RESEARCHES ON THE IMPACT OF HYPERMILLING TECHNIQUES AND FUEL SAVING DEVICES IN ORDER TO REDUCE POLLUTION IN URBAN AREAS

Catalin Zaharia [1]***, Adrian Clenci***

UDC: 629.1.02

INTRODUCTION

Green driving describes techniques that drivers can use to optimize their automobile fuel economy. The energy in fuel consumed in driving is lost in many ways, including engine inefficiency, aerodynamic drag, rolling friction, and kinetic energy lost to braking (and to a lesser extent regenerative braking). Driver behavior can influence all of these, (2). Since climate change and humanity responsibility has been widely accepted, many drivers have a new goal in mind: fuel efficiency. Eco-driving style is therefore often referred as smart driving because of the necessary complex tradeoff between the multiple goals the driver has to manage with.

Studies usually simplifies the green way to drive using simple advices easily understood by drivers (11), but sometimes leading to a misunderstanding of the fuel efficient driving strategy. Other studies used trial experiments before and after a training program to assess the eco-driving impact.

Effects of eco-driving on fuel consumption are well described in the literature, but results are often optimistic: CO2 emissions reduction can be up to 30% according to many studies. The key question for policy makers is “how big” of an emission reduction we can get by encouraging an eco-driving style, taking into account the diversity in the way to learn eco-driving: just reading a few driving tips, taking a course with a professional, or doing practical exercises with equipped vehicles? Moreover, there is a need to understand the best way to teach and learn eco-driving style, especially for young drivers, (11).

ECODRIVING BASICS

Eco-driving primarily consists of a variety of driving techniques that save fuel and lower emissions.

Maintenance - key parameters to maintain are proper tire pressure and wheel alignment, and engine oil with low-kinematic viscosity referred to as low "weight" motor oil. Inflating tires to the maximum recommended air pressure means that less energy is required to move the vehicle. According to (10), under-inflated tires can increase rolling resistance by approximately 1.4 percent for every 1 psi drop in pressure of all four tires. Equally important is the scheduled maintenance of the engine (i.e. air filter, spark plug), and addressing any on-board diagnostics codes/malfunctions in the Engine Control Unit and related sensors, especially the oxygen sensor.

[1] *University of Pitesti, Automotive Dept., 1, Tg. din Vale, +40348453190, 110040, Romania, catalin.zaharia@upit.ro*

Efficient speeds and choice of gear (manual transmissions) - maintaining an efficient speed is an important factor in fuel efficiency. Optimal efficiency can be expected while cruising with no stops, at minimal throttle and with the transmission in the highest possible gear.

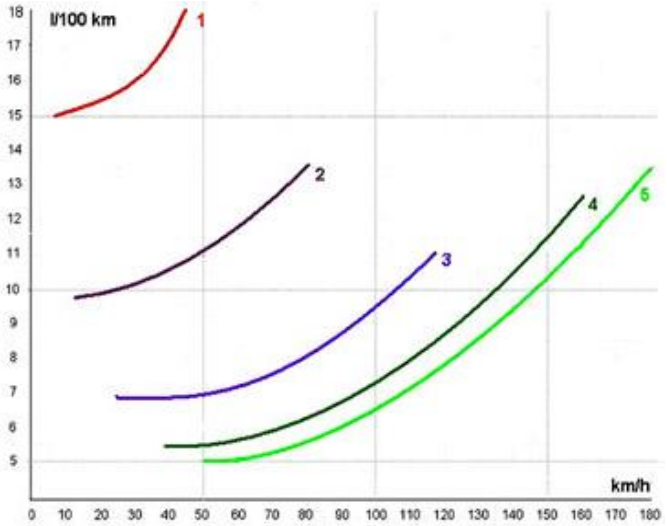

Figure 1 *Fuel efficient driving, (12)*

As seen in figure 1, 50 Km/h is best approached in 5th gear.

Engine efficiency varies with speed and torque, as can be seen in a plot of brake specific fuel consumption (bsfc). The graph contains also the isopower curves. For instance, 20 KW could be obtained in different ways: if using the highest possible gear imposing a low engine speed and a high engine load (e.g. 1500 rpm and 8 bar bmep, resulting from the intersection with the ideal green curve), then the bsfc will be about 265 g/KWh; at 3000 rpm and 4 bar bmep, i.e. with a lower gear, the bsfc increases at 330 g/KWh (figure 2).

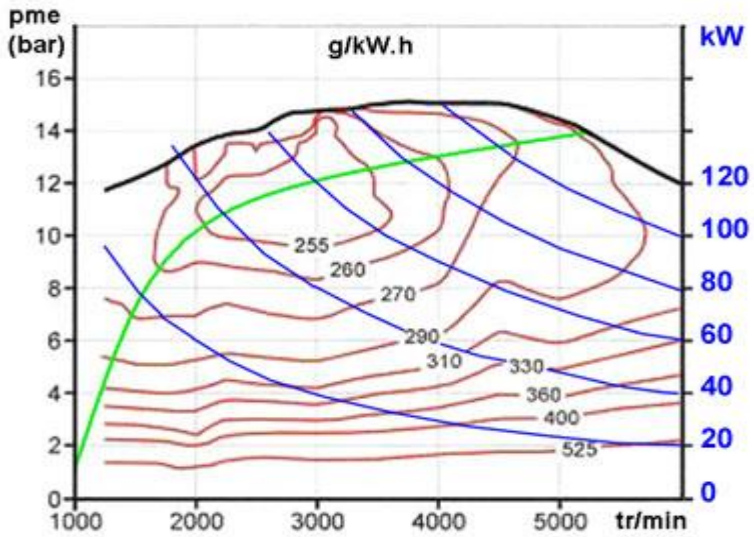

Figure 2 *Brake specific fuel consumption, (12)*

Anticipation - a driver may further improve economy by anticipating the movement of other traffic users. For example, a driver who stops quickly, or turns without signaling, reduces the options another driver has for maximizing his performance. By always giving road users as much information about their intentions as possible, a driver can help other road users reduce their fuel usage. Similarly, anticipation of road features such as traffic lights can reduce the need for excessive braking and acceleration.

Energy losses - understanding the distribution of energy losses in a vehicle can help drivers travel more efficiently. Most of the fuel energy loss occurs in the thermodynamic losses of the engine. The second largest loss is from idling, or when the engine is in "standby", which explains the large gains available from shutting off the engine.

Very little fuel energy actually reaches the axle. However, any mechanical energy that doesn't go to the axle is energy that doesn't have to be created by the engine, and thus reduces loss in the inefficiency of the engine. In this respect, the data for fuel energy wasted in braking, rolling resistance, and aerodynamic drag are all somewhat misleading, because they do not reflect all the energy that was wasted up to that point in the process of delivering energy to the wheels.

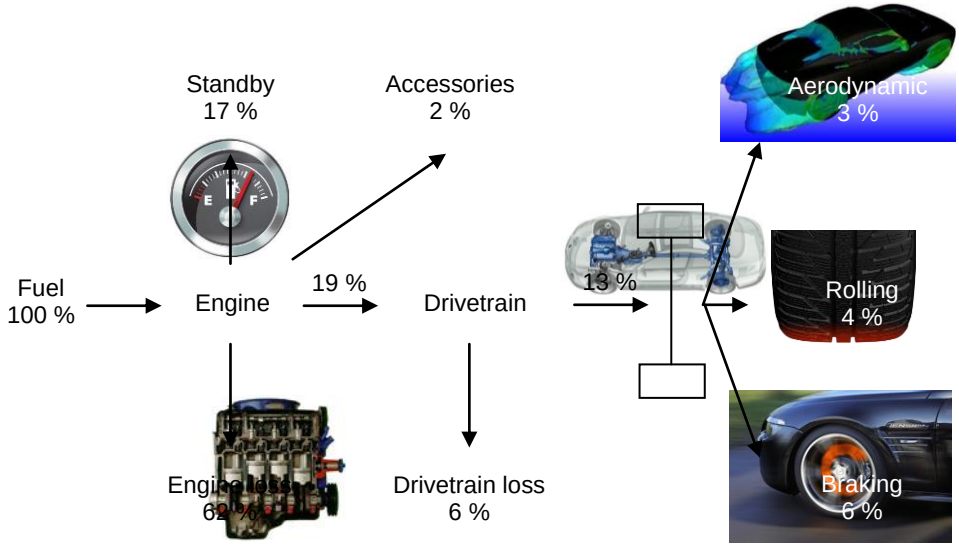

Figure 3 *Energy flows for a late-model midsize passenger car – urban driving, (10)*

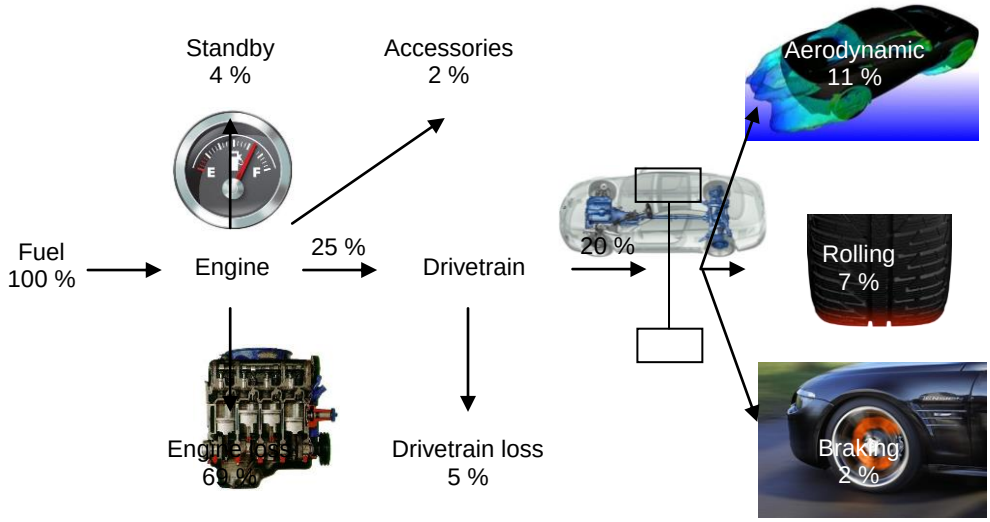

Figure 4 *Energy flows for a late-model midsize passenger car – highway driving, (10)*

The images (figure 3 and 4) report that on non-highway (urban) driving, 6% of the fuel's energy is dissipated in braking; however, by dividing this figure by the energy that actually reaches the axle (13%), one can find that 46% of the energy reaching the axle goes to the brakes. Also, additional energy can potentially be recovered when going down hills, which may not be reflected in these figures, (10).

Any statistic such as this must be based on averages of certain driving behaviors and/or protocols, which are known to vary widely, and these are precisely the behaviors which hypermilers leverage to the full extent possible.

ECODRIVING TOOLS

In order to meet the regulation regarding the reduction of fuel consumption, most of automobile manufacturers have generalised the solution of informing the driver about the moment of changing gear through the appearance on the instrument panel of certain icons under the form of arrows pointing to the inferior or superior plan, thus indicating to a higher/lower gear (figure 5), (1, 3). One may notice such systems came on the market with the introduction of the 6 gears box, the possibilities of approaching the driving being increased.

Figure 5 *Gear change indicator – Audi A4 B8*

In what follows, some more complex solutions adopted by certain automotive manufacturers will be presented.

Honda's Ecological Drive Assist System - EcoAssist^{TM} – represents a feedback system for the driver, accomplished with the purpose of contributing to the developing and maintaining of a driving style that is more efficient from the point of view of fuel consumption, (6, 7). The system monitors the driving style and can display its impact on the fuel economy of the automobile. The driver can then make adjustments in the style of driving in order to maximize fuel economy.

Nissan Motor Co, Ltd., launched the ECO accelerator pedal – the first technology of this kind in the world, designed to help drivers diminish fuel consumption (figure 6). When the ecological pedal system is turned on, each time the driver presses the accelerator, he/she activates a mechanism that registers fuel consumption. In case the system detects an excessive pressure, the ECO pedal pushes back the driver's leg, thus sending the information that he/she is using more fuel than necessary. An ecological consumption indicator integrated in the instrument panel provides in real time the driver with the levels of energetic consumption, thus helping him/her improve the driving conditions. The ECO pedal system can be activated or deactivated, function of the driver's preference. Nissan has commercialised automobiles that are equipped with ECO pedal since 2009. The research done by Nissan showed that, by using ECO pedal system, the drivers can diminish their energetic consumption by 5-10%, function of the driving conditions, (9).

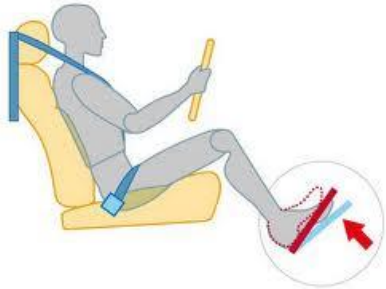

Figure 6 *Eco accelerator pedal – Nissan*

Software and hardware based

DriveGain Ltd. – DriveGain App., (10) The DriveGain App uses the iPhone's built-in GPS system to calculate the vehicle's speed and rate of acceleration and deceleration. The visual displays include a recommended gear indicator and some sliders that drivers try to keep in the green. In addition, the App calculates fuel consumption, CO_2 emissions and fuel cost per mile. By following the on-screen cues, DriveGain claims that it can help users save money on fuel while reducing CO_2 emissions by up to 660 kilograms per year. The App's database has over 16,900 different vehicles to choose from, however hybrid vehicles are not yet supported.

*Garmin Ltd.: ecoRoute, (10)***.** With the ecoRoute software on the GPS systems, drivers can save money on fuel costs by finding more fuel-efficient routes. These routes are selected by factoring in fuel consumption data, the number of stops and speed limits, as well as further traffic circumstances. ecoRoute also gives a real-time feedback on the efficiency of the way of driving. ecoRoute's Fuel Report automatically calculates details about the travel time and fuel usage. The Drivers can see time and distance traveled as well as the cost of fuel used

and average fuel economy. The ecoRoute Driving Challenge makes a game out of saving gas by keeping a running score that reflects the current driving habits.

PH Informática – EcoSpeed, (10). EcoSpeed is an iPhone App that is available for free at the Apple App Store. The speedometer uses the gearbox settings and GPS data to help the Car Owners to drive more efficiently and save money. It also presents useful information while driving. Features of the app are: gear adviser, speedometer, top speed alert, sound alerts, GPS position, GPS signal.

Quality Alliance Eco-Drive – App., (10). By capturing refueling behavior and tire pressure settings, users of this iPhone App receive information about fuel consumption, saving potentials with ideal tire pressure, price development of fuel and the CO_2 emissions. The app can be downloaded for free.

Toyota Motor Marketing Europe – A Glass of Water, (10). The iPhone App – "A Glass of Water" mimics a glass of water placed on a car's dashboard and challenges users to not spill a drop. Toyota estimates that the gentler driving style encouraged by this App would help consumers lower their fuel consumption by 10 percent, resulting in the lowering of CO_2 emissions by 2 million tons a year. The App reacts to the driving behavior as if the driver had an actual glass of water on his dashboard: accelerating too fast or braking too suddenly will spill water. It also records the driving distance, time, fuel consumption and water spilled. After each drive the users can analyze their results and see on a map where they can improve their driving for the future. The results are automatically uploaded to the "A Glass of Water"-Website and compared to other participants.

Volkswagen AG; MTV Networks – CO_2 monitor, (10). By interviewing over 26,000 young people worldwide, Volkswagen and MTV Networks compiled the "MePublic" social media study. The international study gives an insight into media use and value concepts among the group of 14- to 29-year-olds known as "digital natives". As the study shows, the young people would also like to see networking extend to the car. With the help of the iPhone App "CO_2 monitor", fuel consumption and other driving data is transmitted to a Volkswagen website and included into a driver ranking. Volkswagen is seeking to motivate its customers to develop an awareness of environmentally-friendly and fuel-efficient driving with this edutainment competition.

KIA Motors Corp. – Eco Driving System, (10). The KIA Eco Driving System consists of an eco-lamp on the dashboard, which will guide the driver to drive in the most economical way. A green lamp will come on to indicate high fuel efficiency driving (i.e. traveling at a constant speed), while a red lamp will indicate low fuel efficiency (i.e. sharp acceleration, sudden braking). A white lamp will come on to show normal fuel efficiency or standby mode. The system is designed to encourage eco-driving by providing real-time feedback to the driver.

Nissan Motor Co. Ltd. – Eco-Drive and You, (10). Nissan is adding a new service called "Eco-Drive and You" for its on-board CARWINGS navigation system in Japan. Since January 2007, Nissan CARWINGS members have been provided a range of services that have included fuel-efficiency rankings among owners of the same model and advice on efficient driving methods. The service has now been expanded to provide the same content found online via the onboard navigation system of car owners. Car owners can monitor their

fuel consumption habits, experience better fuel-economy as well as receive helpful driving tips while on the road. The service has three main components:

- ecodrive check (audio and video display). This displays average fuel consumption, fuel consumption trends and the fuel consumption history and comparison to the last two records.
- ecodrive ranking (audio and video display). This displays average fuel consumption history, the driver's ranking among CARWINGS members with the same model and fuel expense annual savings.
- driving advice (audio guidance). This covers various topics for the driver, which also includes tips on better fuel efficiency.

Toyota Motor Corporation – Eco Drive Indicator, (10). Based on a comprehensive determination that takes into consideration factors such as accelerator use, engine and transmission efficiency and speed and rate of acceleration, the Eco Drive Indicator, located on the instrument panel, lights up when the vehicle is being operated in a fuel-efficient manner. This is supposed to raise the driver's awareness towards environmentally considerate driving and contribute to fuel economy. Although results may vary – depending on the level of traffic and conditions such as the frequency of starts from stop and of acceleration, as well as distance driven – the Eco Drive Indicator can improve fuel efficiency by approximately 4 % (as measured by Toyota).

Fiat Group Automobiles Germany AG: eco:Drive, (10). eco:Drive was launched in October 2008 as a software application that is free to download at Fiat's website. It works by asking drivers to plug a USB stick into their Blue&Me infotainment system (presented in all new Fiat models), where it records telemetric data from the car's network. Plugging the USB into a computer allows the Fiat servers to analyze the journey data, on an anonymous basis. Algorithms measure driving efficiency based on four parameters: steady acceleration, steady deceleration, early gear changes and moderate and consistent speed. Drivers receive a star rating (out of five) for each of these indicators, and their performance overall on the four indicators is used to calculate an eco:Index score out of 100 – a higher score means more efficient driving. Drivers receive tailored advice on how to improve their performance on each indicator, and thus their overall eco:Index. Through their computer, they can track improvements over time, set targets and see how much CO_2 they are saving. "ecoVille" – an online community which shows the latest number of drivers using eco:Drive and the total CO_2 emissions that eco:Drivers have saved up to date, has also been developed in connection to the application (figure 7).

Figure 7 *Ecodrive - Fiat*

Ford Motor Company: Econo Check, (10). The Ford Econo Check App calculates potential fuel savings for any car - based on make, model, age and annual mileage - and picks up fuel efficient driving tips on any iPhone or iPad. Ford Econo Check enables Ford vehicles to be

fitted with a data logger to monitor how they are driven. Once the Econo Check chip is removed and data downloaded, a tailored report advises how modifying gear changes, anticipation, acceleration and braking will improve fuel economy. Resulting savings are also shown, which can be up to 25 % a year according to a study of 50,000 drivers.

PLX Devices Inc.: Kiwi, (10). The Kiwi is a plug and play device compatible with all 1996 vehicles and up. Kiwi plugs into the existing on board diagnostic port (OBDII), located near the steering column. From this port, Kiwi is able to obtain detailed sensor information about the vehicle. A multitude of sensor data including vehicle speed, RPM, engine load, oxygen sensor readings are all analyzed to determine the vehicle's optimum driving efficiency. The PLX Kiwi uses mathematical algorithms to analyze the engine's performance and driving behavior. The drive green lessons are designed to improve smoothness, drag, acceleration, and deceleration parameters. The Kiwi software operates much like a game. While driving, the daily goal is to obtain the highest "Kiwi Score" possible through an ecodriving style.

FES GmbH – ECOdrive III, (10). Connected to the control unit of passenger cars, transporters or trucks, the ECOdrive III allows its user to regulate the engine speed and maximum speed of the vehicle. The maximal engine speed depends on the charge and loading of the vehicle. If the vehicle has to drive uphill or with a higher loading the system allows a higher engine speed to always guarantee the adjusted maximum speed.

SR-Car Expert e.K. – Eco Tuning, (10). SR-Car Expert's Eco Tuning leads to a reduction of fuel consumption by changing the motor software of the vehicle. The remaining durability of the vehicle and an additional reduction of CO_2 emissions are further features of the Eco Tuning software. During several test rides, the tuning could lead to an average reduction of the fuel consumption by 15-20 %.

OFF-BOARD METHOD TO EVALUATE THE DRIVER BEHAVIOR

Prior to use a car, people may be trained in ecological & economical Driving (Eco^2Driving) by using a driving simulator. Because the training journeys are not made in a real vehicle, fuel can also be saved. In addition, there is no need for a test track. Important facts (5, 8):
- eco^2drivers use 10 to 15 per cent less fuel than people without course experience – even at a slightly higher average speed.
- eco^2driving influences positively the ride comfort and vehicle wear and tear. Eco^2drivers achieved significantly better measurable values than persons without course experience.
- eco^2drivers remain eco^2drivers.
- theoretical knowledge of basic eco^2driving rules alone is insufficient. Practical experience is essential to master the technique: a clear indication of the benefits of eco^2driving training.

Car simulators are used in various research areas: evaluation of driver's behavior, their education and training, testing and implementing new systems, research on the dynamics of wheeled vehicles, traffic safety studies.

To use a car simulator in research and education the virtual reality system must reproduce the vehicle dynamics and its interaction with the environment in a most realistic manner. It is well known in the specific literature that a car simulator cannot reproduce 100% real life situations or sensations and accelerations experienced by the driver because of reduced space working and limitations actuators.

Car simulators reproduce the vehicle dynamics and its interaction with the environment (traffic signs, buildings, other vehicles, etc., figure 8). This kind of simulation was used for the first time on the fly simulator.

Figure 8 *Driving simulators*
(CARRS – Q: Center for Accident Research and Road Safety)

Applying this concept in the automotive industry, generated a wide interest, Volkswagen built the first such simulator in 1970. Over the past 40 years, car simulators have become research tools used with confidence in different applications.

Different systems are tested to study their performance and limitations before being implemented in an expensive prototype vehicle. Therefore, different studies are performed using a simulator under conditions which would not be safe to be performed in the real world.

A topic of great interest in the automotive industry is the development and implementation of advanced driving assistance (ADAS). Testing these systems together with the study of acceptance by the user is essential before implementation in mass production.

Car simulators cannot play in an identical mode vehicle accelerations that it simulates, regardless of available workspace and the number of degrees of mobility.

Therefore, different strategies are used in order to achieve a realistic virtual environment, for example: development of intelligent control algorithms, the use of a visual field of 360^0, simulation of vehicle noise, etc. Nevertheless, the use of these systems presents different disadvantages: validation of results, limited workspace, mistyped simulation components and that can cause discomfort to the user.

CONCLUSIONS AND FUTURE WORKS

This study will contribute at developing a simulation model of automobile functioning with the goal of realising a graphical interface that will assist the driver in real time for the adoption of a driving style with minimal influence on fuel consumption, implicitly on CO_2 emissions.

The study will establish a set of rules that meet the needs of automobile users with the primary purpose of adopting an eco^2driving. This set of rules will be implemented in the activity of University of Pitesti driving school STUDENT AUTO.

Figure 9 *Driving school STUDENT AUTO – University of Pitesti, Romania*

Therefore, the authors will use techniques of semiempirical modelling of internal combustion engine and equipping the automobile with specific devices and testing it with various drivers on a predefined urban route (the city of Pitesti). These tests will contribute to the establishing of the particularities related to the driving styles observed. For the simulation, the authors will take advantage of the possibilities offered by the CRUISE software, provided by the AVL List Austria, to whom many thanks are addressed.

REFERENCES

[1] Barth, M., Kanok Boriboonsomsin, "Energy and emissions impacts of a freeway-based dynamic eco-driving system", ScienceDirect, Journal of Transportation Research Part D 14 (2009) 400–410

[2] Barkenbus, Jack N. "Eco - driving: An overlooked climate change initiative", ScienceDirect, Journal of Energy Policy 38 (2010) 762–769

[3] Beckx C., L. Int Panis, I. De Vlieger & G. Wets, "Influence of gear – changing behaviour on fuel use and vehicular exhaust emissions", Proc. 8th Highway and Urban Environment Symp. – In Highway an Urban Environement, Springer, Netherlands, p. 45 – 51, 2007.

[4] Beusen, B., Steven Broekx, Tobias Denys, Carolien Beckx, Bart Degraeuwe, Maarten Gijsbers, Kristof Scheepers, Leen Govaerts, Rudi Torfs, Luc Int Panis, "Using on-board logging devices to study the longer-term impact of an eco-driving course", ScienceDirect, Journal of Transportation Research Part D 14 (2009) 514–520.

[5] Cumpelik, J., "ECODRIVE – driver training", Conferinta ECODRIVEN - EEBV, Prague, novembre 2008

[6] C.J.G. van Driel, F. Tillema, Dr. M.C. van der Voort "Directives for new-generation Fuel Economy Devices", CE&M research report 2002R-004 / VVR003 ISSN 1568-4652

[7] De Vlieger I., D. De Keukeleere & J. G. Kretzschmar, "Environmental effects of driving behaviour and congestion related to passenger cars", Proc. Int. Symp. Transport and Air Pollution, Graz, Austria, 31 may 1999, Atm. Env., vol. 34, no. 27, p. 4649 – 4655

[8] Hennig, W., "Best practice training & evaluation. Improving fuel economy, reducing CO_2", Conferinta ECODRIVEN - EEBV, Prague, November, 2008.

[9] Orofino, L., "EcoDrive: Driver behaviour evaluation system to reduce CO_2 emissions", FISITA 2010, F2010E052, may – june 2010, Budapest, Hungary,

[10] www.wikipedia.fr, "Fuel economy – maximizing behaviors",

[11] www.cieca.be, "Driving training and driving tests",

[12] www.auto-innovations.com, "Comment consommer moins"