Incorporating Vertical Acceleration 
for Defining Driving Behaviour

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ABSTRACT

Acceleration of a vehicle is composed of three components: longitudinal, lateral, and vertical acceleration. Longitudinal and lateral accelerations have been frequently considered as components for investigating driving behaviour, with the aim of improving road safety. But in particular situations during the motion of the vehicle, also vertical acceleration is relevant. In this paper, the authors want to demonstrate that vertical acceleration is also a relevant parameter to be considered in terms of road safety. The authors focus on the difference registered by considering only lateral and longitudinal acceleration and by considering also vertical acceleration in the analysis of driving behaviour through real tests on the road. All the parameters were registered through a global positioning system (GPS) device and a tri-axial accelerometer, which allow the geo-referenced kinematic parameters of the vehicle to be detected. For this purpose, over 110 tests covering about 600 kilometers were completed. All the experimental surveys were conducted in a good weather condition, under dry road pavement conditions, on weekdays, during day time and out-of-peak hours, in order to have no influence from the traffic flow. Each path was repeatedly run by the driver in order to collect the instantaneous speed and acceleration along the pattern. During the tests, about 40,000 instantaneous values of vehicle position have been registered. The survey interested a segment of the Italian National road n.107 (S.S. 107), in Southern Italy. The authors found that by considering vertical together with longitudinal and lateral accelerations, a higher number of unsafe driving conditions can be identified. More specifically, the proposed methodology allows 20% extra of dangerous driving conditions to be registered. For this reason, the authors retain that also vertical acceleration should be considered in the definition of the safety domain, because it determines the intensity of the exchange forces between the tires and road pavement, and in some cases, it leads to a loss of friction. Definitively, the authors retain that vertical acceleration is not only useful as indicator of comfort on board, but it has an important role also in terms of road safety.

KEYWORDS
Driving Style, Kinematic Parameters, Longitudinal and Lateral Acceleration, Real Test on the Road, Road Safety, Transportation, Vertical Acceleration

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1. INTRODUCTION

Vertical acceleration is one of the three components of the acceleration of a vehicle. It is relevant in particular situations during the motion of the vehicle. As an example, this kind of acceleration becomes important when a driver riding in his car and accelerating horizontally hits a bump on the road; in this situation, the car jumps into the air and then drops back on the road due to gravity. This is surely a condition of discomfort for the driver, but it can be also considered as a risk for the driver. Even if car manufacturers have introduced car suspension systems to absorb the shocks from imperfect roads and the energy of vertical acceleration, the presence of vertical acceleration has to be considered like the other two components of acceleration (longitudinal and lateral) when researchers study the motion of the vehicle.

The aim of this paper is to demonstrate the importance of considering vertical acceleration as an indicator of road safety, required for investigating car drivers’ behaviour. The authors start from a methodology proposed by themselves which permits to classify car drivers behaviour in terms of safe or unsafe driving conditions according to the instantaneous values of accelerations (lateral and longitudinal) and speeds recorded by real tests on the road (Eboli et al., 2016). The aim of this paper is to verify that the analysis of driving behaviour conducts to different results if also vertical acceleration is considered as regards only longitudinal and lateral acceleration are analysed. An experimental survey was carried out on a rural two-lane principal arterial road in Southern Italy. The survey interested a segment of the Italian National road n.107 (S.S. 107) which is a rural principal arterial road connecting the Tyrrhenian with the Ionian coast of the Calabria region. The analysis focused on a road segment 5 km long, having two lanes (one for each direction). All the parameters were registered through Global Positioning System (GPS) device and a tri-axial accelerometer, which allow the geo-referenced kinematic parameters of the vehicle to be detected.

After this introduction, the author reports a background concerning the literature studies investigating vertical acceleration. In section 3 they introduce the methodology proposed for defining driving style. The experimental survey supporting the research is briefly described in section 4. After, the author discusses the results by highlighting the differences registered by considering vertical acceleration in addition to the other two components of acceleration generally investigated for defining driving behaviour. The paper ends with a conclusive section.

2. LITERATURE REVIEW

A suspension system should be able to isolate a car body from road disturbances for providing good ride quality by reducing the vibratory forces transmitted from the axle to the vehicle body. This reduces vehicle body acceleration. Thus, ride quality can be generally quantified by the vertical acceleration of the passenger locations. In the case of typical suspension system without passenger or seat model, it can be quantified by the sprung mass acceleration (Rajamani, 2006).

Shirahatt et al. (2008) introduced vertical acceleration in a suitable optimizing technique applied at design stage to obtain the suspension parameters of a passive and active suspension for a passenger car which satisfies the performance as per ISO 2631 standards. They found that seat acceleration and sprung mass vertical acceleration are reduced by about 90% in case of active suspension as compared with passive suspension.

Tong and Guo (2012) used vertical acceleration for investigating on a new-type suspension which could even vertical loads of each wheel, reduce the torsion of vehicle body and improve the wheel ground adhesion.

Many other researchers analysed vertical acceleration with the aim of studying the comfort of the passengers on board. It needs to consider that vehicles travel at various speeds and experience a large spectrum of vibrations. Due to road roughness and vehicle vibration, occupants are subjected to accelerations in different directions, and this conditions cause discomfort. Such vibrations are
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