DEVELOPMENT OF A DRIVING CYCLE FOR BRASOV CITY

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Abstract: *A driving cycle is a standardised driving pattern, described by means of a velocity-time table. The typical driving profile comprises accelerations, decelerations and stops and it is simulated on a laboratory chassis dynamometer. The European Driving Cycle is the common reference in Europe, but this cycle could not describe satisfactorily the driving characteristics in Brasov.*

The objective of this paper is to propose a realistic driving cycle for Brasov, based on real data collected using the instrumented vehicle method. The onboard data acquisition equipment was GPS devices and the collected data covers typical roads of the city. It was developed a dedicated software tool for analysing data and for identification of the driving pattern. The process has three steps: first, each track is represented as a collection of point and line entities, with custom metadata attached; second, a speed/time diagram is generated for each recorded track; finally, a representative diagram is created after an automated analysis of all the existing diagrams.

Key words: *driving cycles, NEDC, vehicle dynamics, road traffic, vehicle speed*

1. INTRODUCTION

The vehicle's driving cycle is a set of data concerning the speed versus time variation. Usually, the driving cycles are established by organisations from various countries or regions, as standard conditions for testing the vehicles performances, like fuel consumption and emissions level.

Some cycles are established theoretically, like the official European Driving Cycle, other are determined experimentally, based on measurements of driving characteristics and identification of driving patterns. There are two kinds of driving cycles:

- transitory cycles, with many changes in speed;
- modal cycles, with longer periods of driving at constant speed.

As examples, the north-american cycle FTP-72 (also FTP-75) and the european HYZEM cycle are transitory cycles, since the New European Driving Cycle NEDC and the japanese 10-15 cycle are modal cycles.

The standard cycles used in European Union are ECE 15 (also known as UDC – Urban Driving Cycle) for cities and EUDC (Extra Urban Driving Cycle) for extra-urban roads. By putting together four ECE segments and one EUDC segment it results the New European Driving Cycle, NEDC (figure 1).

The main parameters of a driving cycle are: average speed, maximum speed, duration and length. For the composing segments of EUDC, these parameters are listed in table 1.

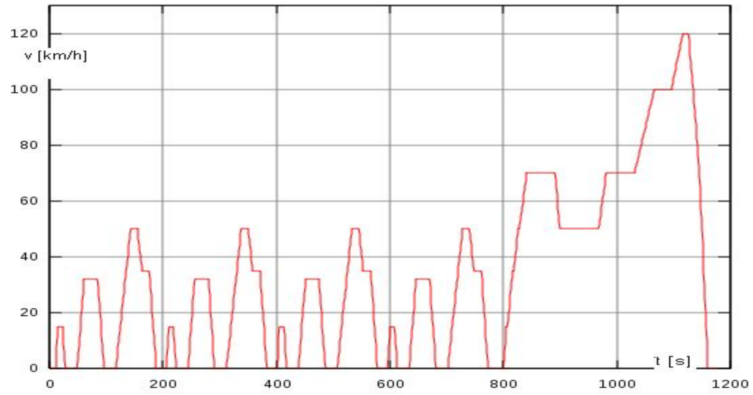

Fig. 1 – New European Driving Cycle – NEDC

Tab. 1

Characteristics	unit	ECE 15	EUDC
Distance	km	4x1.013	6.955
Duration	s	4x195	400
Average speed	km/h	18.7	62.6
Maximum speed	km/h	50	120

2. METHOD FOR A DRIVING CYCLE DEVELOPMENT

Basically, the process of a driving cycle development involves the following steps:

- recording the driving conditions using one one more vehicles equiped with data acquisition devices;
- analysis of data collected in order do describe the driving conditions;
- development of one or more representative patterns for the existing conditions, based on the recorded speeds and sometimes also on accelerations, starting conditions, gear shifts, temperatures or loads.

The data acquisition consists in recording the travel speed on representative roads, followed by a statistical analysis of all data, to identify a typical pattern.

In time, two main methods for collecting data were identified [7]:

- the *chase car* protocol – a chase car installed with a range-finder laser system collects second-by-second speed/time profiles from hundreds of target vehicles assumed to represent typical driving behavior;
- the *instrumented vehicle* protocol – speed sensors are installed on vehicles and the travel speed of each instrumented vehicle is recorded; the vehicle should follow the traffic flow.

A modern version of the instrumented vehicle protocol is represented by the use of GPS devices, encouraged by the down scaling of the electronic devices, price decrease and performance augmentation of GPS receivers [8]. Using GPS devices for road traffic study presents also other important advantages:

- the existence of a very precise and universal time information;
- the existence of three-dimensional position data, that can be derived to obtain other useful information as height, slope or, combining with time data, velocity and acceleration.

The GPS data acquisition method was used for collecting traffic data in Brasov city. First, there were selected representative routes covering almost the entire city area. Different vehicles were driven over all these routes, for many times, during the entire year 2009. Figure 2 shows an example of data (speed and acceleration) collected on the same track. The upper graph shows the evolution of speed and acceleration on time; the lower graph shows the evolution of speed and acceleration on space.

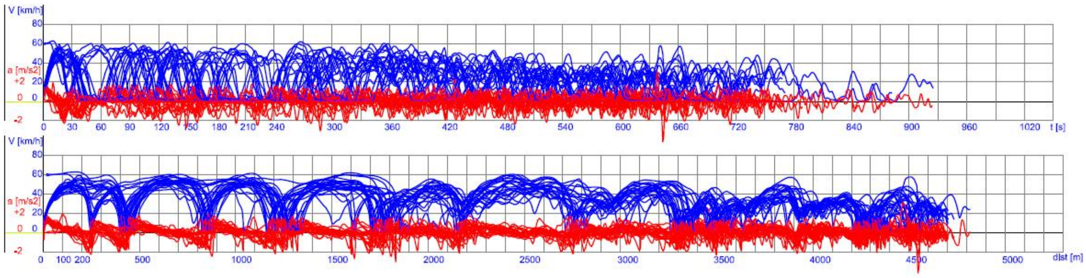

Fig. 2 – Analysis of the vehicle speed (blue) and acceleration (red) for many passings on the same track

It is obvious that is not an easy job to extract a representative driving pattern from the speed/time diagrams. A good method, described also in [5], is to split each diagram in *driving pulses*. For each pulse are calculated the same parameters as for the global cycle (average speed, maximum speed, duration and distance). Then these parameters are statistically analysed. So it is possible to obtain a series of driving pulses, which can lead to a *modal cycle*.

In order to obtain a transitory cycle, we need to calculate the global parameters of the complete driving cycle. Based on data collected for the entire city, the diagrams in figure 3 were plotted. Also, the average and maximum speeds were determined.

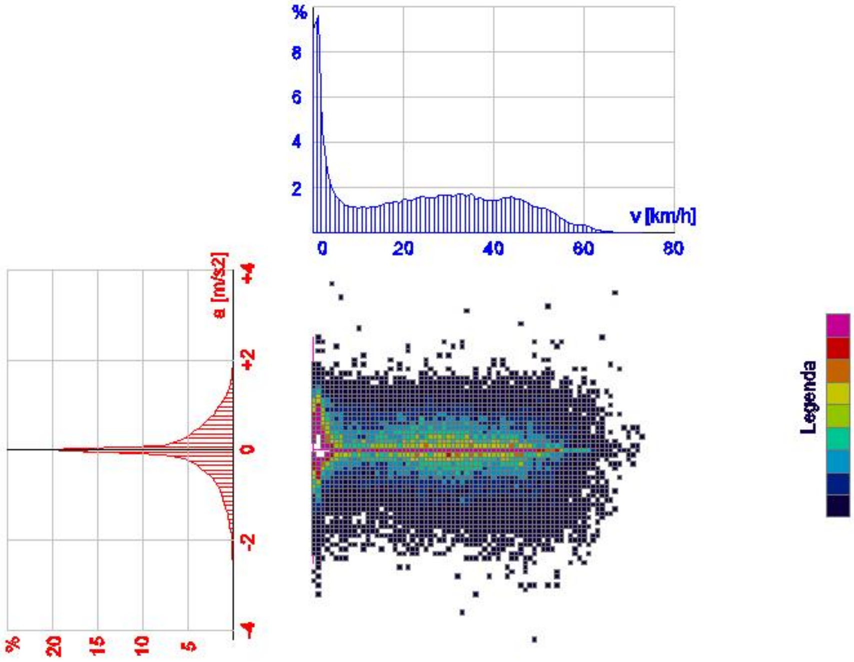

Fig. 3 – Mono- and bi-parametric probability density functions of vehicle speed and acceleration – all urban tracks analysed

All diagrams were created using a custom CAD application, developed in AutoLISP, with the use of extended data associated to the geometric entities (points and lines). The application is in fact a library of functions and global variables. Each function can be called separatelly, but it depends also by the status of the variables - this mean that a certain order of calling the functions is mandatory.

The first step is to import data from GPS receivers. GPS data are stored in simple text files or *gpx* files. The content of the selected file is added in a list - the list is a global variable of the program. Then the track is drawn based on information stored in that list. The geometric elements of a track are points and lines. Each of them has some metadata associated: geographic coordinates, time, speed, acceleration and others.

The next step is to draw the speed versus time diagram for each track. From the diagram it can be extracted the driving parameters. Finally, data from all the speed/time diagrams can be used to calculate the global parameters and to identify the representative driving pattern.

3. BRASOV DRIVING CYCLE

After analysis of all collected data (see figure 2 and figure 3), the parameters determined by experiments, in Brasov, are:

- duration: 710 seconds;
- length: 4.44 km;
- average speed: 22.5 km/h;
- maximum speed: 73 km/h.

The parameters calculated for each of the recorded tracks were compared with the parameters of the global cycle, and also the number and shape of the driving pulses. The speed/time diagrams of the most representative tracks (passings) were used to establish the final proposal of a driving cycle for Brasov city (figure 4).

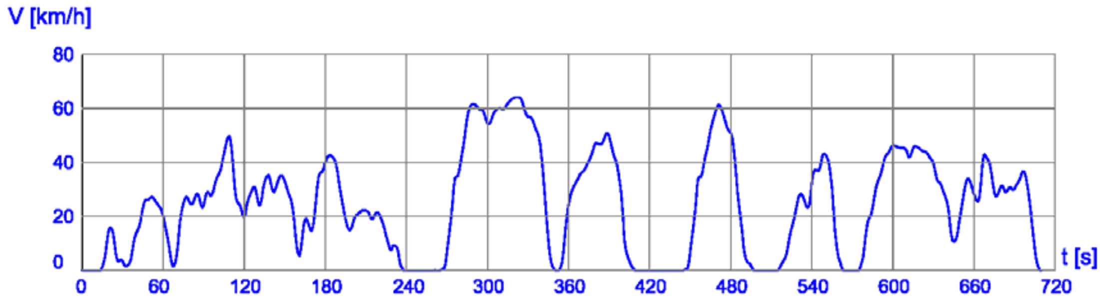

Fig. 4 – Proposed driving cycle for Brasov

The general parameters of the driving cycle were calculated again. The new values are slightly different from those listed above, as effect of the transitory character. The final parameters are:

- duration: 710 seconds;
- length: 4.87 km;
- average speed: 24.7 km/h;
- maximum speed: 64 km/h.

Apparently, there is a big difference between the maximum speed determined previously and the final maximum speed, but we should take into consideration that the maximum of 73 km/h was just a peak value, for all tracks recorded.

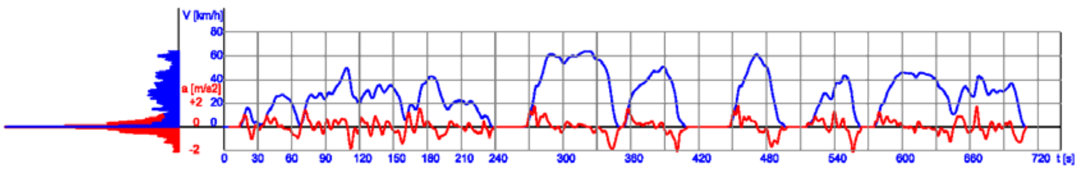

Fig. 5 – Speed and acceleration for the representative driving sequence

For the resulted driving cycle it was calculated the probability density function for speed and acceleration – see the lateral diagram in figure 5. Also the bi-parametric probability density of speed and acceleration may be determined from the original diagrams – figure 7.

Figure 6 shows the similar diagrams for the standard European urban driving cycle (UDC). Comparing the 3D diagram in figure 6 with the 3D diagram in figure 7, it is obvious that the transitory cycle is more realistic than the modal cycle.

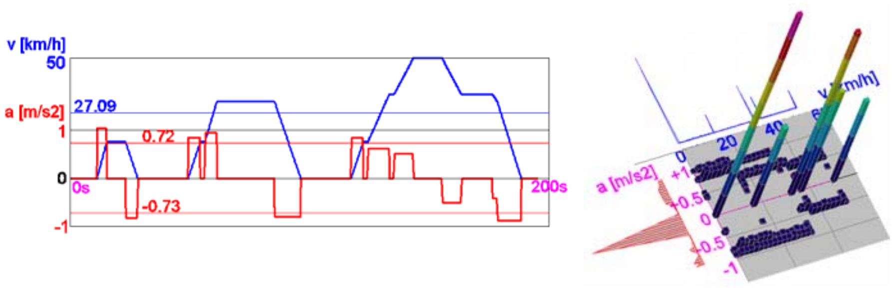

Fig. 6 – Mono- and bi-parametric probability density functions
of vehicle speed and acceleration – EDC (European Driving Cycle)

The diagrams on left side of figure 7 represent the probability density of vehicle speed and acceleration for the resulted driving cycle (upper) and for all records cumulated. The diagrams for the single track (the driving cycle) are not so smooth because the number of points is smaller than for the cumulated records. However, the profiles of the diagrams are similar.

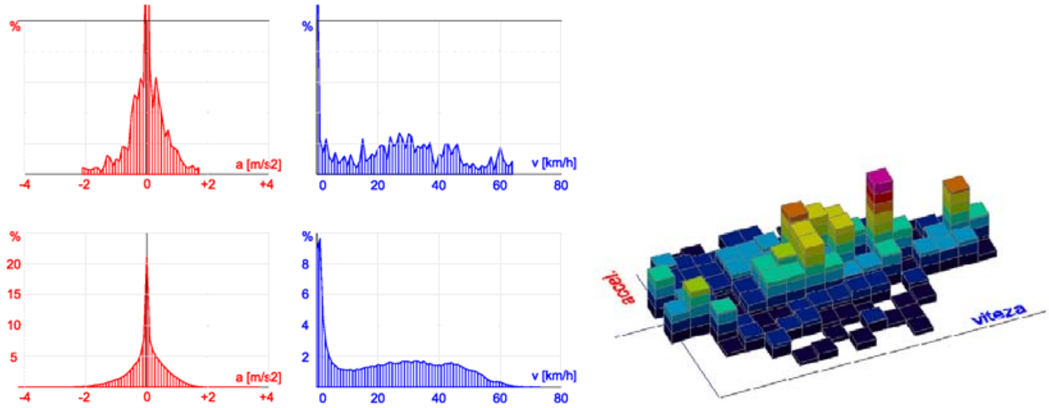

Fig. 7 – Mono- and bi-parametric probability density functions
of vehicle speed and acceleration – Brasov Driving Cycle

Finally, a comparison of the parameters of some driving cycles is presented in table 2. The cycles are: the European Urban Driving Cycle ECE 15 (4 times, like in NEDC), the North-American cycle FTP-72, the driving cycle of New York City (NYDC) and the proposed driving cycle for Brasov. Except for the ECE 15 cycle, all other cycles considered are of transitory type.

Tab. 2

Characteristics	unit	ECE 15	FTP-72	NYDC	Brasov
Distance	km	4x1.013	12.07	1.89	4.87
Duration	s	4x195	1369	598	710
Average speed	km/h	18.7	44.6	11.4	24.7
Maximum speed	km/h	50	91.2	44.6	64

4. CONCLUSIONS

A typical driving profile in an urban area consists in a complicated series of accelerations, decelerations and stops. The main goal of the driving cycles is to estimate the emissions level and the fuel consumption for various vehicle models. Since the road traffic is different for different cities, a single driving cycle can not be representative for all cities.

There are significant differences between the parameters listed in table 2. This demonstrates the importance of having a real driving cycle for each area where a certain vehicle model is used.

The driving cycle determined for Brasov city is just a proposal and it is valid for the years 2009-2010. More data will lead us to a more accurate driving cycle. However, significant differences are not expected too soon.

It was demonstrated again that the GPS devices are suitable for collecting traffic data, even in urban areas, where the signal is affected by the buildings. The rate of one record per second is just enough for this purpose, and affordable handheld devices are available on the market.

The data collected for this study can be used also in future traffic studies, in speed analysis or to establish the speed profile of some roads in the city area.

5. REFERENCES

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