Principle of measuring the effectiveness of eco-driving using information and communication technologies

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Abstract—**Eco-driving is a set of driving techniques which lead to a reduction in fuel consumption and CO_2 emissions. According to different authors, the use of eco-driving can reduce fuel consumption of 5% to 30%. Modern information and communication technologies can provide support to the driver by giving an insight into the parameters of driving (average fuel consumption, CO_2 emissions, maximum speed, maximum revolutions per minute, etc.). This paper will present a set of information and communication technologies that enable the collection and analysis of parameters for determining the effectiveness of eco-driving. Collection of data on vehicle and driving, real-time display and post-processing of that data is one of the ways to support the driver. Further analysis and comparison of data on vehicle and driving determines efficiency of eco driving techniques.**

Keywords-information and communication technologies, fuel efficiency, eco-driving, CO_2 emissions

I. INTRODUCTION

Increase in the number of vehicles entails increase of environmental pollution with harmful gases and increasing use of energy (oil, gas) as a fuel. This represents a global environmental problem. Interest of many private and public entities is to eliminate environmentally harmful influences or to reduce them to the minimum. Primarily, due to economic reasons, interest of each driver is to minimize the fuel consumption of his vehicle. In addition to financial benefits, the assumption is that the minimization of fuel consumption will lead to a reduction of the vehicle's harmful gases for the environment.

Each saving in fuel consumption represents a cost reduction of using a car. Depending on the driving style and the number of traveled kilometers, significant savings are possible on a daily basis. However, considerable levels of fuel savings and a reduction of CO_2 emissions can be visible on a monthly or annual basis.

The potential of eco-driving in that form found a possibility of using primarily through reduction of fuel consumption. Since the above does not require almost none material expenses, represents an interesting solution.

Information and communication technologies can give an insight into parameters of the vehicle (such as current fuel consumption, CO_2 emissions, revolutions per minute etc.) and because of their price range represent an acceptable solution. Use of modern information and communication technologies created the premise for simple and accurate measuring and analyzing the effectiveness of eco-driving. Mentioned way of reduction of fuel consumption and CO_2 emissions can be applied to any vehicle. This can significantly affect a global environmental problems(reduction in fuel consumption and CO_2 emissions) and furthermore it can improve budget of an individual or a company.

II. ENVIRNOMENTALLY EFFICIENT WAY OF DRIVING

According to [1], eco-driving is a driving style that reduces fuel consumption, greenhouse gas emissions, noise pollution and accident rates. These are smart, smooth and safe driving techniques that lead to an average fuel saving of 5-10%.

Inevitably is that the environmental impact depends on the type of vehicle, but also on a driver who controls him. Although technical specifications of a vehicle define average values of harmful gases that are exhausted into the environment, the fact is that these figures vary depending on the type of driving - thus depending on the driver. The link between the driver, the vehicle and the environment is a way of driving, seen in Figure 1. In the forefront in terms of reducing fuel consumption and negative environmental impacts ecodriving is certainly representing a range of procedures that can reconcile those three mentioned segments.

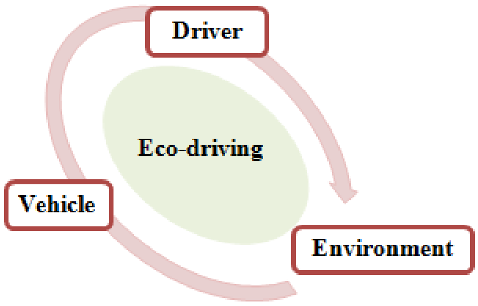

Figure 1. Eco driving segments

Eco-driving techniques are primarily aimed at drivers of cars and vans. In general terms, eco-driving is a set of rules that has been developed to decrease fuel use. It involves both efficient driving practice and vehicle maintenance.

A. Driving principle

According to [2], eco-driving can be characterized as a smarter and more efficient driving style that in the best possible way uses possibilities of modern technologies in traffic with simultaneous increase of traffic safety.

The advantages of using eco-driving are multiple and are primarily related to [3]:

1) Safety

a) Increases safety in road traffic

b) Improves driving capabilities

2) Environment

a) Reduces greenhouse emissions (CO_2)

b) Reduces local harmful emissions

c) Reduces noise

3) Driving economy

a) Reduces fuel consumption

b) Reduces the maintenance costs

c) Reduces the costs due to traffic accidents

4) Social responsibility

a) Contributes to more responsible driving

b) Reduces stress during driving

c) Increases comfort in driving for drivers and passengers

According to [1, 4], There are two stages to eco-driving: before the journey and after the journey. Before the journey, drivers are advised to:

- maintain the vehicle properly according to the manufacturing standards
- consolidate trips to bypass congested routes
- unload as much as possible as soon as possible
- check tyre pressures regularly and keep the tyres properly inflated (if tyre pressure is only 25% down, fuel consumption will be up by 2%)
- aerodynamic shape of vehicle

During the journey, the drivers should:

- drive at a steady speed by using the highest gear possible
- accelerate and break smoothly by allowing a safe distance between vehicles
- decelerate smoothly using the retarder and the engine break
- close windows at high speeds
- anticipate traffic flow (look ahead as far as possible and adjust driving accordingly)
- minimize the use of heating and air conditioning
- use of cruise control
- driving up hills:- you need to be in the highest possible gear with almost maximum acceleration
- decrease the speed to a maximum legal limit to avoid unnecessary overtaking of other vehicles on the road
- avoid idling altogether
- avoid driving through the city center

B. Fuel savings

Changing the style of driving is one of the factors that will have most influence on the reduction of fuel consumption. Aggressive driving style with rapid acceleration and braking with repeated rapid accelerations have largely negative impact on fuel consumption. Fuel consumption at the moment of movement of the car is significantly higher than when the vehicle is moving and holds a constant speed. Energy-saving driving style is reflected through a predictable driving style.

Low fuel consumption enables substantial cost savings over the year. If we reduce the fuel consumption of 1 liter per 100 kilometers for the vehicle which annually on average exceed 15 000 km, we will save about 1500 kunas per year assuming a fuel price of 9.90 kunas per liter. Significantly reduce in fuel consumption (by up to 25%) can be achieved by driving economically without additional technical measures. In order to achieve more economical fuel consumption and thereby reducing CO_2 emissions for cars with built-in petrol and diesel engines, it is necessary that drivers always have in mind the advice on energy-saving way of driving (eco-driving) [5].

The potential of fuel savings by using eco-driving techniques have been studied by many authors and according to their analyses the possible cost savings are from 5% to 30% (Table 1).

TABLE I. FUEL SAVINGS ACCORDING TO SOME AUTHORS

Reference	Fuel savings
(Barkenbus, 2010)	10%
(Kolman, 2009)	30%
(Mele, 2008)	26%
(Walden, 2008)	25%
(Onoda, 2009)	5-15%
(Barth & Boriboonsomsin, 2009)	10-20%
(Hitchings & Ward, 2010)	18%
(OECD, 2010)	25%
(Barić & Zovak & Periša, 2013)	32%

C. *Vehicles and CO_2 emissions*

Historical statistics as well as future projections indicate that there is a need for sustainable road transportation on the global arena. CO_2 emissions from burning fossil fuels are a major contributor to the global warming effect, and road transport almost entirely relies on oil. Unless the trend of ever-increasing CO_2 emissions is reversed, the world can witness global events of extraordinary magnitude.

According to [6], carbon dioxide, particularly from transport and industry, is a major greenhouse gas that contributes to global warming and thereby climate change. Due to human activities such as the combustion of fossil fuels, deforestation, and the increased release of CO_2 from the oceans (due to the increase in the earth's temperature), the concentration of atmospheric carbon dioxide has increased by about 35 per cent since the era of industrialization began.

Distribution of CO_2 emissions by sector in the EU countries in year 2010 is evident in Figure 2.

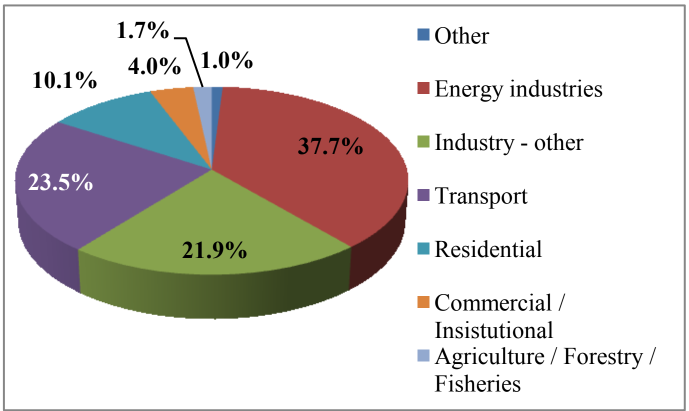

Figure 2. CO_2 emissions by sector: EU-25, [7]

III. INFORMATION AND COMMUNICATION TECHNOLOGIES

Given that the car's electronic computer unit (ECU) can not display the data about fuel consumption, and especially the detailed parameters such as CO_2 emissions and similar, it is necessary to use the devices and tools that will be able to display required data. In this context, this paper wants to show modern information and communication technologies that enable the collection, storage and analysis of the data and selected parameters that were gathered while driving.

The basic set of used and necessary equipment/tools that can be used for the purpose of collecting data on driving style is as follows:

- OBD (On-Board diagnostics) device
- Smartphone/tablet device powered by Android operating system
- Diagnostic application package

In the continuation of this paper will be explained each segment of the system for collecting and analyzing data about the driving.

A. *On-Board diagnostics device*

On-board diagnostics device, or OBD, is an automotive term referring to a vehicle's self-diagnostic and reporting capability. OBD systems give the vehicle owner or repair technician access to the status of the various vehicle sub-systems.

According to [8], OBD-II provides access to data from the engine control unit (ECU) and offers a valuable source of information when troubleshooting problems inside a vehicle. OBD-II device requests for various diagnostic data and a list of standard parameters that might be available from the ECU. The various parameters that are available are addressed by "parameter identification numbers" or PIDs.

During normal operation, your vehicle is constantly monitoring a little more than 100 standard Parameter ID (PID) codes. Every vehicle must be capable of sending or receiving these codes over its OBD-II connection. These codes tell the tale of the systems monitored by your vehicle's emissions system, everything from fuel system status to engine and vehicle speed to the status of the vehicle's various O_2 sensors [9].

The entire OBD-II device for a car consists of the following elements:

- OBD II diagnostic port of the car
- OBD II external diagnostic device/adapter

OBD II external diagnostic device/adapter is actually a different hardware and software solutions that can connect to the OBD-II port in the car in order to access the car's ECU.

For the purposes of this paper it was used a built-in OBD-II diagnostic port of the car and OBD-II diagnostic external device (ELM OBD-II Bluetooth adapter), shown in Figure 3.

Figure 3. OBD-II Bluetooth external diagnostic device and location of OBD-II port in used vehicle

OBD-II port in the car is the point of connection of the control unit/computer of a vehicle with adequate devices for reading all possible information on the state of the individual subsystems of that vehicle. One possible device for reading data of vehicle is an OBD-II diagnostic external bluetooth device.

OBD-II diagnostic external bluetooth device is equipped with bluetooth communication module which allows you to connect adequate devices to display the data collected of the vehicle, via bluetooth communication technology.

B. *Smartphone device*

Another essential element in the process of collecting and analyzing data via the OBD-II car's interface is a smart terminal device (smartphone) or a tablet device. According to [10], mentioned device according to its characteristics must meet the requirements necessary for the connection with OBD-II bluetooth external diagnostic device.

The function of smart terminal devices is the ability to connect to the OBD II bluetooth external diagnostic device via bluetooth connection. This ensures the hardware component of the system to access data of the vehicle. The specificity of the device is an operating system that is necessary to use - Android OS. Specifically, the application package or a software solution that is used in this study can be installed specifically to a device that is powered by Android operating system. The quality of the device (CPU speed, amount of RAM, etc.) affect the performance of the application package, and of course, operating system Android must be used.

C. *Diagnostic application package*

The third essential segment necessary to enable the functionality of the entire system for collecting data on vehicle ie driving is adequate application / software package. Very important is to note that in the market there are a number of applications that are based on the same functionality - installation on the device and connection to the ECU of the vehicle via the vehicles OBD-II interfaces and protocols. Some applications are dependent on the platform/operating system of device.

For the purpose of this research it was chosen one of the most popular application packages that enable the collection of necessary data - Torque Pro (OBD 2 & Car). Mentioned application can be downloaded from the Google Play store at a price of 4,95 $ (July 2013).

According to [11], Torque Pro (OBD 2 & Car) is a vehicle/ car performance/diagnostics tool and scanner that uses an OBD-II Bluetooth adapter to connect to your OBD-II engine management/ECU. It can use the Global Positioning System (GPS) to provide tracker logs with OBD engine logging so you can see what you were doing at any point in time. It can also show and reset a fault codes like a scan tool.

Some of the features and capabilities for measurement of application Torque Pro (OBD 2 & Car) include:

- CO_2 emissions readout
- 0-100 km/h speed timings
- Driving speed
- Fuel consumption (average or current)
- Massive fault code database
- Turbo boost feature for vehicles
- Graph data
- Alarms and warnings
- GPS Speedometer/Tracking and real time web upload capability
- Send logging information to web or email

IV. WORKING PRINCIPLE OF THE SYSTEM FOR DATA COLLECTION

Modern information communication and sensor technologies (explained in chapter 3) aims to provide high quality and cost-effective solution that will provide insight into the condition of the vehicle while driving, as well as data processing and analysis after driving. Due to the functionalities that allows mentioned hardware - software solution (OBD-II diagnostic device, smart mobile device and diagnostic application package Torque Pro) this solution was used in the research.

A. *System architecture*

Internal communication and flow of data exchange of the system for the collection and exchange of information on the status of the vehicle/driving is shown in Figure 5.

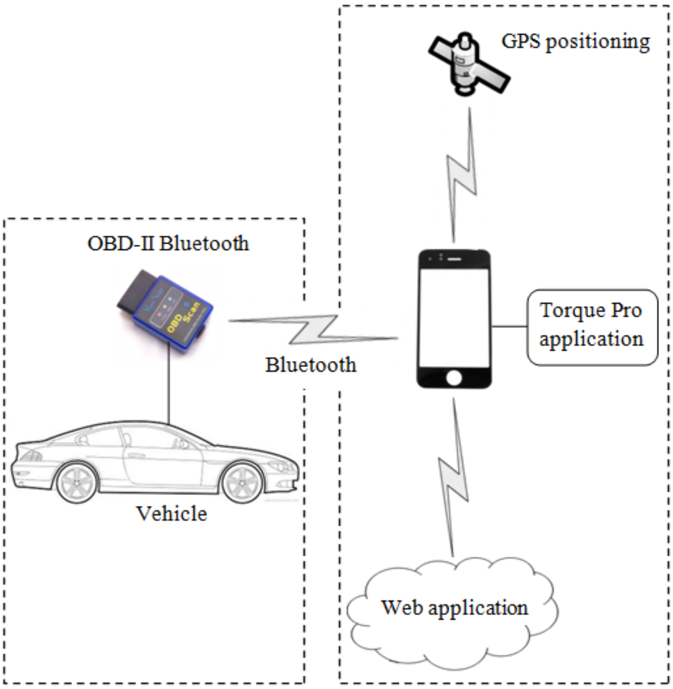

Figure 4. System architecture for data collection on the status of the vehicle

As it can be seen in the Figure 4, the vehicle is fitted with OBD-II bluetooth external diagnostic device which has the function of connecting to ECU of the vehicle's motor and a smartphone. The connection between the vehicle’s ECU and the OBD-II bluetooth adapter is OBD-II interface.

OBD-II bluetooth device communicates with a smartphone via bluetooth communication link. Further, it is necessary to install and run the application Torque Pro (OBD 2 & Car) on smart mobile device. Mentioned application allows you to read the data on the status of the vehicle that collects OBD-II bluetooth device. This application can be adjusted to the needs and determine the parameters that we want to collect.

Mentioned information and communication technologies represent some of the telematics solutions of the vehicle in the form of creating additional support for the driver while driving.

Figure 5. OBD-II Bluetooth device connected to the smartphone in the vehicle

B. Data acquisition and analysis

Since Torque Pro (OBD 2 & Car) application offers a wide array of data that can be collected and stored, for the purposes of this study it was necessary to determine the data that will be useful for further analysis. Table 3 lists the data which can be extracted as most useful and those data can be used for the further analysis.

TABLE II. EXAMPLES OF COLLECTED DATA AND CHARACTERISTIC VALUES

Data	Example of the data
GPS time	Mon Sep 09 06:45:38 2013
Device time	09-ruj-2013 06:45:06.404
Latitude	16.04345988482237
Longitude	46.247885380871594
GPS speed [km/h]	25.65
OBD speed [km/h]	25
CO_2 emissions (average) [g/km]	92.28427887
CO_2 emissions (current) [g/km]	189.34254456
Revolutions per minute (motor) [rpm]	2283
Average trip speed [km/h]	49.93790054
Fuel used [liter]	3.84667087
Average fuel consumption [liter/100km]	6.79409647
Trip time [s]	3887.59106445
Trip length [km]	65.62412262

Information on driving and the vehicle can be collected during the entire trip. These data can be stored in the previously mentioned web server that allows the retrieval of data at any time, and their adjustment for the required measurements.

C. Systems based on similar principles

In addition to a number of applications such as application package Torque Pro (OBD 2 & Car) that seek to collect and display data on the vehicle / driving, using the OBD-II protocol, there are projects that are based on similar principles and architectures. One of these projects is the "ecoDriver" whose fundamental purpose is to create a information and communication support for the driver to save energy and reduce harmful gas emissions.

The target of ecoDriver project is a 20% reduction of CO_2 emissions and fuel consumption in road transport by encouraging the adoption of green driving behaviour. More specifically, drivers will receive eco-driving recommendations and feedback adapted to them and to their vehicle characteristics. The ultimate goal is to deliver the most appropriate eco-driving advice or feedback for any given situation [12].

Outcomes of the ecoDriver project are based on real-time feedback on driving style. By adapting the eco-driving human-machine interfaces (HMI – graphical interfaces, haptics, voice messages) to the driving style, system effectiveness and acceptance is trying to be maximised.

Main goals of the ecoDriver project are [12]:

- Achieve a 20% reduction of CO_2 emissions and fuel consumption in road transport
- Test and compare the effectiveness of nomadic and built-in navigation systems
- Maintain or even enhance driver safety
- Explore how eco-driving related CO_2 reductions might be affected by different future technological, political, and lifestyle scenarios

The next similar solution to the application Torque Pro is an application DrivingStyles intended for smartphone/tablet devices based on Android operating system. By using modern information communication and sensor technology it is possible to collect and store data on driving style of each driver. It is very important to mention that this application also connects to the OBD-II diagnostic bluetooth device that is connected to the car's electronic communication unit. Simple registration allows users to store a particular driving route and it's later review and analysis. Using modern algorithmic procedures application DrivingStyles determines the driving style of the user and makes a recommendations to improve it.

V. CONCLUSION

Eco-driving can contribute to significant fuel savings and reduction of CO_2 emissions in road traffic. Since the change of driving style does not require material costs and has an impact on the budget of an individual or a company in a positive way, there is an obvious potential of using mentioned driving techniques.

Real data collected by modern measurement techniques by using modern information communication and sensor technologies allow us an accurate and detailed insight into the possibility of using eco-driving in the terms of the reduction of fuel consumption and CO_2 emissions.

The potential of the implementation of modern information communication and sensor technologies (bluetooth OBD-II device, smart terminal device and diagnostic application package) is visible through real time measurement of required parameters of driving and storage of that data for further analysis, comparison and improvement.

Significant is the fact that specified hardware and software equipment requires very low costs which is an additional reason for using mentioned technologies. Based on given data it is possible to analyze the driving behavior of the individual and to provide specific recommendations and features to enhance the driving style.

Continuation of this paper will be a research that will be based on a comparison of conventional methods of driving and the eco-driving. Based on collected data using information and communication technologies through both driving modes in the case of one vehicle and the identical driving route will be determined the value of fuel savings and reduction of CO_2 emissions.

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