Eco-Driving

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Eco-driving is a multidimensional concept that includes driving behavior, route selection and all other choices or behaviors related to the vehicles' fuel consumption (e.g., the use of quality fuel, the use of air conditioning, driving at peak hours, etc.).

Keywords: eco-driving ; fuel consumption ; driving behavior

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1. Introduction

Alleviating human-driven climate change and reducing pollution of the environment, as well as the high level of dependence on non-renewable resources for energy production are considered as some of the most important challenges targeted as priority by both the United Nations sustainability goals and the European Union Green Deal [1][2]. In general, the transport sector is responsible for the production of the highest volume of greenhouse gases, estimated about 30% of the manmade emissions [3], having increased by 22% from 1990 [4]. The transport sector consumes about 20–25% of the total energy produced [2][5][6], the 65–75% of which is related with road transport [6][7].

The amount of harmful emissions is related to fuel consumption efficiency and thus, studying fuel consumption of transportation systems, and especially road transportation, is vital, as well as ways to reduce it. In previous years, many attempts have been made to decrease harmful emissions and increase fuel efficiency, like the enforcement of stricter standards concerning the vehicles' engine (Euro V and VI), new generation motors (electric and hybrid), alternative fuel and fuel of better quality (high-octane and biofuel) [8]. Moreover, the environmental issues as well as the high price of fuel have shifted the drivers' interest towards reducing fuel consumption, which is also reflected by their choices when buying a new vehicle [9].

Although the use of alternative fuel and electric vehicles together with a turn to renewable energy sources is a possible solution to the above-mentioned environmental issues in the long term, reducing emissions of the current vehicle fleet as much as possible would be a promising alternative with short and medium term benefits [6]. Because of the latter, research interest on ecological driving (eco-driving) and the effect of driving behavior on fuel consumption has recently increased.

Although the relationships between fuel consumption and driving behavior is being studied from the beginning of automotive history, it still remains popular because of the environmental and financial impacts of fuel consumption. For example, transportation and logistics companies are always seeking for new chances of fuel saving, in order to reduce operational costs [10].

2. Defining Eco-Driving

Eco-driving is the adoption of a driving behavior (or a driving style) that aims at saving fuel and reducing harmful emissions of greenhouse gases (GHG) [11]. In general, it refers to the adjustment of the vehicle's moving speed (in relation to traffic conditions) and the choice of routes that minimize fuel consumption [12][13]. Therefore, eco-driving can be seen as a set of choices and behaviors adopted by drivers that are connected with an energy-efficient way of using a vehicle. Increasing research interest on eco-driving implies that, although vehicles' motors efficiency has improved due to recent technological achievements and integration of new fuel types, drivers have not improved their behavior accordingly. However, it is expected that with proper information and training of the drivers, eco-driving would contribute to decreasing fuel consumption and harmful GHG emissions [14].

Recent research has revealed that eco-driving is capable of reducing fuel consumption by an amount ranging from 15% to 25% and GHG emissions by at least 30% [8][10], [15][16]. In contrast, the total fuel savings achieved by engines and vehicles of the latest technology is estimated at about 10–12%, which is significantly lower [8]. According to other researchers, an overall ecological behavior, including the purchase of the vehicle, as well as its usage, and ecological decision-making concerning mobility, are considered to lead to fuel consumption reduction of the order of 40–45% [17].

More formally, eco-driving refers to the adoption of a driving behavior that maximizes the efficiency of the vehicle's engine [18]. It should be made clear that the notion of eco-driving is a multidimensional one, that integrates driving behavior, as well as all decisions directly or indirectly related with fuel saving and GHG emissions reduction, e.g., the choice of vehicle. An ecological driving behavior, i.e., accelerating smoothly and maintaining a constant speed, plays a very important role [19], but it has to be combined with other actions, like the prudent use of the air-condition, in order to lead to maximum fuel saving [9]. All the pieces that constitute the notion of eco-driving are summarized in Figure 1 below. In this paper we focus on the driving behavior, without underestimating though the effect of other parameters.

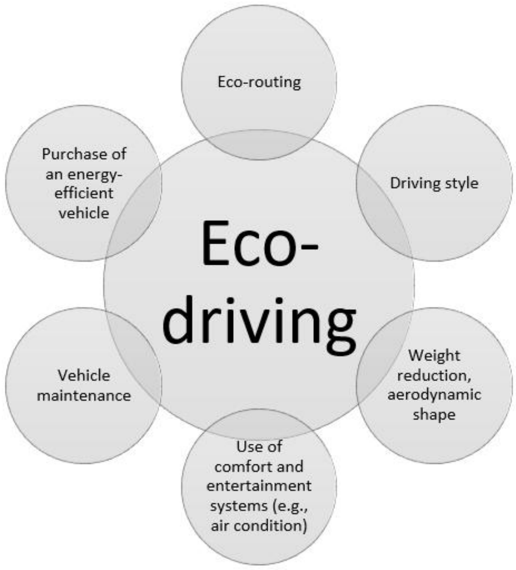

Figure 1. The broad notion of eco-driving.

3. Observing Eco-Driving

In order to study and model driving behavior and its effect on fuel consumption, it is essential to observe it in real-world conditions. The most efficient way to collect such data is through naturalistic driving experiments. In this kind of experiments, the participants simply drive according to their daily needs and habits, revealing their actual diving behavior under the occurring traffic conditions. Concurrently, a device is used to record the most important variables connected to driving behavior, e.g., speed and acceleration [20], as well as numerous other information. The above method ensures the validity and representativeness of the data collected.

On-board diagnostic scanners (OBDs) are the devices most usually exploited to record the above information. OBDs are not integrated with most cars, but are sold separately and are connected at the corresponding port of the vehicle's engine control unit. The data that can be collected using the above device are, among others, fuel consumption, GHG emissions, moving speed, acceleration, brake usage etc. and the time resolution is usually one second [21]. The majority of the OBD devices are also equipped with GPS sensor and thus they can also record the exact position of the vehicle [22].

Furthermore, modern smartphones are equipped with various sensors, including an accelerometer and GPS and have enhanced computing capabilities [23]. Taking into account that the vast majority of the drivers are smartphone users and the rapid development of telecommunication networks, it is possible to collect a vast amount of data in a relatively low cost. Indeed, compared to an OBD, a smartphone is able to collect almost all the data required, except from fuel consumption and GHG emissions [24]. It is also a way to collect data more massively (from more drivers) when the required number of OBDs are not available [19].

The combination of smartphones and OBDs offers new possibilities and many intelligent transportation systems applications can occur [25], including harsh events detection, safety monitoring and driving behavior evaluation [26], novel motor insurance schemes implementation [27] etc. The two devices may act complimentary to create a rich database with many features and variables, related with the exact position of the vehicle, its speed and acceleration, fuel consumption etc. [14].

The above methods of observing driving behavior have already been used in various researches related with fuel consumption [9][20]. Usually, a smartphone application is also developed and installed at the participants' smartphones that allows data-sensing and storing and, most importantly, communication between the participant and data collectors.

Furthermore, through the application, the users are informed about their performance. In fact, as research shows, by gaining knowledge of the impact of their actions on fuel consumption, drivers are more likely to adopt more environmentally friendly practices [15][28].

Although the above-mentioned data collection method offers many advantages, there is also a major drawback: it is not possible to collect external information, such as weather and traffic conditions and road geometry, which significantly affect fuel consumption and driving behavior [22]. The lack of this kind of information makes the modeling process more challenging and complicated. For example, drivers move slower due to heavy congestion or rainy weather conditions. By observing their driving behavior without being aware of the conditions, it can be wrongly interpreted that they drive at low speed in general. Additionally, moving with an average speed of 60 km/h on a road with zero inclination is totally different, in terms of fuel consumption, from moving on a road with high inclination.

Recent studies have shown that different driving behavior can be detected between people of different age, gender, social and cultural aspects etc. For example, it is more possible that younger drivers' behavior is influenced by emotions such as anger and anxiety while driving, which will increase aggressive and unsafe driving behavior and may increase the risk of an accident [29]. Similarly, men are also found to be more skilled but also more unsafe and risky drivers [30]. Moreover, there has also been observed variation of the driving behavior in different countries or regions. Specifically, in [31], Ozkan et al. compared the answers of a questionnaire survey on driving behavior between respondents from six countries (Finland, Great Britain, Greece, Iran, The Netherlands, and Turkey). It was revealed that there does indeed exist a difference on traffic culture between the Western/Northern Europe countries and Southern Europe, Turkey and Iran, with the first being considered as safer. Specifically, drivers from these countries may only commit minor violations of traffic laws, such as speeding on motorways, while drivers from the other countries commit more usually serious ones and are more possible to drive risky and aggressively. Furthermore, drivers from "unsafe" countries are also less aware of their behavior.

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