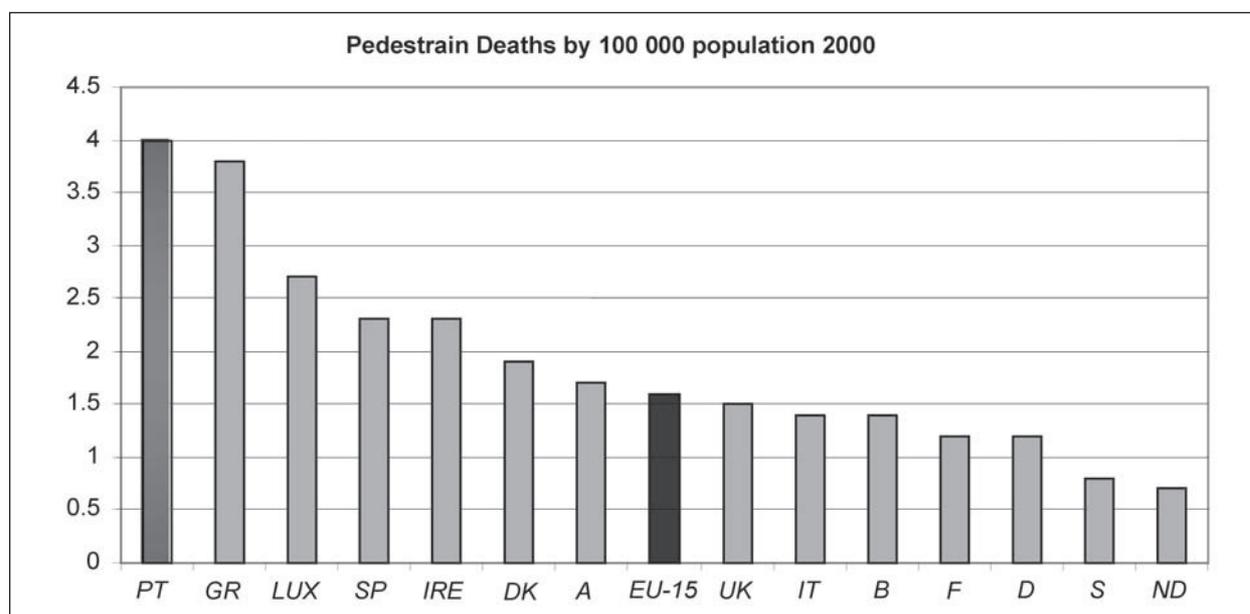
Fig. 7: Pedestrian fatalities in Eur-15 in 2000 (Source IRTAB)
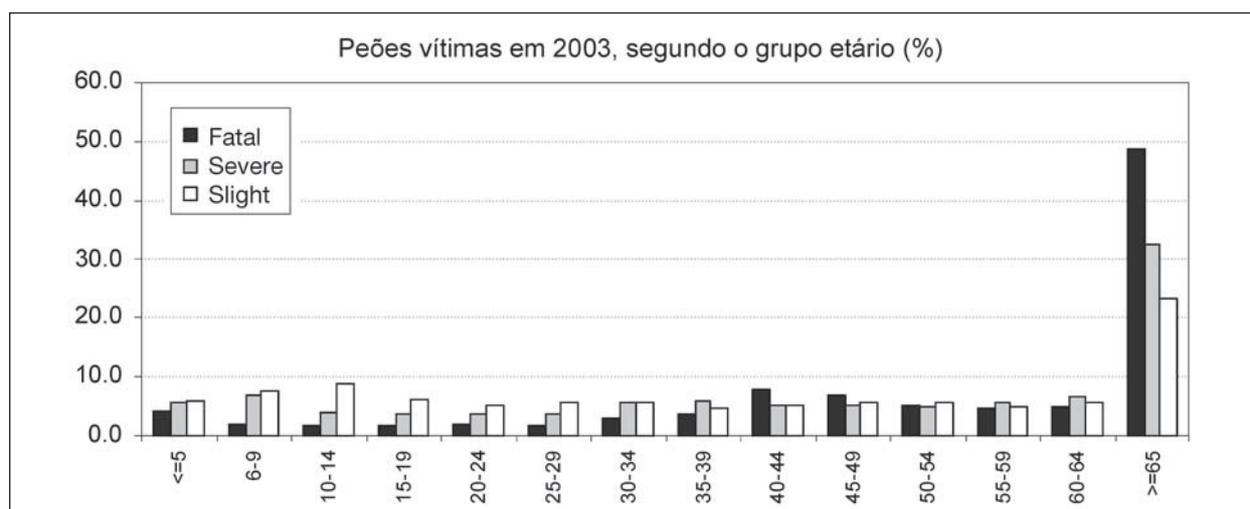
Fig. 8: Pedestrian fatalities in Portugal by age group

CASE N.	Pedestrian Age	Pedestrian Fatality	Vehicle Type	Impact Speed	Speed Limit	Primary Contrib.	Light	Weather
1	42	No	SUV	40	50	Driver	Day	Dry
2	75	Yes	Car	55	50	Driver	Night with public lights	Dry

Tab. 3: Pedestrian accidents in Portugal: case studies

The last years' improvements in vehicle safety, in particular to protect pedestrians, have some impact especially in the consequences of the impacts.

On urban roads in Portugal, data about the traveling speeds show that 70% of the drivers exceed the speed limits. Impact speed has a major influence on injury outcome. The influence of the vehicles speeds in the consequences of the accidents is a very important aspect to be deeply analyzed.

Discussion

Pedestrians and motorcyclists are worldwide two groups of risk. However in Portugal, the contribution of these groups to the overall injuries is much higher than the European average. From

the accidents already analyzed especially involving motorcycles, speed has an important contribution to the severity of the injuries.

From this work countermeasures to reduce the number of fatalities are to be proposed. Some aspects already identified include the dimensions and the visibility of the license plates, the riding training for motorcyclists, rider qualification and training in emergency situations and speed limit enforcement.

Concerning pedestrians, their improper actions are problematic. Education can be a good solution for kids and younger persons but it is very difficult to apply to older persons (60 years and more), so special countermeasures for this group of risk have to be analyzed. Illegal and dangerous parking of the cars as also a better design of the urban roads for pedestrian protection are also aspects that have been identified but their contribution to the injuries of pedestrians must be quantified.

For the in-depth study of accidents and accurate reconstructions of these accidents the data collected by the authorities are very important. Procedures to more accurately collect the information such as scale-diagrams elaborated with CAD software, more detailed reports including more specific data related with motorcycles and pedestrians, detailed photographs of the vehicles on the scene as also of the accident scene and obstacles or barriers are necessary.

An accurate reconstruction to accidents involving pedestrians and motorcyclists requires 3D reconstruction tools as also biomechanical models. Also the increase of the quality of the computerl models and the development of new formulations, procedures and models with tools and methodologies from multibody dynamics, vehicle dynamics, crashworthiness and even optimization are two of the objectives of the work going on.

The issues already identified as important for the determination of crash risk and influence in accidents include for motorcycles:

- Daytime headlights for motorcycles are mandatory, but not always respected by motorcyclists.

- License plates for motorcycles have small dimensions when compared with other European countries, and sometimes hidden or intentionally deteriorated licenses plates are detected on Portuguese roads.

- The Portuguese legislation is not clear if illumination of the license plates is mandatory or not, and an important number of motorcycles do not have it.

- Turn-lights are sometimes neglected.

- Mirrors are not mandatory.

- No limits for the top speed or engine power of motorcycles are mandatory. The risk of injury versus engine power is to be evaluated.

- Moped or mofa vehicles are limited by law at an engine size lower than 50cm^3 or a top speed of 45km/h. Tampered vehicles are to be investigated.

- A regular mechanical inspection is not mandatory for two wheels vehicles. The influence of mechanical malfunctions or the quality of critical parts such as tires in accidents is to be included.

Other issues related with pedestrians

- The number of pedestrians respecting traffic lights and crossing outside crosswalk areas (when they are available) is by simple observation poor and is to be quantified.

- The conditions and characteristics of the roads in zones of accumulation of accidents of pedestrians are to be investigated.

- The effect of a higher vehicle age when compared with other Europeans countries and its effect on the severity of the injuries.

Ongoing and future measures to conduct an in-depth study of the accidents

- Collaboration with the traffic police and traffic authorities in order to improve the quality of the accident reports, diagrams and sketches, and accident databases. For instance the accident databases present the same lacks concerning accidents involving motorcycles and pedestrians.

- Video surveillance of accident scenes to collect information about the behavior of motorcyclists and pedestrians in these areas. Digital video and digital photographs will provide a more

relevant data including behavior of pedestrians and motorcyclists, environment conditions and their contribution to the accidents which can also be used to estimate the speed of the vehicles in these areas.

Acknowledgements

References

1 Portuguese Directorate-General for Traffic (DGV): Road Statistics 2003 (in Portuguese available at www.dgv.pt)

2 MASUREL, P.: Investigating explanatory factors in fatality trends and rates between EU countries investigating differences in definitions and collection procedures, Transport Statistics: Road Safety, Department for Transport, United Kingdom, 2003

3 STEFAN, C., HÖGLINGER, S., MACHATA, K.: Case study: Motorcycle accidents, KfV – Kuratorium für Verkehrssicherheit, Austria, 2003

4 Maids Project: Final Report 1.1, 2004

5 HURT, H. H., QUELLET J. Z., THOM, D. R.: Motorcycle accident cause factors and identification of countermeasures. Technical report, Vol. 1. US Department of Transportation, National Highway Traffic Safety Administration, Washington, DC, 1981

6 FONTAINE, H., GOURLET, Y.: Fatal pedestrian accidents in France: a typological analysis. Accident Analysis and Prevention 29 , 303–312, 1997

7 HARRUFF, R. C., et al.: Analysis of circumstances and injuries in 217 pedestrian traffic fatalities. Accident Analysis and Prevention, 30 (1), 11–20, 1998

8 GÅRDER, P. E.: The impact of speed and other variables on pedestrian safety in Maine. Accident Analysis and Prevention, 36, 533–542, 2004

9 PC-CRASH "A Simulation program for Vehicle Accidents": Technical Manual, Version 6.2, 2002

10 OECD, Motorcycles: Common International Methodology for On-Scene, In-Depth Accident Investigation, Paris, OECD/DSTI/RTR/RS9/ICC, 2001

11 Madymo Software (www.madymo.nl)

12 ELANDER, J., WEST, R., FRANCH, D.: Behavioural correlates to individual differences in road-traffic crash risk: an examination of methods and findings. Psychol. Bull. Vol. 113, pp. 279–294, 1993