Driving style influence on car CO_2 emissions

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ABSTRACT

Road transport is a major contributor to environmental pollution and driving style is one of the most significant among factors in the environmental impact of a vehicle. In the past two decades a new driving style, called eco-driving, has been developed to reduce CO_2 emissions in driving and nowadays it is a climate change initiative not to be overlooked. CTL (Centre for Transport and Logistics) has developed an innovative tool to acquire data from vehicles and to measure car fuel consumption and emissions on the road. In order to quantify the driving style influence on CO_2 emissions CTL also developed an analytic method working with the acquired data and based on eco-driving rules.

A large on road campaign (10 cars, 270 drivers, 120.000 km) was made using such tools and methods. CO_2 emissions as a function of average speed of the route measured in the campaign overlap on COPERT specific CO_2 –speed function based on the EEA emission inventory. If all the monitored drivers had adopted the eco-driving driving-style CO_2 emissions would have been up to 30% lower than the measured average at the typical urban speed (between 10 and 40 km/h on average) which is where the driver influence is higher.

1 INTRODUCTION

Road transport is one of the major causes of the environmental pollution. According to a recent study[1] it is responsible for about 30% on the total emissions of CO_2 into the atmosphere. Among the actions individuals can take to reduce their green-house gases associated with personal transportation there is to operate their current vehicles more efficiently[2]. Quantifying the potential of the latter, of operating vehicles more efficiently, is the subject of this paper as the environmental impact differences between drivers, driving the same vehicle, are not negligible.

Recent studies[3] have shown that in certain situations the driver's driving style can result in differences in terms of fuel consumption (and therefore CO_2 emissions) up to 40% between a calm driver and an aggressive one. One of the possible actions to reduce the environmental impact caused by road transport is therefore to educate drivers to adopt a driving style that is as eco-friendly as possible.

Eco-driving is a new approach to driving style developed since the mid '90s and in the last decade has been the subject of some initiatives and projects at European level to define it precisely. The latest of these European initiatives is the Ecodriven project[4]. Beside Europe, the growth of the eco-driving awareness is also testified by the many websites promoting this driving style in the U.S.[5,6,7] and worldwide[8].

Though research projects are continuously updating the eco-driving "rules" the basic characteristics of eco-driving remain the same and they can be summarized into the following two main concepts.

- Adopt an anticipatory driving style avoiding unnecessary accelerations and braking. These situations are the ones, into a driving cycle, consuming more fuel (note that in this paper the expression "driving cycle" always refers to a wider concept than usual, containing all possible factors influencing vehicle emissions[16]).
- Use the engine as efficiently as possible. As the engine efficiency increases with the engine load and the internal friction loss decreases with decreasing the engine speed, the combination of high loads and low engine speeds allows to spend less fuel for the same power supplied by the engine.

In this paper the five basic rules of eco-driving resulted from Ecodriven are taken as reference. They can be found on the project final report[9] or on the project website[4].

About the effects of eco-driving, over the years some studies[9,10,11,12,13] have shown an average reduction in fuel consumption of 10% to 15% when eco-driving is adopted. These studies evaluated the efficiency of eco-driving by analyzing driving behavior before and after eco-driving trainings[12] or else eco-driving efficiency with fixed driving cycles on a chassis dynamometer[10] or simply evaluated differences among different drivers in terms of fuel consumption[14].

All these studies stated the efficiency of eco-driving or which of the monitored drivers got the best results in terms of fuel economy but in general they were not able to state if such an efficiency or such a result in terms of fuel consumption only depended on the driving style. It is not easy to state to what a higher or lower value of fuel consumption is due thus two values of fuel consumption are usually not comparable if the scope of the comparison is to find where their difference come from. In fact fuel consumption depends not only on driving style but also on car, route, traffic level and some others unpredictable factors.

The main limitation of the methodologies of the current literature is that they are not completely able to distinguish the influence of the all factors affecting the fuel consumption from that of driving style because, to date, a systematic methodology quantifying the driver influence on fuel consumption does not exist yet. The lack of a common methodology guaranteeing the isolation of the consumption rate only due to the driver behavior brings to uncertainties when comparing different fuel consumption values even coming from tests with fixed route, fixed car and fixed hours (the latter trying to have the same traffic conditions as far as possible). In fact also in these cases the fuel consumption could be affected by many factors: a different number and/or duration of the stops during the run; a more or less request of energy depending for example on the different number of overtaking or simply depending on the different amount of power needed to keep up with traffic; etc. Therefore different fuel consumption values could not only depends only on the different driving style adopted, even in the better designed experiment.

What explained in the two paragraphs above suggested the need to develop a methodology assessing and quantify the influence of the driver on the vehicle's fuel consumption independently from other factors as car type, route ambit and traffic level. This methodology, described in the first section of chapter 2 of this paper, has led to the definition of an Ecoindex quantifying the influence of the driving style on fuel consumption comparing driver behavior with that of an ideal driver following the eco-driving rules. This system has been applied on a monitoring campaign of 10 vehicles (section 2.2) equipped with the CTL fleet management devices[15,16].

Chapter 3 is about the findings of the work and finally chapter 4 provides the conclusions.

2 METHODOLOGY TO MEASURE THE DRIVER'S DRIVING STYLE

2.1 The algorithm to calculate the Ecoindex

The goal of this work is to isolate the rate of fuel consumption (and therefore CO_2 emissions) due to the behavior of the driver from those due to the vehicle, route and traffic conditions.

The basic concept to reach such goal is the following: given a real driving cycle recorded by an on board device it is possible to calculate the ideal minimum fuel consumption that the driver could get with the same vehicle, on the same route and with the same traffic conditions if he had followed the eco-driving rules. Being able to perform this calculation means having a minimum reference consumption that differs from the measured one only by the rate due to the driver. The difference between the two fuel consumptions (the measured and the minimum ideal calculated applying the eco-driving rules) is therefore due only to the driver and it could be saved by driving following the eco-driving rules.

An algorithm has been developed with the task to modify an acquired driving cycle remodeling it as if the driver had adopted the eco-driving driving style and with the task to recalculate the fuel consumption (and the CO_2 emissions) on the modified cycle.

The main steps the algorithm performs are the following:

- it takes a real driving cycle;
- it modifies the real driving cycle according to the eco-driving rules utilizing a vehicle motion model;
- it computes the fuel consumption (and therefore the CO_2 emissions) of the modified cycle (that is the minimum ideal fuel consumption obtainable following the eco-driving rules);
- it calculates the Ecoindex that is the ratio between the fuel consumption of the modified cycle and the fuel consumption of the real cycle.

The objective of the algorithm is to recalculate a driving cycle and the power needed to run this cycle so first action the algorithm does is to extract from a database the data of a driving cycle gathered with the CTL on board acquisition tool. These data include instantaneous values (every Δt = 0.5 seconds) of speed, traveled distance, engine speed, engine load, gear engaged and many others useful for the modification process.

In addition to these data, the algorithm also needs the characteristics of the vehicle by which the driving cycle has made: the rolling resistance coefficients, the front section of the vehicle, the air drag force coefficient, the mass of the vehicle and the apparent mass value for each gear ratio (this value takes into account all the rotating parts from the engine to the wheels involved in the acceleration process), the total transmission ratio for each gear, the wheel rolling radius, the map expressing the power delivered by the engine to the wheels (depending on load and revolutions), the map expressing the equivalent force to the wheels due to the engine braking during the release phases (as a function of the engine revolutions and the engaged gear).

An in depth description of how the algorithm works is not the objective of this work. Upcoming papers will deal with that topic. What is worthwhile to report here is a brief description on which are the contents it is based on.

First of all the modified driving cycle has to respect all the constraints of the original: the same number of stops and their spatial position, the same number of local minima of the original speed diagram and the same spatial position of the local minima of the original speed diagram. Respecting these constraints allows to generate a modified cycle theoretically coming from the same "environment" of the original in terms of traffic conditions and more in general of every event affecting the speed diagram (e.g. pedestrian crossing, status of traffic lights, actual traffic, etc.).

The two cycles have to differ only for the driving style adopted thus the algorithm contains the translation of the practical eco-driving rules for the drivers into analytical rules on the basis of which modify a driving cycle. Essentially the two main concepts of eco-driving reported in the bullet point list of the chapter 1 of this paper have been translated into analytical rules.

- Referring to "adopt an anticipatory driving style" it has been decided every local minimum of the speed-distance plot has to be reached in the most efficient way. This means getting there leaving the accelerator in time and the gear engaged (with a manual transmission) in order to take advantage of the cut-off mode of the engine (zero instantaneous fuel consumption).
- Referring to "use the engine as efficiently as possible" every instantaneous working condition of the engine has been recalculated in order to respect the suggested limits of engine speed: 2000 RPM for diesel engines and 2500 RPM for gasoline engines.

Finally the total trip time has to be the same as the original. Driving adopting the eco-driving style does not mean driving slower but means driving smarter, in a more efficient way.

The calculation of the modified cycle is based for each time interval Δt on equation 1 during deceleration phases and on equation 2 during accelerations phases. Both the equations come from the balance of forces acting on the vehicle wheels.

$$a = \frac{F_{res\,engine} + (f_0 + kv^2)mg\cos\alpha + {}^1\!/_2\,\rho SF\,C_x v^2 + mg\sin\alpha + R_\varepsilon}{m_c} \tag{1}$$

where

$F_{res\ engine}$ is the force equivalent to the wheels due to engine braking during release
f_0 and k are the rolling resistance coefficients
v is the vehicle speed
m is the vehicle mass
α is the road slip angle
ρ is the air density
SF is the vehicle frontal section
C_x is the air drag force coefficient
R_ε is an additional drag force term due to the uncertainty on the actual value of all the coefficients in the equation
m_c is the apparent mass value

$$a = \frac{P_{eng}}{m_c v} - \frac{(f_0 + kv^2)mg\cos\alpha + {}^1\!/_2\,\rho SF\,C_x v^2 + mg\sin\alpha + R_\varepsilon}{m_c} \tag{2}$$

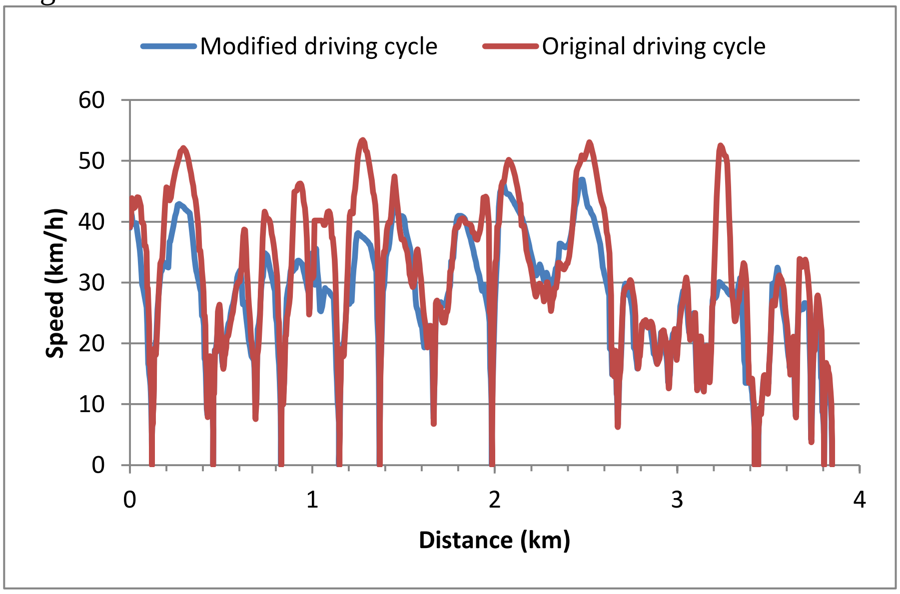
where

P_{eng} is the engine power of the original cycle or, if the acceleration of the original driving cycle is too high to be obtained by following the eco-driving rules, is the maximum engine power achievable following the eco-driving rules

In the ideal case that a driving cycle is executed properly applying all the eco-driving rules the algorithm will run in any case (it cannot know a priori the "goodness" of a driving style) but it will get a modified ideal driving cycle very similar to the original which will generate a minimal fuel difference between the two cycles.

Figure 1 shows the comparison between a modified driving cycle and the corresponding original as a function of the traveled distance. It can be seen that each of the local minimum remains in the same space abscissa so that it can be said the two driving cycles come from the same route in the same conditions. They perfectly match on a speed-space plot even if one is real and the other one is theoretical. It can be seen that on the one hand some parts of the modified driving cycle are well overlapped over the original driving cycle (for example the section between 2.7 and 3.2 km). It means that the original driving style adopted is compatible with the eco-driving driving style.

Figure 1. Comparison between a modified cycle and the corresponding original one as a function of the traveled distance.



On the other hand some other sections, like the one between 0.8 and 1.4 km, are on the contrary not overlapped so it means that the original driving style adopted there in that section has been not compatible with the eco-driving rules and so, as a result, the outcome speed shape is quite different from the original one.

Finally, after reconstructing all the modified cycle starting from the original, the algorithm calculates the Ecoindex using the equation 3.

$$Ecoindex = \frac{calculated\_ideal\_fuel\_consumption}{real\_fuel\_consumption} \tag{3}$$

where

calculated_ideal_fuel consumption = is the fuel consumption calculated for the modified cycle
real_fuel_consumption = is the fuel consumption measured in the real cycle

To calculate the fuel consumption of the vehicles (and therefore the consequent CO_2 emissions) specific models have been developed: a different set of models were developed and validated for vehicles equipped with gasoline and diesel engines. Such models are based on the instantaneous parameters collectible from the OBD/CAN line of the vehicles. As the engines are equipped with different fuel injection systems and therefore different kind of sensors on board (and therefore different parameters running on the OBD/CAN line), if some sensors are missing (for example the intake airflow sensor), different models to calculate them are needed.

In general to calculate the fuel consumption the intake airflow and the air fuel ratio are needed, both for gasoline and diesel engines: if the engine is equipped with these sensors and their values are available from OBD/CAN line the consumption is directly calculated; if any value is not available, a model has to be developed. If the intake airflow is missing it can be calculated as in a recent study[17]: for each RPM a linear correlation between the Calculated Engine Load (an index of engine torque supplied by the engine, always available from OBD instrumentation) and airflow is observed. With this correlation, to calculate the airflow only two points for each RPM are needed: the chosen points are those at full throttle and those at idle (a pair of points for each RPM). Two curves are then needed: the airflow curve at full throttle (during the dynamometer acceleration test) and the airflow curve in idle when the engine is set to different RPM. All the values for all the conditions of the engines lie on the straight lines between these two curves.

The air-fuel ratio, if not available from the instrumentation, can be calculated in two different ways for gasoline and diesel engines. For gasoline engines when the engine is at partial loads, the air-fuel ratio is always stoichiometric with a little addiction of fuel due to the positive accelerator pedal gradients, as in some studies[15,18], while at full loads is a function of RPM only. Diesel engines have a different system of fuel dosage and the air-fuel ratio is directly influenced by the torque supplied (so by the engine load) so the air/fuel ratio is a function of engine load with an exponential equation[19].

2.2 On road campaign

The sample of vehicles monitored in the on road campaign on which the following results come from has been selected to respect the proportionality between the number of cars monitored for each market segment and the percentage of cars sold each year in that segment. Further restriction that it has chosen to follow is to have at least two cars for each maker and model so that the results are robust and less dependent on possible anomalies of every kind in one vehicle.

Ten car rental vehicles have been monitored from April to December 2010, collecting data for a total of about 115 000 km. The sample consists of 278 different drivers, of which 215 men (77%) and 63 women (23%).

Rental vehicles have the advantage that each vehicle is driven by many different drivers. On the other hand users rent unknown vehicles (they need adjustment) usually in situations where their own are not available (non-systematic trips). The rental therefore solves the problem of the driver's awareness of being monitored and generates a problem of naturalness while driving. To offset this negative effect in this campaign it has been chosen to monitor some car-sharing vehicles, which are often used by the same users as their own, and some vehicles of rent-a-car who are rented for longer periods so that the user has enough time to adjust to the vehicle. The proper combination of the two types of rental allows overcoming both the problem of habit to use the vehicle and the problem to use the vehicle on unusual paths.

To get the cars to be monitored two collaboration agreements were done. First agreement with Roma Servizi per la Mobilità Srl (Rome car-sharing service provider) for monitoring four vehicles of its fleet, the second one with AVIS Autonoleggio Spa (established car-rental society) for monitoring six vehicles.

3 RESULTS

The results reported in this chapter are aggregated results compiled from the instantaneous data collected on the on road campaign described in section 2.2. Data aggregation set is formed by routes. In this work it has been considered a route all the amount of instantaneous data gathered from the vehicle (from the CAN line through the CTL acquisition tool[15,16]) included between two stops longer than 15 minutes. Routes shorter than one kilometer were not considered because they are too short to properly run the algorithm to calculate the Ecoindex and so to properly evaluate the influence of the driver on the car fuel consumption and CO_2 emissions.

3.1 Ecoindex

Figure 2 shows the results from the acquisition campaign in terms of Ecoindex as a function of the average speed of each route. Lower values of the Ecoindex lie on about 0.5 till an average speed of about 70 km/h. Beyond that average speed threshold the lower values lie on 0.8-0.85 and the values spread decreases. This finding means that under an average speed of 70 km/h the driver has a great influence on car fuel consumption: the Ecoindex spread is almost 50%; over that threshold the influence of the driver diminishes: the Ecoindex spread is about 10-15%.

Driving cycles with an average speed less than 70 km/h are thus the better situations to rightly evaluate how the driver influences the fuel consumption of a vehicle because they are cycles where a driver can accelerate, decelerate and change gear frequently and more in general there are a lot of situations in which his driving behavior can differ from an ideal fuel efficient behavior.

Driving cycles with an average speed over 70 km/h, mainly highways routes, are on the contrary less suitable to evaluate how the driver influences the fuel consumption of a vehicle because they are cycles where a driver mainly use the final gear available and the high cruising speed becomes the main factor influencing the car fuel consumption. In these cases the driver's behavior has less opportunity to differ from an ideal fuel efficient behavior and thus to have a considerable influence on the car fuel consumption.

Continuing at looking at Figure 2, but this time restricting the analysis under the 70 km/h threshold, the plot shows the Ecoindex mean value does not depend on average speed of the route and the values variance remains almost constant. As route type (urban, extra urban or highway) and traffic congestion can be measured with the average speed, in a first approximation it can be said the Ecoindex does not depend on route type and traffic conditions.

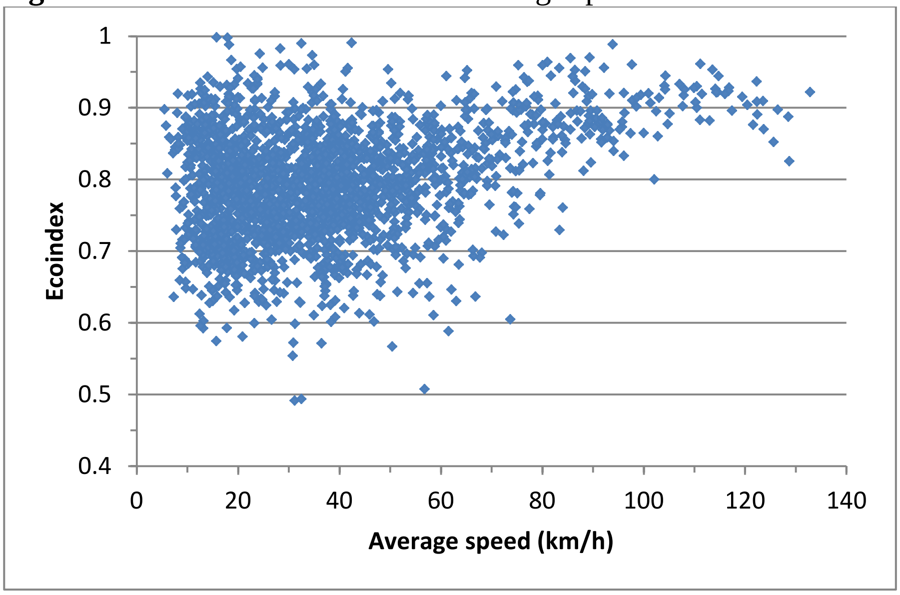
Highway routes have to be considered as a separate case. The average speed has no influence on the mean Ecoindex value too but the mean value increases up to 0.9 and the values spread diminishes.

These results reflects the aim to define a parameter representing the influence of the driver on the vehicle fuel consumption independently from other factors such as route type and traffic conditions:

looking at Figure 2, considering a congested urban driving cycle with a 10 km/h average speed, or considering an urban driving cycle in more flowing conditions with an average speed of 30 km/h, or considering an extra-urban driving cycle with a 50 km/h average speed does not affect on what values the Ecoindex can assume. All these three situations are comparable in terms of quantifying the driver influence on car fuel consumption. Directly considering the fuel consumption value to quantify the driver influence on car fuel consumption is not completely proper because in this manner there is no possibility to separate the driver influence from the influence of the average speed on the vehicle fuel consumption. Aiming at comparing different drivers, the route, the traffic conditions and more in general the average speed have to be fixed and this is almost always not possible. It requires specific tests and more in general the definition of constraints to be rigidly respected to make the results comparable. And, as said in the introduction chapter of this paper, there is no certainty to get fully comparable results.

On the contrary the Ecoindex represents not only a tool to rightly quantify the influence of the driver on car fuel consumption but represents also a tool to compare the influence on car fuel consumption of different drivers driving in different situations and conditions. There is no more need to fix the route, the traffic conditions and in general the average speed. The Ecoindex can be successfully applied on large campaigns free from constraints or parameters to be respected.

Figure 2. Ecoindex as a function of average speed.



3.2 Obtainable reductions of CO_2 emissions

The curves in Figure 3 and Figure 4 represent the fitting of the CO_2 emissions, both from the real cycles and from the modified cycles, coming from each of the routes monitored in the campaign described in the section 2.2. CO_2 emissions from the real cycles overlap on COPERT[20] (COmputer Programme to calculate Emissions from Road Transport) specific CO_2 –speed function based on the EMEP/EEA Emission Inventory Guidebook[21] (this inventory is the reference emissions inventory in Europe, coming from many years of researches and campaigns). This finding testifies the goodness both of the sample of vehicles chosen for the campaign and of the fuel consumption and emission models utilized here (see the last part of section 2.1 for a brief description of such models).

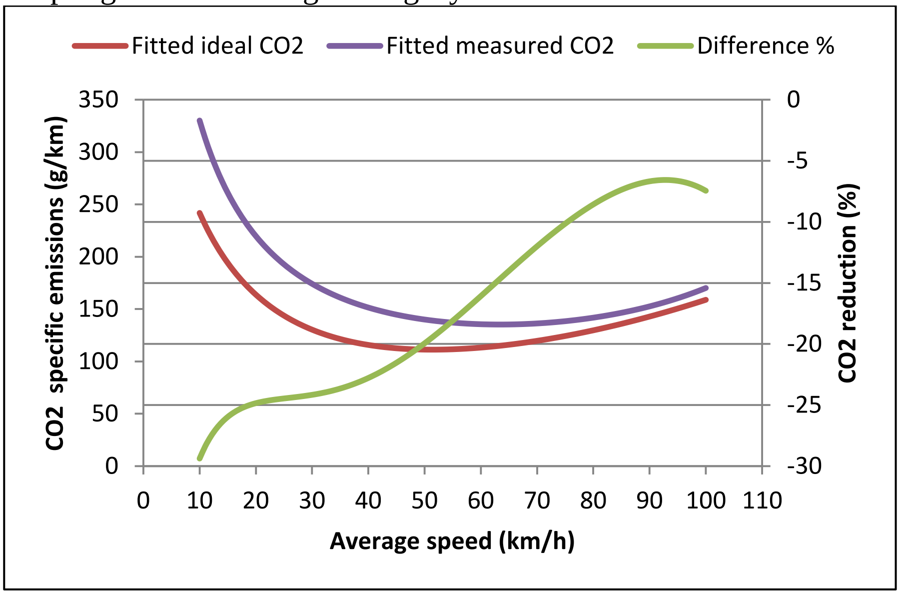
Figure 3 and Figure 4 show the obtainable average CO_2 reductions if all drivers had adopted the eco-driving style. Such reductions are shown as a function of the average speed of the route respectively for gasoline and diesel cars. Comparing the emission values between the real and the ideal mean curves (Figure 3 and Figure 4) the average saving in terms of CO_2 can be quantified as a function of the average speed of the route. This theoretical saving is obtainable teaching to every driver the eco-driving driving style.

Figure 3 (it refears to gasoline vehicles) shows that the reduction is higher at low average speeds and diminishes gradually with increasing of average speed. It starts from a reduction of 30% at an averge speed of 10 km/h, it flattens on a reduction af about 25% from 15 to 40 km/h and finally, over this value, the obtainable reduction diminishes gradually until 80-90 km/h from which the driver influence on fuel consumption and CO_2 emissions expires. Analyzing Figure 3 it could seem that the difference between the measured and the minimum ideal CO_2 curves becomes constant over 90 km/h of average speed of the route but it is only due to the fact that over this value of speed there are not enough data from the acquisition campaign to validate the fitted curve there.

The outlined findings strengthen the fact (previously outlined in section 3.1) that beyond a certain average speed of the route, typical of highway routes, the influence of the driver on car fuel consumption diminishes than routes with lower average speed. The reason of that comes from the fact that in an urban or rural route there are typically a lot of acceleration, deceleration, gear changes and other unpredictable driving behaviors so the driving style can greatly influence the trend of the driving cycle and therefore the fuel consumption and the CO_2 emissions of a vehicle. In a motorway route, on the contrary, this is not true. Speaking of driving style running on a highway at a steady speed makes little sense (as long as the driver uses the correct gear). For this reason, since the ideal fuel consumption is calculated by modifying the original driving cycle respecting the total travel time, the modification of a route section at a steady speed always provides a section at the same steady speed and the fuel consumption will be obviously the same.

Finally, the more the average speed of the route is low the more the driver's driving style is important in vehicle fuel consumption. Lowering the average speed of the route the obtainable CO_2 reductions following the eco-driving rules increase and, on the other hand, increasing the average speed of the route the obtainable CO_2 reductions following the eco-driving rules diminish.

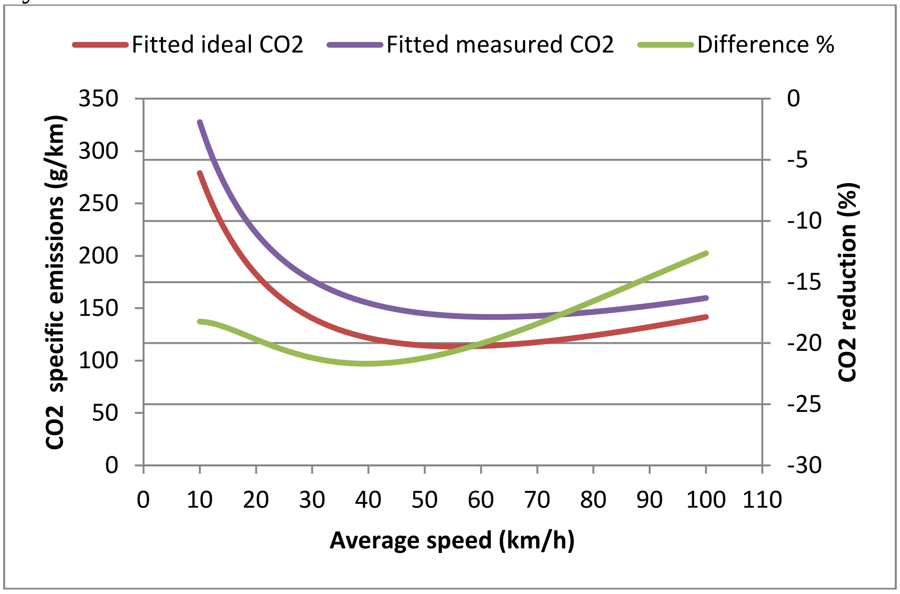
Figure 3. Obtainable CO_2 average reduction for gasoline vehicles adopting the eco-driving driving style.



Regarding the diesel fuelled vehicles (Figure 4), findings are quite the same of gasoline vehicles however the obtainable CO_2 reductions at low average speeds are lower than those obtainable with gasoline fuelled vehicles.

The main reason of this difference is mainly due to the fact that diesel vehicles are tipically easier to drive at low speed. The intrinsic charactristic of diesel powered vehicles is to have an adequate engine torque at low revolutions that allows drivers to start the vehicle easily without wasting too much energy (and fuel) when engaging the clutch. In general this is less true with the gasoline fuelled vehicles, expecially for those monitored in the campaign of this work, due to the fact they have small engine torque at low RPM compared to diesel fuelled vehicles. Starting driving these vehicles is not as easy and requires on average to use the clutch more than diesel vehicles and so fuel waste is higher. For this reason when modifying the original driving cycle on the basis of eco-driving rules the obtainable CO_2 (and fuel) reductions are lower with diesel cars at low average speeds because on average people use to drive this kind of vehicles better than gasoline vehicles.

Figure 4. Obtainable CO_2 average reduction for diesel vehicles adopting the eco-driving driving style.



4 CONCLUSIONS

The objective of this work has been to define an index to quantify the driver influence on car fuel consumption and CO_2 emissions. This index has been called Ecoindex. The Ecoindex is the ratio between the fuel consumption on the modified cycle and the fuel consumption on the real cycle.

The methodology to calculate the Ecoindex is based on an algorithm that modifies a real driving cycle imposing retrospectively the eco-driving rules and respecting all the constraints of the driving cycle (i.e. number and position of stops, average speed, accelerations and decelerations, etc.). The modified cycle differs from the real one only for the adopted driving style. The fuel consumption and the CO_2 emissions are recalculated on the modified cycle and they represent the minimum values obtainable on the considered route, with the same traffic conditions and with the same car if the driver had adopted the eco-driving style. So the difference in fuel consumption and CO_2 emissions between the original cycle and the modified cycle is only due to the driver behavior and to the driving style and it could be saved following the eco-driving rules.

The Ecoindex allows to compare the influence of the driving style on the vehicle's fuel consumption independently from other external factors affecting the fuel consumption like the average speed of the route, the traffic conditions, the vehicle's characteristics and others. There is no need to set a test fixing the route, the hours of the trip, the car and other factors. The Ecoindex can be applied in any campaign free from constraints.

A large on road campaign has been carried out and lasted six months. It comprised ten rental cars and a total of 278 different drivers. Data from driving cycles (instantaneous kinematic parameters and engine parameters) have been acquired with the CTL onboard acquisition tool connected to the CAN bus of the vehicles.

Findings from this campaign show that the Ecoindex values spread is almost 50% for an average speed of the route under 70 km/h and reduces to 10-15% over that threshold. So the driver influence on car fuel consumption and CO_2 emissions is higher at low average speeds of the route and diminish with increasing of average speed.

Considering only the routes with an average speed under 70 km/h, the average speed does not have influence on the mean Ecoindex value and the variance remains almost constant. As route type (urban, extra urban or highway) and traffic congestion can be measured using the average speed as a quantification indicator, as a consequence of that the Ecoindex does not depend on route type and traffic conditions so the aim to define a parameter representing the influence of the driver on the vehicle fuel consumption independently from other factors affecting the fuel consumption (such as route type and traffic conditions) has been reached. Future developments will consolidate these first results on this topic.

In terms of fuel consumption and CO_2 emissions, results show that if all the drivers had adopted the eco-driving style the obtainable reductions are higher at low average speed of the route and decrease with increasing average speed. In particular the maximum obtainable reduction is about 30% at 10 km/h of average speed of the route for gasoline fuelled vehicles and about 22% at 40 km/h for diesel fuelled vehicles. In both cases, however, obtainable reductions cancel over 80-90 km/h of average speed of the route where the driver influence on car fuel consumption is almost negligible. So in general the driver influence on car fuel consumption and CO_2 emissions is higher at low average speed of the route and diminishes with increasing the average speed. For this reason the benefits of eco-driving are variables as a function of average speed and are higher in situations (typically urban and medium-low average speed extra urban ambits) where driving cycles shape is greatly influenced by driver behavior (in terms of gear box, engine, clutch and throttle usage).

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KEY WORDS

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Eco-driving
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