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Real Use of the Dynamic Capacities of Motorcycles

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Abstract

Motorcycle crashes are on the increase in most occidental countries whereas there is a decrease in crashes involving cars. Motorcyclists are more likely to be injured or killed than car occupants. It can be explained by their vulnerability on the road but also by their riskier behavior. There is a need to extend the knowledge on Power Two-Wheeler (PTW) mobility and crash mechanisms. This paper aims to explore the real use of PTW's dynamic capacities by the riders in a French Naturalistic Riding Study with 26 equipped motorcycles. The results concern 36500 km traveled during one year. Data used are syntheses aggregating the time spent in every combination of longitudinal acceleration and roll or yaw rate, included the speed information. The motorcyclists endure rarely high levels of dynamic demands: in acceleration and deceleration they exceed $\pm 4 \text{ m/s}^2$ only 0.2% of the time and in lateral their roll rate exceeds $20^\circ/\text{s}$ only 0.8% of the time and their yaw rate 1.4% of the time. This kind of data also allows discriminating different behaviors between a sporty and a smoother way of riding a motorcycle.

I. Introduction

In France, users of Powered Two Wheelers (PTW) are less than 2% of the traffic but, in the accidents, they represent 43% of serious injuries and 22% of fatalities [1]. Approaches using Naturalistic Driving Studies are efficient to get a better understanding of accident mechanisms and to improve road infrastructure safety ([2], [3], [4]). Several studies on crash causes show that the most frequent cause is the human behavior. For example Singh in [5] reported that, in the National Motor Vehicle Crash Causation Survey 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. Concerning PTW users, two specific issues could also explain the statistics: the role of infrastructure, not designed for them, and the handling ability of this kind of vehicle.

This paper aims to characterize the real use of PTW's dynamic capacities thanks to a specific algorithm implemented in the Event Data Recorder (EDR) equipping a fleet of private motorcycles. The real time collection of "synthesis data" provides the global distribution of accelerations, rotation rates and speeds, which are characteristic of the couple rider-motorcycle dynamics.

First the dynamic parameters are analyzed in terms of time spent with medium or high demands, in longitudinal direction (accelerations / braking) and in lateral direction (cornering). Then the analysis focuses on the highest values reached at least once by the riders. The dynamic behavior of the whole fleet will be presented as well as two examples of the variability of riding behaviors (calm/sporty riding). Then a specific itinerary travelled several times by two riders will be presented, where the differences in the dynamic parameters are due to the different behaviors of the riders, in longitudinal (number and intensity of braking and accelerations, level of speeds) and in lateral (more or less leaning of the motorbike). Finally the levels of speed are analyzed. This kind of exposure data is rare, at least in France, and is necessary to better estimate the real motorcyclists' behavior.

II. Material and Methods

A. Experimentation

In 2014-2017, the French Foundation for Road Safety (FSR) supported a new program to acquire Naturalistic Riding Data and to know more about the PTW dynamics of and the use of road infrastructures by riders. 26 private

motorcycles were implemented with smartphones used as Event Data Recorders (EDR). During one year, the devices continuously collected data on riding behavior and manoeuvres performed by the riders, thanks to accelerometers, gyro meters and a GPS. Trajectories and syntheses of dynamic parameters were collected in real time for all their professional and personal journeys. From the experiment about 3000 journeys were exploited, representing 36500 km (Fig. 1).

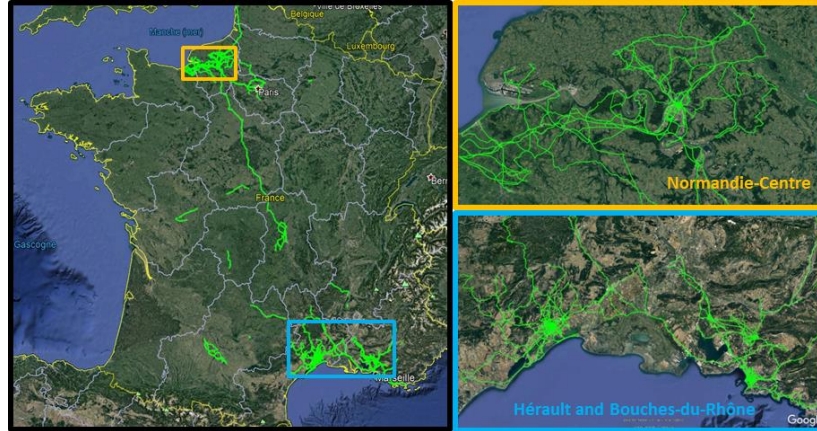


Figure 1 – Map of the trajectories with zooms on Normandie-Centre, Hérault and Bouches-du-Rhône

B. Data

The syntheses are based on the principle of “friction circle”, developed by Lechner & Perrin [6], whose experiment with cars aimed at acquiring knowledge on the behavior of the couple driver-vehicle in usual driving situations. For cars, the syntheses aggregate the time spent in every longitudinal and lateral combination of acceleration, data being stored in matrices [7]. This concept was transposed for motorcycles using the roll or yaw rate instead of the lateral acceleration to take into account the specific behavior of PTWs.

This kind of data provides different levels of knowledge. The distributions of the dynamic parameters show the repartition between high/low and right/left dynamic demands. Accelerations and rotation rates are counted by intervals of 1 m/s² and 10°/s, the speed by 5 km/h. The following vehicle dynamics’ parameters are analyzed in terms of time spent beyond the usual values and also considering the exploration of extreme values:

- Longitudinal acceleration (accelerations and braking)
- Lateral acceleration (cornering)
- Roll rate (speed of leaning)
- Yaw rate (speed of rotating around the vertical axis),
- Speed.

The measured signals were filtered before the synthesis algorithm was applied, especially accelerations which are quite noisy for motorcycles. The first interval 0-5 km/h was not taken into account in all the results because the motorcycles are often leaned and eventually on a stand before starting or after stopping. These periods would distort the distribution of dynamic parameters, especially the lateral acceleration.

The three-dimension graph adds the time spent in each combination of values. It provides an overview of the dynamic real use of the motorcycle(s). A fourth dimension in the same graph, thanks to the colors applied according to the level of speed, completes the information.

III. Results

A. Level of accelerations and rotation rates

Fig. 2 presents the distributions of the main parameters during all the journeys of motorcycles. Considering the longitudinal acceleration, it can be noticed that the motorbikes were 56% of the time in acceleration and 44% in deceleration. The dynamics of a motorcycle is different from a passenger car. The motorcyclist leans with his motorcycle which at first glance implies that he endures little to no lateral acceleration in the motorcycle coordinate system. As expected there is very few lateral accelerations beyond 1 m/s² and more roll rate and yaw rate beyond

10°/s.

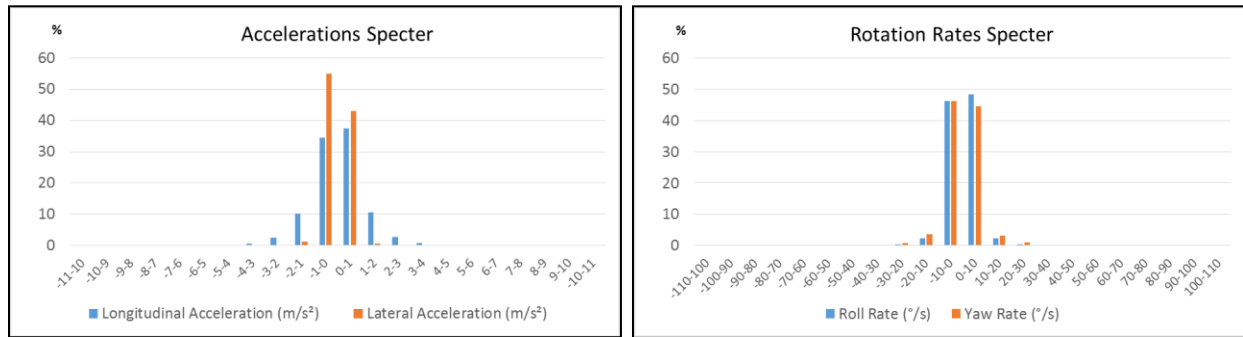


Figure 2 – Distribution of Longitudinal and Lateral Accelerations (Left) and Roll and Yaw Rates (Right)

The table 1 summarizes the times spent beyond 2, 3 and 4 m/s² for accelerations and 10, 20, 30°/s for rotation rates. In acceleration, the longitudinal acceleration exceeded 1 m/s² 14.5% of the time, 2 m/s² 3.8% of the time, and 3 m/s² only 1% of the time. Beyond 4 m/s² the proportion falls to 0.2%. In deceleration, the level exceeded -1 m/s² 13.5% of the time, -2 m/s² 3.2% and 3 m/s² 0.7%. Only 0.2% of the time was spent beyond -4m/s². The roll rate exceeded 10 °/s 5.4% of the time, 20°/s only 0.8% of the time and 30°/s only 0.2% of the time. Concerning the yaw rate, the percentages are 9.2% beyond 10°/s, 1.4% beyond 20°/s and 0.5% past 30°/s. Overall the motorcyclists endure rarely high levels of dynamic demands.

Table 1: Time spent beyond medium and high values of dynamic parameters

Time spent (%)		
Dynamic Parameter	Threshold	Time spent (%)
<i>Deceleration(Braking)</i>	1 m/s ²	13.5
	2 m/s ²	3.2
	3 m/s ²	0.7
	4 m/s ²	0.2
<i>Longitudinal Acceleration</i>	1 m/s ²	14.5
	2 m/s ²	3.8
	3 m/s ²	1.0
	4 m/s ²	0.2
<i>Lateral Acceleration (Absolute Value)</i>	2 m/s ²	0.2
	3 m/s ²	0.1
	4 m/s ²	0.0
<i>Roll Rate</i>	10°/s	5.4
	20°/s	0.8
	30°/s	0.2
<i>Yaw Rate</i>	10°/s	9.2
	20°/s	1.4
	30°/s	0.5

B. Crossing of dynamic parameters: extreme values of accelerations and rotation rates

The crossings of dynamic parameters in two dimensions highlight the maximal extended area of the demands endured at least once by a motorcyclist during his travel, thus especially the extreme values reached. Fig. 3 presents the following crossings:

- The crossing between longitudinal and lateral accelerations, which is more representative of the cars dynamic demands
- The crossing between longitudinal acceleration and roll rate, which is more relevant for PTWs
- The crossing between longitudinal acceleration and yaw rate, which is more comparable between both

types of vehicle.

The intervals taken into account are 1 m/s^2 for accelerations and $10^\circ/\text{s}$ for the roll rate and the yaw rates; the ranges are $\pm 15 \text{ m/s}^2$ for accelerations and $\pm 150^\circ/\text{s}$ for rotation rates with a last class for values beyond these limits. It can be noticed that the maximal deceleration value is 15 m/s^2 and the maximal acceleration value is beyond 15 m/s^2 , which can be linked to a braking and a high acceleration but also to big jolts. There are sometimes quite high lateral accelerations until $\pm 11 \text{ m/s}^2$ also eventually linked to jolts, but the roll rate extreme values are far higher, at least once to the maximal values of $\pm 150^\circ/\text{s}$ and more often to $\pm 120^\circ/\text{s}$. The yaw rate is less extended than the roll rate, to $\pm 100^\circ/\text{s}$ and sometimes $\pm 120^\circ/\text{s}$.

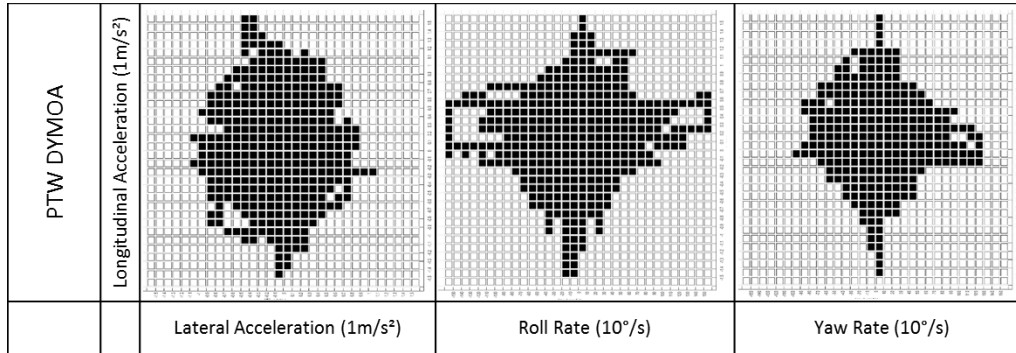


Figure 3 – Crossings of longitudinal acceleration with lateral acceleration roll rate and yaw rate: highlight on extreme dynamic demands

C. Crossing of dynamic parameters: discriminating behaviors

The left graph of Fig. 4 shows the dynamic behavior of the whole fleet during one year, with the crossing between the longitudinal acceleration and the roll rate. This three-dimension representation also gives the opportunity to show the variability of riding behaviors and to compare calm riding with more sporty riding. The colors characterize the levels of speed of the motorcycles, from low speed in blue to high speed in red. Examples of a calm rider and a sporty rider are displayed in the right part of Fig. 4, where the levels of longitudinal acceleration and roll rate are clearly different.

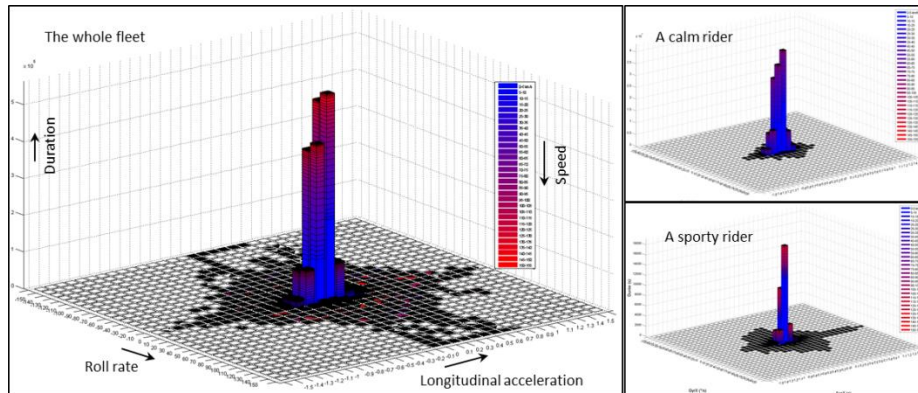


Figure 4 – 4D-representation of the dynamic demands - Left: the whole fleet of motorcycles – Right: Two extreme riders, one classified as “calm” and one considered as “sporty”.

However the difference between two riders can partly be attributed to the type of roads taken, if for example one rides often on sinuous roads (frequently cornering), the other on highways or high speed roads (less cornering) or a third often in urban areas (more braking and accelerating). A comparison is done at Fig.5 on a specific itinerary travelled 4 times by a rider and 3 times by another, where the differences in the dynamic parameters are only due to the different behaviors of the riders, in longitudinal (number and intensity of braking and accelerations, level of speeds) and in lateral (more or less leaning of the motorbike). The first rider spent in average 9 min 01s for his journey at an average speed of 57.7 km/h and the second driver 10 min 17s at a speed of 45.3 km/h. This difference

in speed and time is translated into different dynamic behaviors: the first rider reached longitudinal accelerations from -7 m/s^2 to 6 m/s^2 and roll rates from $-40^\circ/\text{s}$ to $+50^\circ/\text{s}$, whereas the second reached -5 m/s^2 only in braking and values from $-20^\circ/\text{s}$ to $30^\circ/\text{s}$ for roll rates.

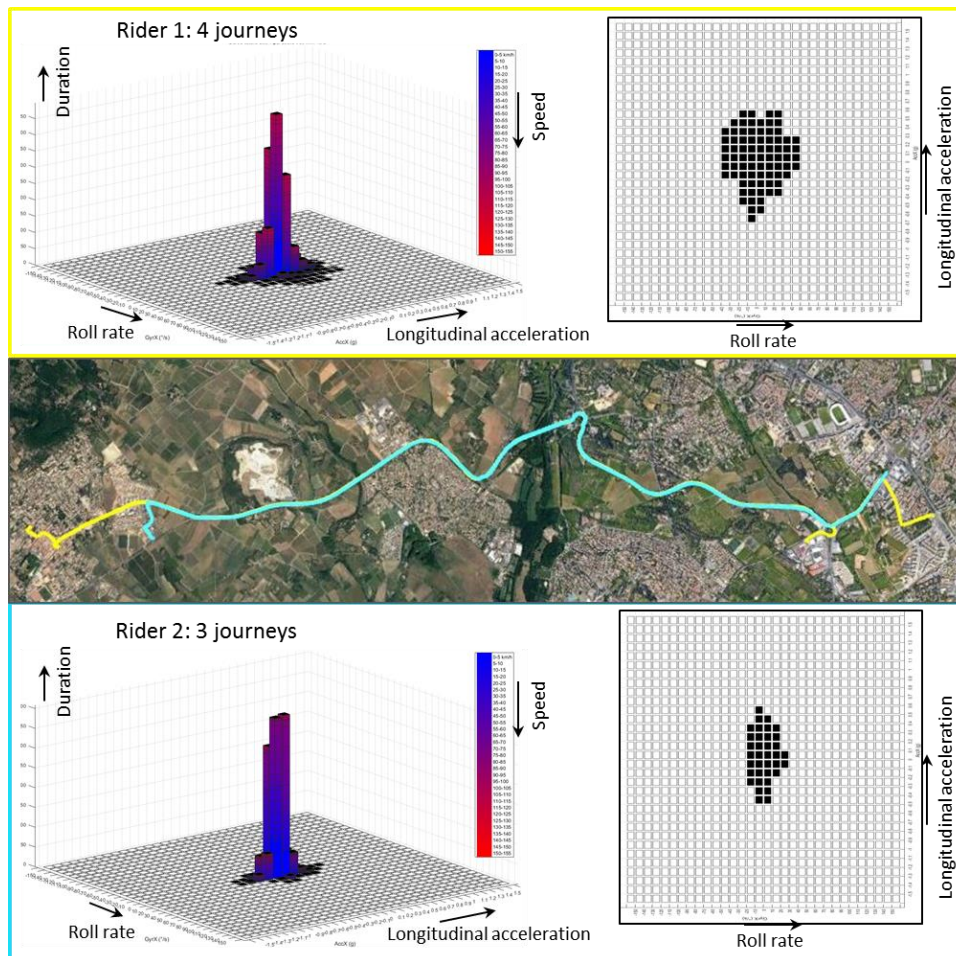


Figure 5 – Comparison of dynamic syntheses of two riders on the same itinerary.

D. Levels of speed

The dynamic demands of the motorcycle are linked to the speed. The left part of Fig.6 presents the speed distribution for the whole fleet during the experimentation, thus for the 36500 km traveled. The motorcyclists spend 24% of their time in the interval 0-5 km/h, due to the periods before starting and after stopping. Apart from this category, they are often riding at a speed between 20 and 60 km/h, probably in urban areas, with a maximum between 35 and 40 km/h. It can be notice a slight rise of time spent around 100 km/h, just after the legal speed limit of 90 km/h on national and regional roads in France, and a more pronounced rise around 125 km/h, just before the 130 km/h speed limit on highways. The motorcyclists are 2.6% of the time above this limit of 130 km/h and 1% of the time beyond 150 km/h. On the right part of Fig.6 is shown the comparison between the journeys of riders 1 and 2 on the same itinerary. The repartition of speeds is clearly different: the rider 2 is a lot more often above 75 km/h than rider 1.

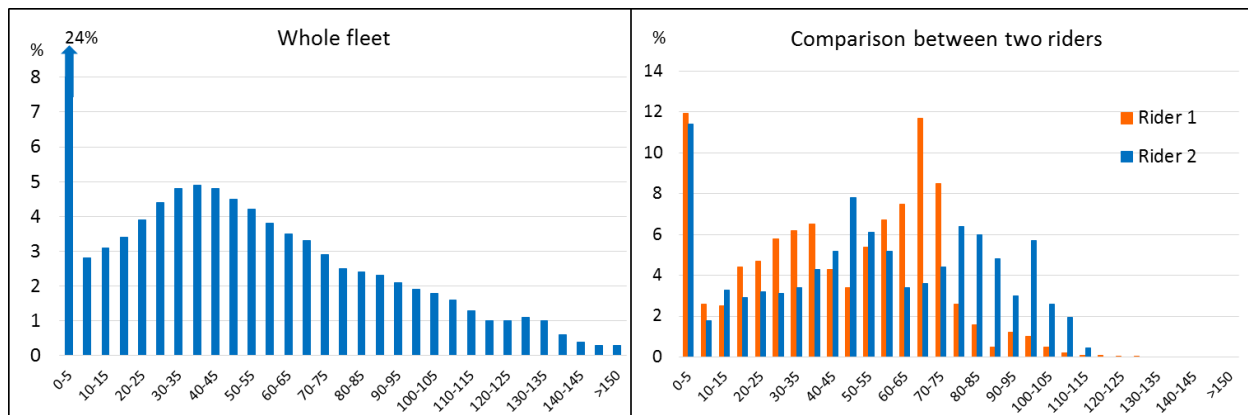


Figure 6 – Speed distribution: whole fleet of motorcycles (Left) – Comparison between riders 1 and 2 (Right)

V. Conclusion

Road exposure data are rare for PTWs. The real use of vehicle dynamic capacities by riders was analyzed using data from a Naturalistic Rider Study experimentation conducted in France with 26 equipped motorcycles that traveled 36500 km. The distribution of accelerations roll and yaw rates and speeds as well as the crossing between the longitudinal acceleration and the roll rate or the yaw rate characterize the dynamics of motorcycles. The motorcyclists endure rarely high levels of dynamic demands; especially in acceleration and deceleration they exceed $\pm 4 \text{ m/s}^2$ only 0.2% of the time and their roll rate exceeds $20^\circ/\text{s}$ only 0.8% and their yaw rate 1.4% of the time. This kind of data also enables to differentiate different riders' behaviors between a sporty and a smoother riding. The distribution of speed levels also provides interesting information and is contrasted between riders on the same itinerary. The synthesis data do not enable to know where the extreme dynamic values occur. Other studies are based on road driving hazardous situations called incidents, such as presented in [8].

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