



*Proceedings of 7th Transport Research Arena TRA 2018, April 16-19, 2018, Vienna, Austria*

## Road riding hazardous situations for motorcycles

Claire Naude <sup>a\*</sup>, Thierry Serre <sup>a</sup>, Christophe Perrin <sup>a</sup>, Michèle Guilbot <sup>a</sup>, Vincent Ledoux <sup>b</sup>

<sup>a</sup>*IFSTTAR TS2 Laboratory of Accident Mechanism Analysis, 304 chemin de la Croix Blanche, 13300 Salon de Provence France*

<sup>b</sup>*CEREMA Technical Division of Territorial Development and Urban Planning, 2 rue Antoine Charial, 69426 LYON France*

### **Abstract**

The decrease of road accidents these recent years has induced the interest to work on road driving hazardous situations called incidents. Otherwise, in France, users of Power Two-Wheeler (PTW) are less than 2% of traffic but, in the accidents represent 43% of serious injuries and 23% of killed persons. This paper provides a descriptive analysis of the incident database acquired during one year with a fleet of 30 motorcycles and a few cars equipped with an Event Data Recorder. The objective is to acquire knowledge on their accident mechanisms and improve their safety. For the 395 motorbikes' and 32 cars' incidents collected, the analysis of the triggering criteria, the dynamics parameters and the road configurations illustrates the great variety of situations and shows how the behaviours of riders are different from those of car drivers. The investigations on the causes of the incidents indicate that the more frequent cause is the driver (94%), but the road environment and the other road users could have been involved in 40% of the cases each.

*Keywords:* road incident; event data recorder, rider behaviour; motorcycle; infrastructure; vehicle dynamics.

---

\* Corresponding author: Claire NAUDE Tel.: +33 4 90568624; E-mail address: Claire.naude@ifsttar.fr

## 1. Introduction

The decrease of road accidents these recent years has induced the interest to work on road driving hazardous situations called incidents. The objective is to focus on “grey spot” defined as incidents accumulations instead of “black spot” defined as accidents accumulations. In order to identify incidents, some approaches were conducted using Naturalistic Driving Studies such as [Dingus et al., 2006; Wu et al. 2014]. In 2012-2014 the French government supported a new program with the collection and the analysis of road driving hazardous situations (called incidents). In this project 50 specific Event Data Recorders were installed in company vehicles of public fleets. In all, 340 incidents and 1240 events were collected after 12 months of collection.. The results of this project [Serre et al., 2014; Ledoux et al., 2014; Naude et al., 2017] proved that such an experiment is efficient to improve the road infrastructure safety diagnosis and to get a better understanding of accident mechanisms. But this work was focused only on cars while the motorcyclist accidentology stays raised. Indeed, in France, users of Power Two-Wheeler (PTW) are less than 2% of traffic but, in the accidents represent 43% of serious injuries and 23% of killed persons [ONISR, 2014]. One of the different issues can be due to the dynamic capacity of this kind of vehicle, the behaviour of motorcycle riders, their use of road infrastructure, etc [Koenen, 1983; Evangelou, 2004, Cossalter, 2006]. Much thought and study has gone into an improved understanding of motorized two-wheeler accidentality such as the MAIDS project – In-Depth Investigation of Motorcycle Accidents [MAIDS, 2010]. But a lack of knowledge remains and it is still difficult to evaluate the influence of such aspects on the PTW accidentology. So it appears important to better understand these issues by observing the behaviour of PTW users in real conditions. Few studies try to identify driving situations which can be considered as critical such as [Attal, 2016] but these researches are almost limited to a low amount of data.

So, in 2014-2017 the previous French program based only on cars has been extended to PTW in order to acquire naturalistic riding data. The same methods of diagnosis, mostly based on the analysis of incidents, were applied to motorcycles. In this experiment thirty private motorcycles and a few private cars were implemented with Event Data Recorders during one year of collection. This paper provides a descriptive analysis of the incident database collected, in order to investigate the different causes of these hazardous situations and how they are similar or different to cars’ incidents. From a qualitative point of view, this paper will present the distinction between simple events, which are due to road development, and real incidents due to driver behaviour and/or to vehicle dynamics. Quantitatively, results concern the analysis of the vehicle dynamics: the speed, the level of accelerations and rotational angular rates are especially studied as well as the locations of incidents in term of road configuration. Finally, a global statistic description highlights the different causes of the hazardous situations, between a road infrastructure cause, a human cause and a vehicle dynamics cause.

## 2. Material and Methods

### 2.1. Description of the sample

In this experiment about thirty private motorcycles (n=26) and a few private cars (n=6) were implemented with a specific recorder. Three French areas were considered: Normandy-Centre (Rouen), Hérault (Montpellier), and Provence-Alpes-Côtes d’Azur (Marseille, Aix-en-Provence, Salon de Provence). The number of volunteers for each of these areas was respectively 12, 12 and 8. Only men were considered and vehicle types were various but PTW were limited to motorbike with an engine size higher than 125 cm<sup>3</sup>. The volunteer drivers accepted to have the system active by default during all their travels, but they could deactivate it by pushing a button. All legal conditions were respected to protect personal data, especially by using a dedicated smartphone as a recorder with only the necessary applications [Guilbot et al., 2016]. The experiment lasted 1 year (July 2016- June 2017).

## 2.2. The EMMAPhone device

The recording device is based on a mobile phone Samsung Galaxy S5 dedicated for the experiment and called EMMAPhone (Embedded data smartphone for accident mechanisms). It was fixed under the saddle of the motorcycle, near the centre of gravity. For the cars it was under the driver's seat. It provides the following functionalities:

- Acquisition of data from internal accelerometers and gyrometers (three axis accelerations and rotational angular rates) and data provided by a GPS (trajectory and speed).
- Video recording of the front scene, with an endoscopic camera fixed in front of the motorcycle or on the car dashboard. The quality of the video recording was voluntarily set low to prevent the recognition of face or number plate without any complicate data processing.
- The EDR records separately:
  - Global information on the complete travel (GPS position) with a 1Hz frequency
  - Information on the specific incidents (accelerations, angular speeds) with a 100Hz frequency.
- The device "triggers" an incident when speed, accelerations, rotational angular rates or their accelerations exceed predefined thresholds (see below). A file containing the details of all acquired signals 30 seconds before and 15 seconds after the trigger is thus created.
- Advanced communication functionalities: the device sends data using GSM network. The acquisition process and the data transfer were secured.

## 2.3. Incident criteria

Different specific thresholds were set for motorcycles and cars. A bibliographic study and several tests campaigns with equipped motorcycles on track lead to the following thresholds [Serre et al., 2014; Naude et al., 2017; Costa et al., 2017]:

- Less than  $-6 \text{ m/s}^2$  for the deceleration and more than 10 km/h for the speed, (Criterion 1)
- More than  $80^\circ/\text{s}$  for the norm of the three rotational angular rates: yaw, roll, pitch, (Criterion 2)
- More than  $300^\circ/\text{s}^2$  for the norm of the three rotational angular accelerations, derived from the rates, (Criterion 3)

For the cars, a unique criterion was implemented in the device: more than  $6 \text{ m/s}^2$  for the norm of the longitudinal and lateral accelerations associated to a speed more than 10 km/h. (Criterion 4)

## 3. Results

### 3.1. Events/Incidents

The exploitation of the different recordings led to classify the triggers into two categories such as it has been done in the previous project [Serre et al, 2014]:

- The short trigger which corresponds to a road default such as a pothole, a subsiding cutting or road cracks, or to a specific road layout such as a speed bump, a manhole, a railway or a cobbled area. They are called "events" and will not be studied quantitatively in this paper, but detailed examples are given.
- The longer trigger which is due to the driver such as hard breaking or turning. They are called "incidents". Two examples are given in this paper, and the whole incidents are quantitatively analysed.

### 3.2. Global results

More than 3200 journeys and about 41000 km travelled were recorded and analysed.

427 incidents and more than 700 events were collected, including:

- In motorcycles, 395 incidents for 36500 km travelled, being 1.08 incidents per 100 km.
- In cars, 32 incidents for 4500 km travelled, being 0.71 incidents per 100 km.

The geographical distribution of the travels and the incidents in Figure 1 shows that some roads are more subject to incidents.

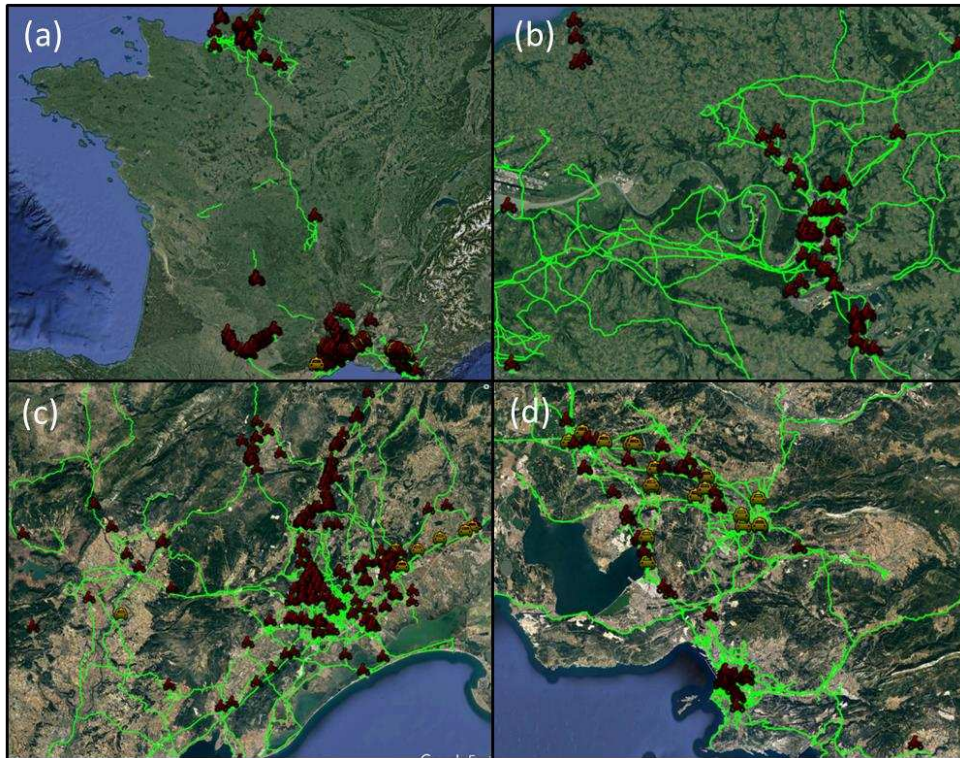


Fig. 1 Distribution of incidents in: (a) France (b) Normandy-Centre (c) Hérault (d) PACA. Travels (green), motorcycles' incidents (red), cars' incidents (orange) with google earth satellite view

### 3.3. Examples of events

#### 3.3.1. Passing on a tram railway

This event presents two close triggers when the motorcyclist passes on a tram railway at a crossroad, as can be seen on his trajectory at Figure 2 (a). The two resulting big shakes on the rotational angular accelerations are visible on Figure 2 (b). The speed of the motorcyclist is about 50 km/h when passing the rails. Figure 3 shows two images among the 450 of the video recorded, one just before the triggering where the rails are visible in front of the motorcycle, the second at the time of triggering. These rails crossing the road at an intersection are not dangerous for the cars but might be for the motorcycles in a turning manoeuvre.

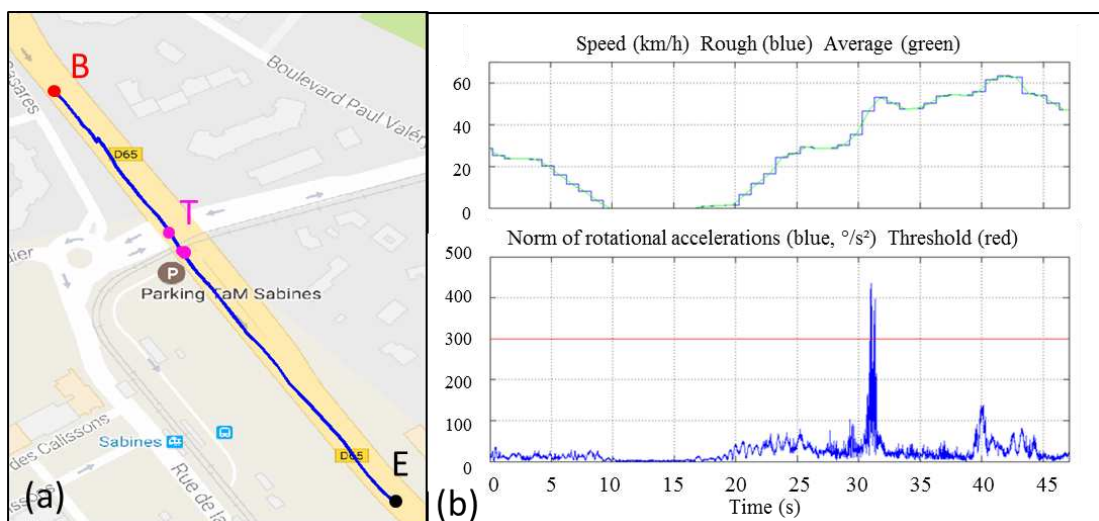


Fig. 2 (a) Map: Beginning of recording (B), Triggering (T) End (E); (b) Speed and norm of rotational accelerations



Fig. 3 Selected images of the video: (a) View of the tram rails; (b) Triggering when passing on the rails

### 3.3.2. Accumulation of events

Every road default or layout where an event triggers is not necessarily a site where to focus on to improve road safety. The interest of events is their accumulation at some locations because it can reveal the potential danger of the road default or the layout especially for a motorcycle. It can orientate the action of the road manager, for example in the case of a subsiding cutting with manholes, as shown at Figure 4 where 10 events were collected in the same place.



Fig. 4 Accumulation of 10 events on a subsiding cutting

### 3.4. Examples of incidents

#### 3.4.1. Longitudinal incident: Braking caused by the overtaking of a heavy goods vehicle

In this example, the motorcyclist approaches a toll, as can be seen on Figure 5. His speed is about 100 km/h and he applies three times the brake, the first exceeds the threshold (Figure 6 (a)). A few images of the recorded video at Figure 6 (b) show that a heavy goods vehicle overtakes him by the left to go towards a queue on the right, thus crossing his straight line trajectory.

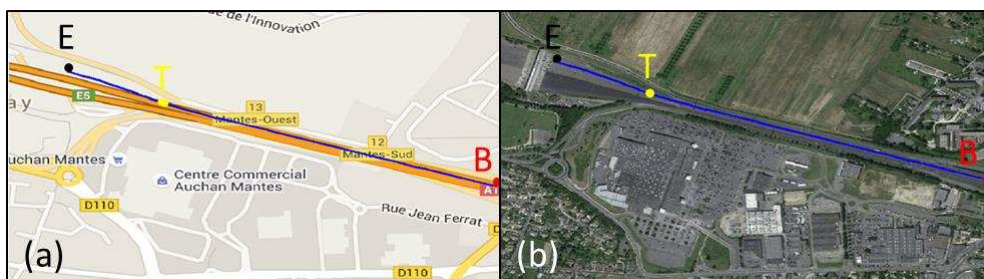


Fig. 5 (a) Map; (b) Satellite view of the trajectory: Beginning of recording (B), Triggering (T) End (E)

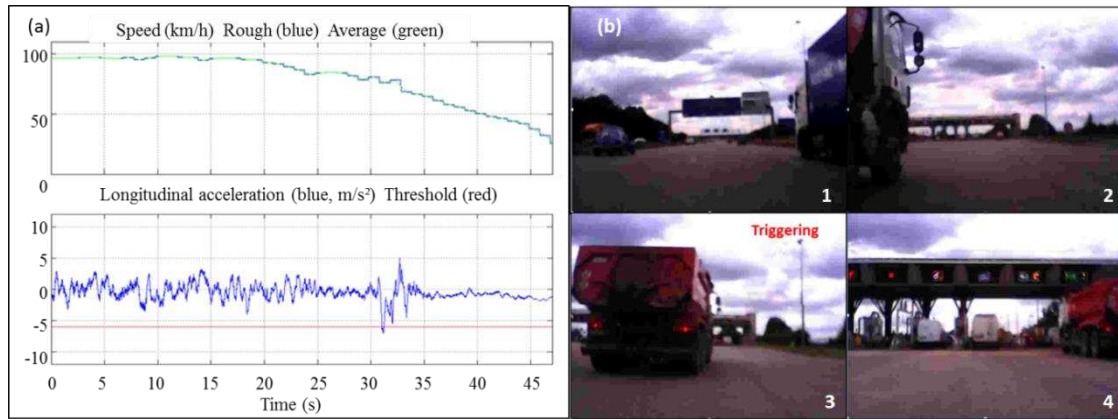


Fig. 6 (a) Speed and longitudinal acceleration; (b) Selected images of the video

### 3.4.2. Lateral incident: A succession of bends

This incident occurred in a sinuous route (Figure 7). The triggering on the norm of the three rotational angular rates comes up during the high and sudden swaying of the motorcyclist between a left and a right successive bends, at a speed of 75 km/h. It is the combination of a peak of the yaw rate ( $55^\circ/\text{s}$ ) and a peak of the roll rate ( $63^\circ/\text{s}$ ) that leads to the overtaking of the threshold ( $80^\circ/\text{s}$ ), as can be seen at Figure 8 (a). A selection of images at Figure 8 (b) shows the swing of the movement.

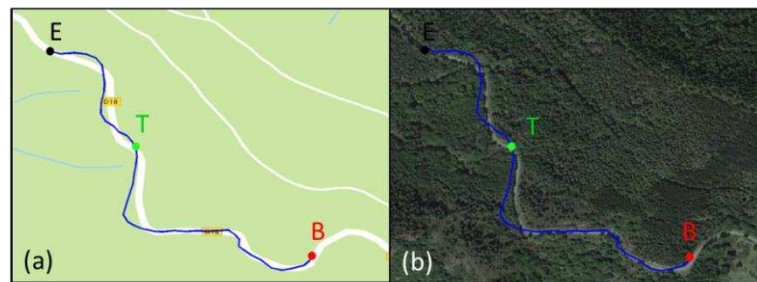


Fig. 7 (a) Map; (b) Satellite view of the trajectory: Beginning of recording (B), Triggering (T) End (E)

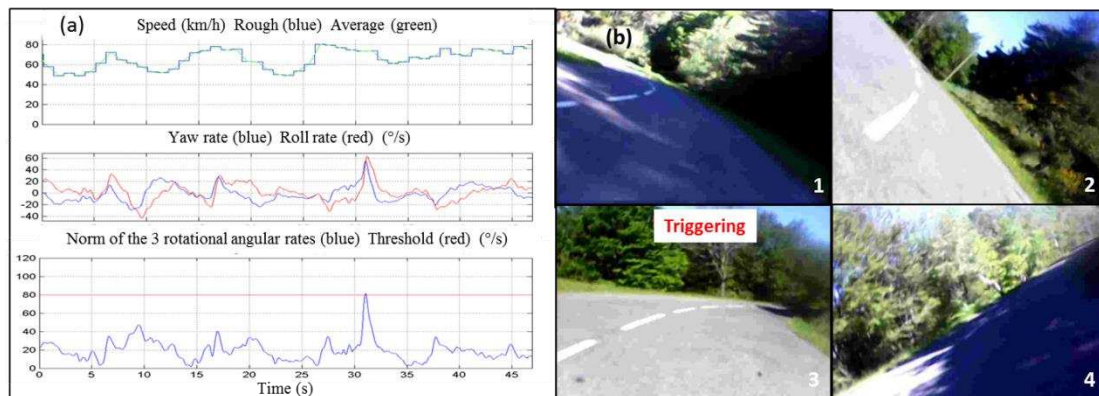


Fig. 8 (a) Speed, Yaw and Roll rates and norm of 3 rotational angular rates; (b) Selected images of the video

### 3.5. Accelerations and rotational angular rates

Among the 395 motorcycles incidents, the great majority (96%) triggered on Criterion 1, with the longitudinal deceleration exceeding  $-6 \text{ m/s}^2$ . Only 4% of the incidents are linked to a lateral triggering: 2% on the Criterion 2, with the norm of the three rotational angular rates exceeding  $80^\circ/\text{s}$ , and 2% on the Criterion 3, with the norm of the three rotational angular accelerations exceeding  $300^\circ/\text{s}^2$ . However among the longitudinal triggered incidents, there is not only hard braking. Figure 9 shows the distribution of all the incidents according to the type of dynamic demand:

- 86% of the incidents are hard braking.
- 3% are lateral triggering incidents (some of them triggered on the Criterion 3).
- 9% are linked to vertical wavering that fell back on the longitudinal acceleration, during journeys on highways at a high speed.
- 3% are linked to sudden bumps, high enough to be classified as incidents and not as simple events.

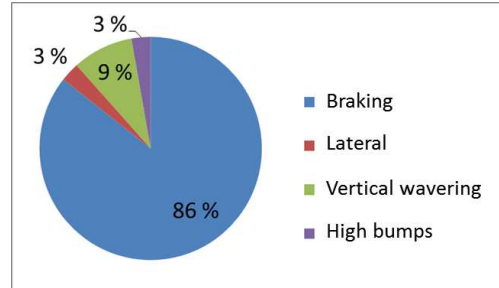


Fig. 9 Distribution of the 395 incidents according to the type of dynamic demand

The extreme values of the principal parameters of motorcycle dynamics were calculated during the periods of triggering, for all the incidents. Their averages are presented in Table 1, with the duration of the triggering, in order to be compared by type of dynamic demand and by type of vehicle.

Vehicle Type Number	Long. Acc.	Lat. Acc.	Roll rate	Pitch rate	Yaw rate	Ang. Acc. Norm.	Speed	Duration
	m/s <sup>2</sup>	m/s <sup>2</sup>	°/s	°/s	°/s	°/s <sup>2</sup>	Km/h	s
Motorcycles All 395	Min	-6.7	-0.6	-4.2	-2	-4	80	
	Max	-4.4	0.6	4	4	2	179	0.45
Motorcycles Braking 314	Min	-7	-0.5	-3	-1	-3	76	
	Max	-5.3	0.4	3	4	1	123	0.46
Motorcycles Lateral 11	Min	-1.3	-1.2	-25	-12	-13	50	
	Max	1.5	1.5	38	-1	33	363	0.80
Motorcycles Vertical 35	Min	-6.6	-0.8	-3	-2	-2	128	
	Max	-4.3	2.3	3	2	2	175	0.39
Motorcycles Bumps 11	Min	-4.5	-0.3	-3	-8	-10	60	
	Max	-0.7	0.9	3	5	-1	612	0.12
Cars All 32	Min	-3.1	0.4	-1	-1	-21	51	
	Max	-2.0	1.9	2	2	12	30	0.87
Cars Braking 11	Min	-6.7	-0.3	0	-1	-2	68	
	Max	-5.8	0	1	1	-1	20	0.45
Cars Lateral 21	Min	-1.2	L 5.6 R -6.6	-2	-1	8	42	
	Max	0	L 6.4 R -6.0	2	3	18	35	1.09

Table 1. Minima and maxima average for dynamics parameters according to the type of demand and the type of vehicle.

Overall, the comparison between cars and motorcycles incidents brings the following observations:

- The levels of longitudinal deceleration are higher for the motorcycles (-4.4 to -6.7 m/s<sup>2</sup>) than for cars (-3.1 to -2 m/s<sup>2</sup>), for all incidents. It can be explained by the greater proportion of braking incidents with motorcycles.

- The levels of lateral acceleration are low for the motorcycles, even for the incidents with lateral triggering. It is linked to the fact that the motorcyclist inclines his motorcycle to negotiate a bend or to turn, and as a result the lateral acceleration in the coordinate system of the vehicle is low.
  - The speeds during the triggering periods are clearly higher for motorcycles (80-88 km/h) than for cars (51-56 km/h).
  - For motorcycles, the duration of triggering is almost half of the cars' one (0.45 s versus 0.87 s).
- A focus on the braking incidents highlights the following aspects:
- The longitudinal accelerations are similar between both types of vehicle, with a larger interval for the motorcycles.
  - The duration of triggering is also similar (0.46 s versus 0.45 s).

For the lateral triggering incidents:

- The lateral accelerations exceed in average 6 m/s<sup>2</sup> for the cars, as expected since it is the value of the threshold, whereas they are very low for the motorcycles.
- On the contrary the level of roll rate is much higher for the motorcycles (between -25 °/s and 38 °/s) than for the cars (between -2°/s and 2 °/s). Both observations are explained by the different behaviours of the vehicles in turning.
- The average level of the norm of rotational angular accelerations is also much higher for motorcycles (363 °/s<sup>2</sup>) than for cars (35 °/s<sup>2</sup>), showing the extent and the capacity of the motorcyclists' swinging.

### 3.6. Road configuration

Figure 10 provides additional knowledge about the distribution of incidents as a function of the road layouts involved, whatever the manoeuvres concerned. For the motorcycles (a), 12% of the 395 incidents are located on highways, and 42% on straight line on other roads. Almost half of these 42% occurred just before a crossroad, with often the presence of traffic lights and/or zebra crossing. Bends are involved in 18% of cases, whereas turns to right/left in 5 % of incident. The remaining 24% are roundabouts, with 22 % in the right bend entrances or approaching the roundabout (and often braking), 1 % in the right bend exits, and 2 % in the central part of the roundabout. It has to be pointed out that a large part of the incidents are braking even in the bends or before turning manoeuvres.

The comparison with cars' incidents is difficult because its number is low. Yet it can be noticed there are more than twice incidents in bend for cars than for motorcycles. These incidents are often triggered because of the lateral acceleration which exceeds the threshold. However there are seven times less incidents in straight line road.

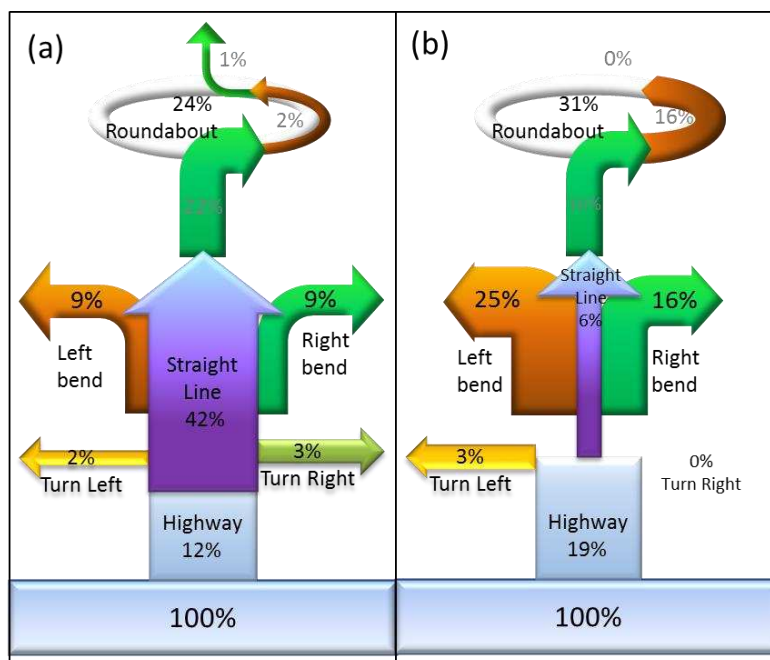


Fig. 10 Distribution of the incidents according to the road configuration: (a) 395 motorcycles' incidents; (b) 32 cars' incidents

### 3.7. Causes of incidents

An analysis of the different causes of the incidents, between a road infrastructure cause, a human cause and a vehicle dynamics cause, was carried out essentially by examining the video recordings. This analysis gives a first approximation of the potential role of the different elements involved in the situation, with the aim of having a global idea of their frequency. Among the 395 motorcycle incidents, 187 video recordings were collected. In the other situations there have been some technical problems in real time or for sending data. Some of these video recordings had a very poor quality, due to the resolution deliberately low but also because of bad weather or bad light conditions. However data on some incidents without video were sufficient to enable the analysis of the potential causes. In 207 cases this analysis could be performed, being 52% of the motorcycles incidents. For the 32 car incidents, 15 had a video recording with a sufficient quality to do the same study.

The results presented at Figure 11 concern the proportion of these incidents which derive from the infrastructure, the vehicle, the driver or other road users. A part of them combine several of these potential causes. In 40 % of the motorcyclists' incidents the road infrastructure could have played a role. For example it can be linked to a problem of visibility or a lack of road signs. For cars' incidents the proportion is only 20% (but the sample is very small).

The motorcycle could have been involved in the occurrence of the incident in 19% of the cases, whereas no car incident can be attributed even partly to the vehicle. It has to be notice that the role of a motorcycle eventually involved in an incident is a lot more hypothetical than the other possible elements, because a technical problem is rarely detectable on the video recording of the scene in front of the vehicle. The incidents considered in this category presented generally some signs on the other recorded data, such as wavering of the rotational angular rates or accelerations, which could have another cause.

94% of the motorcyclists and 100% of the car drivers are considered as involved in the occurrence of the hazardous situation. The other road users, such as cars, motorcycles, heavy trucks, cyclists or pedestrians played a role or could have played a role in the incident in 39% of the motorcycles incidents and 27% of the cars incidents. It is often the combination of two or three of these elements that could have been involved. It must be pointed out that the rider/driver is almost always implicated in the incident because even when the infrastructure or other road users have played a key role, often he/she did not anticipate and adapt his/her speed.

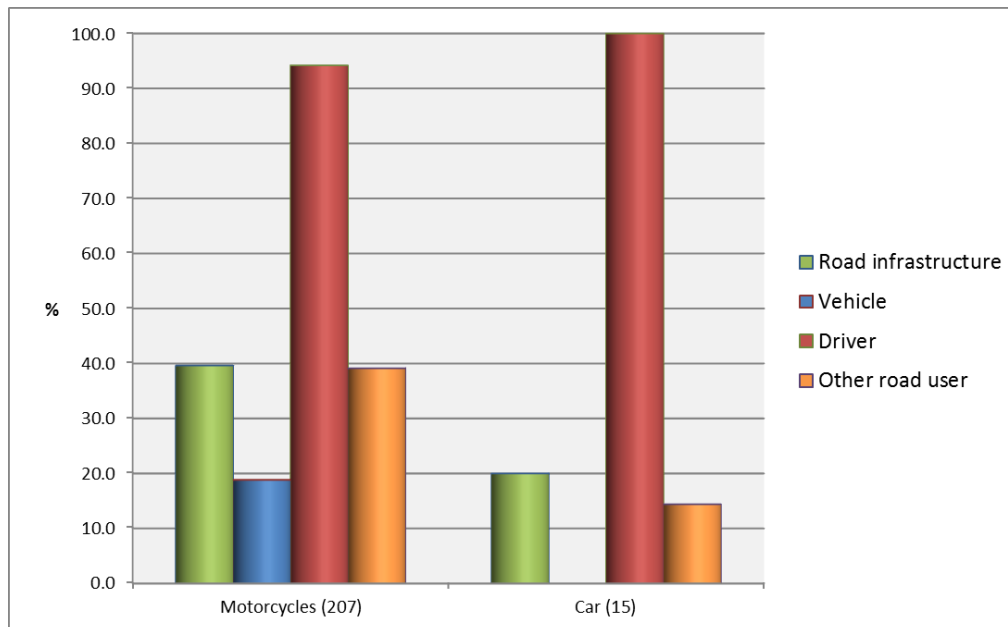


Fig. 11 Potential role of road infrastructure, vehicle, driver and other road user in the incidents

#### 4. Discussion and conclusion

The collection of more than 1100 interesting driving situations, during 41000 km travelled, led to distinguish the incidents and the simple events. The events were not analysed in this paper but could be exploited in the future to help the road managers to focus on local defaults or bad design of some road layouts, especially when problems appear for motorcycles and not necessary for cars.

The 395 motorcycles incidents and the 32 cars incidents were analysed in detail. The rates of incidents per 100 km are 1.08 for motorcycles and 0.71 for cars but depend of course on the triggering threshold. These kinds of incidents are representative of safety relevant situations, thus they can be used to acquire knowledge on the motorcycles' accident mechanisms and improve their safety. According to the data acquisition performed in this experiment, the threshold used to detect incidents could be reviewed and defined more accurately.

The analysis of the triggering criteria, of the dynamics parameters and of the road configurations illustrates the great variety of situations and circumstances with different levels of intensity. Moreover it shows the different behaviours between motorcycles and cars.

The results on the causes of the incidents show that the more frequent cause is the driver, in agreement with most of the studies on car crashes causes. For example Singh [2015] reported that, in the National Motor Vehicle Crash Causation Survey conducted in US from 2005 to 2007, on a sample of 5,470 crashes, the critical reason was assigned to the driver in 94 % of the crashes. This proportion could be even higher for motorcyclists' crashes. It has to be noticed that the quality of the recording video and the camera field of view were sometimes insufficient to see in the environment all the elements necessary to identify their role in the incident (road signs, other road users...). A field survey by experts on the location of the incidents could refine or even modify the analysis of the causes, especially concerning the role of infrastructure. It was done in the previous project already quoted with 50 cars recording incidents during one year [Ledoux et al., 2014]. The expertise included sometimes propositions of modification of the road lay out.

The next step would be to carry out in-depth case studies of motorcycles' incidents to better understand accident mechanisms.

#### Acknowledgements

The authors would like to thanks the French Road Safety Foundation which support the project and the "Mutuelle des Motards" for their valuable help to recruit volunteers.

#### References

- Koenen, C., 1983. The dynamic behaviour of a motorcycle when running straight ahead and when cornering.
- Evangelou, S., 2004. Control and Stability Analysis of Two-wheeled Road Vehicles. University of London.
- Cossalter, V., 2006. Motorcycle dynamics. Lulu. Com.
- Dingus, T.A., Klauer, S.G., Neale, V.L., Petersen, A., Lee, S.E., Sudweeks, J., Perez, M.A., Hankey, J., Ramsey, D., Gupta, S., Bucher, C., Doerzaph, Z.R., Jermeland, J., Knippling, R., 2006. The 100-Car Naturalistic Driving Study Phase II – Results of the 100-Car Field Experiment, U.S. DOT HS 810 593. Department of Transportation, National Highway Traffic Safety Administration, Washington DC.
- MAIDS, 2010. <http://www.maids-study.eu/>.
- Serre, T., Naude, C., Fournier, J-Y., Dubois-Lounis, M., Chauvet, S., Lechner, D., Ledoux, V., 2014. Causes of road driving hazardous situations. Transport Research Arena international conference, Paris, Apr.
- Ledoux, V., Subirats, P., Violette, E., Bonin, Y., Serre, T., Naude, C., Guilbot, M., Lechner, D., 2014. Using event data recorder to detect road infrastructure failures from a safety point of view. European Transport Conference, Francfort, Sept, 2014.
- Observatoire national interministériel de la sécurité routière, L'accidentalité routière en 2014. La documentation Française.
- Wu, K-F., Aguero-Valverde, J., P.Jovanis, P., 2014. Using naturalistic driving data to explore the association between traffic safety-related events and crash risk at driver level. Accident Analysis and Prevention 72(2014) 210-218.
- Attal, F., 2016. Classification de situations de conduite et détection des événements critiques d'un deux roues motorisé. [Online]. Available: <https://tel.archives-ouvertes.fr/tel-01271020/document>.
- Guilbot, M., Serre, T., Naude, C., Ledoux, V., 2016. Legal conditions for implementing EDRs in public fleets of vehicles, 11th ITS European Congress, Glasgow, United Kingdom June 6-9, 10p.
- Naude, C., Serre, T., Dubois-Lounis, M., Fournier, J-Y., Lechner, D., Guilbot, M., Ledoux, V., 2017. Acquisition and analysis of road incidents based on vehicle dynamics. Accident Analysis & Prevention, ISSN 0001-4575. On line March, 9<sup>th</sup>, 2017. In Press.
- Singh, S. (2015) Critical reasons for crashes investigated in the National Motor Vehicle Crash Causation Survey. Traffic Safety Facts. DOT HS 812 115. U.S. Department of Transportation, National Highway Traffic Safety Administration (NHTSA). Washington, DC.
- Costa L., Perrin C., Serre T., 2017, Using of Pacejka tire model within a power two-wheelers multibody model for emergency situations analysis. EUROMECH 578 (European Mechanics Society), 10-13 April 2017, Madeira, Portugal, 15p.