Lower emissions through new transport technology solutions

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ABSTRACT

Traffic control at intersections requires the industry to balance a large number of contradictory objectives. An intersection should be safe, have sufficient capacity, accommodate public transport, have a low ‘annoyance factor’, be cycle and pedestrian friendly and produce low levels of noise and emissions. Lowering CO_2 and other emissions, in particular, involves a difficult balancing act. Take for instance the service that cyclists and pedestrians get at an intersection; when the waiting time for this user group gets too long, they will cross without the benefit of a green signal, compromising safety and making cycling and walking a less attractive mode of transport. Making the waiting times for cyclist and pedestrians comfortably short, however, will generate significantly more stops for motorised vehicle traffic along with the associated increase in emissions. The EcoFlex pilot seeks to achieve the right balance with a real-time, low cost measurement of the actual emission level.

The key to emission control is reducing the number of stops of motorised vehicles. The impact of the vehicle type is significant; heavy goods vehicles (HGV) produce far more emissions than a small hybrid car. The FREILOT pilot project uses cooperative technology to give a bit of priority to HGVs in selected fleets. This cooperative technology makes it possible to enforce environmentally friendly driving behaviour. In the FREILOT project, fleet operators and local authorities can negotiate the details of the service at intersections, thereby guaranteeing a fair balance.

ECOFLEX

Across the world, air quality regulations are breached due to localised high pollution episodes, or “hotspots”. Advances in air pollution monitoring techniques enable hotspots to be identified more effectively; however, challenges remain as to how best to reduce the incidence and impact of these episodes. Where road traffic is the dominant source of pollutants, ITS measures, including alternative traffic management strategies, may be deployed to mitigate the hotspot and contribute towards regulatory compliance.

The EcoFLEX project seeks to demonstrate how a low-cost sensor network for local air quality can be used as input for a dynamic traffic management system. Based on the current state of the air quality, the traffic management strategy will be adapted in order to improve the local air quality real time in an urban environment.

AIR POLLUTION

Air pollution is a hot topic. European legislation requires local authorities to take action to improve the air quality as this is of great importance to the quality of life within communities and because pollution has a direct impact on the health of citizens [1] . It is important to continuously monitor the air quality and continue to improve on it. Traffic makes a significant contribution to urban air pollution and it is therefore important to reduce vehicle emissions, without compromising mobility. One of the methods to achieve a reduction in pollution levels is to optimise the traffic flows with specific traffic control measures. Suitable traffic control can lower local emissions by using measures which reduce the dynamics of the individual vehicles and vehicle flows [2-4]. In the case of signalised junctions, one of the methods is to reduce the number of stops for motorised traffic by adapting the signal timing. Doing this in an urban setting is always a compromise. Short waiting times for pedestrians and cyclists lead to extra stops for motorised traffic, lowering air quality locally and creating a less favourable living environment. The opposite has drawbacks too: less stops for cars means longer waiting times for pedestrians and cyclists which is undesirable. Therefore it is preferable to apply these measures only in the case of poor air quality conditions [5]. Gains can be achieved by a simple air pollution-responsive traffic control system which is only activated when a certain air quality threshold is reached or expected to be reached.

THE ECOFLEX PROJECT

The goal of the EcoFLEX project is to demonstrate the principle of using pollution sensitive traffic control for lowering vehicle emissions, based on an air quality indicator. EcoFLEX has an emission reduction target of 15%, which has direct impact on local air quality.

Traditionally, air quality measurements are done at a few fixed locations in a large urban area and on long time scales, e.g. daily, hourly or quarter of an hour averages. However, when one seeks to use air quality measurements for local instantaneous traffic measures, more detailed data in both time and space is necessary. For this purpose, an air quality sensor network was developed in the MESSAGE project by the University of Newcastle [6] which is now commercialised as EnviroWatch sensors.

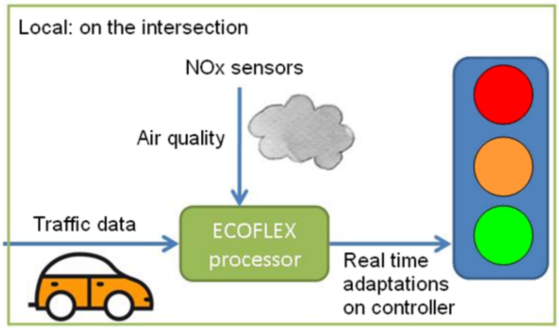

Figure 1 EcoFlex principle

The trade-off between favouring pedestrians and cyclists versus motorised traffic is a difficult one. On the one hand it is more environmentally sound to minimise stops for motorised traffic so emissions remain as low as possible, while on the other hand it is better in the long run to minimise travel time for the pedestrians and cyclists to encourage environmentally friendly behaviour. A common tool to balance those interests is assigning weights, measures of importance, so an objective function can be evaluated to select the best choice. But this importance is not a fixed quantity. Instead, it would be a great help to be able to switch to a low-emitting setting when *necessary*; when air quality is poor, and prioritise slow traffic when *possible*; when air quality allows it.

Therefore a traffic light controller is extended with the EcoFLEX processor, which processes real time data from a low-cost NO_2 sensor network. The sensors measure the local NO_2 concentrations at and around the intersection. NO_2 has been chosen as an environmental trigger for the green control scheme, since this substance is seen as the indicator for traffic-related emissions. Based on the processed sensor data and a decision algorithm that takes into account the traffic intensity, a control signal is generated. This control signal indicates which control strategy should be used:

- If the air quality is high, the system optimises for minimum waiting times for pedestrians and cyclists (and optionally for low-volume side-roads).
- If the air quality level becomes too low, the system switches to minimisation on stops for motorised traffic (EcoFLEX mode).

The EcoFLEX mode will remain active until the air quality has improved enough and reaches the threshold to switch back to the strategy with minimal waiting times.

EcoFLEX may be applied to stand-alone controlled junctions, but network arrangements are also possible allowing scalability, with a consequent further increase in environmental benefit. In this case a central EcoFLEX application will be used in the traffic management center, optimising on environmental indicators over an entire network.

FREILOT

In the FREILOT project industry (a.o. Volvo and Peek), cities (Helmond, Bilbao, Krakow and Lyon) and research institutes, work together to evaluate technologies that can save fuel for heavy goods vehicles and reduce CO_2 production.

THE FREILOT SERVICES

Within the FREILOT project, a number of services have been defined, all aiming at reducing fuel use by heavy goods vehicles. There are four types of service, each with a different perspective:

- The driver - support for eco-driving
- The vehicle – intelligent acceleration and speed limiters
- Fleet management – real-time delivery space booking
- Traffic management – energy efficient intersection control

The energy efficient intersection control in FREILOT works by giving priority to vehicles of fleets that are enrolled in the FREILOT scheme.

The services can be used in isolation and in combination. Some of the combinations can be used in schemes in which different actors all can benefit in different ways.

An example of this is the combination of energy efficient intersection control and on-board acceleration and speed limiters. From a purely technological viewpoint these services already augment each other. The situation is even better when one considers that city authorities can supply priority only to vehicles that are well behaved (i.e. have acceleration/speed limiters or eco-driving support).

This paper will look in some more detail at the energy efficient intersection control service.

ENERGY EFFICIENT INTERSECTION CONTROL

Heavy goods vehicles have a big impact on the overall efficiency of a controlled intersection. Acceleration of a big and heavy vehicle is very energy costly and produces a lot of emissions. Giving priority to these vehicles reduces the number of stops. As long as this priority is not too high, the overall traffic flow will also benefit. In the mildest form of priority, the green will only be extended a few seconds when a HGV in the scheme would be the first vehicle to stop when the light turns to red. This not only has a direct positive effect for the vehicle involved, but also benefits overall efficiency by avoiding platoons with a HGV in front.

Fuel efficiency can even be improved just by giving information to the drivers. By individually indicating to the drivers whether their light will be red or green and what the best speed is to approach the stop line, unnecessary acceleration is avoided.

All of the above needs technology to communicate between vehicle and driver and the traffic light controller. Cooperative systems technology is ideally suited for this.

COOPERATIVE TECHNOLOGY

The last ten years have seen the development of a European standard for communicating between vehicles (V2V), between vehicles and infrastructure (V2I) and between vehicles, infrastructure and back offices. The EC has set radio bandwidth apart for the use in Intelligent Transport Systems (5.9 GHz). ETSI and CEN are currently preparing the necessary standards.

In the initial EC co-funded research projects (CVIS[10] and Safespot[12]) many efficiency and safety applications of cooperative technology have been pioneered. New research projects (like eCoMove) explore the possibilities for fuel efficiency by means of cooperative systems technology.

Although the standards were not quite stable at the start of the FREILOT project, cooperative technology was selected for two of the pilot sites. Since the start of the project, the development of cooperative systems technology has accelerated. The first commercial products are now expected to be available in 2011.

The main components for a cooperative systems are an on-board unit (OBU) and a road side unit (RSU). Many projects (and companies) are working on OBUs. An interesting solution is an open systems prototype from the Dutch SPITS project[13] .

Figure 3 on-board unit from the SPITS project

FREILOT uses a commercially Android based tablet device with a separate 5.9 Ghz radio and window antenna.

In Helmond (one of the pilot sites), 14 intersections have been equipped with a prototype of a soon commercially available road side unit. The same unit is also used in the Krakow pilot site.

In practice the communication range of this unit is between 500 and 800 meters.

Figure 2 commercial road side unit

SIMULATIONS AND PRELIMINARY RESULTS

At the FREILOT pilot sites an extensive set of data is collected to be able to show just how effective the FREILOT services are. Not everything can be easily measured. For the instrumented vehicles in the pilot a good estimate of the fuel consumption can be made, but for the other vehicles micro simulation is used.

Exploratory Simulation

Before the start of the FREILOT project a simple micro simulation study with AIMSUN was performed[7] to explore the potential benefits of HGV priority.

In the simulation the following alternative control strategies were compared:

- Distributed adaptive control with neutral optimisation criteria (explained below). *The neutral strategy*.
- Distributed adaptive control, optimised for stop reduction on the main routes together with additional emphasis on the stop reduction of heavy goods vehicles. *The fuel reduction strategy.*

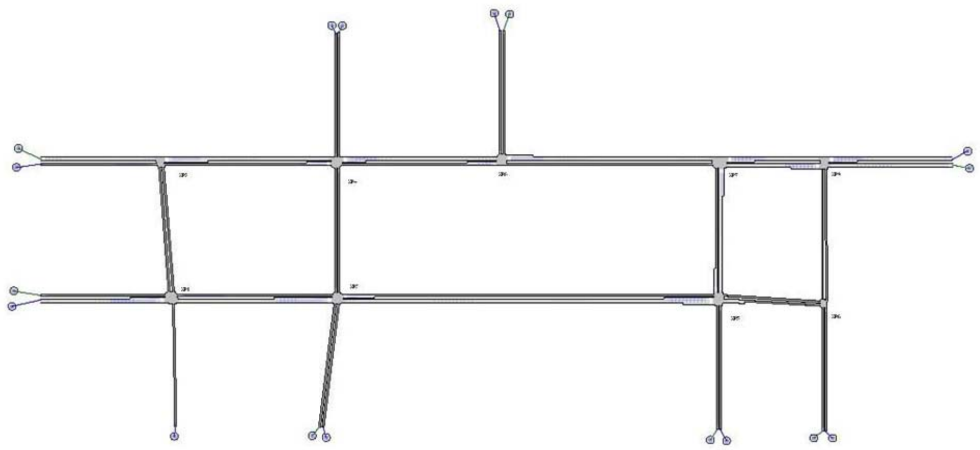

Figure 4 network used for simulations

The first of the alternatives represents state-of-the-art adaptive urban traffic control, without special attention to stop reduction or specific vehicle types.

The alternative strategy applied two optimisations to achieve fuel efficiency:

- Stop reduction for the main routes.
- The detection of heavy goods vehicles between 100 and 10 meters from the stop-line and giving these specific vehicles additional weight in the optimisation.

The two strategies were tested with three different traffic demand scenarios. The three scenarios all have most of the heavy goods vehicles on the main routes. The basic scenario has traffic volumes that are near saturation of the network (the 100% scenario). The other two scenarios have 65% and 30% of the traffic.

In the simulation two vehicle types are used. Modern small private cars and 10-16 ton modern heavy goods vehicles. The heavy goods vehicles constituted 22% of the total traffic volume. Parameters for the AIMSUN fuel consumption model were taken from [9] . The averages for fuel reduction and stop reduction in the fuel reduction strategy can be found in the following table.

	30%	**65%**	**100%**
Fuel Consumption HGV	-5.5%	-12,7%	-20.3%
Fuel Consumption overall	-7.0%	-10.8%	-16.0%
Stops HGV	-40%	-33.3%	-51.9%
Stops overall	-15.4%	-11.1%	-33.3%

Table 1 simulation results for HGV priority

Not only did the fuel reduction strategy result in improved fuel efficiency, it also improved average network performance. Average speeds increased between 15 and 30% depending on the scenario.

It should also be noted that in the comparison, two ‘good’ strategies were compared. When the fuel reduction strategy would be compared with a badly tuned fixed time system or an uncoordinated vehicle responsive system, the gains would be significantly higher (see e.g. [8]).

Preliminary results from the FREILOT pilot

The HGV priority is tested in three of the FREILOT pilot cities. The types of traffic control are quite different in these three locations. In Lyon, fixed time coordinated corridors are implemented, in Krakow each of the intersections is locally optimised while in Helmond networked distributed adaptive control is used.

For each of the locations a baseline measurement is made. In addition to various traffic parameters (flows, cycle times, etc.), the trips of all vehicles in the pilot fleet are logged on a second by second basis. Based on the vehicle logs detailed speed profiles are made that can be used to estimate fuel consumption and emissions for the vehicles.

The baseline situation is without priority or feedback to the driver. From the Helmond site there are initial results from three months of operation with priority and feedback to the driver. For one of the intersections the results are shown in Figure 5.

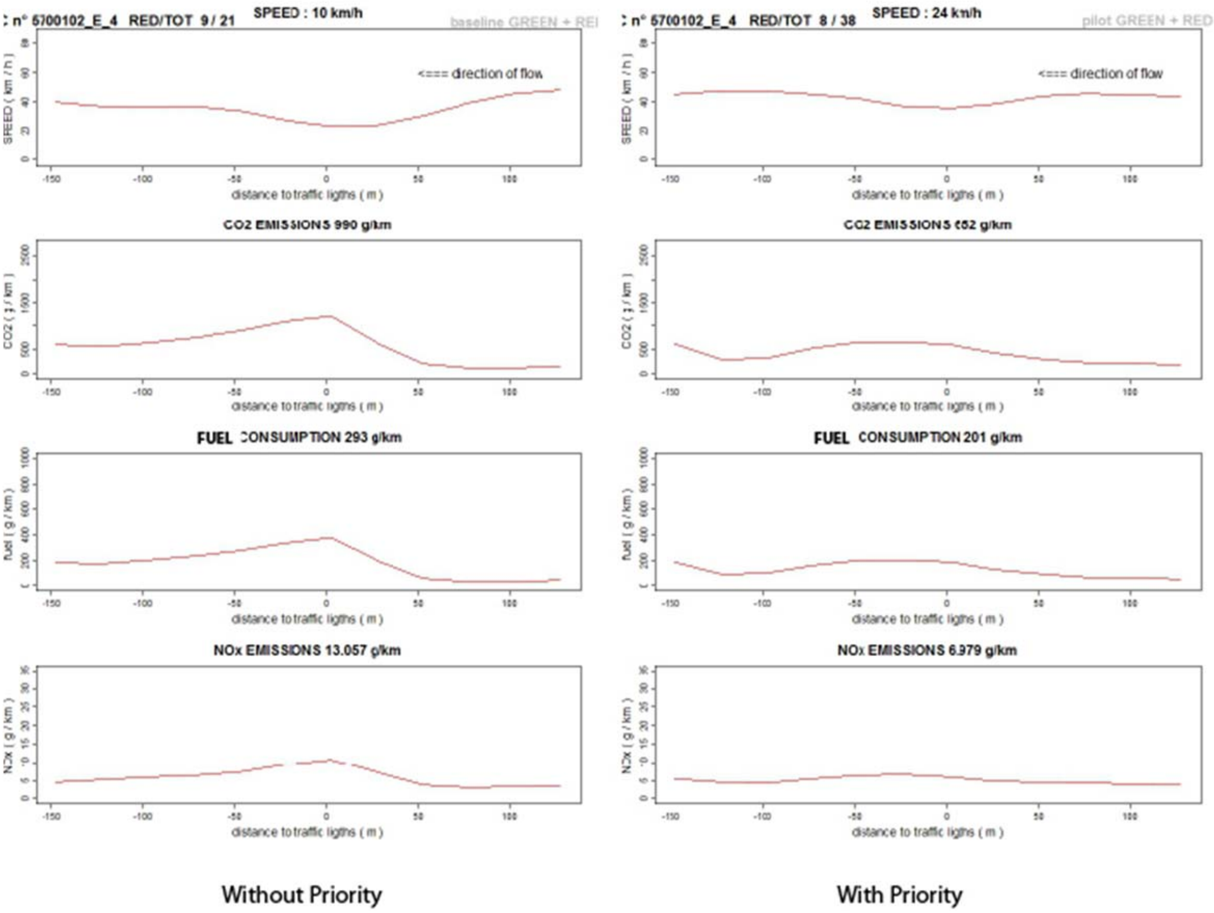

Figure 5 preliminary results for one intersection in Helmond

Note that the diagrams must be read from right to left and represent averages of all trips in the fleet during the measurement periods. In the situation without priority, the average speed drops significantly when approaching the stop line. In the situation with priority, a lower number of vehicles has to stop, which leads to a significantly higher average speed, lower fuel consumption and emissions.

It must be noted that these are preliminary results. Full results over the total one year measurement period for all location will be available early 2012. Results will be available on www.freilot.eu.

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REFERENCES

[1] World Health Organisation. (2005) Health effects of transport-related air pollution, World Health Organisation Regional Office for Europe, Copenhagen, Denmark. ISBN 92-890-1373-7

[2] K. Hirschmann and M. Fellendorf, “A toolbox to quantify emission reductions due to signal control,” 89th Annual Meeting of the Transportation Research Board, Washington, D.C.: 2010.

[3] S.K. Zegeye, B. De Schutter, H. Hellendoorn, and E. Breunesse, “Reduction of Travel Times and Traffic Emissions Using Model Predictive Control,” American Control Conference, 2009.

[4] M. Mahmod, B. van Arem, R. Pueboobpaphan, and M. Igamberdiev, “Modeling reduced traffic emissions in urban areas: the impact of demand control, banning heavy duty vehicles, speed restriction and adaptive cruise control,” 89th Annual Meeting of the Transportation Research Board, Washington, D.C.: 2010.

[5] S.V.D. Elshout, M. Mahmod, I. Arts, and B.V. Arem, Decision making on short term traffic measures to influence traffic related air pollution., University of Twente, 2009.

[6] North, Robin J et al., “Field Deployments of the MESSAGE System for Environmental Monitoring”, TRB Volume: 50 Issue Number: 11, Publisher: Hemming Group, Limited ISSN: 0041-0683, 2010

[7] Turksma S, Vreeswijk J, “Fuel efficiency in cooperative network control systems”, ITS World Congress NYC 2008

[8] David A, Niedermaier A, “ADAC-Test Partikelemissionen: Vergleich Partikelfilter / Grüne Welle” ADAC e.V., June 2005

[9] Knudson T, Bang B, “Miljomessige konsekvenser av bedre veier”, SINTEF, 2007

[10] CVIS: www.cvisproject.org
[11] FREILOT: www.freilot.eu
[12] Safespot: www.safespot-eu.org
[13] SPITS: www.spits-project.com