Potential network effects of Intelligent Speed Adaptation

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Abstract

The number of road accident victims is high in the European Union with around 42,000 fatalities and 1.6 million injuries a year, and inappropriate speed has been identified as a major cause. The European Commission has recognised the contribution that new technologies can make to reduce this number of injuries. One of these technologies is Intelligent Speed Adaptation (ISA). The PROSPER project is designed to examine the efficiency of ISA in comparison with traditional physical means, to examine how road users react to an introduction of ISA and to identify obstacles in introducing the technology.

One part of the project contains network microsimulation. Network modelling is a good way to estimate the influence of introducing speed limitation measurements on the complete network performance without actually introducing it and making big investments. Subjects that are being examined are effects on speed, travel time, fuel consumption and pollution. Networks from Sweden, the Netherlands, Belgium and the United Kingdom are being simulated. The comparability of the results between these countries will also be looked into.

Keywords: ISA, network microsimulation, PROSPER, emission and fuel consumption modelling.

1 Introduction

1.1 Intelligent Speed Adaptation

The number of road accident victims is high in the European Union with around 42,000 fatalities and 1.6 million injuries a year, and in-appropriate speed has been identified as a major cause. The road safety problem has been identified as a major obstacle against the development of sustainable mobility on the
European roads. The European Commission has recognized the contribution that new technologies can make to achieve the goals of the Common Transport Policy through road speed reduction. The Council resolution of June 2000 explicitly identifies "the use of advanced assisted driving technology which has considerable potential for improving road safety" and "technology relating to speed limitation devices and to identify any technical, organizational, administrative and legal difficulties in introducing them" as important measures for further investigation.

Intelligent Speed Adaptation or ISA is a speed limitation device that takes legal speed limits into account based on a combination of GPS and GIS-maps which hold the speed limit data. Systems can vary from warning systems, that indicate when the speed limit is exceeded, to an active counterforce on the acceleration pedal that prevents drivers from exceeding the legal speed limit. Such a system with counterforce is currently being tested in Ghent. The counterforce exercised on the pedal discourages the driver to exceed the limit, but can be overridden.

1.2 Prosper objectives

In this paper we present and discuss preliminary results of the work done in work package 4.1 of the European Prosper project (5th framework). PROSPER stands for Project for Research On Speed adaptation Policies on European Roads and the project is responding to the Key Action "Sustainable Mobility and Intermodality", and specifically to research task 2.3.1/16 "Road Speed Management Methods Assessment" defined in the call.

The main objectives of Prosper are to answer the following questions:
- How efficient are road speed management methods based on information technology (ISA) in comparison with traditional physical means?
- How will road users across Europe react to such developments?
- What are suitable strategies for implementation and what obstacles have to be overcome?

One of the main objectives of work package 4.1 is to use network μ-simulation to provide evidence of the effect of ISA on network capacity and environmental effects. This is being done by Vito for the site Ghentbrugge, which is part of the test site for ISA in Ghent (Belgium). The preliminary results of this study are dealt with in the following paragraphs. Other modelling sites examined by other partners are parts of the cities of York (UK), Stockholm (Sweden) and the province of Noord Brabant (NL).

Partners involved in Prosper are SNRA - Swedish National Roads Administration, SWECO VBB VIAK, Transek, Langzaam Verkeer, VITO - Vlaamse Instelling voor Technisch Onderzoek, AVV, TNO UCT - University of Cape Town Institute for Transport Studies, University of Leeds (ITS), CERTU, Lund University, INTRA - Ingeniería de Tráfico SL, Endresz Ltd., UKTD - University Kaiserslautern and MIRA.
2 Methodology

2.1 Traffic simulation

Traffic simulation means using software programs to simulate current traffic situations and examine effects of changes on this traffic situation. A possible change is the introduction of ISA. Different ISA-scenarios will be examined by varying penetration rates (from 0 to 100 % ISA), simulating several networks and varying speed limits (30 kph zone instead of 50 kph). Traffic simulation makes it possible to estimate the influence of introducing ISA on the complete network performance without actually introducing it and making big investments. Beside the cost reduction, network simulation makes it possible to examine performance of the complete network, including non-ISA vehicles. In field trials data are logged for ISA-vehicles, but changes in speed of other vehicles (e.g. because they drive behind an ISA-vehicle) cannot be measured. Taking this effect into account is possible with traffic simulation models. The models used within Prosper are Saturn and Dracula.

Saturn is developed at the Institute for Transport Studies of Leeds and distributed by WS Atkins of Epsom. It contains an assignment and simulation model. The assignment model chooses routes based on link cost-flow relationships. There are two general inputs for this model: a trip matrix which specifies the number of trips from zone i to zone j and the network which specifies the physical structure of the road. Based on this information first route choice is made and first delay times are calculated.

The simulation model uses this information to calculate more accurate cost-flow relationships, by providing a more detailed representation of what’s actually happening at the junctions. If for instance queuing delay is above a certain level, the cost of that particulate route is increased and route assignment is recalculated. This interaction between simulation and recalculating assignment is an iterative process that will stop after a certain convergence rate is achieved [1].

In addition Dracula is also used in combination with Saturn which is a junction based model that only makes detailed simulations of what happens at the junction itself. It takes not into account how individual speed profiles differ and how these vehicles influence each other’s speed. This makes a simulation within Saturn alone insufficient to examine the effects of ISA on network performance and environment. That is why a complementary simulation within Dracula is needed. Dracula uses the assigned routes of Saturn as an input and calculates individual second-by-second vehicle movements by applying car-following and lane-changing rules. These movements are used to compute travel time, queuing delay, average speed and speed distribution of the complete network [2].
2.2 Hypothesis to be tested

With the network simulations of different ISA - scenarios, we will try to give an answer to the following hypotheses:

- By introducing ISA safety will increase.
- By introducing ISA pollution will decrease.
- By introducing ISA fuel consumption will decrease.
- By introducing ISA, travel time will not increase.
- ISA will have a larger effect on urban roads than on motorways.
- ISA will have a larger effect in off-peak hours and less effect in peak hours.
- The effects of ISA in Sweden, The Netherlands, Belgium and the United Kingdom are comparable.
- Non-overridable ISA will have bigger influence on traffic performance than overridable ISA.

Differences in road types can be examined because of the different character of the examined networks. The Ghentbrugge area has a more urban character, while motorways are included in the Dutch and Swedish networks. Effects of ISA in different countries will be examined by using country-specific speed distribution profiles. This data is being gathered in other work packages within the PROSPER project.

2.3 Calculating exhaust emissions

In Europe, most inventories of exhaust emissions at the fleet level or for a city are nowadays calculated according to the Copert-methodology from the MEET project [3] The MEET-functions estimate emissions per kilometer for different types of vehicles. This methods has two important drawbacks for application in the Prosper project (emissions of different ISA-implementation scenarios in the future).

1. MEET does not provide emissions factors for Euro III or IV cars. Scaling the available measurements relative to the decrease of the standards would clearly be unsatisfactory because actual emissions may now be much closer to the emission standards than before.
2. MEET calculates emissions per kilometer for trajectories using one average speed value. Using this method together with μ-simulation models would yield spurious results that would obviously indicate higher emissions and fuel consumption with ISA in urban areas. MEET emission functions have a quadratic form that predicts higher emissions at lower speeds because of implied higher traffic dynamics (stop & go).

In order to properly evaluate the effect of ISA on the emissions of a car a much more detailed analysis is necessary, that takes account of both instantaneous speed and acceleration (the traffic dynamics). Unfortunately such detailed sets of data are not widely available. To get a first indication of potential effects, we have used results from the vehicle based emission model VeTESS.
that was developed by MIRA and Vito in the European DECADE project [4] [5].
The VeTESS model was used to calculate emissions for two modern vehicles (one petrol & one diesel) in urban driving. This includes detailed modeling of the effect of different loads on the engine and transmission. Data from two real world urban driving cycles from the DECADE project (one in Mol, Flanders & one in Barcelona, Catalonia) were used to estimate emission factors in a format that Dracula can handle.

Clearly this approach cannot give a quantitative estimate of the total emissions of a future fleet (of which we cannot know the composition and technology). Nevertheless, using the most detailed available emissions from modern European cars should allow us to estimate the sign and magnitude of the effect on emissions at different levels of ISA implementation.

At present no detailed enough information could be obtained on emission factors for PM from petrol cars, which may be an important source of PM outside of Belgium. In Belgium approximately half of the fleet of passenger cars are now diesels, and this fraction is expected to keep increasing [6].

![Figure 1: Belgium: location if the city of Ghent and the study area Ghentbrugge (in black).](image)

### 3 Results

Preliminary results are presented for the Ghentbrugge network, that was modelled by Vito.
3.1 Network

The Ghentbrugge study area is shown in figure 1. It is a small urban network of 2*2 km. It has 2 main roads and several smaller urban roads. The legal speed limit is 50 kph, except for a small part of the main road where it is 70. In this example only the morning peak is presented. During this peak period +/- 2500 vehicles per hour are moving on the network. The speed and position of each individual vehicle is updated every second.

The road network as simulated in Dracula generates a graphical display represented in figure 2. The motorway which passes Gentbrugge at the southwest end of the study area is not included in the model. However, the approach and the exit of this highway and thus the traffic entering or leaving the network are taken into account.

![Figure 2: Simulation of the Ghentbrugge road network within Dracula.](image)

3.2 Preliminary results of the network simulation

In the basic scenario (no ISA) we calculate a total travel time of 210 vehicle hours from which 105 queuing delay time during the morning peak. This indicates that there is some congestion within the network. The average speed is 30 kph which is a great deal below the legal speed limit of 50 kph.

With a penetration rate of ISA of 50 %, total travel time increased to 219 vehicle hours and average speed is reduced to 28.7 kph. This indicates that ISA
doesn’t have a big influence on travel time, which is not surprising as this is a congested area and not often vehicles are able to drive just at or above the speed limit.

While interpreting these results it is important to understand why there is a difference in average speed and travel time. Besides speed limit data also free flow speeds are determined for every street. Free flow speed is the speed at which an average vehicle drives in a street when this vehicle is not hampered by other traffic. Obviously the choice of this free flow speed and the amount in which this speed exceeds the speed limit has an enormous effect on the consequences of ISA. This means that this free flow speed data entered into the model should be accurate. In this example there are roads with a speed limit of 50 who have a free flow speed of 52 kph and roads with a limit of 70 who have a free flow speed of 75.

3.3 Preliminary results for exhaust emissions

First results show that our method is feasible. Two synthetic drive cycles were derived from the original DECADE urban drive cycles recorded in Mol and Barcelona. Top speed was computationally limited to 30km/h. This top speed is considerable lower than the original top speeds (~50km/h), but average speeds are only marginally reduced. These speeds are very similar to those obtained from the preliminary network modeling in Ghent. As a working hypothesis we have assumed that these synthetic drive cycles mimic the effect of ISA in Ghentbrugge. In the final phase of the project we will make further calculations in which real driving cycles of ISA cars are used so that the presumed effects on the driving dynamics are also taken into account. This necessitates a change in the Dracula software.

Effects of speed limitation depend on the emission factors, the driving cycle and the vehicle type. Effects on CO and VOC are erratic and hard to explain, but levels in modern cars are so low as to be of little importance. An example of results for a modern diesel vehicle is shown in figure 3. The difference in emissions between the original urban drive cycle (with top speeds up to 50km/h) and the speed limited drive cycle (top speed limited to 30 km/h) was calculated. In this example average speeds were reduced from 25.2 to 22.7 km/h in Mol and from 14.8 to 13.9 km/h in Barcelona.

If the average speed reduction is used with the MEET approach, estimated emissions increase for all pollutants (left side of the graph). This is due to the mainly quadratic form of most emission functions. Emissions of CO₂, NOₓ and PM show either no effect or a moderate to strong decrease. This is especially relevant because these pollutants cause the most important environmental effect and impacts on public health [7] [8]. Further testing is necessary to elucidate the effect of changes in e.g. acceleration patterns on emissions.

Often enough the positive effect of ISA on traffic emissions is stated but not measured or tested. A limited number of other teams have previously attempted to quantify the possible effect of ISA on emissions (e.g. [9] ). Using the VTI emission model VETO, they calculated emissions of CO₂, CO, NOₓ and HC for a Volvo 940 within limited operational intervals. They estimated that fuel
consumption had decreased by 2% (0.8% to 3.5% depending on road type). Emissions of NOx and HC were found to decrease by approximately 8%.

![Figure 3: Difference in emissions between a normal urban drive cycle (up to 50km/h) and a synthetic speed limited (at 30 km/h) drive cycle (modern diesel car).](image)

### 4 Conclusions

Preliminary tests with the network in Dracula indicate that flows and speeds on selected roads agree well with other models and traffic counts.

We expect that the network modelling effort will allow us to give an answer to most hypothesis (see paragraph 2.2) by the end of 2004.

ISA may well decrease emissions of the equipped vehicles and the other vehicles on the network. Potential savings appear largest for PM.

More work is needed to apply the emission calculation to more vehicle types and incorporate changes in acceleration patterns.

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