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► **To cite this version:**

Claire Naude, Thierry Serre, Maxime Dubois-Lounis, Jean-Yves Fournier, Vincent Ledoux. Using EDR to evaluate the loss of control risk. 11th ITS European Congress - Delivering future cities now, Jun 2016, Glasgow, United Kingdom. 10p. hal-01367371

HAL Id: hal-01367371

<https://hal.science/hal-01367371>

Submitted on 16 Sep 2016

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ITS-EU-SP0083

Using EDR to evaluate the loss of control risk

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Abstract

EDRs (Event Data Recorders) enable to record potential crashes but also incidents, i.e. critical situations where the vehicle reaches high dynamics demands in longitudinal, lateral or combined direction. This study is based on various situations acquired by EDRs in a bend considered as a zone of interest, because numerous losses of control were reported in the past. The noise of lateral acceleration was quantified in the bend by two methods for 116 recordings, from normal driving passages to critical situations called incidents. The results show that in the most difficult part of the bend, the noise of incidents is superior to normal driving passages, showing that the vehicles come closer to their grip limits. This criterion is useful to evaluate the loss of control risk and the severity of an incident. This approach is complementary to other researches taking into account the dynamical driving parameters of the vehicle.

Keywords:

Loss of control, EDR, Noise.

Introduction

EDRs (Event Data Recorders) are often used to better understand the road driving behaviour and main approaches concern Naturalistic Driving Study, such as Guo & Fang [1] or Hallmark & al. [2]. During the driving task, the most interesting and relevant situations are not only crashes but also hazardous situations which are considered as incidents, and sometimes called near-crashes. These risky situations are critical because the vehicle reaches high dynamics demands in longitudinal, lateral or combined directions. The car behaviour is out or at the limit of driver's control, and ends without car impact. Incidents detection relies on the analysis of vehicle dynamic parameters recorded by Event Data Recorders. Under slightly different circumstances these incidents could have resulted in injury or material damage crashes.

In order to better understand accident mechanisms, the objective of this study is to compare normal driving with incident situations on specific sites where accidents occurred. It is focused on lateral incidents linked to loss of control accidents.

Different approaches can be explored to estimate if a lateral incident could have turned into a loss of control. Focusing on the level of the lateral acceleration in a bend, which depends on the speed and the radius of curvature, Lechner & al. [3] developed a method based on real passages in bends and

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simulated the driving behaviour of the car at higher speeds until the loss of control. Bagdadi & Varheli [4] estimated the severity of a safety critical situation such as a traffic conflict by using the jerk (i.e. derivative of acceleration) after appropriate filtering of signals. They take into account the difference between the consecutive negative and positive peaks of jerk observed during a braking. This method is evaluated on braking tests carried out by equipped vehicles with EDR and video, with an expert observer used to the Swedish traffic conflicts method. It was then applied to Swedish naturalistic driving data. The method could be transferred to lateral jerk in steering, in order to characterize the brutality of the solicitations. Moreover, it could be interesting to take into account the potential high levels of sideslip during an incident. Yet the simplified calculations for sideslip angle are not reliable. Doumiati & al. [5] developed an observer of sideslip angle based on Kalman Filter, which could enable to estimate the closeness of a loss of control when the vehicle drifts without a high level of lateral acceleration (wet/icy road, worn tires...).

This paper deals with a new approach based on the noise of the acceleration signal recorded by EDR. It consists in quantifying this noise for lateral situations and evaluating its relevance to estimate the severity of the incident. The hypothesis is to consider that the noise of the acceleration signal increases with the loss of control risk, leading to think that the vehicle comes closer to its grip limits. The study is based on various and numerous recordings in a zone of interest with a bend where the vehicles often reach high levels of lateral acceleration, and where many losses of control accidents have been reported in the past.

Material and methods

Experimental context

In 2010, the French government decided to support the SVRAI project (Saving Lives through Road Incident Analysis Feedback) to complete accidentology with incidentology data in order to prevent accidents. This project relies on the use of an Event Data Recorder called EMMA (Embedded data logger for accident mechanisms) specifically designed by IFSTTAR-LMA (Ledoux [6], Lechner [7]). 51 EMMA were implemented on public light vehicles fleets, in three regions of France. The data collection started in August 2012 and lasted one year.

EMMA acquires different signals from internal and external sensors:

- Longitudinal, lateral and vertical accelerations for usual vehicle behaviour, at 100 Hz,
- Longitudinal and lateral acceleration in case of a crash (35g accelerometers), at 100 Hz,
- GPS location and speed at 1 Hz,
- Eventually driver behaviour data providing by the CAN bus of the car.

The data are analysed, using real-time processing performed by embedded software, to detect some driving situations considered as risky, during which the vehicle reaches high dynamics demands in longitudinal, lateral or combined directions.

The processing is based on the following principles: when acceleration and jerk signals exceed simultaneously the thresholds, an event is triggered.

From previous works (Bagdadi & Varheli. [8], Nagai & al. [9], Lechner & Perrin [10], Mongeot & al

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[11]) the thresholds for triggering an incident in this experiment were set as follows:

- Speed < 80 km/h, and Acceleration norm > 0.6 g and Jerk > 2 g/s,
- Speed > 80 km/h and Acceleration norm > 0.5 g and Jerk > 2 g/s,
- Speed > 100 km/h and Acceleration norm > 0.4 g and Jerk > 2 g/s.

The acquired data 30 s before and 15 s after the trigger are stored in the device. The file containing the whole data set is automatically sent to a secured server using GSM network.

The device is also able to provide this data set when the vehicle is circulating on specific and predefined road sections. These road sections, called zones of interest, were chosen at the beginning of the experiment and corresponded mostly to black spots where crashes had been reported. When the equipped vehicle enters in such a zone defined by a GPS position and a length (square zone), the device stores the 30 s before, the driving through the zone, and the 15 s after its end. The car's drivers were not informed about zones location.

A preliminary analysis of the data recorded in the experiment stressed out the necessity to distinguish the different types of passages: normal driving without any dynamical triggering, slight events which are non-risky situations and real incidents, corresponding potentially to critical driving situations. Slight events are mostly characterized by very short durations of acceleration peaks. Real incident criteria have higher durations of accelerations, resulting from driver's actions beyond a 3 Hz frequency. Examples of slight events and incidents are presented in Serre & al. ([12], [13]).

The sinuous zone of interest chosen

The study relies on the data collected over one zone of interest. This zone corresponds to a secondary road with a succession of left and right curves, and a speed limitation of 70 km/h. Figure 1 shows this zone with the trajectories of 2 specific recorded passages, one in each direction. The GPS location was implemented in the EMMA device in order to trigger in the most difficult bend (noted as n°2 on the figure). It is a bend of 86 m with a mean radius of curvature of 70 m and a minimum radius of 67 m.



Figure 1 - Presentation of the zone of interest with one passage in each direction

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This zone was chosen because:

- Several accidents occurred in this bend in the past. They were analysed by the IFSTTAR teams devoted to the in-depth study of accidents in the area of Salon de Provence, in the South of France. The methodology of these studies is detailed in Girard [14] and Ferrandez & al. [15].
- During the one year-experiment, this road section was circulated 249 times with different levels of lateral acceleration by 2 different equipped cars. The three different types of situations occurred in the same bend: passages with incidents, with slight events and without triggering (neither incident nor slight event).

The interest is to compare acceleration data recorded in the 3 different situations and to see if there is a hierarchy between them. For the recordings in one circulation direction (noted direction 1 on Figure 1), which is the direction of all the accidents in this bend, the levels of acceleration will be compared as well as the noise of the signal in the most difficult part of the bend.

Noise of the signal

The noise of lateral acceleration was calculated thanks to two different formulas: the order 2-moment (1) and the effective value of the noise (2):

$$M_1 = \overline{noise^2} \quad (1)$$

$$M_2 = \sqrt{\frac{1}{b-a} \int_a^b noise^2} \quad (2)$$

where noise is the difference between the raw acceleration and its running average on 1 s. a and b correspond respectively to the start and end of the time interval considered.

Both methods were used for lateral acceleration, focused on one second around the GPS point for a passage without triggering, or around the triggering point for the others (0.5s before the point and 0.5s after). When there were several triggering points in the bend, the period taken into account was around all the points (see example Figure 5). The same calculations were also done 5s around the GPS or triggering point(s). At a speed between 60 and 70 km/h, in one second the vehicle travels between 16 and 20 m, which correspond to the central part of the bend, whereas 5s gives a distance between 83 and 98 m that correspond to the whole bend. These calculations allow the comparison of the noise just near the triggering and the noise in the bend.

Results

Level of lateral acceleration

The data set in the zone of interest consists of 59 incidents, 20 slight events and 170 passages without any event. The difference between both directions, as it can be seen in Table 1, highlights the different levels of lateral acceleration in the most difficult bend, that is a right curve for direction 1, and a left curve for direction 2. The higher dynamic demands are found in direction 1, for almost half of the passages, since events and incidents represent 47.8% of the whole passages against 18.1% in direction 2. Moreover, it has been noticed that for similar levels of speed the level of lateral acceleration in the

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same bend is higher in direction 1 than in direction 2. For this reason and because all the accidents reported were also in direction 1, the study is focused on this direction.

	Passages without triggering	Slight events	Incidents	Total	% event	% incident	% event +incident
Direction 1	61	11	44	116	9,5%	37,9%	47,8%
Direction 2	109	9	15	133	6,8%	11,3%	18.1%

Table 1 - Distribution of the various recordings according to the direction

In direction 1, the mean levels of speed and accelerations of the 116 passages are shown in Figure 2.

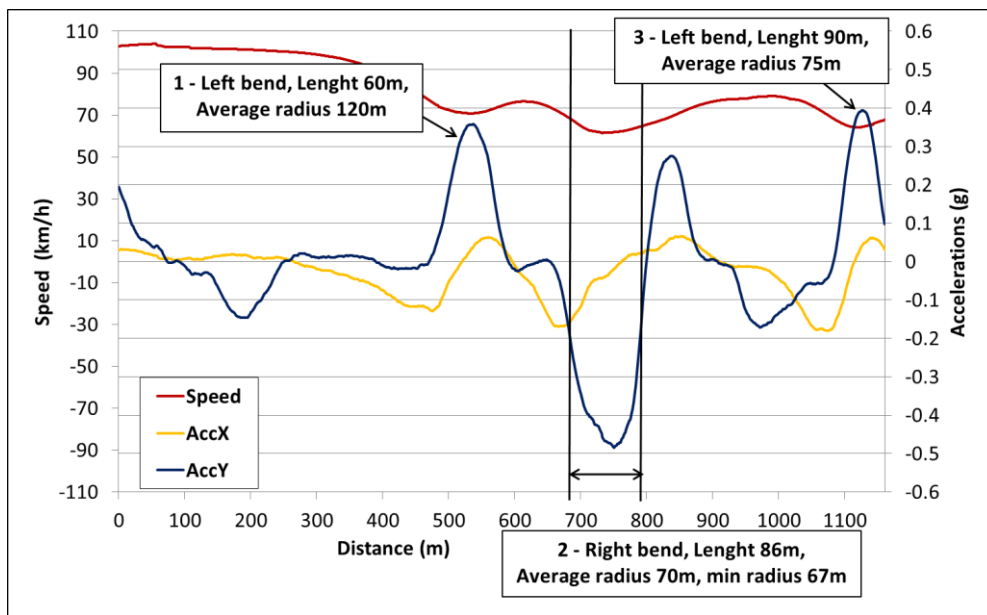


Figure 2 - Mean levels of speed, longitudinal acceleration (AccX) and lateral acceleration (AccY) of the 116 passages on the site in direction 1

The bend number 2 really appears as the bend where the highest level of lateral acceleration occurs. Figure 3 shows the average lateral acceleration for the three types of passages: passages without triggering (in green), slight events (in blue) and incidents (in red). For the incidents the lateral acceleration reaches 0.56 g in the considered bend, while for the events it reaches 0.51 g, and for the normal passages without triggering it is lower (0.42 g).

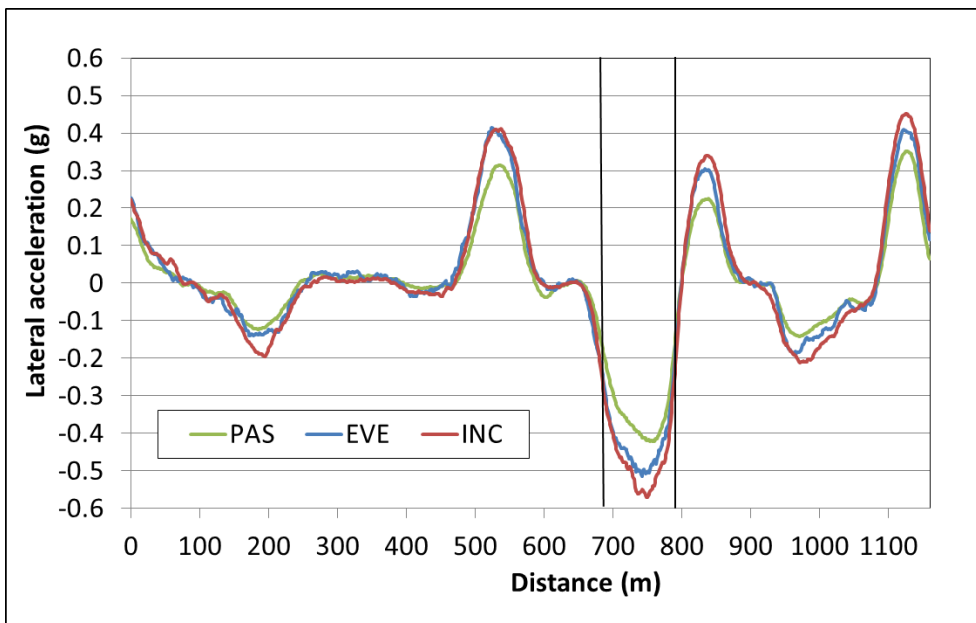


Figure 3 - Average levels of lateral acceleration on the site in direction 1: passages without triggering (green), slight events (blue) and incidents (red)

The same hierarchy is observed on Figure 4 for the average speed of the three groups of recordings. However some events and some incidents trigger with a lower speed than other passages without triggering. It can be explained by the different trajectories of the vehicles in the bend which modify the radius of curvature.

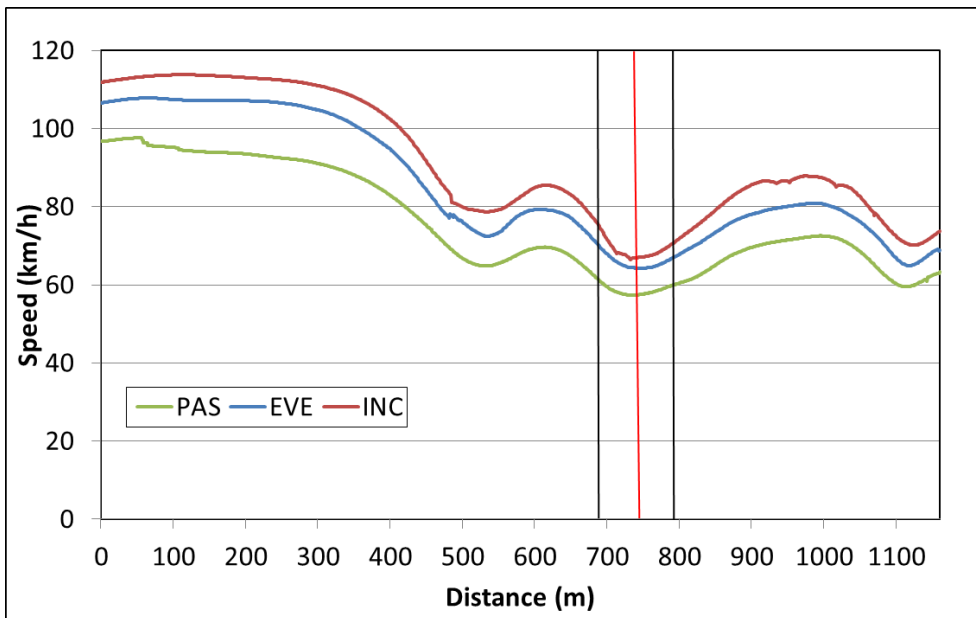


Figure 4 - Average levels of speed on the site in direction 1: passages without triggering (green), slight events (blue) and incidents (red)

Noise of the acceleration signal

The average level of noise of the lateral acceleration was calculated for the three groups of passages by 2 methods, the order 2-moment of the noise and the effective value of the noise, and each of them

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was calculated on two periods: 1s and 5s around the GPS point or the triggering point.

An example of calculation is shown on Figure 5. There are two triggering points, spaced out by less than 1s, thus the first period of calculation extends from 0.5s before the first triggering until 0.5s after the second triggering (signal in red), and lasts more than 1 s. It can be noticed the higher level of noise in the short period around the triggering for both calculations.

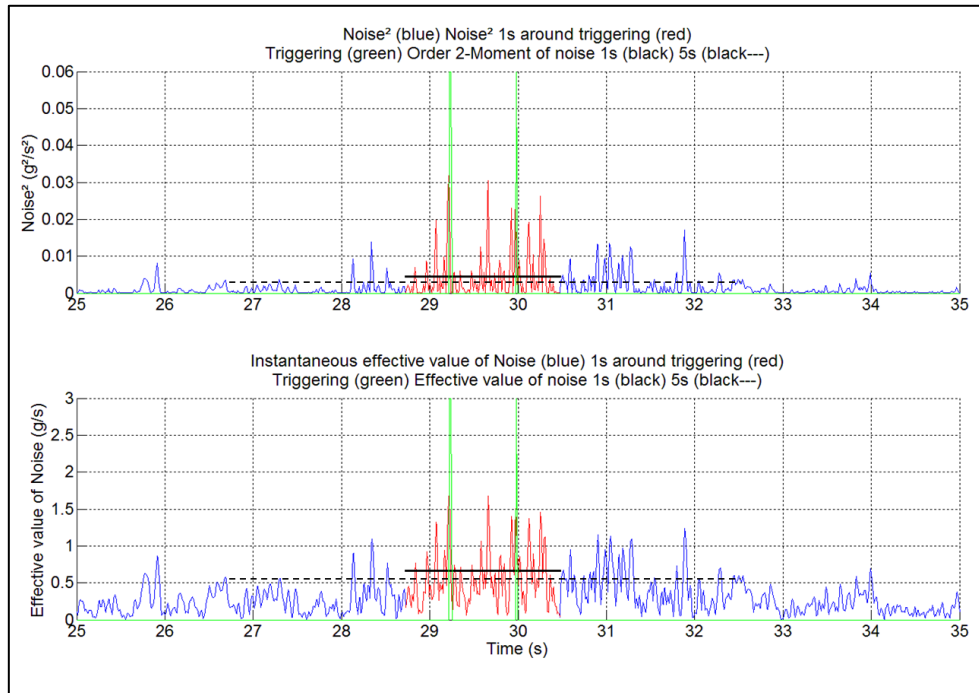


Figure 5 - An example of calculation of the levels of noise of the acceleration 1s (black continuous dash) and 5s (black spaced dash) around the triggering points of an incident for both methods

Figure 6 shows the hierarchy obtained with the average of the different calculations for the three different groups of recordings, brought back to a similar scale in order to be compared (M1 value was multiplied by 15).

For both methods, the hierarchy is in accordance with what was expected: in the most difficult part of the bend, the noise of incidents is superior to the noise of slight events, which is superior to the noise of passages. The results calculated on 5s, along the whole bend, respect the same hierarchy. Moreover, it can be noticed that the levels of noise on 5s are significantly lower than on 1s, for the slight events and the incidents, but not for the passages without triggering. This result is also logical and proves that the noise is significant when the vehicle lateral acceleration increases and goes near the grip limits.

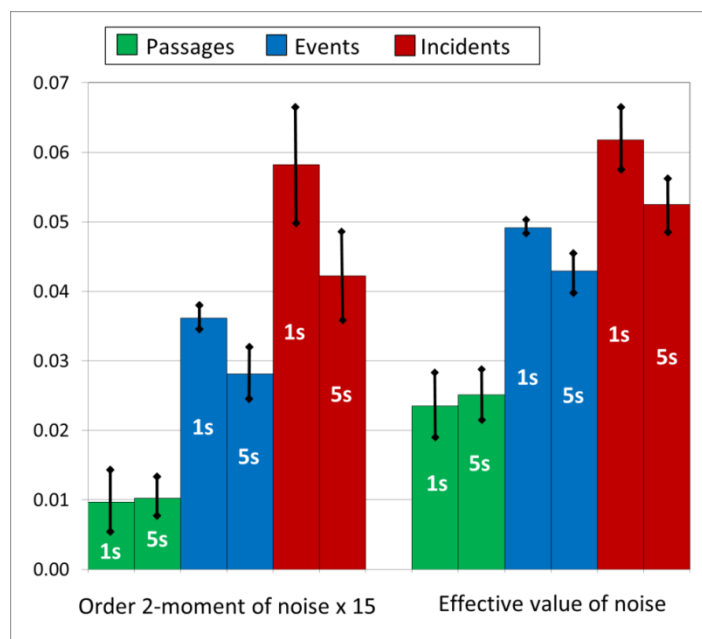


Figure 6 - Comparison of the hierarchy obtained with the order 2-moment of noise and the effective value of noise for lateral acceleration of passages (green), events (blue), and incidents (red), in the same bend, 1s and 5s around the GPS point or the triggering point(s), standard deviations (black dash)

Discussion and conclusion

In the bend considered, the hierarchy of lateral acceleration levels and the hierarchy of the noise of this acceleration are distinct between passages without triggering, slight events with a short triggering, and incidents with a longer triggering. Both criteria classify the incidents more severe than events and events more severe than passages without triggering. It was almost obvious for the levels of acceleration because of the definition of the events and the incidents, but it was not for the noise of the acceleration. The results confirm the observations done on numerous incidents. The effective value method could be chosen in further studies because it better discriminates the different situations. The calculation of the noise of lateral acceleration might be used to estimate the severity of an incident with lateral triggering since it characterizes when a passage in a bend is critical. It might also be useful to trigger a driver assistance system. To achieve this, the calculations should be performed in real time on the period preceding the triggering and not around the triggering as it was done in this study.

This method could be extended to longitudinal triggering, since in braking the noise of the longitudinal acceleration may also be an indicator of the closeness of grip limits. Apart from the levels of longitudinal acceleration, lateral acceleration and speed around the triggering, and from the noise calculated according to this method, other criteria will be studied to estimate the severity of an incident:

- The risk of “loss of control” in a bend for lateral triggering incidents, with the calculation of the speed increment necessary for the lateral acceleration to exceed a loss of control threshold, taking into account the radius of curvature of the trajectory,
- The peaks of jerk (i.e. derivative of acceleration) which express the brutality of the solicitations

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endured by the vehicle,

- The consideration of the possible triggering of an active safety system such as the EBA (Emergency Brake Assistance), the ABS (Anti-lock Braking System) or the ESC (Electronic Stability Control).

The goal of these studies is to be able to highlight the most severe incidents in a further experiment with many vehicles equipped and many incidents recorded.

The study is also interesting because in this case there is clearly a link between accidents and incidents. Actually, 4 accidents were reported in the considered bend between 2002 and 2012 by the IFSTTAR teams devoted to in-depth study of accidents in the area of Salon de Provence, in the South of France. During the experiment, there was also an accumulation of incidents, especially in the same direction as the accidents (direction 1). The study of all passages gives elements for the understanding of the mechanisms of accidents. All the 4 accidents reported in the bend occurred with a dynamic loss of control, on wet road and by young drivers. These conditions, in addition to the difficulty of the bend, explain the occurrence of crashes.

All the losses of control reported and most of the critical incidents occurred in the right bend. This double difference between right bend and left bend is confirmed by the statistical results of the project SVRAI on all the incidents, where it was noticed a large difference between the numbers of incidents in right/left curves (i.e. 41/14%), and higher levels of lateral acceleration in right turns than in left turns. As it is explained in Lechner & al. (2015), the vehicles circulate on the right side of the road in France. This point has several consequences. First, on 2 way traffic roads, the drivers can feel more confident to reach high lateral accelerations in right curves, as the opposite lane of traffic on the left may act as a possible recovery area. Moreover, the right hand side driving offers more capabilities to increase the radius of curvature of left curves, by cutting the path using the opposite lane of traffic. Finally, considering a given curve, when a vehicle turns on the right, the radius of curvature is slightly lower than when the vehicle turns on the left; consequently the lateral acceleration (equal to V^2/R if one neglects the side slip and the road banking) is slightly higher.

Acknowledgements

The authors thank the French Government (DSCR) for supporting the SVRAI project (Saving Lives through Road Incident Analysis Feedback). They thank other participants to the project, from IFSTTAR Laboratory of Accident Mechanism Analysis: Sebastien Chauvet, Olivier Bellot, Emmanuel Michel, Daniel Lechner and Michele Guilbot, for their contribution to the experiment.

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