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Driving for decarbonization: Assessing the energy, environmental, and economic benefits of less aggressive driving in Lisbon, Portugal

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ABSTRACT

This work assesses the impacts of aggressive driving behavior on pollutants emissions and energy consumption at a city level. Furthermore, it performs an economic analysis considering the potential avoided emissions and fuel savings and discusses potential policy measures to address this topic. The results showed that aggressive driving significantly impacts energy consumption and emissions, with energy consumption increasing by more than ~200% and emissions by 330% for aggressive driving compared to non-aggressive driving (in MJ/km and in g/km, respectively). This increment was found to be even higher for diesel vehicles than for gasoline vehicles. On the contrary, gasoline vehicles showed higher percentages of increase for most emissions (CO, NO_x and NO). Results also revealed that aggressive driving impacts are higher for local streets when examining the city level. Moreover, the economic analysis showed that significant cost reductions may be achieved by avoiding aggressive driving, reaching up to 52.5 k€ on a daily basis. In conclusion, this study is of particular relevance to policy makers and urban planners, enabling to obtain a comprehensive overview of the impacts of aggressive driving behaviors at a city level and providing new insights to perform further developments and to assess the feasibility of the implementation of policy measures.

1. Background and literature review

Fuel consumption and pollutant emission rates are highly dependent of vehicles use (journey type, frequency, etc.) and of their operating conditions (speed, accelerations, temperature conditions, etc.) and are influenced by both traffic conditions and driving behavior [1,2]. Thus, a realistic assessment of emissions cannot be carried out without taking into account the vehicles' real operating conditions [1]. In this context, since the 1970's, vast research has been carried out focused on the characterization of driving patterns and its influence on exhaust emissions and fuel consumption [3–7].

In a first approach, research has focused on the description of real traffic driving patterns, on the differences between different driving conditions and on the creation of representative driving cycles with the ultimate goal of improving vehicle testing or the vehicle itself in terms of its environmental performance [1,5,8,9]. Initially, these studies were performed using the chase-car technique. For example, Jensen [10] used this technique to measure approximately 800 driving patterns on 13 streets and roads, in order to evaluate the relationship between emissions and travel speeds on different types of roads (city, highways, express roads and motorways). Emissions were estimated using an emission model with the results indicating the existence of a clear relationship between travel speed and emissions. Also, in contrast with travel speed, the type of road was found not to be crucial to the magnitude of emissions. However, a posterior study found that speed in itself did not cause large environmental effects [4]. In this study, urban driving patterns were investigated to find which properties have main effect on emissions and fuel-use. A regression analysis was performed revealing that only nine of the 16 pattern factors considered had considerable environmental effects. The more important factors were associated with different aspects of power demand and acceleration, with gear-changing behavior and with the effect of certain speed intervals. To obtain the data to perform these analysis five cars were equipped with data-logging devices and driven by 29 randomly chosen families for two weeks each. To enable the connection with external conditions, GPS receivers were used to register the coordinates [11]. Using the

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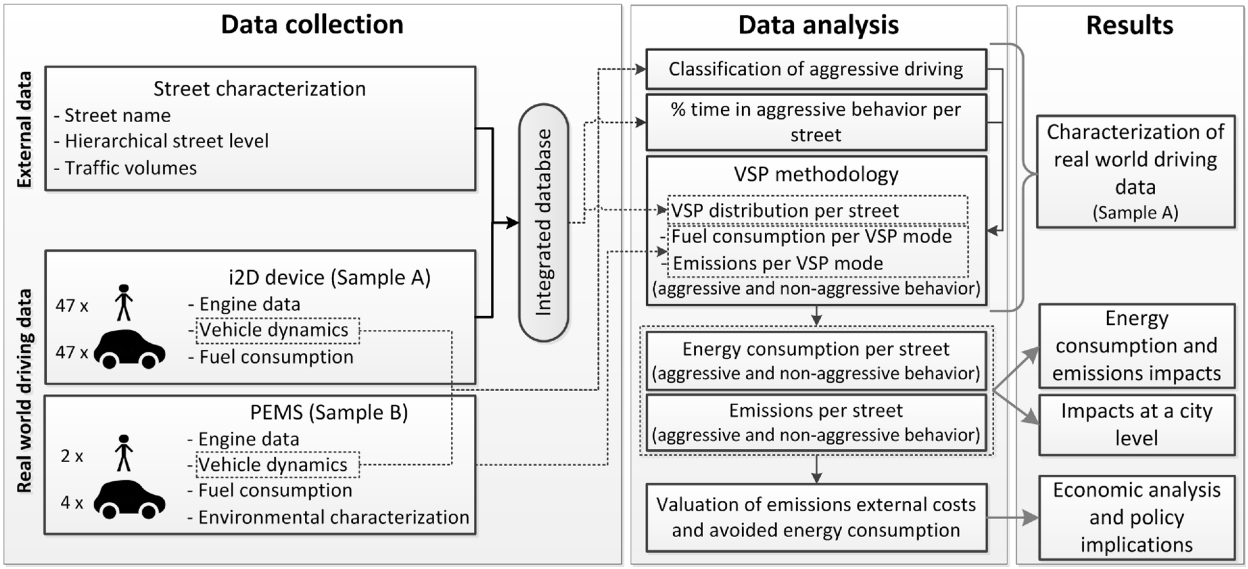

Fig. 1. Generic overview of the methodological approach.

same dataset, Brundell-Freij and Ericsson [2] studied the influence of street characteristics, driver category and car performance on urban driving patterns, finding that street and traffic environment affected driving behavior in connection with driver variables and car performance.

In other studies, data have been collected using instrumented private cars, but on a smaller scale. de Vlieger [12] used on-board instrumented vehicles to analyze emissions (carbon monoxide – CO, hydrocarbons – HC and nitrogen oxides – NO_x) and fuel consumption rates considering the effects of road type, driving behavior and cold start. Three types of driving behavior were considered (calm, normal and aggressive), with aggressive driving being associated with increases on emissions and fuel consumption. In a posterior study by the same author, these results were confirmed, finding that depending on road type and technology, fuel consumption increased up to 40% for aggressive driving compared to normal driving [13]. In another study using a similar approach, fuel consumption was found to increase from 78.5% to 137.3% for petrol vehicles and from 116.3% to 128.3% for diesel vehicles, due to aggressive driving. Regarding exhaust emissions, the higher increases when driving aggressively occurred on newer petrol vehicles' for CO, HC and NO_x [14]. More recently, a study by Gallus, Kirchner, Vogt and Benter [7] assessed the impact of different driving styles and route characteristics on on-road exhaust emissions. Two diesel test vehicles were measured in a Real Driving Emissions (RDE) compliant test route. The authors found that aggressive driving leads to higher emissions as compared to normal driving, 20–40% and 50–255% for carbon dioxide (CO_2) and NO_x, respectively. However, both CO and HC emissions were found not to be substantially different between driving styles. The authors mentioned that for CO and HC emissions other parameters were probably more important (e.g. ambient temperature or the cold start). Dia and Panwai [15] also evaluated driving behaviors and their impacts on road safety, environmental quality and network efficiency. However, these authors performed a simulation-based study. In fact, the authors mention that systematic observational studies of actual driving behaviors at a network-wide level are highly desirable but are still limitedly available. Regarding the analysis performed, the authors found that aggressive drivers increased substantially fuel consumption and CO_2 emissions (333% increase for motorway simulations and 138% increase for urban conditions) when compared to defensive drivers. Furthermore, the authors concluded that the negative impacts of aggressive driving behavior outweigh by a factor of three any benefits that can be obtained through reductions in travel times.

There are several research studies analyzing aggressive driving impacts on emissions and fuel consumption. However, most of these studies compare trips performed either in normal driving conditions or in aggressive driving behavior, but disregarding instantaneous driving decisions for large data samples to assess the impacts of aggressive driving on emissions and fuel consumption. Moreover, the assessment and quantification of the impacts of aggressive driving at a city level is scarce, in spite of its influence on energy consumption and pollutant emissions, particularly relevant in terms of air quality degradation and consequently urban population health. In this sense, the aim of this work is to assess and quantify the impacts of aggressive driving behavior on pollutants emissions and energy consumption at a city level. Furthermore, a simplified economic analysis is performed, providing a measurable quantification of the potential avoided emissions and fuel savings. Finally, new insights to the definition and implementation of policy measures are also discussed.

2. Methods and data

The data used and methods applied for this work are described in the following sections, namely through a characterization of the monitored drivers sample, the data collection methods and the data analysis performed. A generic overview of the methodological approach is presented in Fig. 1. Firstly, two distinct methods were applied to collect data: Sample A) an on-board data logger (i2D device); and Sample B) a Portable Emission Measurement System (PEMS). Data from Sample A was combined with street characterization data (such as hierarchical street level[1]) enabling to build an integrated database. This database was used to characterize the case study area in terms of vehicle dynamics (by using the Vehicle Specific Power – VSP – methodology [16]) and to obtain the percentage of time spent in aggressive driving behavior (aggressive driving was defined on a second-by-second basis considering acceleration thresholds per speed – see Section 2.2.1). Furthermore, Sample B provided data on energy consumption and pollutants emissions for both aggressive and non-aggressive driving behaviors (to notice that non-aggressive driving comprehends both normal and calm driving behaviors). Using the VSP methodology, the information obtained from both samples was combined in order to obtain a characterization of the energy and environmental impacts of

[1] Level 1 – arterial streets; level 2 – minor arterial streets; level 3 – distributor and collector streets; level 4 – local streets.