Analysis of traffic accidents involving two-wheeled vehicles

Christian Caparrós Hernández

Supervisor; Prof. Dr. João Manuel P. Dias, Prof. Ramón Peral Orts

September 2008

Abstract – This article shows the results obtained after the analysis of the traffic accidents database involving two-wheeled vehicles, as a trying of identifying the most common cause of accidents in Portugal. In addition, real accidents involving PTW has been simulated by the software PC-Crash, finding about all the parameters which have influence on an accident. Finally, the controversy situation generated due to about possible alteration of the Portuguese traffic law in benefit of motorcycles will be discussed, analysing the Spanish current situation after the change of the mentioned law.

Keywords – Two-wheeled vehicles, Reconstruction of traffic accidents, Fatality rate, Reglamento General de Conductores alteration, Código da Estrada alteration

1. Introduction

Road safety is one of the main problems in developed countries. A total of 42,955 European citizens died in traffic accidents in 2006 [1]. According to ETSC [2], traffic accidents are the main cause of death and hospital admissions for younger-45-years-old European citizens. In addition, 3.5 million of accidents annually take place in the European roads, having an associated cost of 166 trillions of Euros. In spite of notably decreasing the rate of fatalities, Portugal is still one of the European countries with the highest rate of road fatalities, mainly compared with the old EU\(^1\) formed by 15 countries, being traffic accidents one of the main causes of death in Portugal [3].

PTW drivers are, like the pedestrians, the most vulnerable users, as a consequence of their specially characteristics. Due to their narrowness and acceleration they have the ability to overtake and to filter past other traffic. Therefore, they are not often seen by the four-wheeled vehicles, being run over by them. In addition [3], a PTW can easily become unstable and capsize if braking, accelerating or a slippery road surface cause a wheel to lose adhesion, being particularly critical if the machine is leaning to take a bend. Therefore, PTW have the highest probability of being involved on an accident [4]. In fact, a motorcycle rider has a 35% higher likelihood of suffering an accident compared with cars users.

\(^1\) European Union
Furthermore, PTW users are completely exposed to suffer injuries once the accident has taken place, due to the lack of external body work. Therefore, the probability of suffering serious injuries or dying is much higher than for the other typologies of vehicles. The users whose vehicles had non-external bodywork are the ones which the highest rate of fatality once the accident has taken place. Thus, the likelihood of dying in case of an accident is three times higher for motorcycles users compared with cars, being two times higher in case of the bicycles. Therefore, it is actually important to find about why the accidents happen to be avoided in the future.

2. Analysis of the PTW accidents in Portugal

All the PTW accidents happened in Portugal for 2007 have been analysed, being a total of 9,807 accidents.

Table 1: Accidents frequency by PTW category in 2007 [5]

<table>
<thead>
<tr>
<th>Type</th>
<th>Frequency</th>
<th>Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Moped</td>
<td>4435</td>
<td>45,19%</td>
</tr>
<tr>
<td>&lt;50cc motorcycles</td>
<td>625</td>
<td>6,37%</td>
</tr>
<tr>
<td>&gt;50cc &lt;25kW</td>
<td>1289</td>
<td>13,15%</td>
</tr>
<tr>
<td>&gt;50cc &gt;25kW</td>
<td>2019</td>
<td>20,6%</td>
</tr>
<tr>
<td>Bicycle</td>
<td>1383</td>
<td>14,1%</td>
</tr>
<tr>
<td>Engine-powered bicycle</td>
<td>56</td>
<td>0,57%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>9807</strong></td>
<td></td>
</tr>
</tbody>
</table>

Mopeds were involved in the 45,19% of the total PTW accidents for 2007. Obviously, the frequency of the accidents depends on the vehicle fleet. Mopeds fleet [6] is more than 2.5 times higher than all motorcycles fleet together, so a moped rider has less possibilities of being involved on an accident than a motorcycle. Road safety is not only measured by the total number of victims, being also important the grade of the victim; fatal, seriously injured or slightly injured.

The greatest rate of fatalities is covered by >50cc and non-power restricted motorcycles, representing a 42, 55% of total fatalities. However, mopeds presents the highest rate of seriously injured and slightly injured, covering a rate of 39,03% and 45,32% respectively. Thus, it is possible to affirm that, even mopeds accidents rate is the highest one, the consequences of these accidents are not as serious as they are in >50cc and non-power restricted motorcycles. This is due to >50cc and non-power restricted motorcycles are more designed to run in motorways, where vehicles can run in much higher velocity than in urban roads, so the accidents consequences are more serious.

![Figure 1: Fatalities, seriously injuries and slightly injuries by PTW category in 2007](image)

More than the half of the accidents happened as a consequence of side on-crashes against moving vehicles and losses of control, representing a percentage of 37,01% and 19,83% respectively. Side on-crashes are so common in the PTW due to the lack of attention [3] by the four-wheelers vehicles. Car drivers do not have mental perception of a collision with lighter vehicles like PTW, being an impending danger to them personally, feeling protected by the body car. In the other hand, losses of controls are quite usual for the PTW due to their own defining characteristics; PTW are single track vehicles, so they can easily become unstable in many situations. In addition, riders need to avoid wheel-locking making the best use of brakes in emergency situations. Also, road markings can produce steering instability, carrying out the loss of control of the vehicle.

The road safety in the Portuguese roads varies according to the different districts. The highest rate of
accidents was covered by Faro district, happening 209.2 accidents per 100,000 inhabitants. Faro district is closely followed by Aveiro, Coimbra and Leiria. In these districts is found the IP5 motorway, which has been considered as one of the most dangerous motorways in the world [7]. On the contrary, the safest Portuguese districts are Bragança and Portalegre, covering a rate of 50.67 and 55.02% accidents per 100,000 inhabitants, respectively.

Figure 2: PTW accidents per 100.000 inhabitants by district in 2007

The most conflictive time of period is from 17.00 to 20.00 hours. This is due to workday ends at this time, being roads full of users, increasing the likelihoods of suffering an accident. The rate of accidents moderately increased at weekends and in summer time. The first reason is that [3] exists a big community of PTW users who drives as a hobby, riding in their free time, being in weekends when normally workers can enjoy their free time. The second reason is related with the optimum weather conditions, due to the lack of protective body against the external condition, being during the summer time when increases the users of PTW.

3. Reconstructions of real PTW accidents

Real PTW accidents were simulated with the aim of calculating crash vehicles speeds, studying all the accident circumstances and corroborating all the factors which took part in the accident. The tool used to carry out the accidents simulations was the software PC-Crash. PC-Crash is a collision and trajectory simulation tool that enables the analysis of vehicle collisions and other incidents. Results are viewed as 3D-animations and reports, tables and graphs. Accidents were simulated using two different kinds of models: vehicle’s model without passengers, defining vehicles, directions, velocities, accelerations and all the parameters which take part in the accident; and multi-body models which include three-dimensional bio-mechanic models of the human body so injuries suffered by the passengers can be calculated. Multi-body system is consisted by several rigid bodies, which represent the different parts of the human bodies like head, torso, pelvis, etc are interconnected by joints. For each body different properties like geometry, mass contact stiffness and coefficients of friction can be specified. The geometry for each body is specified by defining a general ellipsoid.

Figure 3: a) Multi-body pedestrian used by PC-Crash
   b) Multi-body motorcycle and used by PC-Crash

A total of eleven real PTW accidents provided by the Portuguese police were simulated. The accidents happened among 2004 and 2007 in Portugal. After the simulations, it was possible to graphically understand how the accidents happened and which were the causes by which were originated, calculating the fundamental factors involved in the accidents, as pre-impact velocities, accelerations, trajectories, etc.

The accidents simulations were started with the construction of the scenes of the accidents. Roads with their corresponding number of lanes, obstacles, signs or even slopes were drawn. The construction of a similar scene of the accident was fundamental to understand how
the accident happened and to can measure the distances covered by the vehicles.

Once the scene of the accident was constructed, the same vehicles which were involved in the accident were added. After including positions, velocities, sequences, trajectories and all the accident parameters, the simulations were run. When the simulations were finished, pre and post impact velocities, kinetic vehicles energies, vehicles deformation, plane and point of impact, etc. were checked to corroborate the results with the police reports. When all the accidents parameters were right, multi-body models were added to the simulation, finding about the riders final positions as well as comparing the real personal injuries with the multi-body injuries showed by the software.

4. Study about the possible Portuguese CD alteration analysing the consequences of the Spanish RCG alteration

Traffic congestion is one of the main problems in developed countries [2], being related with important economic losses associated with wasted time, rise of the environmental pollution and fuel consumption, etc.

Therefore, some European countries have changed their traffic laws in benefit of motorcycles, which can notably reduce the traffic congestion. Concretely, the law which allows car users the driving of the motorcycle hold by the type A1 driving licence has been modified. This changed has generated a controversy situation because motorcycles fatalities have increased since then.

Spain is one of the countries which has change its RGC² allowing car users whose driving licence were older than years the driving of A1 motorcycles, it means under 125cc-power motorcycles. Nowadays, the possible alteration of the CD¹ is being discussed in Portugal, where some non-governmental associations [8] have already asked the Government the change of the mentioned law. The Spanish current situation after the traffic law alteration has been studied, as a trying to determine the advisability of the change.

Under-125cc-power motorcycles were the only motorcycle category which was altered by the RGC alteration. This change in the traffic law allowed more than 13 million of car users the driving of this kind of motorcycles [9]. Since then, the volume of sales involving A1 motorcycles has increased a 690.1%, it means that 124,660 A1 new motorcycles were registered in 2006 compared with 15,776 in 2003. In addition, all the motorcycles categories have been influenced by this new law, increasing the volume of sales of the other categories too. Generally, the motorcycles registration has increased in 270.37% compared with 2003. On the contrary, the motorcycles registration in Portugal is decreasing year by year, being nowadays much lower than the Spanish one.

² Reglamento General de Conductores
³ Código da Estrada
Figure 4: Motorcycles registration in Spain and Portugal [9] [10]

Mopeds characteristics are quite similar to the motorcycles ones, like narrowness, easily way of running, etc, helping to reduce the traffic congestion in the same manner as the motorcycles. However, while motorcycle market has profited from the RGC alteration, mopeds market has strongly suffered the consequences of the change, decreasing the volume of sales year by year. Nowadays, the mopeds registration is a 68.44% lower compared with 2004.

Road safety has notably improved for the last years on the Spanish and Portuguese roads, decreasing the rate of fatalities in a 35% and 50% respectively, since 2000. This improvement in the road safety levels has been shared out among all the vehicles categories, like cars, mopeds, heavy vehicles, etc. However, the number of accidents and fatalities involving motorcycles has notably increased in Spain since 2004. In fact, in 2006 the rate of fatalities was a 38.34% higher compared with the one before the RGC alteration while the total amount of victims increased in 36.35%.

Figure 5: Fatalities, seriously and slightly injuries in Spain [9]

Road safety is not only the measure of the amount of fatalities of victims, being directly related with the number of users, so with the vehicles in used. In spite of the huge rise in the motorcycles fleet, number of victims per one million of motorcycles has increased too in Spain. In fact, it was decreasing year by year until 2004. Nevertheless, the number of fatalities per one million of motorcycles has decreased despite the RGC alteration, decreasing a 8.5% since 2004.

Table 2: Registration of motorcycles, fatalities and victims in Spain

<table>
<thead>
<tr>
<th>Year</th>
<th>Motorcycles</th>
<th>Fatalities</th>
<th>Victims</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>1.234.437</td>
<td>318</td>
<td>9109</td>
</tr>
<tr>
<td>2002</td>
<td>1.355.820</td>
<td>296</td>
<td>7891</td>
</tr>
<tr>
<td>2003</td>
<td>1.429.595</td>
<td>257</td>
<td>7347</td>
</tr>
<tr>
<td>2004</td>
<td>1.550.293</td>
<td>258</td>
<td>7064</td>
</tr>
<tr>
<td>2005</td>
<td>1.768.331</td>
<td>267</td>
<td>7428</td>
</tr>
<tr>
<td>2006</td>
<td>2.041.578</td>
<td>236</td>
<td>8082</td>
</tr>
</tbody>
</table>

Figure 6: Victims and fatalities per one million of motorcycles in Spain
Road safety has improved in Portuguese roads in all the vehicles types, including motorcycles. The number of fatalities, seriously injuries and slightly injuries has notably decreased since 2000.

A total of 5,912 victims of motorcycles happened in 2000 in Portugal. This number decreased until 4,034 victims in 2006, meaning a decrease of 31.76%. Victims and fatalities per one million of motorcycles have also decreased year by year though these rates are still too high compared with the Spanish figures.

Table 3: Registration of motorcycles, victims and fatalities in Portugal [1] [3]

<table>
<thead>
<tr>
<th>Year</th>
<th>Motorcycle</th>
<th>Fatalities</th>
<th>Victims</th>
</tr>
</thead>
<tbody>
<tr>
<td>2000</td>
<td>144,000</td>
<td>212</td>
<td>5912</td>
</tr>
<tr>
<td>2001</td>
<td>158,000</td>
<td>229</td>
<td>5615</td>
</tr>
<tr>
<td>2002</td>
<td>149,000</td>
<td>225</td>
<td>5129</td>
</tr>
<tr>
<td>2003</td>
<td>153,000</td>
<td>213</td>
<td>4884</td>
</tr>
<tr>
<td>2004</td>
<td>159,000</td>
<td>181</td>
<td>5278</td>
</tr>
<tr>
<td>2005</td>
<td>165,000</td>
<td>188</td>
<td>4437</td>
</tr>
<tr>
<td>2006</td>
<td>144,000</td>
<td>137</td>
<td>4034</td>
</tr>
</tbody>
</table>

Figure 7: Number of fatalities, seriously injuries and slightly injuries in Portugal [3]

Motorcycle manufacture is a very important factor for the economy of many countries, covering an important part of the GDP\(^4\). The motorcycle industry business in Europe is worth Euro 10billion to the European economy [11] and employs 200,000 people. In 2005, 2.5million powered two wheelers of all kinds were sold. Furthermore of the motorcycle manufacture, many sorts of accessories are related with the motorcycle economy, like motorcycles gloves, glasses, boots, jackets, etc.

The Spanish manufacture of PTW had been decreasing year by year since 2001. In fact, 44,400 less motorcycles were manufactures in Spain in just two years. However, after the RGC regulation, the manufacture of two-wheeled vehicles started to increase again. Many motorcycles industries came up with new 125cc motorcycles models, facing up with the new market situation [12]. Some of these new models have been manufactured in Spanish PTW factories, increasing the number of employers and the units manufactured, so their benefits. This change in the traffic law was carried out after several years of bad economic results in the motorcycle industry. Since this moment, the motorcycle industry started to get benefits another time. In fact, [13], if the traffic law alteration had been carried out beforehand, some motorcycles factories would have avoided to close down due to a long period in bad economic results.

\(^4\) Gross Domestic Product
More than 80% of the accidents happened in broad daylight and in good weather conditions. The most dangerous period of the day is between 17.00 pm and 20.00 pm due to the ending of the workday, when workers go back home. The rate of accidents moderately increases in weekends when the riders enjoy their free time increasing the use of the PTW and in summer time, because PTW are quite more used when weather conditions are good.

Since the Spanish RGC alteration, the amount of fatalities and accidents involving motorcycles has notably increased while the road safety has improved in the other vehicles categories. This rise is due to, among other factors, the huge increase of motorcycle registration, being higher than 270% compared with last years. Nevertheless, the rate of fatalities per one thousand motorcycles is still decreasing, so it is not possible to affirm that this law alteration has negative consequences for the road fatalities. After the traffic law alteration, the PTW manufacture has increased in 20% in Spain, generating more employment and benefits.

So considering the current Spanish situation after the RGC alteration and the many benefits of driving in motorcycle (low fuel consumption, low CO\textsuperscript{2} emissions, helping to solve the lack of public parking, etc) it is possible to affirm that Portugal should change the CD allowing car users the driving of A1 motorcycles. This new law could notably increase the motorcycle registration in Portugal, increasing the amount of motorcycle sales and helping the motorcycle industry, which is very little developed. Furthermore, if the number of riders increases, it will help to solve traffic congestion and the problem associated with the public space taken by parked cars.

### References


[12] Cinco días, *El nuevo carné permite a Piaggio España salir de pérdidas y ganar 6,9 millones*, Madrid 2004