Influence of Driving Style on Emissions:

Qualification and Measures

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Abstract

The influence of the driving style on the different emissions (NOx, HC, particles, CO, CO2, SO2) and on the primary energy consumption, and the definition of the vehicle parameters influencing the relation between them, is an interesting issue to be assessed in order to allow more realistic estimations of the impact of transport on the air pollution and an optimisation of the emission calculations. To this effect, the government of the Flemish region commissioned a special study. The VUB works out the research project with the as subcontractor the Dutch Technological Institute TNO. The study will show a list of influences on driving behaviour with its corresponding impact on the exhaust emissions, a definition of environmental friendly driving style and the influence of traffic policies on emissions. Finally an indication of possible measures will be reported to the Flemish Regional Government.

This paper gives an overview of project progress and summarises initial project results.

Keywords: Diagnosis, emissions, environment, pollution, modelling

1 Introduction

The influence of driving behaviour on emissions and fuel consumption is not a new fact. Back in 1999 TNO-automotive executed an investigation in order to determine these effects [1]. Other research institutes did also some efforts in order to quantify the correlation between driver and emissions [2].
Within the investigation mentioned above [1], four different driving styles were used, a reference style, being a 'defensive style' (like we all learned in our first driving lesson, a 'sporty' driving style and two supposedly fuel economical driving: a classic approach to economical driving called 'egg-style' and the 'new driving style'. This 'new style' combined defensive driving with a special way of accelerating and shifting : throttling at 75% while keeping motor speed low by shifting to a higher gear very soon. Referenced to the defensive driving style, gives an overview of the results.

Table 1: Results 'The effects of real world driving on fuel consumption on emissions of passenger cars [1]

	Urban			**Rural**			**Highway**		
Driving style	**Sporty** (%)	**New** (%)	**Egg** (%)	**Sporty** (%)	**New** (%)	**Egg** (%)	**Sporty** (%)	**New** (%)	**Egg** (%)
Fuel consumption	50.5	-6.2	2.1	40.9	-10.6	5.4	12.3	0.3	-5.7
CO_2	47.2	-6.9	1.6	36.4	-11.1	5.7	8.6	-0.1	-5.4
CO	1042.4	227.0	203.6	723.3	44.3	-21.9	632.3	45.9	-59.9
HC	269.1	73.8	59.5	382.1	7.1	33.9	205.1	15.3	-22.0
Nox	163.7	34.6	-4.3	89.2	2.1	-22.7	47.2	-6.9	-21.6
PM	107.5	10.9	17.7	83.4	35.8	-4.0	49.7	-43.5	-48.6

The expectations of fuel savings however were not achieved, probably due to the specific throttling advice. This program was executed on behalf of the Dutch programme ‘The New Driving Force’. Further to the conclusions above, it gives some recommendations in order to use your car and its equipment in a less polluting way.

The Flemish study however, executed by VUB and subcontractor TNO, does not end evaluating different types of driving styles and its surrounding behaviour. In addition, the influence on the emissions of policies taken in order to increase transport safety or taken to reduce traffic jams has to be clarified, e.g. zone 30, phased traffic lights, roundabouts. In fact, all these measures have an influence on the behaviour itself; the Government want to oblige a driver to take a certain way of driving.

2 How to evaluate a traffic measure or a driving style?

2.1 Taking measurements

Data (speed, rotational velocity of the motor, throttling position) for a specific measure is collected in an area, representative for that measure. Minutes about traffic density and infrastructure are taken describing the local situation each time something happens. A few drivers cover a couple of times the certain trajectory. More drivers are taken in order to improve the statistical quality of the measurements since different drivers have another driving behaviour.

2.2 Compress data

Before calculating the characteristics of the whole set of data, all the irrelevant data is cut. The different pieces are pasted together again within a manner not introducing dynamics different from the whole cycle. However this could be seen as a point of criticism, these parts are very limited in relation to the cycle for calculating. In order to perform measurements on the roll bench, short representative speed cycles should be extracted from the measured speed profiles. Knowing the characteristics, one can select two representative cycles of about 360s that have their characteristics closely to the original cycle. One of them is representative according to only speed and acceleration, while the other one takes all driving parameters into account. After calculation, also a visual check is carried out making the final decision on which one to be kept for testing on roll bench. Only the definitive mini-cycle are described below. The reason why one takes a mini-cycle of at least 360 s is due to the fact this is the lower limit to fill a bag with tailpipe emissions on the roll bench.

2.3 Testing on a roll bench

The selected mini-cycle is driven on a roll bench with different cars while the emissions are measured. These results correspond very well with results obtained from the original data.
This way, one becomes representative results, corresponding with the original data in a more time-efficient manner. This method, taking measurements on road and afterwards re-driven on the roll bench is already well-spread in the world, except the feature of data compression, that is added to this method by TNO in order to reduce test time on the bench.

3 Traffic measure and corresponding cycles

Measuring traffic policies should be done at a location where the assumed measure appears frequently. In order to take the measurements at a representative location, the recommendations for good locations by AWV (Administratie Wegen en Verkeer; Road and traffic administration of the Flemish Government) were restrained.

During this measurements two drivers were involved with each trajectory.

3.1 Traffic islands

We can find traffic islands on different types of roads, e.g. in a zone 30, there will always be a few of them. In this investigation, we only considered those especially placed to reduce vehicle speed in a built-up area on a road, which goes straight ahead through it.

Measurements were taken on two different locations with either 6 or 7 traffic islands.

3.1.1 Traffic island cycle

The following table gives an overview of the parameters in case of the traffic islands for the full cycle and the compressed one. Within this table, the number in *italic* are relative numbers, while the other ones are absolute values. The comparison between both cycle is done for the *italic* numbers, of course.

Table 2 : Characteristics of the traffic island cycles

	Full cycle	Mini-cycle
N°.of gearshifts	644	35
Average_v [km/h]	*48.8*	*45.8*
Average_n [rpm]	*2086*	*2014*
Average_throttle [%]	*16.5*	*17.1*
Average_shift_rpm [rpm]	*1888*	*2029*
Average_acceleration [m/s2]	*0.57*	*0.57*
Average_acceleration [m/s2]	*-0.58*	*-0.59*
RPA[1] [m/s2]	*0.26*	*0.26*
PKE[2] [m/s2]	*0.54*	*0.55*
Cycletime [s]	6740	360
Cycledistance [m]	91329	4539
%_stop_time [%]	0.0	0.3
Average_duration_stop [s]	*1*	*1*
Average_duration_sequence [s]	*1559*	*262*
StdDev speed [m/s]	*14.07*	*14.01*
max.acceleration[m/s2]	*2.04*	*1.92*
max.deceleration[m/s2]	*-4.63*	*-2.74*
per.accelerating [%]	*50.5*	*50.6*
per.decelerating [%]	*49.3*	*49.2*
StdDev accpower[m2/s3]	*9.59*	*9.22*
Propulsion energy (kj/km)	*534*	*536*

For each measure such a table is constructed, however they are not all integrated within this paper.

[1] Relative positive acceleration
[2] Positive kinetic energy

Figure 1 shows the mini-speed-cycle :

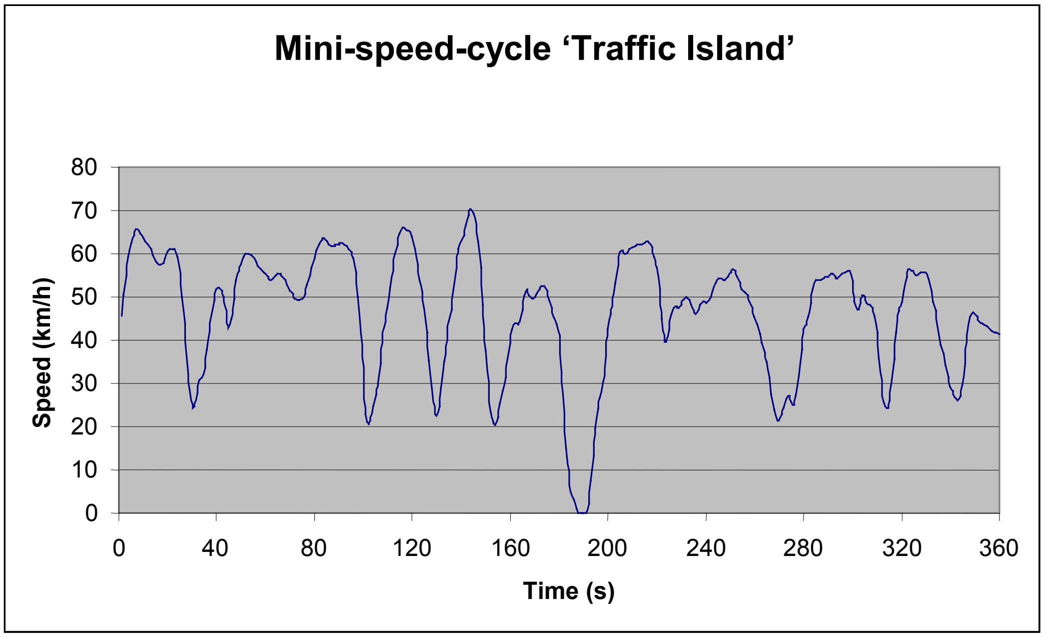

Figure 1 : Traffic island mini-cycle

As one can see in the figure above, there is a certain pattern within this speed cycle: acceleration when leaving the island, driving whether or not a small interval at constant speed, decelerating when arriving at the next speed limiter.

3.1.2 Reference cycle

The first idea was to use a built-up area as reference for the traffic island, as well as for zone 30. Unfortunately, since the built-up area has been chosen especially to be a reference for the zone 30, this was not suitable for the traffic islands. In order to have a new reference, one could take new measurements, but due to a lack of suitable location, the construction of an artificial cycle is assumed.

The construction itself is constituted as follows. First the whole set of data is filtered between 45km/h and 70 km/h since this will be the interval of driving speeds according to AWV. All pieces of a sufficient length were retained and pasted together as described above. Afterwards the same procedure then for the other cycles is repeated. This results in the following graph:

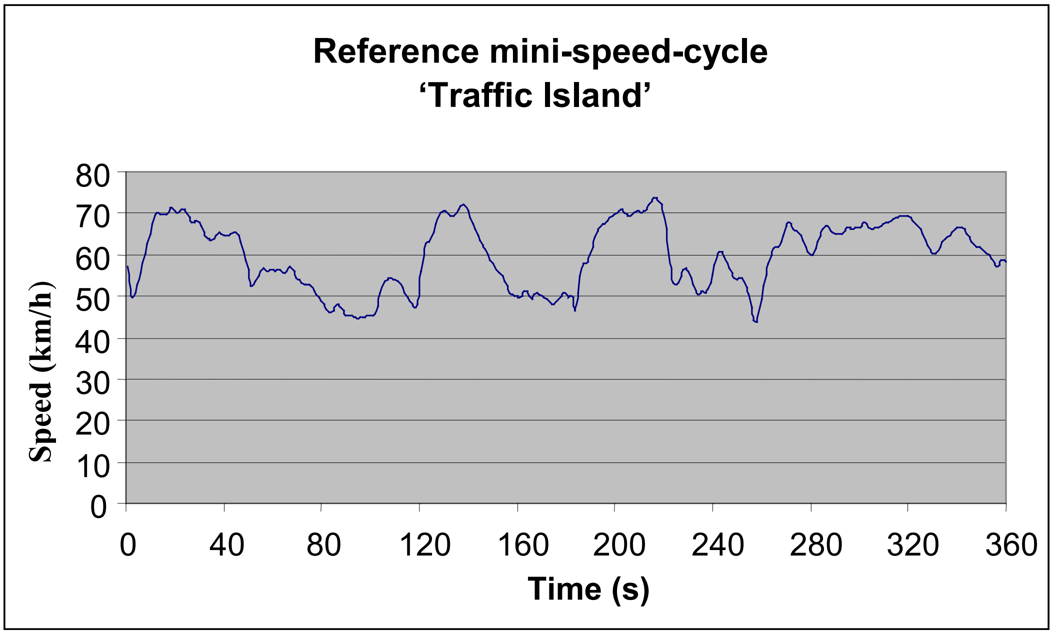

Figure 2 : Speed cycle for reference traffic island

Within a built-up area where no traffic islands limit the speed at certain crossings, the driver won't reduce speed that much.

3.2 Zone 30

A 'zone 30' is a contingent urban area with a restricted speed limit of 30 km/h, especially introduced in medium sized city centres in order to reduce speed and increase safety of pedestrians and cyclists.
The measurements in a zone 30 are easier to treat afterwards since they could be almost fully implemented. Only the few times driving out of the zone is cut from the original data. This facilitates the treatment enormous as well as the reliability. Underneath one can find the mini-cycle for this measure.

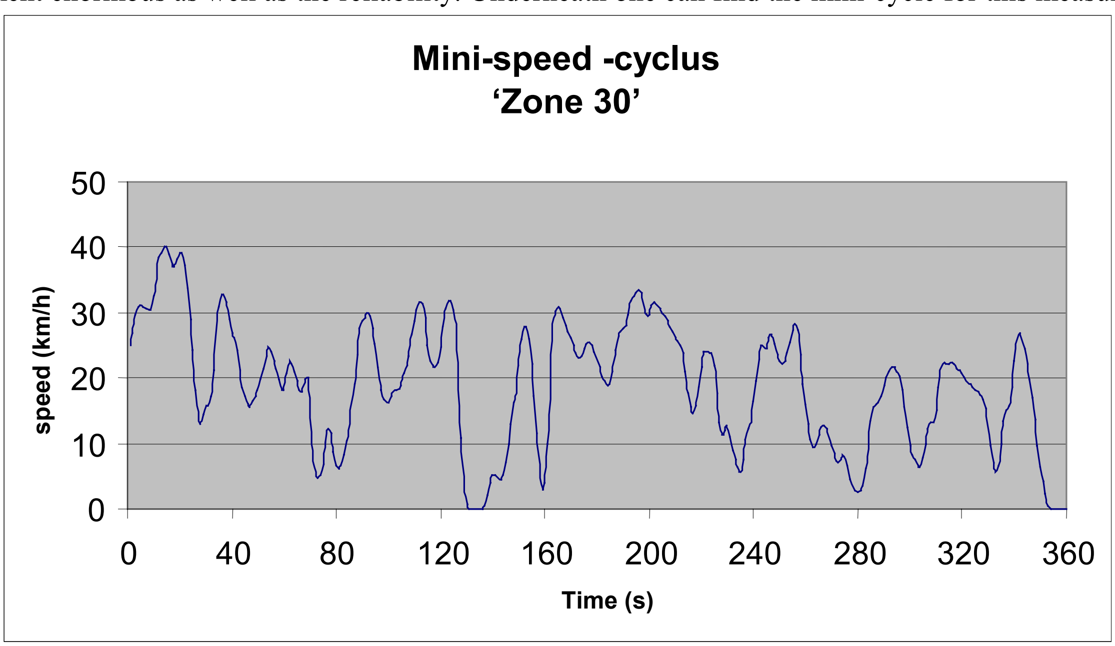

Figure 3 : Mini-cycle zone 30

In a zone 30, the speed is obviously rather low. Accelerations and decelerations aren't high as well, while the stop time is small (2-4%).

3.3 Built-up area

As one can see in the selected speed cycle below, the profile is totally different in a medium sized town without this restriction. The average speed is also low, comparable to the zone 30, but accelerations and decelerations are much higher due to another infrastructure. Stop increases as well up to 10-12% since traffic lights will occur in this situation, while in zone 30 they are only put at entries.

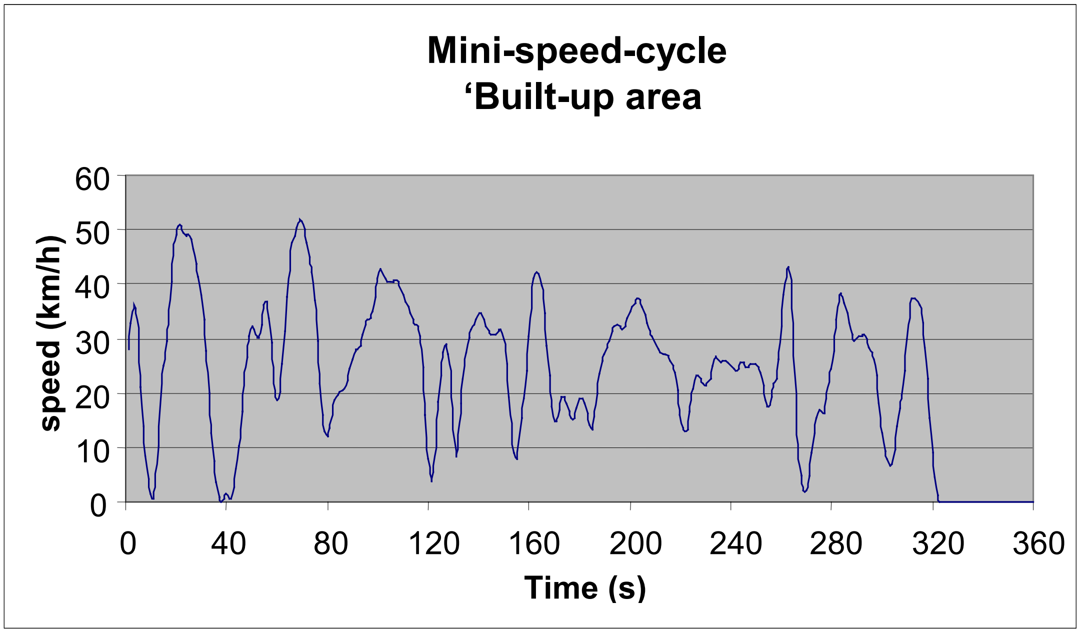

Figure 4 : Built-up area

3.4 Roundabout

In order to get a representative speed cycle, the measurements were done at different locations. Every single location was treated separately and afterwards compared to the other. All the different locations resulted in a same pattern and similar characteristics. The investigators preferred the location where 4 roundabouts formed the city entries one after each other on a ring-road. Since the objective is to compare roundabout with whether or not phased traffic lights, the number of crossing has to be similar in these three situations. Therefore at the chosen location, parts of the measurements where speed was constant, were cut. This resulted in almost the same interval between crossings.

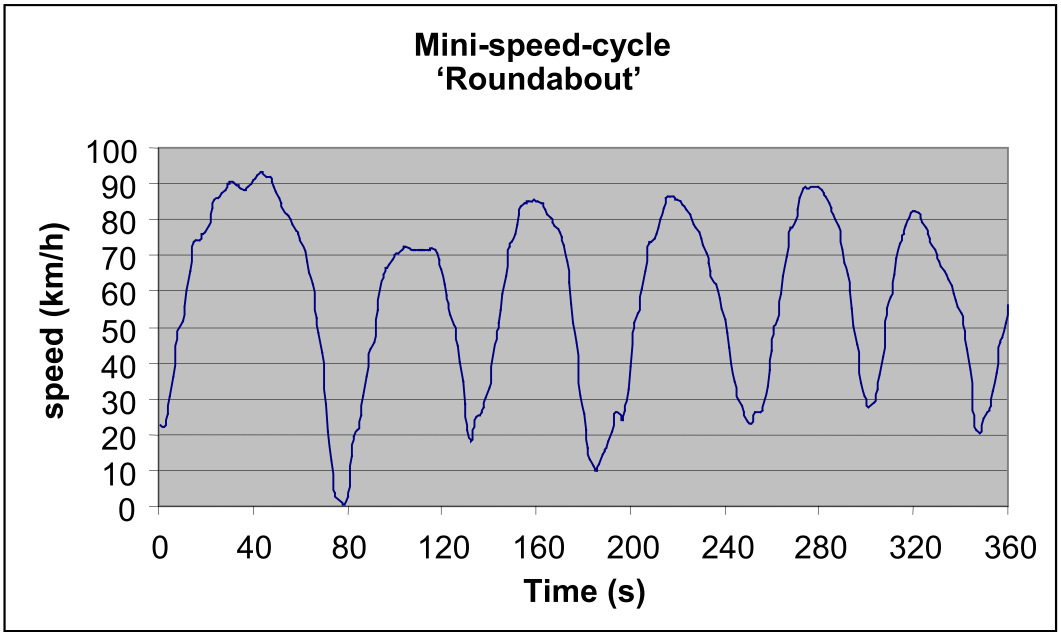

Figure 5 : Roundabout

The measurements on a roundabout so far, were taken during off-peak hours. This means no significant traffic jam occurred. Although during peak hours, traffic jam could happen, but one should take into consideration these measures are especially developed in order to increase transport safety. When planning to put a new roundabout on a crossing, there will always be a study about the length of peak hour traffic jams with specialized programmes. This will be compared with the existing situation and/or traffic lights. Although during the planning there is still an investigation, the best solutions on a crossing with streets of same importance is a roundabout.

3.5 Phased traffic lights

The measurements were done on a road with speed limit of 70km/h. Typically when arriving phased traffic lights, one starts to decelerate in front of the first traffic light. When these traffic lights turn green whether or not a stop was necessary, acceleration to the speed limit is carried out. Further on, phased traffic are passed until the end without any problems; during the trip along phased traffic lights, small accelerations and decelerations occur due to the surrounding traffic and anticipation for next traffic light.

The mini-cycle itself is constructed in a flexible way. It means one can choose the length of it by adding a typical pattern for driving along phased traffic lights, an additional cycle, to the elementary cycle. For the reference cycle the procedure was similar to the other measures : cutting the right parts of the measurements, pasting them together in a way not introducing dynamics, calculating characteristics and finally search for the representative section of it. The length of this part has however not been chosen to 360 s, but to 150 s because the original length of the phased traffic light was about that value. For the reference cycle, the most appropriate part of the phased traffic lights with a length of 95 s has been chosen. This results in the following cycle:

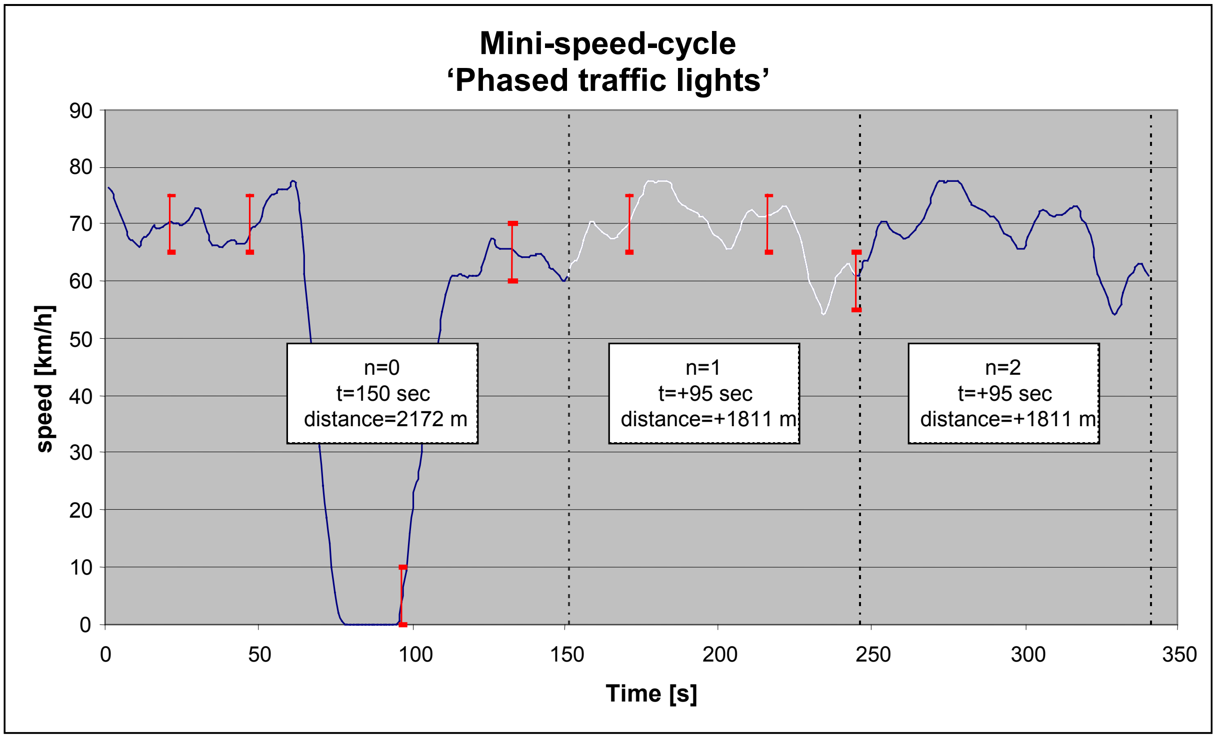

Figure 6 : Possible cycle for phased traffic lights

The red marks in Figure 6 show the different times were one passes a traffic light. The stop within the base cycle indicates that a stop or an deceleration will occur when arriving at phased traffic lights, or when leaving this policy.

Although the cycle seemed very realistic, in reality phased traffic lights are never put on a long distance. Already a large one has a length of 2 km, while the proposed cycle has 6 km of length. So, we just need to drive the base cycle, but this one is practically to short to drive on the roll bench. For those reasons, the mini-cycle for phased traffic lights will be a few repetitions of the base cycle. In fact, it represents a long avenue with modules of 4 phased traffic lights, which is more realistic than the first proposed mini-cycle.

3.6 Traffic lights

In order to create a reference for phased traffic lights and roundabouts, measurements were done on a similar avenue with independent timed traffic light. During the construction of these three cycles, the investigators tried to keep the number of crossing equal. The speed cycle for the traffic lights reference cycle is visualised below.

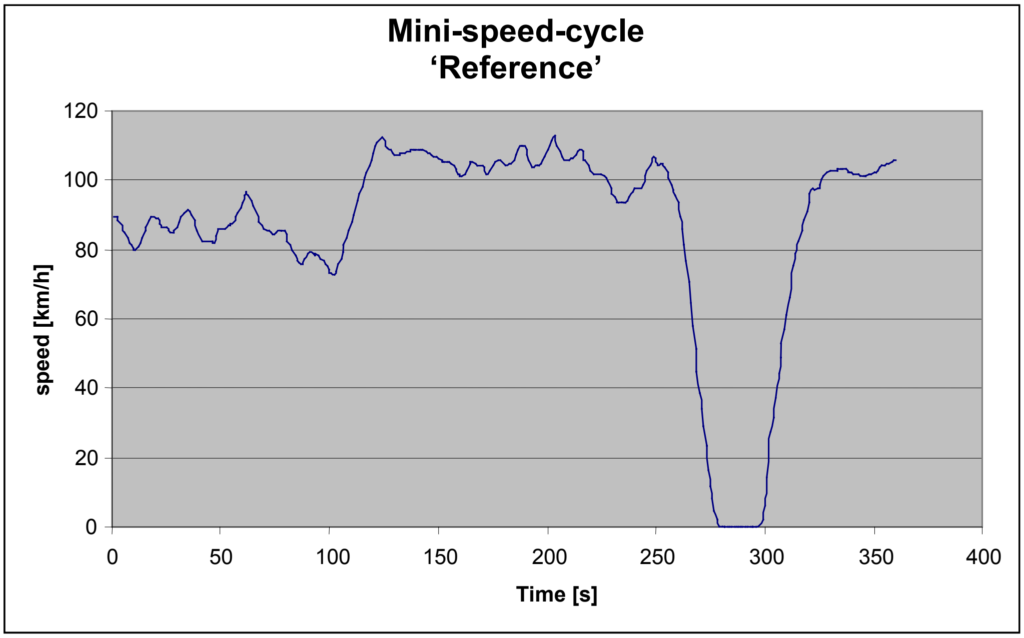

Figure 7 : Traffic lights mini-cycle

When comparing this cycle with the phased traffic lights cycle, they look quite similar.

3.7 Considerations

Since this study wants to how the traffic measures are interpreted in reality, drivers followed normal traffic conditions, and did not drive at the regulated speed, however when the regulations would have been strictly followed, the emissions would have been properly lower. This would have been an assumption, and not been a realistic result; the purpose of this investigation is to evaluate current emission calculations, not taking into account a theoretical way of driving behaviour.

As already mentioned in §3.4, traffic jams are not considered in the evaluation of these policies, because the idea was evaluating the measure in normal conditions, not in those who will happen during a short part of the time. Traffic jams on highways have been already investigated in an earlier TNO-project [3].

4 Upgrading the 'new style driving'

The previous research project established the difference between the technical driving style and the implementation of this driving style by means of slogans. Furthermore, the investigators recognized the sensitivity in the throttling advice. Knowing a couple of new technical items now, one could consider to upgrade the original 'new driving style'. Since it was clear the people could interpret the slogans different than wanted, a combination of these two actions is proposed.

The new concept will be as follows. Non-automotive background people will drive once before the knowledge of the slogans and once after a certain trajectory. These two cycles will be analysed for each of the 20 drivers and the difference before and after will become clear. Afterwards a mini-cycle will be constructed in the same manner as for the policies.

5 Future actions

A powerful simulation tool has been developed at the VUB, Vrije Universiteit Brussels, in the framework of a Ph.D. research [4], allowing to simulate individual vehicles, based on a longitudinal dynamic simulation. The above described cycles will be implemented in the simulation programme in order to evaluate future technologies (electric, hybrid, …) in the different cases, since they won't take part of the measurement campaign on the roll bench where the emissions of the vehicles will be measured. Sensitivity for driving style and traffic measures could be different within these topologies. This could lead to a policy stimulating this kind of vehicles, since the used cycles are normal driving results and not standardized cycles. This simulation programme can assist in the assessment of the individual vehicle parameters in order to evaluate the sensitivity in exhaust emissions for different types of vehicle layout.

Furthermore, when we know the vehicle characteristics that influence fuel consumption and exhaust emissions or even energy consumption, one can define an environmental friendly driving behaviour in relationship with the corresponding drivetrain layout. Having as a base the influence of the traffic policies on the driving behaviour and the related quantified effects on the environment, estimations are made of new and future measures.

The simulation results and the outcomes of measurements on the roll bench will be used in order to qualify the influence of the driving style on the different tailpipe emissions (NO_x, HC, particles, CO, CO_2, SO_2) and on primary energy consumption. This will result in more realistic estimations of the impact of transport on the air pollution. The result has to indicate how the emission calculations should be modified.

The final results of this project are expected by the end of 2001. It will show a list of influences on driving behaviour with its corresponding impact on the exhaust emissions, a definition of environmental friendly driving style and the influence of traffic policies on emissions. Finally an indication of possible measures will be reported to the Flemish Community.

6 Acknowledgements

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7 Conclusions

This paper gives an overview of project progress and summarises the initial project results. It presents the compression of statistical speed measurement into different mini-speed-cycles, able to be driven at a roll bench test facility, cycles, especially developed for the evaluation of traffic measures. The future actions are described in relation to the described intermediate results.

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