DEFINITON OF A METHODOLOGY TO DEFINE A RISK INDEX FOR MOTORCYCLISTS ACCORDING TO THEIR EXPOSURE

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ABSTRACT

The casualty risk of drivers of having a road accident according to their exposure is usually defined by taking into account the frequency of use of the road infrastructure by these drivers. However, this information does not classify drivers according to their characteristics (age, sex, etc.), and does not enable effective measures for each driver profile to be adopted.

The objective of this project was to define a methodology to know the risk of having a fatal accident of a particular user driver group (professional drivers, car drivers, motorcyclists, etc.) according to their exposure to this risk, and according to different driver profiles within each group. An index was also defined, which can indicate this risk. In this study the methodology was applied to motorcyclist road accidents in Spain in 2007. Motorcyclists were classified into different profiles, considering not only the drivers' characteristics but also the type of motorbike they drove. This classification made it possible to discover which groups are more exposed to the risk of having a fatal accident, enabling prevention measures focused on these kinds of drivers to be adopted.

To perform this study a database was created, by merging an existing database which contained information about the victims and the motorbike they drove with another database which contained information about the mileage for each kind of motorbike. Following this the Index of Risk according to Exposure (IREx) for each profile was calculated.

The innovative aspects of this methodology are basically two: IREx assesses the risk by taking into account the mileage of the vehicle, and this assessment is performed separately for each profile of driver and type of motorcycle. The results of the study make it possible to observe some tendencies from which it is possible to draw conclusions which can be helpful in adopting measures to diminish the number of motorcyclist fatalities.

INTRODUCTION

Background

Our planet supports 6 billion people, more than 22m kilometers of roads, 470m passenger cars and 145m vans and trucks. A third of these vehicles travel on roads in the USA and another third in the European Union. According to the World Health Organization, an estimated 1.2m fatalities occur due to road accidents, while another 50m are wounded.

The modern European Union (27 countries) is home to 493m people and 270m registered motor vehicles. Each year there are 1.8m injuries, of varying severity, and 43,000 deaths in road accidents, a figure higher than the US (42,000) which however carries a significantly smaller population (290m) as well as a smaller fleet of vehicles (230m).

These road accidents are responsible for major economic losses, specifically accounting for 1% – 2% of a country's GNP. The European Council of Transport Security estimated the total cost of transport accidents to be about 166b€, 97% of which was related to road accidents.

In 2005, road fatalities of vehicle occupants amounted to 13,771 in the EU (of 14 member states). This represents 53% of deaths (all types) in that year. Of these 13,771 deaths, 9,419 were drivers and 4,349 passengers.

Road accident data from the CASE (Community database on Accidents on the Roads in Europe) database, indicate a high percentage of deaths and serious injuries on European roads, and have consequently led to years of observation, monitoring and acting upon the European citizen's road safety. A clear example is the goal set in 2001 by the European Commission, which aimed at a 50% reduction in road accident fatalities by 2010, a target set in the "European transport policy for 2010: Time to decide". Although the goal was not fully achieved, a significant decrease in fatalities was nevertheless noted (Figure 1). This is very positive, particularly if one takes into account the

increasing number of vehicles on European roads annually and brings optimism to future road safety.

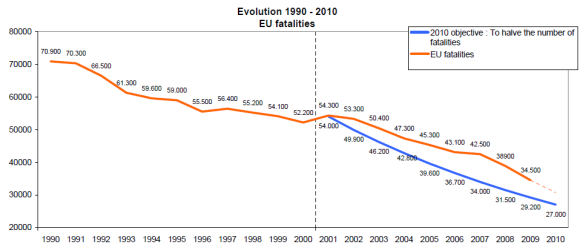

Figure 1. Evolution of road fatalities in the EU-25, 1990-2010 [Source: CARE (EU road accidents database)].

Both manufacturers and European states' governments are continually working to improve vehicle and road safety. The significant reduction of fatalities is largely due to two factors: technological progress of vehicle and infrastructure safety, as well as political measures adopted to improve road safetyand public awareness about road safety.

In Spain, the reduction of fatalities has been higher than the European Union average, coming in 2009 to a reduction of 53% compared to 2001 figures, surpassing the target set by the commission. This demonstrates the effectiveness of measures taken by the government in recent years, such as technological improvements and specific policies which have significantly improved vehicle and road safety and public awareness.

This decline in overall deaths however has not been reflected with the same intensity in **motorcyclists' fatalities**. While it is indeed true that since 2007 motorbikes related deaths have been reduced, previous years saw an increase (see Figure 2).

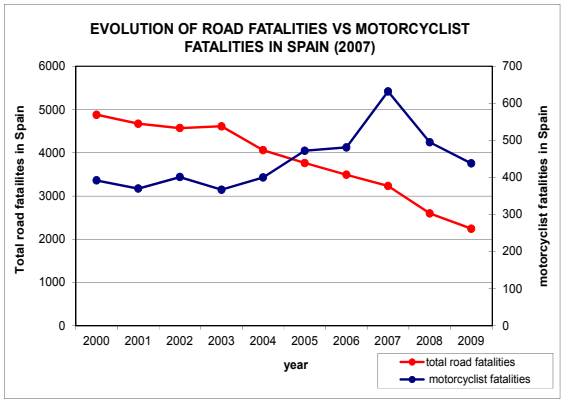

Figure 2. Comparison between absolute road accident fatalities and motorcyclist fatalities in Spain [Source: Statistical Yearbook of accidents (DGT)].

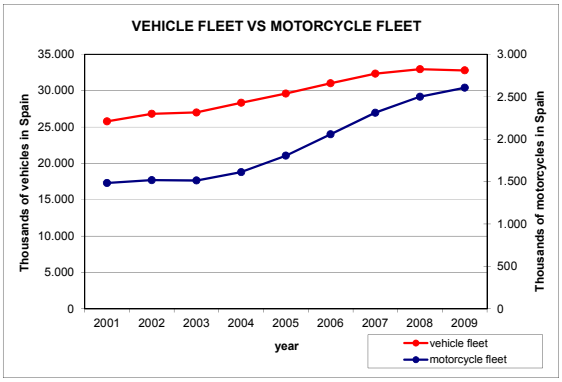

Figure 3. Comparison between vehicles and motorcycles fleets in Spain [Source: Series históricas. Anuario Estadístico General (DGT)].

Looking at Figure 3, it can be seen that over recent years there has been a significant increase in the number of vehicles and also motorcycles. However, in general vehicle accidents over the past decade have been constantly decreasing, whereas motorcycle accidents have been increasing along with the fleet, and only in the last few years has there been a significant decrease. Therefore, we can conclude that there is essentially no valid reason to justify the high number of motorcyclist accidents in the early years of 2000 due to the increase of the fleet of motorbikes.

Objectives

This paper presents a methodology **to determine the risk of suffering serious injuries or death** depending on the specific **exposure** of different groups of road users and average mileage travelled by each of them. In a road accident, the probability of having an (motorcycle) accident should be associated with accident data and the number of kilometers travelled by different groups of motorcyclists and motorcycles. Using the methodology outlined in this study, the several profiles of riders and motorcycles are reviewed, and the chance of them being involved in a road accident, regardless of its severity, can be evaluated.

An indicator was defined, to assess this risk of having a road accident for each group (type of motorcycle and/or engine type), based on accident data and mileage done by the different profile of driver, in other words their real exposure to this risk. Furthermore, this profile classification (by driver age, type of motorbike and engine power) allows us to identify which groups are exposed to more risks, i.e. demonstrating the influence of the profile of the driver and/or type of motorcycle in the overall accident statistics.

WORK METHODOLOGY

Definition of the different profiles

Before starting working with the provided data, the profiles in which the drivers (in this case riders and motorcycles) would be studied and divided had to be pre-defined.

For a number of reasons, an important one being climatic conditions, motorcycles are popular in all age ranges in Spain. The sample through the accidentology data went through the following classification:

- 18 to 24 years old
- 25 to 34 years old
- 35 to 44 years old
- Over 44 years old

In the case of the bikes, two different parameters were taken in consideration to classify them: type of motorcycle and engine displacement. Regarding the former, 8 different types were identified (Annex I, Figure 10):

- Sport
- Naked
- Scooter
- Touring
- Cruiser
- Trail
- Offroad
- Supermotard

Trail, Offroad and Supermotard motorbikes have been included in the same group (the group in this paper is called T.O.S.) assuming the same driver conditions and behavior for them.

Regarding the engine classification, 4 categories of engine size were distinguished:

- 0 cc to 125 cc
- 126 to 500 cc
- 501 to 750 cc
- Over 750 cc

As previously mentioned, characteristics of the distance travelled by different groups of riders which were also considered, came from the technical inspection stations (known by their Spanish abbreviation as ITVs) around Spain.

Methodology

From a practical point of view, this approach of collecting and merging the data in this study consisted of the following steps:

1.- Verification that the sample size was **sufficient** and analysis of the representativeness of the sample using statistics tools (e.g. testing of Pearson χ^2). Once the sample is validated, single file creation coming from the 3 source databases is carried out.

2.- **Building a comprehensive database**, based on information from the motorcycles fleet, in which there are details for the total number of motorcycles relative to one biker profile. These groups are arranged by type of bike, age of owner and engine power. An example of this can be found in Table 1:

Table 1.
Example of a bike/motorcyclist group classification

MOTORCYCLE FLEET			
Type of motorcycle	Age of the owner	Cubic capacity [cc]	number of motorcycles
SPORT	25-34	0-125	6.317
		501-750	6.683
		>750	1.850

3.- Data available from mileage and technical inspection centers in 2007 (ITVs) are added into the table, an example of which can be found in Table 2:

Table 2.
Example of a table in which previous data have been merged with data from the ITVs for a group of motorcyclists

MOTORCYCLE FLEET				ITVs	
Type of motorcycle	Age of the owner	Cubic capacity [cc]	number of motorcycles	milage per year	Nº Motorcycles ITV
SPORT	25-34	501-750	6.683	0-2.000	4
				2.001-5.000	49
				5.001-10.000	131
				10.001-15.000	59
				15.001-20.000	13
				20.001-25.000	1
				>25.000	0
		>750	1.850	0-2.000	2
				2.001-5.000	11
				5.001-10.000	20
				10.001-15.000	16
				15.001-20.000	5
				20.001-25.000	1
				>25.000	0

4.- **Accidentology data merge**, with those relating to motorcycle fleet and annual mileage travelled, distributed under the same criteria for different groups of riders. Table 3 provides an example of this:

Table 3.
Table in which all required data (motorcycle fleet, mileage, fatalities) are merged together

MOTORCYCLE FLEET				ITVs		ACCIDENTS
Type of motorcycle	Age of the owner	Cubic capacity [cc]	number of motorcycles	milage per year	Nº Motorcycles ITV	fatalities
SPORT	25-34	501-750	6.683	0-2.000	4	88
				2.001-5.000	49	
				5.001-10.000	131	
				10.001-15.000	59	
				15.001-20.000	13	
				20.001-25.000	1	
				>25.000	0	
		>750	1.850	0-2.000	2	43
				2.001-5.000	11	
				5.001-10.000	20	
				10.001-15.000	16	
				15.001-20.000	5	
				20.001-25.000	1	
				>25.000	0	

5.- Calculation of the average annual mileage for each group of motorcycle and motorcyclist. The average value of different mileage ranges which are data from ITVs is taken; e.g. if the range is 2000-5000 km/year, 3500 km/year is averaged. The ITV data is obtained considering the number of kilometers travelled by motorcycle from the last inspection to the one performed in 2007, and dividing it by the number of years passed between them. If the inspection performed in 2007 is the first ever, the mileage is going to be divided by the age of the motorcycle.

The annual mileage averages are estimated for all the motorcycles in the ITV sample, classifying them according to the driver profile. This information is then automatically associated with the annual mileage average covered by the victims belonging to the remaining motorcycle groups. This can be seen in Table 4.

Table 4.
Example of the average mileage calculation

MOTORCYCLE FLEET				ITVs		MILEAGE PER YEAR	ACCIDENTS
Type of motorcycle	Age of the owner	Cubic capacity [cc]	number of motorcycles	milage per year	Nº Motorcycles ITV	Km/year average	fatalities
SPORT	25-34	501-750	35.346	0-2.000	4	8.348	88
				2.001-5.000	49		
				5.001-10.000	131		
				10.001-15.000	59		
				15.001-20.000	13		
				20.001-25.000	1		
				>25.000	0		
		>750	11.636	0-2.000	2	9.100	43
				2.001-5.000	11		
				5.001-10.000	20		
				10.001-15.000	16		
				15.001-20.000	5		
				20.001-25.000	1		
				>25.000	0		

6.- Calculation of the accident mortality rate of each group. The number of fatalities of a specific profile is divided by the number of motorcycles corresponding in that group. An example can be seen in Table 5:

Table 5.
Example of the mortality rate ad index of risk according to exposure (IREx) calculations

MOTORCYCLE FLEET				ITVs		MILEAGE PER YEAR	ROAD ACCIDENTS		
Type of motorcycle	Age of the owner	Cubic capacity [cc]	number of motorcycles	milage per year	Nº Motorcycles ITV	Km/year average	fatalities	mortality rate	IREx fatalities [x10e-8]
SPORT	25-34	501-750	35.346	0-2.000	4	8.348	88	0,25%	29,82
				2.001-5.000	49				
				5.001-10.000	131				
				10.001-15.000	59				
				15.001-20.000	13				
				20.001-25.000	1				
				>25.000	0				
		>750	11.636	0-2.000	2	9.100	43	0,37%	40,61
				2.001-5.000	11				
				5.001-10.000	20				
				10.001-15.000	16				
				15.001-20.000	5				
				20.001-25.000	1				
				>25.000	0				

7.- The risk index according to exposure, or IREx, is the number of motorcyclist fatalities divided by the total average mileage covered by the respective group, expressed per 100m (10^8), or in other words, the accident mortality rate over the annual average mileage driven by the specific group (Equations 1 and 2).

$$\text{IREx} = \frac{\text{Total road fatalities}}{\frac{\text{mileage}}{\text{year}}\ \text{of the fleet}} \times 10^8 \quad (1)$$

$$\text{IREx} = \frac{\text{Mortality rate}}{\frac{\text{mileage}}{\text{year}}\ \text{of the motorcycle}} \times 10^8 \quad (2)$$

Finally, to actually assess this risk, three different indicators of victims were defined and used:

- **Absolute number of victims** (fatalities per year for each group)
- **Relative number of victims** or **accident mortality rate** (annual death toll of each group, depending on the total number of motorcycle fleet for this group)
- **Risk index based on their exposure**, or IREx (victims relative to the annual mileage travelled by the rider)

RESULTS

Once the database was created from fatal accidents, mileage and motorcycle fleet data, the analysis of the risk of having a fatal road accident in terms of exposure by mileage (IREx) was done, by taking into account the profile of the driver and/or the type of the motorcycle.

A risk index according to exposure (IREx) was defined to evaluate the degree of this risk and to precisely show the influence of the driver and motorcycle profile on the accident rates.

Absolute number of victims

This is an absolute value which does not take into account the average mileage conducted annually by each profile, or the number of motorcycles in the fleet for the same profile.

The data showed that for Spain, in 2007 **the greater numbers of fatalities in motorcycle accidents (number of deaths greater or equal to 10) were**:

- Motorcyclists of **all age groups riding a sport motorcycle**, between **501 and 750 cc**.
- Motorcyclists **over 24 years of age**, riding a **sport bike over 750 cc**.

- Motorcyclists aged **25 to 44 years old**, riding a **naked motorcycle, between 501 and 750 cc.**
- Motorcyclists **older than 24 years old**, riding **scooters of less than 126 cc**.

Mortality rate

This rate represents the relative number of deaths as a function of the number of motorcycles that comprise the fleet for that profile.

By relating this absolute number of fatalities to the total number of motorcycles of the same profile, a very accurate result can be represented for each of the profiles defined.

IDIADA's study showed that the profiles of motorcyclists with **the highest accident mortality rate (higher than 0.25%)** were:

- Young motorcyclists aged **between 18 and 24** years old, with a **sport** type of motorcycle **between 501 and 750 cc**. Accident mortality rate: 0.70%
- Young motorcyclists aged **between 18 and 24** years old, with a **sport** type of motorcycle **over 750 cc**. Accident mortality rate: 0.51%
- Young motorcyclists aged **between 25 and 34** years old, with a **sport** type of motorcycle **over 750 cc**. Accident mortality rate: 0.34%
- Young motorcyclists aged **between 18 and 24 years** old with a **large displacement cruiser motorcycle (> 750 cc)**. Accident mortality rate: 0.76%

Index of risk according to exposure

So far in this study, the risk of a user (i.e. a motorcyclist) of having a road accident was determined by the total number of victims and their mortality rates. However, none of this data has been related in any way to the annual mileage covered by those particular profiles of motorcyclist.

The concept of accident mortality rate (percentage of deaths over the number of motorcycles for this group) will be linked directly to the annual average mileage. A driver's risk of being involved in a road accident will be assessed according to his respective distance travelled.

Accident mortality rate vs annual mileage:

With the aim of creating a first notion on the global risk indicator considering the riders' exposure, two scatter plots can be found below (the data used to plot these are: Spanish statistics of fatal accident of riders in 2007, Spanish fleet data and mileage of Spanish riders in 2007).

In Figure 4, the mortality rate of each profile is plotted against the average mileage travelled by a motorcycle belonging to this profile. On the right side, we can see three profiles whose accident mortality rate is significantly higher than the rest (red circle).

1. Young motorcyclists aged **between 18 and 24** years of age, riders of a **sport** type of motorcycle of large displacement **(>750 cc)**. This group travels on average 5,917 km/year and has an accident mortality rate of 1.71%

2. Young motorcyclists aged **between 18 and 24** years of age, riders of a **sport** type of motorcycle **between 501 and 750 cc.** This group travels on average 7,723 km/year and has an accident mortality rate of 0.80%.

3. Young motorcyclists aged **between 18 and 24** years of age, riders of a **naked** type of motorcycle of large displacement **(> 750 cc)**. This group travels on average 3,500 km/year and has an accident mortality rate of 0.56%.

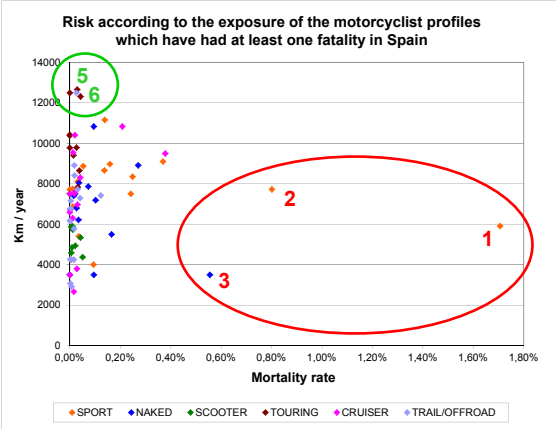

Figure 4. Risk according to the riders' exposure in Spain. All groups mentioned include data per average mileage.

The green circle encompasses the groups of riders with a **lower risk exposure,** those who are involved in accidents, but have a lower mortality rate on a relatively **high number of annual mileage**. This group of riders includes among others, the following significant groups:

1. Motorcyclists over **44 years old**, riding touring type of motorcycle of high

displacement (>750cc). This group travels on average 12,667 km/year and has an accident mortality rate of 0.03%.

2. Motorcyclists aged **between 35 and 44 years of age**, riding **touring** type of motorcycle of high displacement engine **(>750cc)**. This group travels on average 12,314 km/year and has an accident mortality rate of 0.04%.

Index of Risk according to exposure (IREx):

- IREx Definition

To assess each profile's risk exposure, an index of risk according to their exposure has been defined, where the rate of accident mortality rate comes as a function of the corresponding annual mileage travelled by that profile.

It is therefore an objective indicator of a motorcyclists' exposure to the risk of having a fatality, interpreted as the number of deaths in motorcycle accidents divided by the total average mileage covered by the respective group, expressed per 100m (10^8), or in other words, the accident mortality rate divided by the average annual mileage recorded for one motorcycle of the corresponding group, multiplied by 10^8 (see equations 1 and 2).

- IREx OF THE MOTORCYCLE ACCIDENTS IN SPAIN DURING 2007

In the bar chart below (Figure 5), the IREx for the motorcyclists killed in road accidents during 2007 is represented as defined above. This graph shows only information about profiles which have available data related with the average annual mileage. Similarly to the previous graphs, this figure was created using data relating to Spain only.

At first glance, three different but logical trends can be noticed: firstly these exposing their group's riders to high risk **[IREx > 30]**, others with relatively intermediate exposure **[10 < IREx < 30]**, and other with low exposure **[IREx < 10]**. Fortunately, as a whole, the large majority of the groups belong to the latter category of low risk exposure and in turn, there are a few groups encompassed within the higher exposure.

As seen before, the IREx value is dependent upon the number of motorcycles belonging to each profile. Having one victim in a sample of ten motorcyclists is not as representative as having 100 victims in 1000 motorcyclists, even though percentage wise they are both the same. As an example, looking at certain profiles, the small number of motorcycles that they occupy from the entire fleet causes the IREx of these groups to be particularly sensitive to the number of victims. In cases like this, the IREx value can be dependent on one or two accidents, so particular attention must be paid whilst interpreting these results. For example, motorcyclists **between 18 and 24** years of age, riding a sport type of motorcycle **between 126cc and 500cc**. There was **1 fatality** in a sample of **413 riders** in the entire Spanish motorcycle fleet. In this example, but furthermore in these cases, a minimum change of the number of victims could significantly affect the IREx value for that group. In addition these are profiles with few members which only have mileage of one motorcycle, and so the latter is extrapolated to receive the number for the entire profile-specific group, thus introducing another error that must be taken into account.

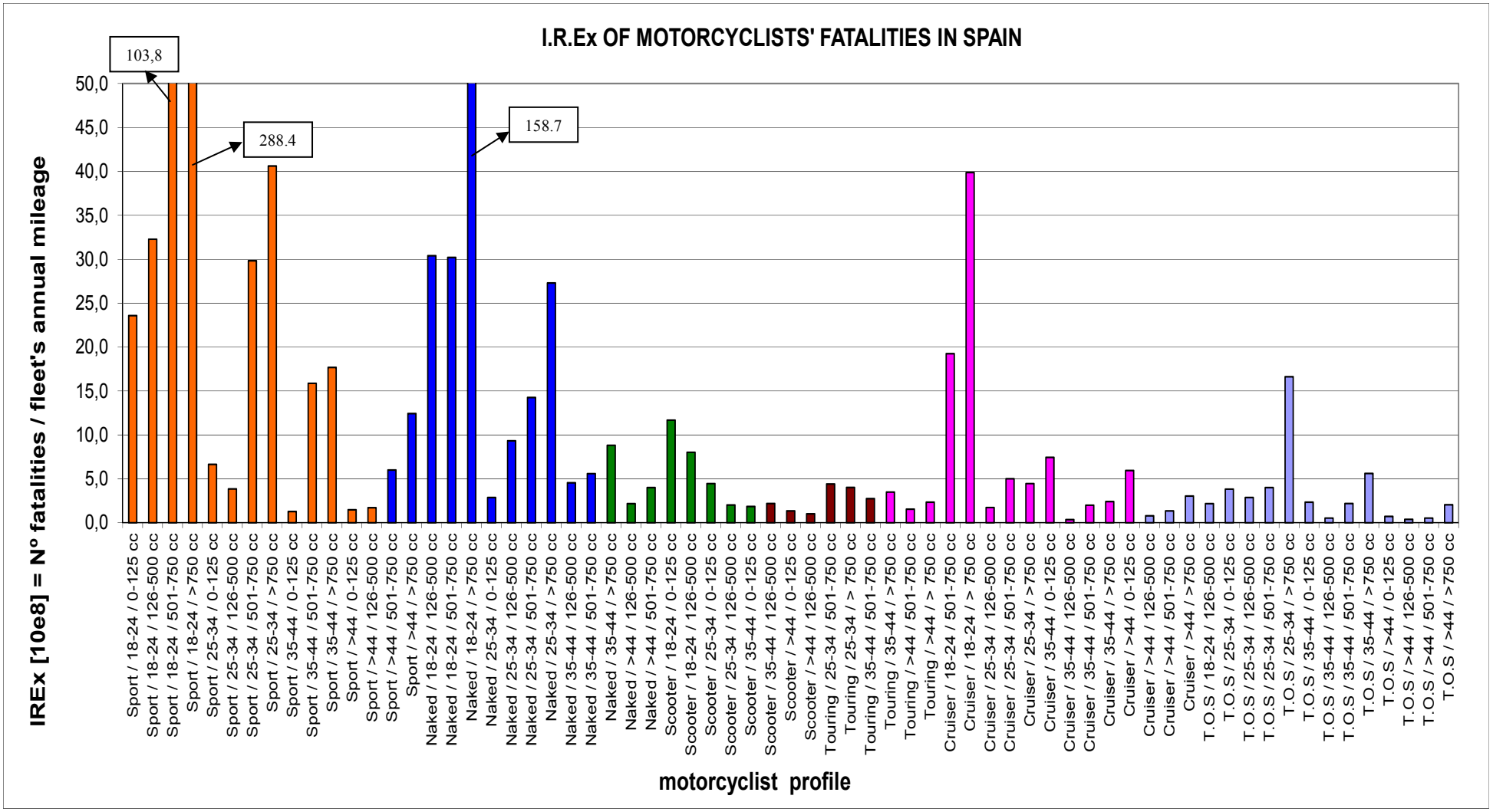

Figure 5. Index of risk according to the exposure (IREx) of the motorcyclists dead in Spain in 2007.

CONCLUSIONS

According to data published in the report of the DGT (Spanish traffic authority) "Las principales cifras de la Siniestralidad Vial: España 2008", there were 93,161 casualty-related road accidents, resulting in 3,100 fatalities 16,488 seriously injured and 114,459 slightly injured. It is important to note that all the way through 2003 up to 2008 there has been a downward trend in fatalities per accident. **However, motorcycle related accidents have in fact seen fatality and serious injury numbers rising.**

Unlike in the past were only the total number of (motorcycle) users and their mortality rates were used to estimate the risks these users (motorcyclists) were exposed to, this study proposes the use of information related to mileage covered by each group of user (motorcyclists) in order to estimate their real risk. Moreover, this study gives these groups of motorcyclist special characteristics and focuses on distinguishing between these different profiles.

This paper presents the methodology defined and the index defined by IDIADA. The IREx (Index of Risk according to Exposure) allows us to analyze the risk of having an (fatal) accident of the different groups of riders, profiles, by taking into account the distance covered by them and their fatality statistics.

From this data file, completed with information by the motorcycle fleet, average annual mileage travelled by each group of motorcyclist and accidents, **three indicators can be defined to assess the risk exposure of these profiles**. These indicators are:

- **Absolute number of victims** (fatalities per year for each group)
- **Relative number of victims or accident mortality rate** (annual death toll of each group, depending on the total number of motorcycles for this group).
- **Risk Index according to exposure** or **IREx** (victims in relative frequency between annual mileage travelled by the motorcyclist)

Risk, in terms of the different groups' exposure, or **IREx**, is proportional to **the number of annual kilometers travelled by those groups**, i.e. a motorcyclist who covers a greater distance is exposed to a greater likelihood of having a potentially fatal road accident. However this mileage is not the only factor, as the **type of driver** and **type of motorcycle** also have a definite influence on the mortality and injury ratio of each group.

By defining this IREx indicator, which considers both accident mortality rate and annual mileage travelled, a clear and objective view of risk exposure for each group of rider (profiles) can be obtained. In the case of the Spanish study, a map of risk exposure has been laid out for each group of motorcyclists, and the appropriate measures can be taken to counter these losses.

The different groups which are analyzed in this study can be grouped according to their risk exposure. In this particular case numerical limits have been defined to allow for this classification of high, medium and low risk exposure. These limits were:

- **Groups with a high Risk Index according to Exposure indicative value.** Motorcyclists with a high accident mortality rate in relation to annual average mileage travelled belong to this group. Groups belonging in this group have an IREx value above 30 **[IREx > 30].**
- **Groups with a medium Risk Index according to Exposure indicative value.** These profiles of motorcyclist, while presenting a relatively high accident mortality rate, also do a lot of mileage. Thus, the end result is actually an average value and a balanced degree of risk exposure. The IREx value for these groups of riders stands between 10 and 30 **[10 < IREx < 30].**
- **Groups with a low Risk Index according to Exposure indicative value.** These groups of motorcyclist present a low death rate whilst covering a high number of kilometers annually. Their IREx value is below 10 **[IREx < 10]:**

The different lines in the scatter plot in Figure 6 represent the limits mentioned in the above points and divide the graph into **identified risk areas**. As in the above figures illustrated in this paper, the data represented in the following plot are only referring to Spain. In addition, in the plot below only the groups with a death rate lower than 0.35% have been considered.

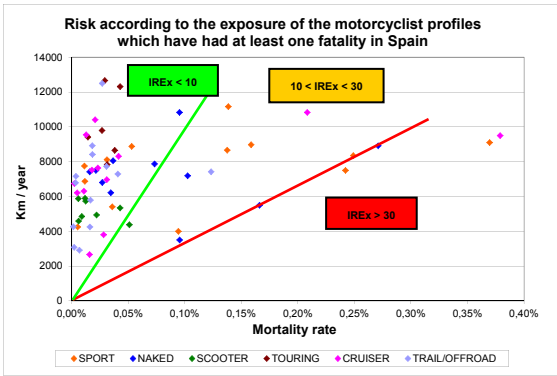

Figure 6. Identified risk areas for Spanish Motorcyclists who carry a mortality rate of less than 0.35%.

These limits can be in turn represented in a differently plotted graph, in which the motorcyclist risk groups can be more visibly distinguished (see Figure 9).

In the case of accidents in Spain in 2007, several clear trends can be identified in the results: the risk is proportional to the engine's displacement and inversely proportional to the rider's age. In other words the younger you are, and the bigger the engine of the motorcycle, the greater the chances of suffering an accident. Furthermore, it can be noted that the types of motorcycles with higher risk exposure are the sport and naked types. The following figure (Figure 7) shows this entire IREx analysis for sport type motorcycles in Spain, 2007. As can be seen, a large displacement and a young driver is a bad combination and produces the highest risk exposure.

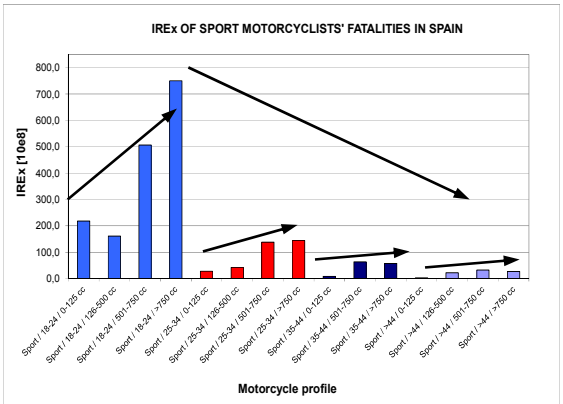

Figure 7. Risk index according to exposure for motorcyclists riding sport type of motorcycles.

Similarly to the previous figure, the graph below (Figure 8) represents the corresponding IREx values for naked motorcycles. Similar trends as the sport type can be clearly distinguished: high displacement and young driver leads to high IREx.

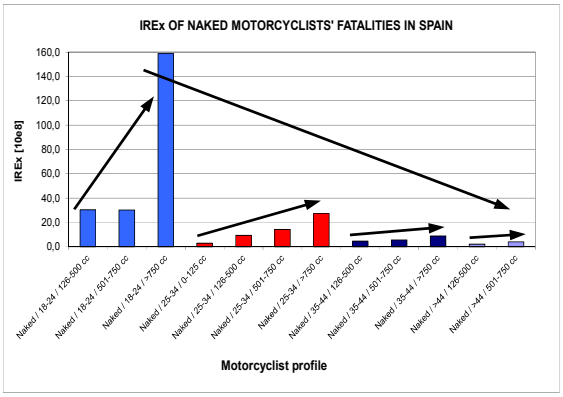

Figure 8. Risk index according to exposure for motorcyclists riding sport type of motorcycles.

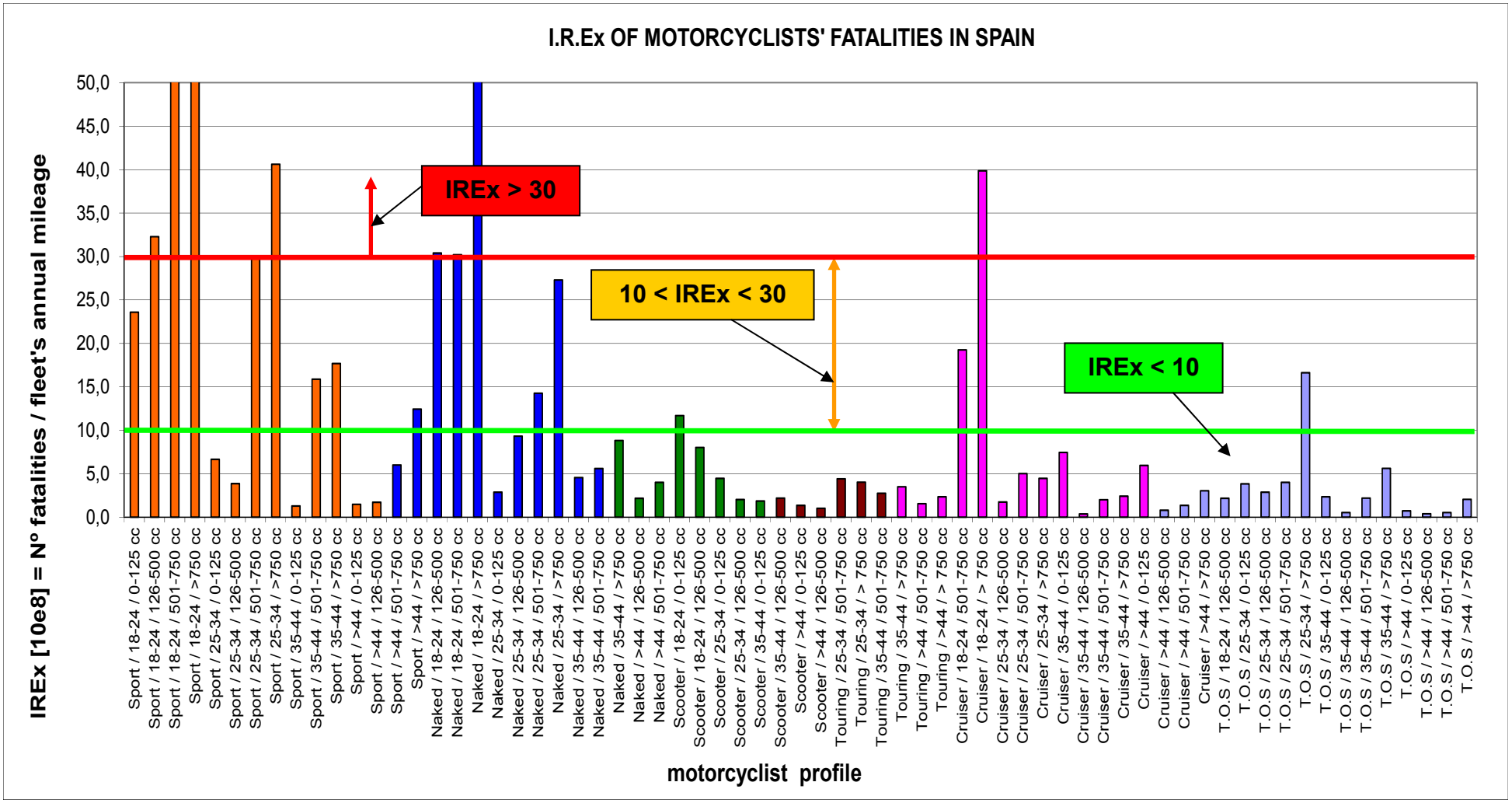

Figure 9. Risk Index according to Exposure of motorcyclists involved in road accidents in Spain, 2007.

ACKNOWLEDGEMENT

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ANNEX 1: CLASSIFICATION OF MOTORCYCLE TYPES

Sport:	Naked:
Scooter:	**Touring:**
Cruiser:	**Trail:**
Offroad:	**Supermotard:**

Figure 10. The classification of the different type of motorcycles which were involved in IDIADA's pilot study.