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Urban Real Driving Analysis with and without Coordinated Traffic Lights Control

J. Kreicbergs[1], M. Gailis[2], A. Grislis[3]

[1]*Riga Technical University, 1 Kalku Str., LV1658, Riga, Latvia, E-mail: Juris.Kreicbergs@rtu.lv*
[2]*Riga Technical University, 1 Kalku Str., LV1658, Riga, Latvia, E-mail: Maris.Gailis@rtu.lv*
[3]*Riga Technical University, 1 Kalku Str., LV1658, Riga, Latvia, E-mail: Aivis.Grislis@rtu.lv*

Abstract

The significance of real driving fuel consumption and emissions compared to laboratory tests has grown both because of emissions testing faults publicity and inclusion of real world emissions measurements in the new worldwide harmonised light-duty vehicles test procedures (WLTP). Urban driving represents approximately one third of distance in the WLTP real driving test. City driving conditions differ essentially by city environments, weather and traffic conditions. To analyse the urban driving variations a 25 km route was selected in Riga city comprising major city transport arteries in both directions. The route contains 15 km of road sections with coordinated traffic lights control. The city street configuration allows formation of green wave just in one direction so the other direction formats an organized traffic restraint. Street sections with three different traffic control conditions have been compared. The sections with coordinated traffic lights control in the green wave direction show the biggest around the clock variations which may be essential to note when real driving emissions are measured. The sections in the controlled traffic restraint direction may be useful for real driving tests where repetitive driving conditions are preferred. Up to five times higher fuel consumption has been measured in peak traffic hours compared to night driving. The paper analyses suitability of the route for urban driving tests by analysing average speeds and fuel consumption during 24 hours of urban traffic changes. The paper blends in a more extensive research on energy consumption in urban driving.
KEY WORDS: *urban driving, fuel consumption, coordinated traffic control, green wave*

1. Introduction

Vehicle emissions and fuel consumption are of constant public and automotive stakeholders concern which peaked after VW diesel emissions scandal publicity. This highlighted findings of previous studies and facilitated research activities comparing the formal test methods with real life driving. Researchers and public organizations in Europe have emphasized the growing difference between the NEDC test procedure and actual fuel consumption and CO_2 emission data [1-3]. A new test procedure WLTP and corresponding driving cycle that is expected to be essentially closer to real world driving has been developed as a part of World Forum for Harmonization of Vehicle Regulations activities and already is in force having an introduction transition period up till 2020. Research and simulation for appropriateness of the new procedure has already started and researchers are trying to find out what improvement can be expected by WLTP introduction [4]. The essential difference of the WLTP procedure is having measurements in real world driving.

Real driving data as contrary to test bench analysis is much harder to be cheated and may be more trusted by car users. Unfortunately it has many disadvantages like being dependent on road environment (city, rural or motorways, plain or with steep grades, congested or deserted), vehicle maintenance, weather conditions, driving styles and driver's intentions. The partial solution to this problem is increasing the car fleet tested but it does not give precise characteristics for every car in use, therefore are attempts of local research activities to obtain seemingly more relevant and definitely more understandable data.

There have been several tries in Latvia to create localized test procedures. Already for years researchers use driving cycle developed for Jelgava city [5]. Some driving cycles are developed even for more narrow usage [6]. Still to have knowledge about the correspondence of the local conditions to the new test technologies, it was decided to evaluate the suitability of using for tests the driving pattern enforced by the coordinated traffic lights control in Riga city because it includes the advantages of real life driving and contains elements of test bench cycles where the speed changes are strongly influenced by traffic lights control plan. The research was also encouraged by affordable GPS technologies and suitability of OBD data for fuel consumption measurements, as proved by other researchers [7].

2. Materials and Methods

There is a very limited choice of road sections with coordinated traffic light control in Riga city. Three main streets leading in and out of the city centre towards outer city on one side and towards two bridges on the other side have non-elastic coordinated traffic lights control with round the clock constant lights timing scheme. The advantage of selecting these streets for the tests is that the streets enclose the active city centre outside the old town where the traffic is highly restricted. The test route was planned to include all three streets in both directions in full length of the coordinated traffic sections. The traffic light plans have been acquired from traffic planning group of Riga City council.

Several cars have been repeatedly driven along the test route, but most of the tests were done with Opel Zafira 2004 with a 1.6i-16V petrol engine. For the results to be more comparable, only results from this car are used in this paper. To ensure a controllable driving pattern, all tests were done by the first author of the current paper. Having experience with eco-driving and other driving styles for these tests a generous driving style was used – economical driving but without any disturbance to the traffic flow by extensive gliding or slow driving, avoiding speeding but without an audible signal or other feedback for precise maintaining of the permissible speed. No stop – start system was used to allow later analysis of the system usability for the test route. The paper analyses 41 times driving along the test route planned at various time of day with a total test length around 1000 km and 45 hours.

Speed, fuel consumption and engine speed have been recorded by OBD logger Auterra DashDyno SPD. GPS time, vehicle speed and GPS position were recorded by GPS logger RaceLogic DriftBox having a 10 Hz recording frequency.

The total test route exported to Google Earth is shown on Fig. 1. The street sections with coordinated traffic light control are shown in white with a thicker line. The street plan and existing speed limits do not allow planning of green wave traffic in both directions, therefore the city planners have decided to make the green waves in the direction out of the city (up and to the right on Fig. 1). The sections without coordinated control are shown with a thinner line.

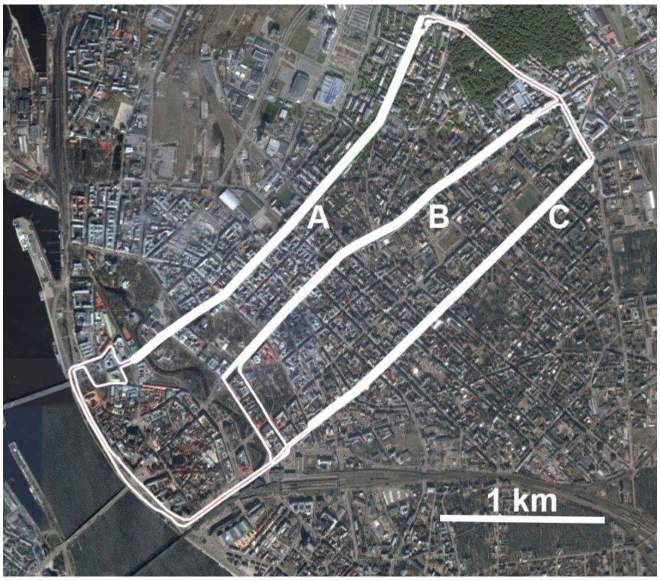

Fig. 1 Test route in Riga city: A – Valdemāra, B – Brīvības, C - Čaka

The lengths of the route, street names with symbols used on Fig. 1 and green wave directions are shown in Table 1, where GW – in the direction of green wave, AGW – against the direction of green wave.

Table 1

Test route sections with coordinated traffic lights

Street	Street on Fig. 1	Control type	Length, km
Brīvības	B	AGW	2.47
Čaka	C	GW	2.35
Kr. Valdemāra	A	AGW	2.76
Brīvības	B	GW	2.54
Čaka	A	AGW	2.35
Kr. Valdemāra	C	GW	2.69

The driving starts at the northern corner of the route, going towards Brīvības Street, continuing the coordinated sections in the sequence shown in Table 1, having shorter connections on Raiņa and Merķeļa Streets, and more extensive connections on Pērnavas Street and the towards and along the Daugava river embankment 11. Novembra krastmala. The total lengths of coordinated sections is 15.16 km, non-coordinated sections 9.48 km, counting 24.64 km for the entire route. Since driving takes slightly different trajectories, average measured distances are given. Some streets change their names along the length covered, just one name for any street is mentioned.

Date from the loggers are exported using OEM software. Any further calculations are done using MS Excel with extensive use of Microsoft Visual Basic for Applications. The first stage of data processing is synchronising OBD data with GPS data, including visual confirmation of matching speed changes recorded by both devices.

The GPS coordinates for street section limits and intersections are taken from Google maps and compared with GPS coordinates given by OEM software. Section start, finish and every street junction position are added to the data table by minimizing the calculated distance between each recorded GPS coordinate and coordinates of section limits using the flat Earth model:

$$D = R \cdot \sqrt{\left(LATr - LATp\right)^2 + cos\left(\frac{LATr + LATp}{2}\right) \cdot \left(LONr - LONp\right)^2}\ , \tag{1}$$

where D – distance between the measured point and the section limit, m; R – Earth radius, m; $LATr$ – GPS coordinate latitude on the route, rad; $LATp$ – GPS coordinate latitude for the section limit, rad; $LONr$ – GPS coordinate longitude on the route, rad; $LONp$ – GPS coordinate longitude for the section limit, rad.

To check the traffic lights green wave operation, the time difference between the recorded GPS time and certain time at the start of the tests was calculated, divided by the traffic lights cycle length obtaining the reminder corresponding to the time from the start of given traffic light cycle.

3. Results and Discussion

The operation of traffic lights one-way green wave is shown on Fig. 2 where the time from the start of the traffic lights cycle is plotted against the distance. The grey lines are in the direction of green wave, the black lines are in the opposite direction against the green wave. Each line corresponds to a single driving along the test route. All three streets have similar traffic lights control therefore the plot is given here for Valdemāra Street only. The distance is shown away from the city centre. The wide spread of green lines along the time corridor in the green wave direction shows good operation of the green wave. The black lines clearly form four places where the traffic is stopped on most occasions.

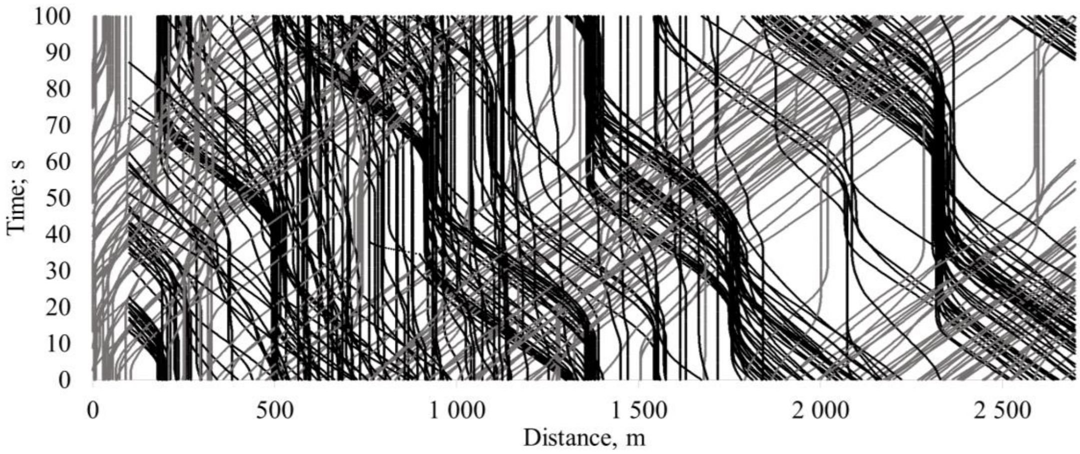

Fig. 2 One way green wave on Valdemāra Street

The functioning of green wave can also be evaluated by comparing average speeds on coordinated street sections. The plot on Fig. 3 showing average speeds at different hours of day for every tested street section both in the direction of green wave and opposite direction, complimented by the average speed for the remaining route sections without coordinated lights control.

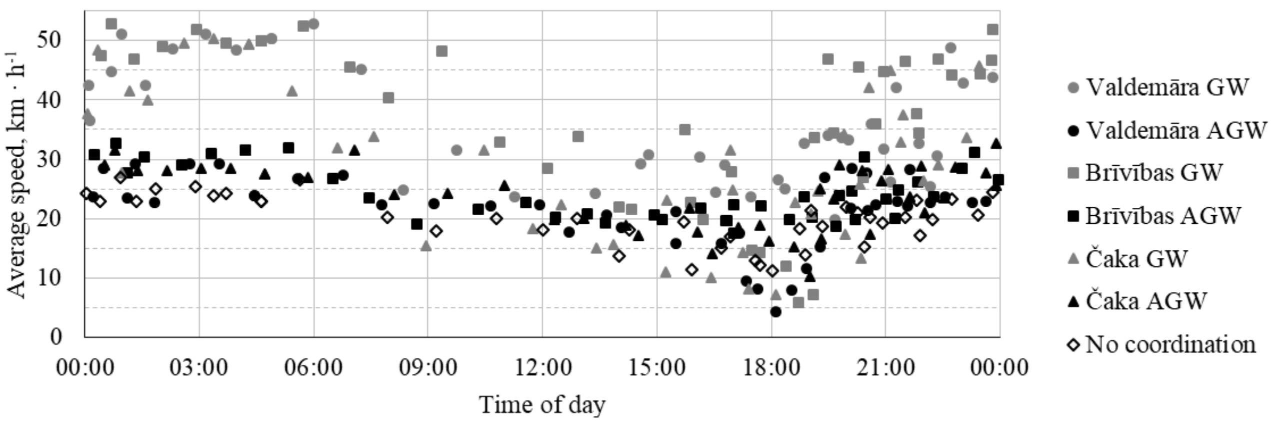

Fig. 3 Change of average speed during day hours on test sections

It can be seen that the street sections with green wave have essentially bigger amplitude in average speed changes during the day and higher spread of speed values during most of the day than on sections against green wave and uncoordinated sections. As expected the average speed values for sections in the direction of green wave are higher while at the afternoon peak hour there is no essential difference between both type of coordinated sections and uncoordinated sections.

The plot does not represent the whole range of possible speeds on given road sections since the tests were not performed during street repair works, there was no occasion of traffic accidents during the tests and the test plan did not include trying to assess the most congested days. All tests were performed on weekdays, excluding weekends and public holidays. It also can be noted that for certain occasions the average speed on the all section is less important than just for the part of the section. The minimum speed recorded was AGW on Valdemāra Street where the exit from the section is leading towards the busiest bridge and therefore the speed on the second part of the section is much more important than the average speed for the whole section.

This paper is a part of broader tests devoted to fuel and energy consumption therefore here the measured fuel consumption values on the tested road sections is displayed.

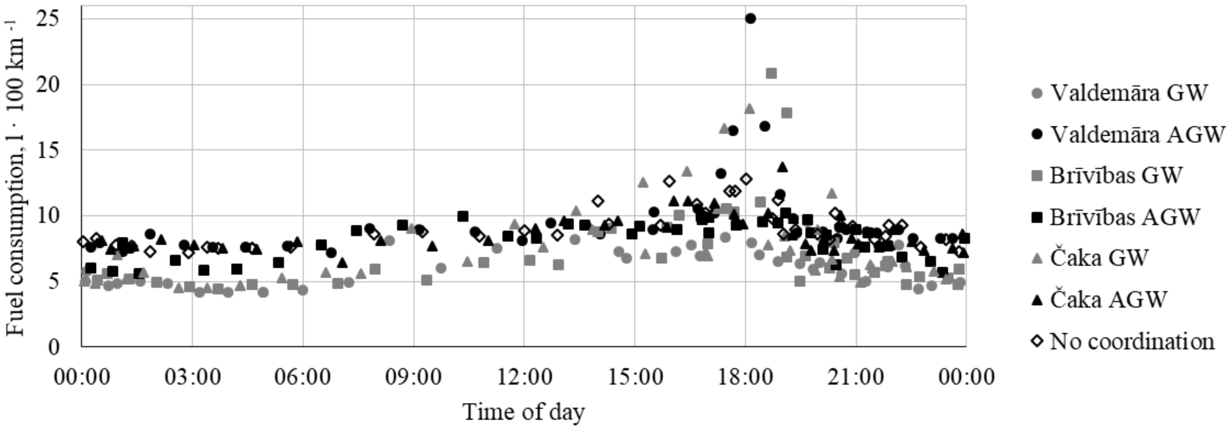

Fig. 4 Change of fuel consumption during day hours on test sections

The fuel consumption measurements on Fig. 4 show just one remarkable peak during the evening rush hour around 6 pm but no essential growth of fuel consumption was observed during the morning rush hours. This could be explained because most of the test sections are located after the bottlenecks on bridges leading the traffic towards the city centre while the same bottlenecks form when the traffic leaves and then the congestions are on the street sections under the investigation.

Having the fuel consumption changing more than five times, Fig. 4 does not always allow to distinguish between the measurements therefore a zoomed-in Fig. 5 is added.

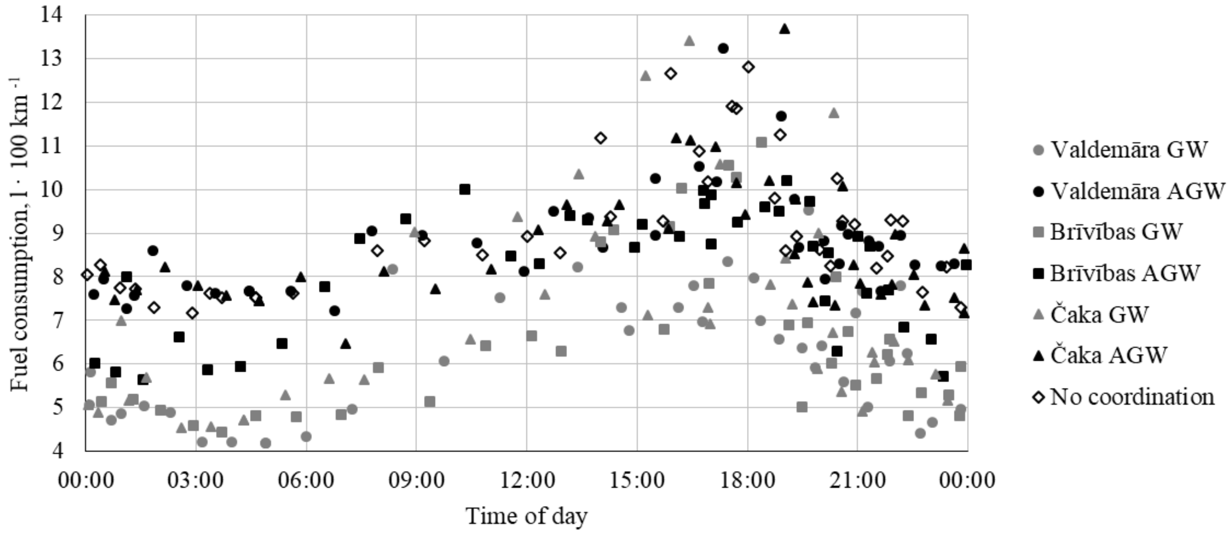

Fig. 5 Zoomed-in fuel consumption during day hours on test sections

Analysing the fuel consumption on the sections with green wave, the lowest values and the less changing performance is seen on Valdemāra Street. This may be explained by the longer total traffic lights cycle of 100 s compared to 80 s on other streets allowing better formation of the green wave and by the fact that there are no bottlenecks at the end of the section. It also confirms that keeping the congestion on the bridge in the morning hours where the extra air pollution is better dissipated than in the city centre and the facilitating leaving the centre is rather successful. Green wave on Brīvības street is quite good during most of the day but does not work well when the traffic is leaving the city after the working hours, most probably due to the narrow bridge across railway at the continuation of the street. The green wave on Čaka Street gives good results during the night but having wide results distribution during and after the working day, possibly because of the narrow street where any single disturbance on the street changes the traffic flow.

The direction against the green wave on Valdemāra Street and Čaka Street gives the highest fuel consumption values and quite similar pattern during the day, with some higher peaks for Valdemāra Street where the bridge crossing problems are more critical. Brīvības Street shows more steady performance against the green wave since not having that good access to the bridges as other streets and due to the noticeable red traffics light wave closer to the city entre does not attract as many traffic as the other streets under investigation.

The objective of the current research was not to fully examine the street grid for city planning reasons but to assess the analysis chances with affordable GPS and OBD technologies. The other point of interest was to look at the results gained by rather simple inelastic traffic lights coordination's schemes while cities introduce more advanced systems.

The most expected result was assessment of repeatable urban real driving tests on different street sections. Some other fuel consumption tests on the selected route have already be done. To obtain repeatable test results in off test bench investigations the measurements have been carried out during the night hours where the steady speed driving with low engine loads on green wave sections alternate with stop and go movement against the green wave. When planning urban driving tests expecting repeatable results during daytime it would be advisable to limit the usage of sections with green wave traffic lights control because they are more subject to changes due to various factors.

4. Conclusions

GPS and OBD technologies allow to perform urban real driving tests examining street sections along the planned route.

To obtain repeatable off test bench driving tests in stop and go traffic, urban routes with extensive inclusion of non-elastic control coordinated traffic lights sections may give steady results.

OBD and GPS measurements may facilitate evaluation of city traffic planning decisions.

The biggest challenge of the current traffic control system in Riga city centre on the streets investigated is Valdemāra Street in the direction towards the bridge.

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