CORRELATING DRIVING BEHAVIOR, SAFETY AND EMISSIONS WITHIN A MICROSCOPIC INTEGRATED ASSESSMENT: THE DICA-VE PROJECT

E. FERREIRA [a], P. FERNANDES [a], B. BAHMANKHAH [a], E. MACEDO [a] and M.C. COELHO [a]
[a] *Department of Mechanical Engineering / Centre for Mechanical Technology and Automation, University of Aveiro*
Email: {elisabetedsf, paulo.fernandes, behnam.bahmankhah, macedo, margarida.coelho }@ua.pt

Keywords: Driving behavior, safety, emissions, Markov Decision Process

Subject area: sustainable cities

1. INTRODUCTION

In Europe, the number of road traffic injuries and deaths is still far too high and therefore the European Union is committed to improve road safety and promoting a total reduction of road fatalities by 2050. This requires the development and implementation of new strategies based on the Safe System approach to prevent serious injury and death for all road users. In addition, road transport is known to be a major source of pollutant emissions. In particular, it is responsible for the emission of harmful gases such as nitrogen oxides (NO_X) and carbon dioxide (CO_2), which have serious impacts on air quality and global warming, respectively (EEA, 12/2018).

It is well known that driver behavior can play a key role regarding traffic accidents, pollutant emissions and fuel consumption.

Such impacts increase when associated with aggressive behavior, experiencing high and extreme levels of fuel consumption, speed and acceleration. A thorough understanding of driver behavior should be an important step in improving road safety. Several studies have been conducted to identify driver behavior in many contexts such as traffic conditions (Habtemichael & Santos 2014; Stanojevic, Sullman, Iovanovic & Stanojevic 2018; Zhang, Qu, Tao & Xue 2019; Harris et al 2014), roads (Feng et al 2017; Lee& Jang; Fitzpatrick, Samuel & Knodler) and weather conditions (Faria, 2018). Also, the relationship of driving behavior with safety (Khattak & Wali, 2017) and (Wali, Khattak, Bozdogan, & Kamrani, 2018) and fuel consumption (Zhang, Zhao, & Khattak, 2020) has been analyzed. However, an integrated analysis of driver volatility with safety and emissions is lacking and has not been deeply explored.

The main objective is to present the project "DICA-VE: Driving Information in a Connected and Autonomous Vehicle Environment: Impacts on Safety and Emissions", which aims to develop an integrated methodology to assess driving behavior volatility and develop warnings to reduce road traffic conflicts and pollutants emissions in a vehicle environment. Volatility can be defined as the extent of driving variations, which can be characterized by strong accelerations, aggressive maneuvers, lane changes and unusual high speed for specific road conditions. Therefore, to be able to alert the driver of his misconduct, thus avoiding dangerous situations and even avoiding an increase in emissions and crashes, it is necessary to understand and pay special attention to the parameters that characterize risky behaviors.

2. METHODOLOGY

First of all, however, it is necessary to do a microscopic study of completely naturalistic real data in order to assess which parameters can make the difference both in terms of safety and emissions.

Then, several vehicles are being tested under different road conditions. Several information have to be extracted, namely: velocity (m/s), acceleration (m/s^2), GPS coordinates, altitude (m), instantaneous fuel and air flow rate (m^3/s), the distance from the leading vehicle (m), its lane position on the road, and instantaneous NO_X (g/s) and CO_2 (g/s) emissions (using a Portable Emission Monitoring System - PEMS). Then, the data must be processed. Here, the safety parameters must be defined and this information combined with emissions will be delivered to Markov Decision Process (MDP). If all safety parameters are within the expected values, then the reward matrix of MDP will consider the environmental impact, else the reward matrix will be defined as a cost matrix in order to punish and provide warnings to the driver. MDP answer will support the decision of the driver that is, if he could keep the lane position or change, and if he could maintain the velocity, accelerate or brake.

Figure 1 shows the flow chart of the proposed methodology for driving support systems, that is, through data collection traffic volumes, fleet composition and vehicles dynamic will allow the computation of safety parameters. The combination of exhausted emissions and computed safety parameters will be introduced in MDP process and at the end driving volatility will be quantified.

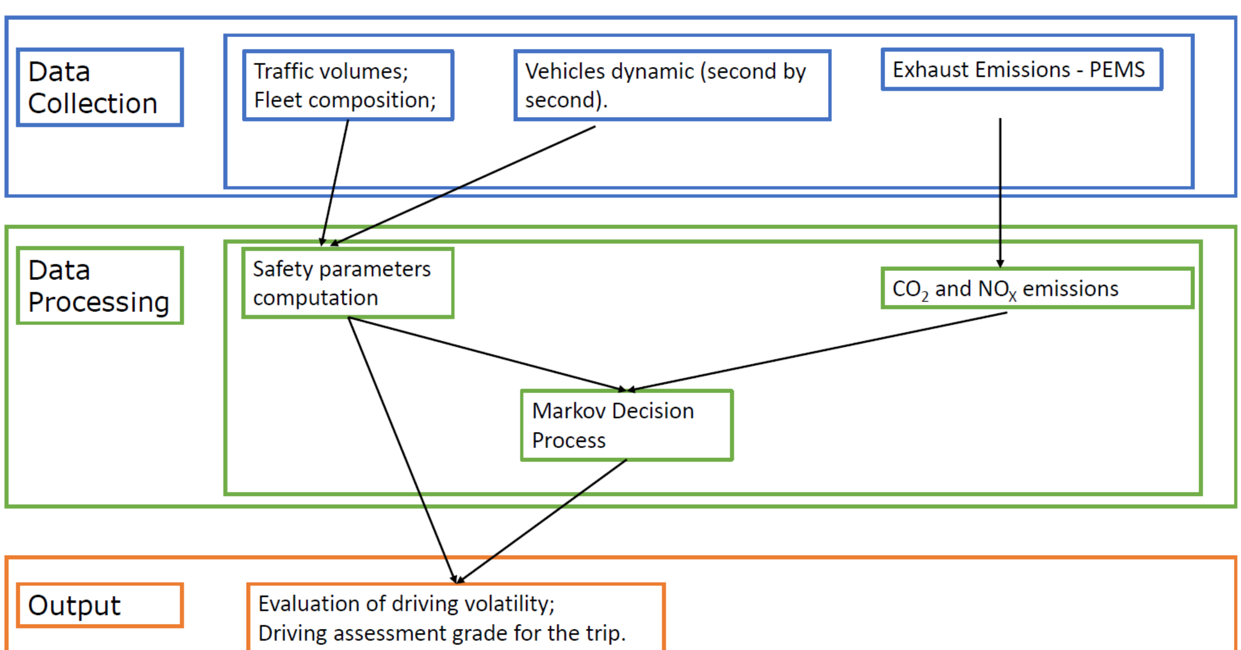

Figure 1: Flow chart of the proposed methodology for driver decision support system.

3. PRELIMINARY RESULTS / DISCUSSION

The naturalistic real data used for driving volatility evaluation was based on the requirement of Real-Driving Emissions (RDE) regulation and all technical information is provided and described on a recent paper of the research team (Fernandes, et al., 2019).

From all the extracted database, CO_2 and NO_X emissions seems to be well correlated. Using ANOVA, vehicular jerk (defined as the second derivative of speed) and acceleration are the variables that are not significantly different between all the drivers and therefore a deep analysis of these two parameters was done.

For example, Figure 2 illustrates driver behavior in a high-speed motorway environment by plotting acceleration, vehicular jerk, CO_2, and NO_X along the route. The peaks observed in the jerk display happen when there are large changes in the acceleration display, whether positive or negative and it is more sensitive to speed changes. These peaks also translate into emission peaks/levels; a delay is observed between the highest jerk and emissions peaks ranging from 2 to 4 seconds.

4. CONCLUSIONS

The main conclusions are that jerk and acceleration are parameters that allow us to evaluate the type of driving and also give us information about safety and emissions consequences.

Therefore, it is easy to justify the integration of these parameters in the driver decision support algorithm.

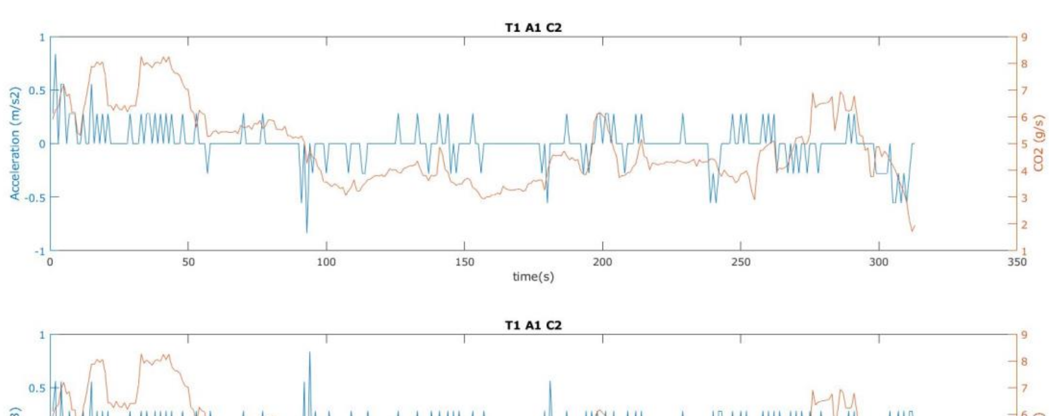

Figure 2: Vehicular jerk, acceleration, CO_2 and NO_X analysis across a motorway.

ACKNOWLEDGEMENTS

The authors acknowledge the support of the projects: UID/EMS/00481/2019-FCT - Fundação para a Ciência e a Tecnologia (FCT); CENTRO-01-0145-FEDER-022083 - Centro2020 Regional Operational Programme, under the PORTUGAL 2020 Partnership Agreement, through the European Regional Development Fund; DICA-VE (POCI-01-0145-FEDER-029463), and inFLOWence (POCI-01-0145-FEDER-029679) projects funded by FEDER through COMPETE2020, and by national funds (OE), through FCT/MCTES; MobiWise (P2020 SAICTPAC/0011/2015), co-funded by COMPETE2020, Portugal2020 - Operational Program for Competitiveness and Internationalization (POCI), European Union’s ERDF (European Regional Development Fund), and FCT.

REFERENCES

EEA. (12/2018). *Air quality in Europe.* European Environment Agency, Ed.

Faria, A. M. (July de 2018). Evaluating the impacts of driver performance and driving environment on fuel consumption, emissions and air quality. Instituto Superior Técnico - Universidade de Lisboa: PhD thesis.

Feng, F., Bao, S., Sayer, J., Flannagan, C., Manser, M., & Wunderlich, R. (2017). Can vehicle longitudinal jerk be used to identify aggressive drivers? An examination using naturalistic driving data. *Accident Analysis and Prevention, 104*, 125-136.

Fernandes, P., Macedo, E., Bahmankhah, B., Tomás, R., Bandeira, J. M., & Coelho, M. C. (December de 2019). Are internally observable vehicle data good predictors of vehicle emissions? *Transportation Research Part-D: Transport and Environment, 77*, 252-270. doi:10.1016/j.trd.2019.11.004

Fitzpatrick, C., Samuel, S., & Knodler Jr., M. (2017). The use of a driving simulator o determine how time pressures impact driver aggressiveness. *Accident Analysis and Prevention, 108*, 131-138.

Habtemichael, F., & Santos, L. (2014). Crash risk evaluation of aggressive driving on motorways: Microscopic traffic simulation approach. *Transportation Research Part F: Traffic Psychology and Behavior, 23*, 101-112.

Harris, P., Houston, J., Vazquez, J., Smither, J., Harms, A., Dahkle, J., & Sachau, D. (2014). The Prosocial and Aggressive Driving Inventory (PADI): A self-report measure of safe and unsafe driving behaviors. *Accident Analysis and Prevention, 72*, 1-8.

Khattak, A. J., & Wali, B. (2017). Analysis of volatility in driving regimes extracted from basic safety messages transmitted between connected vehicles. *Transportation Research Part C:, 84*, 48-73.

Lee, J., & Jang, K. (2017). A framework for evaluating aggressive driving behaviors based on invehicle driving records. *Transportation Research Part F: Traffic Psychology and Behaviour*.

Stanojević, P., Sullman, M., Jovanović, D., & Stanojević, D. (2018). The impact of police presence on angry and aggressive driving. *Accident Analysis and Prevention, 110*, 93-100.

Wali, B., Khattak, A. J., Bozdogan, H., & Kamrani, M. (2018). How is driving volatility related to intersection safety? A Bayesian heterogeneity-based analysis of instrumented vehicles data. *Transportation Research Part C: Emerging Technologies, 92*, 504-524.

Zhang, L., Zhao, X., & Khattak, A. J. (2020). A new fuel consumption model considering vehicle's speed, acceleration and jerk. *Transportation Research Board.* Washington D.C.

Zhang, X., Qu, X., Tao, D., & Xue, H. (2019). The association between sensation seeking and driving outcomes: A systematic review and meta-analysis. *Accident Analysis and Prevention, 123*, 222-234.