



**CETRA** 2018

5<sup>th</sup> International Conference on Road and Rail Infrastructure  
17–19 May 2018, Zadar, Croatia

## Road and Rail Infrastructure V

Stjepan Lakušić – EDITOR



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**CETRA<sup>2018</sup>**

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TITLE

Road and Rail Infrastructure V, Proceedings of the Conference CETRA 2018

EDITED BY

Stjepan Lakušić

ISSN

1848-9850

ISBN

978-953-8168-25-3

DOI

10.5592/CO/CETRA.2018

PUBLISHED BY

Department of Transportation

Faculty of Civil Engineering

University of Zagreb

Kačićeva 26, 10000 Zagreb, Croatia

DESIGN, LAYOUT & COVER PAGE

minimum d.o.o.

Marko Uremović · Matej Korlaet

PRINTED IN ZAGREB, CROATIA BY

“Tiskara Zelina”, May 2018

COPIES

500

Zagreb, May 2018.

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Proceedings of the  
5<sup>th</sup> International Conference on Road and Rail Infrastructures – CETRA 2018  
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# Road and Rail Infrastructure V

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## ECODRIVING POTENTIAL OF ROADS ACCORDING TO THEIR SPEED SECTIONING: BOSNIA AND FRANCE CASES

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### Abstract

Eco-driving is an efficient way to preserve energy resources and limit environment impacts. It is first of all a question of driver behaviour and motivation, vehicle characteristics, but infrastructure parameters could favour – or impede- ecodriving. This study aims to qualify this infrastructure influence, for the speed sectioning parameter of roads. A research evaluating the adequacy between speed changes along a route, vehicle dynamics and the road gradient constitute the frame of this work. Indeed this adequacy has been proven to be descriptive of the ecodriving potentiality of a route, as detailed in a previous experimental evaluation in France (Coiret et al [1]). It is reinforced here with the help of experimental evaluation in Bosnia, with a metro-logical reinforcement : differential gps, temporal tagging system at points of interest, roof anemometer for the influence of wind, is now used to have more accurate data. In particular the better altitude measurements increase results quality, with achievable reductions of 5 % of energy consumptions for given route sections with sectioning optimisation (ie : simple speed limit panels repositioning). We have also researched crucial points on how to compare different countries and their legislation, geography, and traffic conditions. Bosnia and Herzegovina and France are in the context, to indicate that an assessment of quality level in eco-driving of the two countries is taken in consideration. Perspectives are given in terms of traffic software generalization of the experimental results and in terms of speed sectioning revisions in order to reduce linked energy losses and CO<sub>2</sub> emissions. A route model could then be evaluated, for which speed-sectioning and positioning of amenities (speed bumper, traffic lights) could be optimized in energy use of infrastructure, with a concern not to alter the security features.

*Keywords: Eco-driving, speed limitation, GPS, vehicle dynamics, roads, public policy.*

### 1 Introduction

In the time where climate changes is establishing as a strong threat to our societies, transportation turns out to bring scientific practical application to limit it. According to Traveset-Baro and al. [2] transportation accounts for 19 % of global energy consumption and 23 % of energy-related carbon dioxide (CO<sub>2</sub>), and these percentages are set to increase in the future. Results introduced by IFPEN [3] could be understandable fo the given current trends, where transportation energy consumption and CO<sub>2</sub> emissions are expected to increase by almost 50 % by 2030 and over 80 % by 2050. The design of infrastructures depending on their geometry, their traffic capacity, could reduce this negative impact with appropriate measures. Classically, road conception is constrained by safety, mobility efficiency, building and servicing costs. Today, energy savings have to be reach for the use phase of roads and then they have to be early taken into account in the design phase as well as in the use phase. These new

environmental constraints are part of the eco-design approach. Our research is carried out in this frame by optimizing the adequacy between design and use of infrastructure, in order to facilitate eco-driving to drivers, especially where it is currently difficult for its utilization (eg positioning of speed limits imposing significant braking). In specific, we study the effect of variations in existing speed limits on energy lost by vehicles.

Eco-Driving is a volunteer strategy of a driver to lower its vehicle consumption; it is facilitated by new driver assistance functions embedded on modern vehicles but infrastructure should not be a restraint in this orientation. Eco-Driving can be described as a set of rules: anticipate traffic, engage the highest possible gear with small RPM, and others which will be mentioned further in the paper and already studied in the work of Deljanin et al. [4] and Coiret et al.[5]. The aim of the present work is to study the effect of variations of existing speed limits by assessing their adequacy with the dynamics of the vehicles and the longitudinal profile in length (slopes). In previous research published in Coiret et al. [1], we have showed significant results on the gain in energy and fuel consumption based on experimental work , focused on one location in France. A natural question is: can these results be extended to other countries? An interrogation linked to the previous question arises: How the local conditions of each country: legislation, traffic, driver psychology, geography influence this extension? This paper addresses these questions. Complementary experimentations have been conducted in Bosnia-Herzegovina and influence of local conditions of both countries have been discussed: legislation, traffic, geography, psychology on the results.

## 2 Methods and experiment

### 2.1 Methods

We have evaluated the minimum energy cost of a speed limit sign with the following procedure: the driver takes his foot off the throttle pedal as soon as the panel is seen, this moment is called  $t_i$ . We calculate the path of the vehicle coasting with the speed engaged from  $t_i$ , up to the speed limit sign which is reached at time  $t_f$ . If the speed of the vehicle is below than the authorized speed of the panel, the energy cost of the panel is zero. We note the symbol  $t_f$  which is the moment that the vehicle reaches the panel. If the driver has to brake, he must dissipate the excess kinetic energy, noted  $E_b$  (b for brake) in the braking system.  $E_b$  is computed from a model of the vehicle coasting. We consider the vehicle as a point submitted to external forces. According to the mechanical energy theorem:

$$E_b = E_m(t_f) - E_m(t_i) - E_d \quad (1)$$

Where:

$E_m(t) = 1/2 mv^2(t) + mh(t)$  – mechanical energy;

$E_d$  – dissipated by the running resistance

$m$  – mass;

$v$  – speed;

$h$  – altitude of the vehicle.

Mechanical energy is directly provided by the instrumentation of the vehicle. The running resistance when the vehicle is coasting is calculated from the resolution of the following differential equation which is the application of the Newton's second law to the vehicle coasting:

$$m\dot{v} = F_d - mg \sin(\alpha) \quad (2)$$

Where  $g$  is the gravity acceleration, and  $\alpha$  is the slope of the road.  $F_d = a + bv + cw_a^2$  is the running resistance.  $w_a$  is the apparent wind. By definition,  $E_d = \int_{t_i}^{t_f} F_d dt$ .



## 2.2 Experiment

In this experimentation we have used a first generation Peugeot 308 T7 manufactured from the year 2008–2013 presented on Figure 1. It is a diesel vehicle with an average of 6.1 l/100 km data from the manufacturer site. The model that we used is a Peugeot 308 1.6Hdi with a power of 80 KW (110 Hp). The length of the vehicle is 4275 mm, width 1814 mm , height 1496 mm, and a unladen weight of 1322 kg. Pneumatics on the vehicle are Dunlop 195/65 R16 with a pression 3.2 bars on all pneumatics.



Figure 1 First generation Peugeot 308 T7 1.6 Hdi (80KW)

Two acquisition systems were carried out, a light system including:

- a GPS;
- a laptop with Linux system.

3D Vehicle positions are acquired at a fixed frequency of 1Hz with the help of a GPS Usb module “Garmin” and the “gpspipe” command on a linux-based computer/High resolution pictures have been captured at chosen instants, corresponding at the perception time and passing time of each road sign. As the computer clock is synchronise with the GPS / Pictures have been afterwards geotagged with the help of a GPS correlation algorithm [6].

This light system outputs geotagged pictures which are displayed on google earth in order to get a qualitative analysis of the sign. We have used a more complete system based on a raspberry architecture. Several sensors are linked to the raspberry :

- a Gps/Glonass/Sbas Receiver RTK (NV08C -RTK GNSS ) and a 3G Modem to receive the corrections from a fixed basis (we did not use the RTK functionality during the experiments) [7]. This localization system includes accelerometers.
- an anemometer (miniair6-64) [8]

This main system delivers speed, altitude, apparent wind which are the inputs of the equation (1). Then, the energetic cost of the panel is computed.

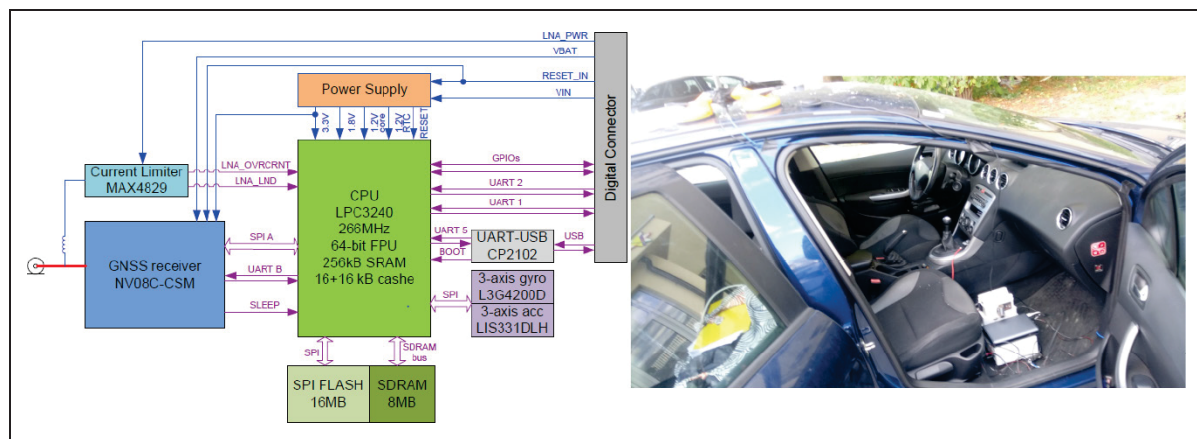


Figure 2 Instrumentation schema and in-car layout

With this instrumented car, different roads of BiH displayed on the Figure 3 were analysed. During driving, the pilot says “Panel” when he sees a panel limiting the speed and takes his foot off the throttle pedal. The copilot takes a picture with the light system and indicate this event to the main system. When the vehicle arrives under the panel, the pilot brakes if necessary and the copilot takes a new picture and updates the main system.

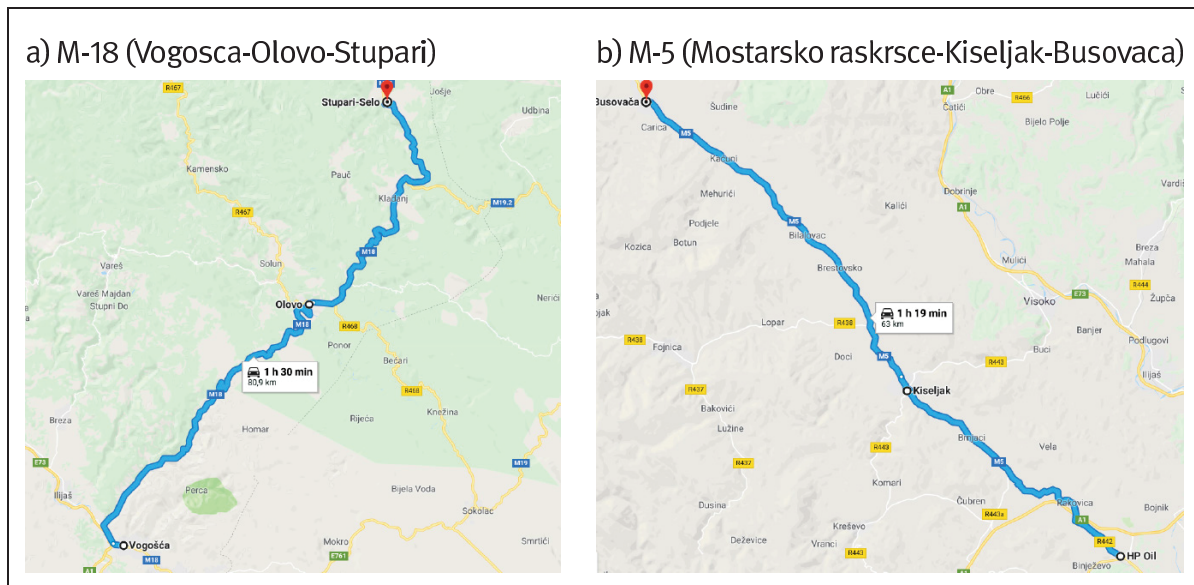


Figure 3 Roads analysed (Source: Google Maps)

### 3 Results

Out of the 140 km of the newly tested roads in Bosnia-Herzegovina, 9 panels have been found to be problematic in the sense of eco-driving capability. In this section, a comprehensive analysis of one of these panels is described. Suspected “negative” example of a panel layout – at the exit of the village “Kobiljaca, Federation of BiH, Bosnia-Herzegovina” (plan of situation hereafter), on the R442 ; M-5 and in the south-north direction, one can already identify a negative example of visible panel imposing a passage from 80 km/h to 40 km / h. The aspect described here as “negative” of the installation of the panel is linked to the fact that the drivers only see the entrance sign in the village when going straight and that braking is necessary, where an implantation of a warning sign would have allowed “eco-driving” (coasting from the warning panel to the speed limitation sign enabling to reach the speed limitation without using disk braking). In the Figure 4. below, it can be noted that probably the residents of the village are frequently crossing the roads and the approximative nearness of schools due to this implementation prompted the road manager to put the entrance sign to the village of 40 km/h and also the curve which is just ahead.

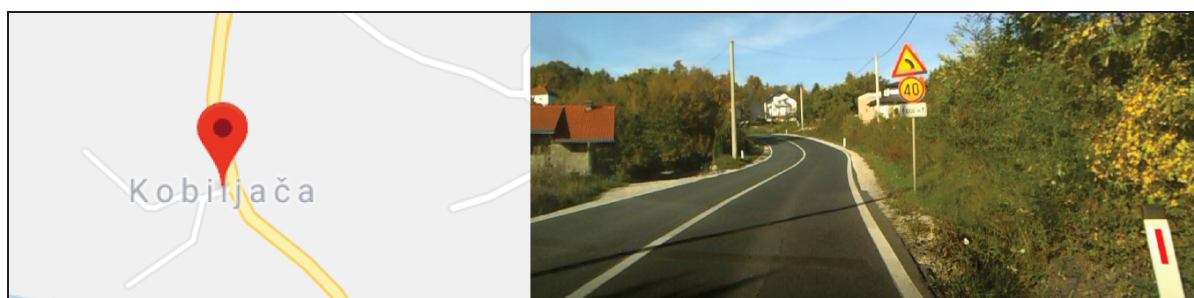


Figure 4 Plan of situation on the R442 (Source: Google Maps) and in-car instrumentation photo



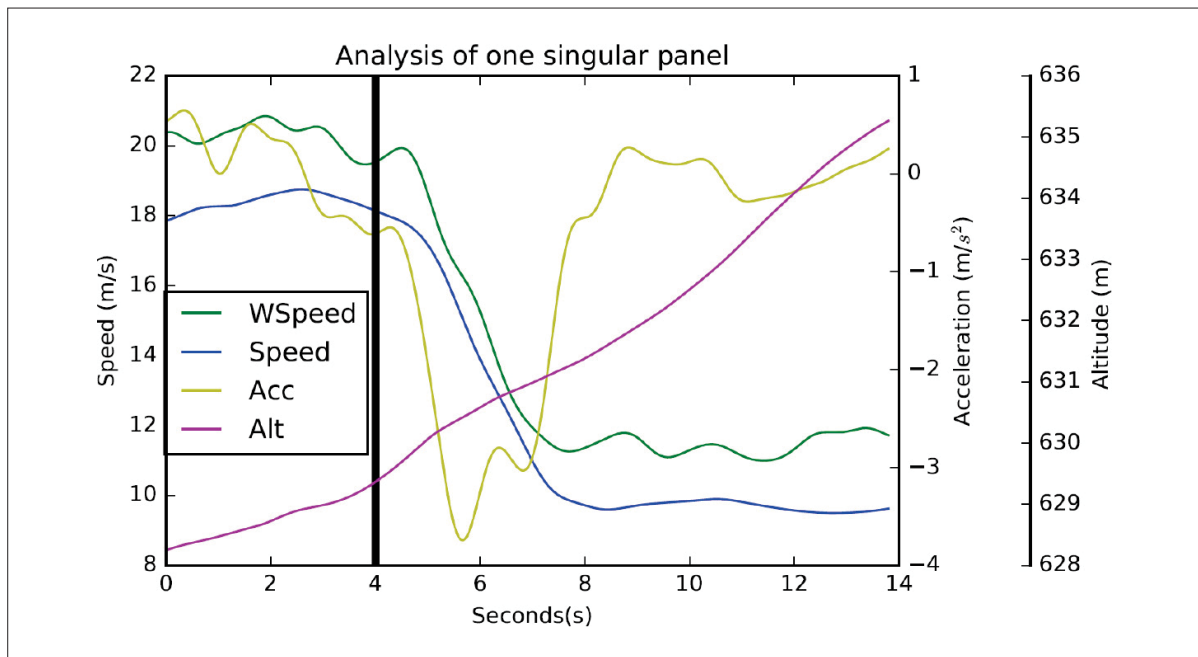


Figure 5 Analysis of one singular panel shown on Figure 4

The Figure 5. presents the apparent wind (Wspeed), the speed and the acceleration (Speed, Acc) of the vehicle and the longitudinal profile of the road (Alt) during the acquisition duration. The vertical bar at 4 seconds corresponds to the instant when the pilot says “panel” seeing the speed limitation displaying on the Figure 2. We can clearly observe that the driver is surprised by the panel : he has to brake almost immediately after seeing the panel (the acceleration curve fell just after the vertical bar).

All of this is in correlation with Figure 2 where we can observe the length of the section, the profile of the road and the speed limitation panel, the driver reacts on the speed variation and the instrumentation panel records all the data needed to perform the analysis. With these data, the cost of the panel (expressed by the equation (1)) is computed. Its value is 140 kJ. If a warning panel would be implanted ahead, this energetic cost could be saved. This analysis of panels was carried out on the 130 km of the studied roads. A gain of 5 % in the spent energy is estimated on specific route only by adding warning signs but under the assumptions that drivers practises eco-driving and the traffic is free-flow.

## 4 Discussion

The results found confirm the interest of the method. However, there is a difference with the French case. While in France, it was easy to find signs that involved disk braking. This type of situation is less frequent in Bosnia (only 9 problematic panels on 140 km). This difference can be explained by difference in legislation, in traffic, in geography.

The speed limitation on national highways in France is 90 km/h and on some roads 110 km/h. In Bosnia-Herzegovina the roads are limited to 80 km/h on the most parts of the national road network. Moreover, the city/village entrances are not properly marked in Bosnia-Herzegovina and the speed limitations at these entrances are not unique: 50 or 60km/h in the different villages or cities. In France those problems are not even posed and the legislation strictly defines the entrance in agglomeration is 50 km/h. These facts imply the difference in speed differentiation are not the same: 40-60 km/h in France and 30-40 km/h in Bosnia-Herzegovina.

Another interesting point of view is the traffic: This is comparable on one point where the French network of roads represents approximately 1 millions km on 40 millions vehicles this represents 40 veh/km and the Bosnia-Herzegovina road networks represents approximately 4000 km on 990 thousand vehicles on the year 2016 data form the statistic department of

vehicles of Bosnia-Herzegovina this represents 250 veh/km. This rough comparison induces a traffic more important in Bosnia-Herzegovina than in France. As a consequence, the speed practised is often lower than the regulated speed in Bosnia-Herzegovina. One of the important factors is that the mountainous terrain of Bosnia-Herzegovina also constrains the speed practised by the users of the road network.

Another difference which diminishes the interest of the method in BiH is the psychology of the drivers: it is, now, about ten years that Eco driving is mediatized in France. An increasing number of drivers are aware of it. This driving style has been more recently publicized in Bosnia. Fewer drivers apply it and the legislation is not following the research progression by optimizing the laws on road security and environment preservation. By listing all of this factors and using the statistics data of the experimentation conducted in France and in Bosnia-Herzegovina this implies that optimization of speed cutting will be more successful in France than in Bosnia.

## 5 Conclusion

Promoting eco-driving is one of the important actions taken by governments to reduce transport-related CO<sub>2</sub> emissions. Infrastructure has a role to play in promoting this practice. In this study, the influence of placement of traffic signs is explored. A method of calculating an energy cost of a panel is defined and applied on a singular point in Bosnia. Approximately 140 km of roads in Bosnia were analysed. However, only 9 panels have a significant energy cost. The expected gains are smaller in Bosnia than in France. This is due to differences in the legislation, geography, traffic and the psychology of the drivers. The next step is to better take in-account these factors in evaluating the energy cost of the panels.

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