DETERMINATION OF ACCIDENT CAUSATION AND RISK FACTORS IN TRAFFIC ACCIDENTS FROM THE POINT OF VIEW OF MOTORCYCLIST USERS

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Abstract - The Powered Two Wheelers (PTWs) accidents constitute one of the road safety targets in Europe. PTWs users' fatalities represent 15% of EU road fatalities [1], having increased the last few years, which is quite opposite than other road users casualties.

To reduce PTW accidents is necessary to know which the accident causations are from different points of view (human factor, vehicle characteristics, environment, type of accident, situation, etc.). In TRACE project ('*Tr*affic *A*ccident *C*ausation in *E*urope', under the European Commission 6th Framework Program, 2006-2008, [2]) a specific task was focused on PTW users point of view, analyzing extensive databases to locate the main accident configurations (type of accident, severity, frequency…), and an in-depth database to obtain the causation factors, the risk factors for each configuration founded in the extensive databases analysis and the variables associated to each causation factor in the PTW configurations.

NOTATION

EU	European Union
EC	European Commission
OR	Odds Ratio
PTW	Powered Two Wheeler
WP	Work Package

INTRODUCTION

The European Commission set the ambitious objective of halving the number of road traffic fatalities by 2010 in its White Paper [3]. Since this paper was published, much progress has been achieved. According to the ERSO's evolution report [4] fatalities in the EU-25 have been reduced by 18,1% between 2001 and 2005.

In line with the objective of improving the road safety, TRACE project (**TR**affic **A**ccident **C**ausation in **E**urope), under the European Commission 6th Framework Program, is to provide an overview of the road accident causation topics in Europe**.** TRACE proposes three different research angles to cover accident causation issues:

- The Road User approach (WP1): it allows detecting the main causation and risk factors for specific road users.
- The Types of Situation approach (WP2): the road user can be confronted with different driving situations that can develop into different emergency situations that deserve specific analysis regardless the road user type.
- The Types of Factors approach (WP3): the factors can be identified and observed according to an innovative split: the social and cultural factors, the factors related to the trip itself and the factors related to the driving task.

Within the first angle ('Road user approach'), PTW users were one of the five user groups analysed. Nowadays, this road users group is especially important because whereas the number of European road deaths has declined considerably in the last years, the number of killed PTW users has risen in 13 out of 27 EU countries [5]. It is well known that, for the same distance travelled, a motorcyclist has on average 18 times the risk of being killed in a road accident that a car driver has.

METHODOLOGY AND RESULTS

The first step carried out in TRACE related to accident causation and risk analysis in PTW accidents was to detect the main configurations where PTW accidents occurred, considering area (urban/rural), road layout (junction or out of junction), severity, accident type (run off, rear end…) and, of course, taking into account the PTW category (moped or motorcycle). To perform these analyses literature review and seven extensive databases available to TRACE were used. The outcome of this procedure was the selection of the most common PTW accident configurations and their main characteristics.

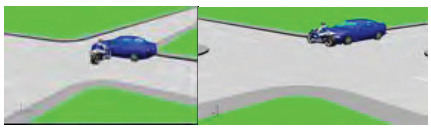
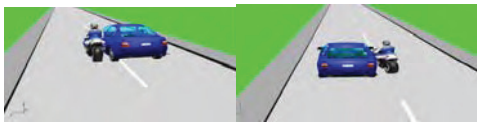
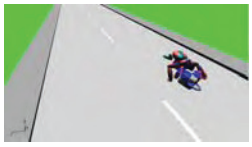
Distribution of the most common PTW accidents configurations			
Type of PTW involved	**Accident Configuration**	**% Fatal & Serious Accidents**	**Illustration**
MOTORCYCLES ACCIDENTS	**1. Motorcycle single accidents:** accidents which involved just one motorcycle on a rural road: run-offs, rollover on the carriageway and collisions with road restraint systems.	27%[1]	
	2. Front-side accidents in rural and urban junctions between motorcycles and passenger cars.	13%	
	3. Side-side accidents in rural and urban non junctions between motorcycles and passenger cars.	5%	
	4. Rear-end accidents in rural and urban non junctions between motorcycles and passenger cars.	5%	
MOPEDS ACCIDENTS	**5. Moped single accidents:** Accidents which involved just one moped on a rural or urban road: run-offs, rollover on the carriageway and collisions with road restraint systems.	21%[2]	
	6. Front-side accidents in rural and urban areas (junction and non junction) between mopeds and passenger cars.	30%	
	7. Head-on accidents in rural and urban areas (junction and non junction) between mopeds and passenger cars.	8%	

Table 1.- Distribution of the main PTW accident configurations (National databases).

[1] This percentage is over the motorcycles accidents, not over all PTWs accidents.
[2] This percentage is over the mopeds accidents, not over all PTWs accidents.

These seven configurations were the starting point to analyze PTW accidents causation issues. After selecting these configurations, a detailed analysis was done over these configurations gathered in one of the most important intensive accident databases in Europe related to PTWs accidents. This in-depth database analyzed was the one generated in 'MAIDS' project ('In-depth investigations of accidents involving powered two wheelers'), from the European Commission 5th Framework Program [6]. 'MAIDS' gathers information from 921 motorcycle accidents (cases) and 923 sample of non-accident motorcycle riders (controls) through interviews which allow study not only the collisions but the risk and the variables which could have an influence since exposure data are available.

The above accident configurations were selected over MAIDS database with the aim of analyzing the following three aspects:

- **Accident causation analyses**: With the purpose of knowing the mechanism of the accident, and therefore, the accident causation, analyses over this information were done in each one out of the seven configurations.

- **Risk analyses**:

  - **Risk factors related to each accident causation** (**Test $\chi 2$ and Odds ratio analyses)**: Once the main accident causes were detected in each scenario, statistical analyses were done with the aim of knowing which factors are related to each accident cause in each scenario. Of course, only accidents from each scenario were used, so the conclusions obtained from these analyses will be focused to know which factors increase the risk for a cause of being the cause of the accident. Cross-tables have been used. When the factor had only two categories 'Odds ratio' (OR) analyses, while test $\chi 2$ have been used for all the cases.

    Unfortunately, in configurations 3, 4 and 7 is difficult to reach any statistically significant conclusion because there are not enough cases. This makes unfeasible to establish any kind of relationship between contributing factors and variables.

  - **Risk factors of being involved in a PTW accident** (**Case-control analyses)**: For each accident configuration, information from accidents (cases) and information from non-accidents (controls) were used to calculate 'Odds Ratios'. This means, the risk for a PTW user of being involved in each accident scenario was calculated related to different factors.

    The outcome was a p-value based on chi-square distribution, an OR estimation (when the variable had only two categories) and their confidence intervals.

    It is very important to notice that without exposure data is not possible to talk about risk. Exposure data are represented by 'controls' in MAIDS database. These are the motorcyclists interviewed that did not have an accident but were supposed to be exposed to the potential risk factors. Over than 60 variables were studied related to environmental factors, mechanical factors and human factors.

    A further step was to perform a multinomial logistic regression[3] model to consider not just the variables individually but the categories of this variable(s) and also the interactions between variables.

[3] Due to low frequencies of some configurations, it was not suitable to perform this analysis in all of them.

Accident causation analyses

In the Table 2, results from the accident causation analysis over MAIDS database (in-depth database) and the seven main scenarios are shown. Accident causations factors are coded within the databases as **Primary** (*Primary contributing factor: The contributing factor which the investigator considers to have contributed the most to the overall outcome of the accident*) or **Contributing** factors (*Contributing factors: Any human, vehicle or environmental factor which the investigator considers to have contributed to the overall outcome of the accident. The precipitating event may or may not be considered to be a contributing factor*). In some cases some contributing factors cannot be coded as primary factors but might be usually correlated to specific primary factors. For instance, the factor 'motorcycle rider drug and/or alcohol involvement' cannot be coded as primary factor within this database but in some configurations is usually present linked to 'Motorcycle reaction failure'.

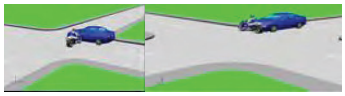
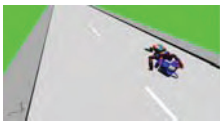
		Distribution of the contributing factors in the most common seven PTW accidents configurations		
		Accident Configuration	**Primary factors**	**Contributing factors (including primary)**
MOTORCYCLE ACCIDENTS	1		-Motorcycle rider decision failure (31%) -Motorcycle rider failure, unknown type (18%)	-Motorcycle rider decision failure (37%) -Motorcycle rider failure, unknown type (32%) -Others (16%): Too fast speed, motorcycle rider unsafe acts, inadequate speed.
	2		-Passenger car driver perception failure (60%) -Passenger car driver decision failure (12%)	-Passenger car driver perception failure (70%) -Passenger car driver unsafe acts or risk taking behaviour (31%) -Motorcycle rider unsafe acts or risk taking behaviour (38%)
	3		-Passenger car driver perception failure (47%)	-Passenger car driver perception failure (53%) -Motorcycle rider unsafe acts or risk taking behaviour (53%)
	4		-Motorcycle rider perception failure (58%) -Passenger car driver perception failure (25%)	-Passenger car driver perception failure (33%) -Motorcycle rider perception failure (58%)
MOPED ACCIDENTS	5		-Moped rider perception failure (41%) -Moped rider reaction failure (19%)	-Motorcycle rider perception failure (63%) -Motorcycle rider drug and/or alcohol involvement (33%)
	6		-Passenger car perception failure (51%) -Motorcycle rider perception failure (14%) -Motorcycle rider decision failure (12%)	-Passenger car perception failure (68%) -Rider unsafe acts or risk taking (49%) -Passenger car unsafe acts or risk taking (36%)
	7		-Moped rider perception failure (41%) -Moped rider reaction failure (19%)	-Passenger car perception failure (38%) -Moped rider decision failure (38%) -Moped rider unsafe acts or risk taking behaviour (62%)

Table 2 .-Contributing factors in the most common seven scenarios in PTWs accidents.

As it can be shown, 'Passenger car driver perception failure' could be considered as the main primary causation factor in front-side accidents between PTWs and passenger cars. In motorcycle single accidents 'Rider decision failure' appears as primary causation factor with 'Inadequate speed' and

'Rider unsafe acts' as contributing factors associated. In moped single accidents, the contributing factors present were 'Rider perception failure' and 'Alcohol and/or drugs consumption'.

Risk factors related to each accident causation (Test $\chi 2$ and Odds ratio analyses)

Once the contributing factors were pointed for each one out of seven configurations, the following step was to identify possible associations between the most important causation factors detected in each configuration and any possible variable related to vehicle, human and environmental aspects.

Configuration 1: Single motorcycles run-off accidents

Contributing factor	Risk factor	p-value	Odds ratio
1 Motorcycle rider decision failure	Odometer (new motorcycle)	0.046	2.92
	Rider age (< 25 years)	0.016	3.44
	Traffic violation in the last 5 years	<0.001	9.33
2 Motorcycle rider unsafe acts	Lack of cargo rack	0.016	4.40
	Rider age (< 25 years)	0.022	2.48
	Traffic violation last 5 years	0.036	2.25

Table 3.- Risk factors related to each contributing factor - Configuration 1.

In this configuration 'Rider decision failure' and 'Rider unsafe acts' were the most common contributing factors, but also, it was important the presence of inadequate speed or too high speed. According to the results, both contributing factors were associated to rider age (younger than 25 years of age) and to had committed at least one traffic violation in the last five years. An example of the interpretation of these results should be 'in case there was an accident belonging this configuration, if the rider ages is higher 25 years old the risk of being 'Motorcycle rider decision failure' the accident causation is 3.44 times higher.

Only statistically significant variables are included in the tables, this means that it was taken as reference p-values greater than 0.05 and all the confidence intervals of the odds ratios did not contain the reference value 1.

Configuration 2: Front-side accidents in rural and urban junctions between motorcycles and passenger cars

Contributing factor	Risk factor	p-value	Odds ratio
1 Passenger car perception failure	Motor displacement (>125 cc)	0.040	2.51
	Lack of front position lamp	0.026	3.62
	Front tyre: not wheel original equipment	0.023	3.46
2 Motorcycle rider unsafe acts	Rider age (25-40 years)	0.048	2.19

Table 4.- Risk factors related to each contributing factor - Configuration 2.

According to the contributing factor 'Passenger car perception failure', the variables associated to it were: 'Motor displacement', 'Front position lamp equipped?' and 'Front tyre, wheel original equipment?'. This result confirmed the conspicuity problem associated to perception failures (found in the literature review).

The variable associated to contributing factor 'Motorcycle unsafe acts or risk taking' was 'Rider age' being the category between 25-40 years old overrepresented.

Configuration 3 4 and 7: As it has said, in configurations 3, 4 and 7 is difficult to reach any statistically significant conclusion because there are not enough cases. This makes unfeasible to establish any kind of relationship between contributing factors and variables.

Configuration 5: Single moped accidents run off accidents

Contributing factor	Risk factor	p-value	Odds ratio
1 Alcohol and/or drugs use	Under secondary school qualification	0.032	8.67

Table 5.- Risk factors related to each contributing factor - Configuration 5.

In this configuration contributing factor 'Alcohol and/or drugs use' was associated to 'Educational status' and obviously to 'Alcohol or drugs' as a risk factor. So the typical moped single run off or roll over accident where 'Motorcyclist alcohol and/or drug use' was contributing factor seems to occur in urban areas to people who had 'no formal schooling or formal education prior to college'

Configuration 6: Front-side accidents in rural and urban areas (junction and non junction) between mopeds and passenger cars

Contributing factor	Risk factor	p-value	Odds ratio
1 Passenger car perception failure	Lack of front turn signals	0.049	2.07
	Lack of driving license (no license held)	0.030	1.74
	Not resident citizens	0.025	4.51
	Not frequent use of the road	0.015	3.96
2 Motorcycle rider unsafe acts	Front suspension in bad condition	0.044	2.62
	Headlamp assembly type (double)	0.046	1.74
	Modified / Enhanced motor power	0.008	3.42
	Gender (male)	<0.001	3.86
	Motorcycle training (no)	0.035	2.61
	Traffic violations in the last 5 years (yes)	0.002	2.89
	Previous motorcycle traffic accident (yes)	0.002	3.05

Table 6.- Risk factors related to each contributing factor - Configuration 6.

The analysis of the contributing factor 'passenger car perception failure' revealed that the variables associated to it were: 'Front turn signals equipped?', 'Driver license qualification', 'No resident, citizenship' and 'Frequency of this road use'.

The second contributing factor analyzed within this configuration was 'Motorcycle rider unsafe acts or risk taking' and the variables which had an association with it were: 'Front suspension condition', 'Headlamp assembly type', 'Motor power enhancement equipped?', 'Gender', 'Motorcycle training', 'Any traffic violations in the last 5 years?' and 'Any motorcycle traffic accident?'.

Risk factors of being involved in a PTW accident (Case-control analyses)

Once the main configurations where PTW accidents occurred were detected, a case-control analysis was performed to determine which variables (risk factors) are associated with the accidents in each configuration. Two steps were followed in order to carry out this case – control analysis:

- Cross tabulations procedure: First, all the variables were studied independently, without taking into consideration its likely correlation with the other factors. This was performed for each selected configuration. The result provides the variables that can be potentially considered as risk factor. To perform this study it was used a cross tabs analysis procedure which outcome was a p-value based on chi-square distribution, 'Odds Ratio' estimation when the variable had only two categories and their confidence intervals. Exposure data with this methodology is represented by 'controls' from MAIDS.

- Multinomial logistic regression: In a second step, a multinomial logistic regression model (where it was possible) was performed. After detecting which variable(s) is risk factor for each contributing factor, a multinomial logistic regression was done to study the 'propensity toward' the categories of this variable(s) for each contributing factor within each configuration.

Configuration 1: Single motorcycles run-off accidents

Risk factor	p-value	Odds ratio
Vehicle year of production (5-10 years)	0.002	2.29
Rider age (<25 years)	0.040	2.09
Lack of driving license	0.002	4.01
Not resident citizens	<0.001	5.87
Under secondary school qualification	0.001	4.05
Not frequent use of the road	0.001	3.53

Table 7.- Risk factors of being involved in a PTW accident - Configuration 1.

Several risk factors have been detected as significant from a statistic point of view. For a better understanding of these results, the following interpretation shows how these factors affect motorcycle user related to the probability of suffering an accident:

- For instance, a rider younger than 25 years of age has an Odds Ratio equal to 2.29, this means that this type of motorcycle riders are 2.29 times more likely (or (129% higher) to be involved in an accident corresponding to configuration 1 than a rider from another age group.
- Single run off motorcycle accidents occurred mostly to riders who did not have experience driving along that road or that area. The lack of driving license increased notably the risk of being involved in an accident of these characteristics.
- It has been seen how no resident motorcyclist or riders who do not know the road had a higher probability to be involved in single motorcycle accidents.

Configuration 2: Front-side accidents in rural and urban junctions between motorcycles and passenger cars

Risk factor	p-value	Odds ratio
Vehicle year of production (>2 years)	<0.001	5.25
Motor displacement (>125cc)	0.011	1.78
Front tread type (all weather, angle groove)	0.035	1.55
Driveline type (sprockets, enclose chain)	<0.001	1.97
Lack of windscreen	0.001	1.89
Lack of right side rear view mirrors, posts equipped	0.033	2.01
Rider age (<25 years)	0.001	2.07
Under secondary school qualification	0.037	1.55
Short length of the trip (<10 Km)	0.001	2.55

Table 8.- Risk factors of being involved in a PTW accident - Configuration 2.

After modelling with logistic regression models procedure, there were new findings: motorcycles with more than 125cc motor displacement, front tyre wheel no original equipment and without front position lamp had a propensity toward to be involved in motorcycles front side accidents. Again motorcycle riders younger than 25 years of age and riders under secondary school qualification appeared as risk groups.

Configuration 3: Side-side accidents in rural and urban non junctions between motorcycles and passenger car

In this configuration it was difficult to reach any significant conclusion because there were not many cases (only 13 cases), which means that any kind of relationship appeared is conditioned by low frequencies. Nevertheless, the main results obtained from comparing exposure data to side to side collisions between motorcycles and passenger cars cases are:

- Motorcycles with front suspension in bad conditions are overrepresented.
- Motorcycles without left side mirrors view posts are overrepresented.

Configuration 4: Rear-end accidents in rural and urban non junctions between motorcycles and passenger cars

Case-control study revealed some associations between this configuration and the variables 'Front crash bars equipped?' and 'Windscreen equipped?'

This type of collisions had a low frequency within database, only 12 cases were registered; consequently a risk analysis could not be performed. However, there was an interesting trend with the variable 'Does the license held qualify the rider for driving the accident vehicle?' because two out of three riders without a qualifying license had a collision. Due to low frequencies is not possible to conclude anything related to causation factor or risk factor.

Configuration 5: Single moped accidents run off accidents

The analysis of this configuration showed the following association:

Risk factor	p-value	Odds ratio
Lack of front position lamp	0.009	2.90
Alcohol and/or drug use	<0.001	8.03
Not permanent physical impairment (tiredness, …)	<0.001	4.59
Previous motorcycle traffic accident	0.049	2.31

Table 9.- Risk factors of being involved in a PTW accident - Configuration 5.

The risk factors 'Alcohol and/or drug use' and 'Not permanent physical impairment' increased notably the propensity toward being involved in a single moped accident. In addition, these two factors are clearly correlated, meaning that most of the times when one of them is present the other one is present too, i.e.: alcohol and drowsiness.

Configuration 6: Front-side accidents in rural and urban areas (junction and non junction) between mopeds and passenger cars

Data from these accidents show association between this configuration and the next variables:

Risk factor	p-value	Odds ratio
Vehicle year of production (>2 years)	0.001	5.95
Front suspension type (no telescopic tube)	0.028	1.68
Front suspension in bad conditions	0.009	2.26
Head assembly type (double)	0.013	1.58
Fuel tank type (saddle)	0.046	2.84
Rear tread type (all weather, angle groove)	0.014	1.81
Modified / Enhanced motor power	0.001	2.79
Lack of driving license (no license held)	<0.001	4.04
Not regulated training	0.026	2.03
Not permanent physical impairment (tiredness, …)	0.002	3.73
Not frequent use of the road	<0.001	5.71

Table 10.- R Risk factors of being involved in a PTW accident - Configuration 6.

The variables 'Vehicle year of production', 'Lack of driving license (no license held) and 'no frequent use of the road' were the ones which increased the risk the most.

Once again the variables 'Lack of driving license (no license held) and 'No frequent use of the road' appeared as risk factors. Logistic regression procedure performed to this configuration showed that no resident drivers, without license held, driving a moped equipped with motor power enhancement and without right side posts rear view mirrors had a propensity toward to be involved in front side mopeds accidents.

Configuration 7: Head-on accidents in rural and urban areas (junction and non junction) between mopeds and passenger cars

Finally, case-control analysis revealed some associations between this configuration and the variables 'Right side rear view mirrors, posts equipped?' (Category 'Yes') and 'Motor power enhancement equipped?' (Category 'Yes').

There was a tendency in the variable 'time travelling' because three out of five moped riders who were driving more than an hour had an accident.

Unfortunately, in this configuration it is difficult to reach any statistically significant conclusion because, as happened with other configurations, due to there are only 12 cases.

CONCLUSIONS

PTW accidents are an important road safety problem nowadays. As it has been said, this road user group is one of the few user groups whose fatalities have been increasing in the last few years (together with pedestrians). This implies that all road safety community (Governments, Associations, Manufactures, Foundations…) should enlarge its effort to stop this trend.

The main objectives of this study was to identify accident causation factors and accident risk factors related to the road users group of powered two wheelers riders.

As it has been explained, for the realization of these analyses, the most relevant seven main scenarios have been detected (from National accident databases available to TRACE project and Literature review) and through one of the biggest PTW In-depth database (MAIDS), the accident causation and risk analyses have been done for each configuration.

After finishing this task, it could be said that the work done over this project related PTW accidents have allowed gathering the following items:

- The causes of PTW accidents (according to MAIDS in-depth database) have been analysed.
  - The main cause of the collisions was a human failure.
  - In the case of accidents between a PTW and a passenger car, the most frequent human error was a failure in perceiving the PTW by the car driver (associated to the traffic environment, traffic scanning error, lack of other vehicle driver attention, faulty traffic strategy or low conspicuity of the PTW).
  - Other variables as 'Year of production', 'Citizenship', 'Rider age' and 'Frequency of this road use' are present in most of the configurations.

- Risk factors for each scenario and for each contribution factor have been identified. Some of them are:
  - Variables 'Year of production', 'Not frequent use of the road' and 'Not resident drivers' are risk factors in the main configurations.
  - 'Motor power enhancement', 'Driver license qualification' and 'Alcohol and/or drugs use' are variables linked to accidents involving mopeds.
  - Usually, contributing factor 'Motorcycle rider unsafe acts or risk taking' has associated the variables 'Any traffic violation committed in the last five years' and 'Rider age'.
  - 'Traffic violation in the last five years' always appeared associated to the contributing factor 'Motorcycle rider unsafe acts'.
  - No resident motorcyclist or riders who do not know the road had a higher probability to be involved in single motorcycle accidents.

DISCUSSION

During this paper, several important aspects related to PTW accidents have been studied. Nevertheless, neither possible counter-measures to avoid the accidents nor injury mitigating actions have been defined. Although the scientific world have already thought about several actions to avoid or to minimize PTW accidents, this paper can help to understand answers to specific questions like how?, why?, who?.. riders are involved or are likely to be involved in PTW accidents, and therefore it could help to define specific actions for PTW safety improvement.

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- In-depth 'MAIDS' database and ACEM ('Association des Constructeurs Européens de Motocyles').

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