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Varhelyi, Andras; Hjalmdahl, Magnus; Risser, Ralf; Draskóczy, Magda; Hydén, Christer; Almqvist, Sverker

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LUND UNIVERSITY

PO Box 117
221 00 Lund
+46 46-222 00 00

THE EFFECTS OF LARGE SCALE USE OF ACTIVE ACCELERATOR PEDAL IN URBAN AREAS

András Várhelyi, Magnus Hjälmdahl, Ralf Risser, Magda Draskóczy, Christer Hydén, Shunji Taniguchi, Sverker Almqvist, Emeli Falk, Hossein Ashouri

Department of Technology and Society, Lund University, Sweden

ABSTRACT

Within the framework of the Swedish national trial with Intelligent Speed Adaptation (ISA) in urban areas, the effects of large scale use of "active accelerator" were evaluated. 284 cars were equipped with the system for a period of 5-11 months in the city of Lund. The driving data of all equipped vehicles were logged with regard to time and speed, both before and after activating the system. Driver behaviour and workload were studied with the help of an instrumented vehicle. Possible system effects, such as speeds, interactions with other road-users and driving against red were studied in the field. Possible changes in driver attitudes and acceptance were studied by interviews. The results revealed that test drivers' compliance with the speed limits increased both according to their own statements and objective measurements. At this stage practically no negative compensatory effects could be found.

BACKGROUND

Speed adaptation via in-car devices has been studied for over 15 years. Estimates of the safety effect of a fully implemented automatic speed management system in Sweden and the UK vary from a 10 percent reduction in injury accidents with an advisory system to a reduction in the range of 20-40 percent with a system that enforces current speed limits and also limits the speed in critical conditions (slippery road, poor visibility) (Várhelyi 1996; Carsten and Comte 1997, Carsten and Fowkes 2000). Earlier field trials (Persson et al. 1993; Almqvist and Nygård 1997; Várhelyi and Mäkinen 1998) and simulator experiments (Comte 1996; Comte 1998a; Comte 1998b) have demonstrated the positive effects of the "intelligent" gas pedal. However, some aspects of negative behavioural adaptations, mental workload and the long-term effects of large-scale use on compliance and acceptance in real traffic needs more research. Based on the promising results from these trials, the Swedish Road Administration started large-scale trials with different ISA-systems (Intelligent Speed Adaptation) in four Swedish cities in 1999. One of the sites was the city of Lund.

THE TEST SITE IN LUND

The test area included the entire city of Lund, which consists of all legislated speed-limits in Sweden, 30, 50, 70, 90 and 110 km/h. However, the ISA system was only active within the 30, 50 and 70 speed limit zones. The system was turned on every time the vehicle entered or started in Lund and it could not be turned off inside the test area. Outside Lund, the system could be used voluntarily.

THE ISA SYSTEM

The ISA system, tested in Lund is also known as "the active accelerator pedal". When the driver attempts to exceed the speed limit, a resistance in the accelerator pedal is activated. If necessary, the driver can override the system by pressing the accelerator pedal harder (kick-down function). A GPS receiver, which identifies the position of the vehicle, was fitted in the test vehicles. The vehicle does not transmit a signal of its own and could therefore not be localised. The vehicles were also equipped with a digital map containing all the current speed limits within the test area.

TEST DRIVER SELECTION

The recruiting of the test drivers was based on letters to a randomised sample of vehicle owners in Lund and a request to companies to allow their company cars to be included in the trial. There were a total of 284 vehicles equipped with ISA. The drivers were assigned to groups with regard to gender, age and initial attitude towards the active accelerator pedal (positive/neutral/negative) (see table 1). A few drivers did not reveal their initial attitude to the system. It was difficult to recruit female drivers over 65 years of age (due to the fact that in this age group cars are mainly registered on the male member of the household) and young drivers (due to the fact that people below 25 years of age don't usually possess cars of recent model, suitable for being equipped with ISA). 38 of the vehicles were company cars (vehicles of local companies and organisations).

Table 1. The number of test subjects according to age group, gender and initial attitude towards the active accelerator pedal.

	Age group											
	18-24			18-24			18-24			18-24		
	pos	neut r	neg	pos	neutr	neg	pos	neutr	neg	pos	neut r	neg
Male	4	1	2	41	7	8	61	13	12	28	3	1
Female	5	0	0	26	3	12	28	12	5	5	0	1

HYPOTHESES

Based on the results from previous studies on ISA a large number of hypotheses were developed on:

- *Users*, such as Attitude, Acceptance, Behaviour, Habits, Exposure,
- *System effects*, such as Speed, Safety, Security, Accessibility, Time consumption, Route choice, Emissions.

EVALUATION METHODS

The evaluation of the effects was designed as a before/after study with control. In order to be able to separate the effects on the test drivers from possible changes in traffic in general, besides observations of the system's effect on the test drivers' behaviour and attitudes, comparable observations of the public in Lund were made (see table 2 for the study design). In order to be able to trace if the ISA test drivers influenced other road users in the test city, comparative observations for control were carried out in the city of Helsingborg.

Table 2: The design of the observational studies on effects of ISA on test drivers and on the public.

Effects	Test drivers	Control	
		Lund	Helsingborg
Attitudes, Acceptance	Surveys before/after	Surveys before/after	-
	Logbook after	-	-
	In-depth interviews after	-	-
	-	Interviews with passengers after	
Behaviour	Data logging in test vehicles before/after	Speed measurements before/after	Speed measurements before/after
	In car observations before/after	Red light violation before/after	Red light violation before/after
		Interactions after	-
Other effects	Accidents before/after	Accidents before/after	Accidents before/after
	Travel times before/after	-	-
	-	Interviews with pedestrians before/after	Interviews with pedestrians before/after
	Emissions before/after	-	-

Interviews

Baseline questionnaire to the public

The aim with the baseline survey was to reveal the attitudes of different road users (not only drivers) to speeds and road safety. Questionnaires were sent to 750 randomly selected inhabitants in Lund with age between 18 and 74 years. 469 persons answered which gives a response rate of 62.5 %.

Recruiting interviews

During the recruitment procedure drivers were asked about their opinion of the different systems used in the Swedish ISA-trial (also at other trial-sites) as well as a few questions from the base-line questionnaire. Further, the drivers were asked about themselves and their vehicle. Then, the private drivers were asked if they were willing to participate in the trial, and if they didn't want to participate they were asked to give a short explanation why not. On company car drivers' participation their employer decided.

Questionnaires to the test drivers

All test-drivers were interviewed three times: before their vehicle was equipped with ISA, after driving with ISA for one month and finally at the end of the test-period. Most of the questions from the base-line questionnaire were repeated, but there were also more specific questions about the active accelerator pedal. The objective of the questionnaire was to study the drivers' attitudes and experiences of the active accelerator pedal, and possible changes after using the equipment for a long period.

Logbook

A number of test drivers (32 persons) were asked to fill in a logbook regarding their experience with the ISA system. The aim of this study was to analyse and to show how the use of ISA over a longer period is experienced by the test persons. The diary gives the possibility to tell about events that could not be predicted, about emotions that come up in unforeseeable situations and that only with great difficulties can be dealt with in another way than allowing and enhancing the individuals to answer at those moments when something comes to their mind or happens to them.

In depth interviews with test drivers

These interviews were carried out on a smaller sample, 26 of the test drivers after de-installation of ISA in their vehicles.

Interviews with passengers on ISA buses and taxi

The aim of the interview study with passengers of buses and a taxi equipped with ISA system was to study how passengers experience the system. Whether they realise that the driver drives in a different way with the system than previously without it, and what kind of difference do they realise. The hypothesis that has been tested was that passengers of ISA equipped cars do not experience the ISA system as disturbing. 60 bus passengers were interviewed when they travelled by an ISA equipped bus, while taxi passengers got an interview form from the driver of the ISA equipped taxi, and they were asked to fill in and send it to us. 15 answered.

Interviews with pedestrians

The aim of the study was to detect system-effects of the implementation of ISA that affect pedestrians. In Lund, 100 pedestrians were interviewed at two intersections in the before period, and approximately 160 at the same intersections in the after period. Parallely, 110 pedestrians were interviewed at two control-sites in Helsingborg during the before period, and at one of them during the after period.

Behavioural observations

Data logging

All 284 vehicles were equipped with data-logging facilities and a flash-memory. This makes it possible to register and save data among others on speed, speed limit, position, time and date, and voluntary use of the system outside the test area. Data was saved 5 times per second when the vehicle was within the test area and once a second outside the test area. The driving data was logged for one month before the ISA was activated and then during the entire trial. The logged data was used to analyse changes in speeds fuel-consumption and travel-time.

In-car observations

A selection of 28 drivers, distributed by age group and gender, was observed using the "Wiener Fahrprobe" method (Risser, 1997). Two observers studied the driver on a standardised test-route in an instrumented vehicle where data such as speed, acceleration and distance to the vehicle in front were registered. One of the observers looked at standardised variables such as speed, yielding behaviour and lane keeping, etc., the other observer made "free" observations looking at driver behaviour and interaction with other road-users. The in-car observations were carried out twice, once before the installation of ISA in the test drivers' own cars and once at the end of the trial.

Studies of system-effects

Field studies were carried out in Lund as well as in a control city, Helsingborg. The objective of the control studies was mainly to keep possible general changes in the traffic-situation under control.

Speed measurements

The aim of speed measurements in field was to reveal if the presence of ISA vehicles in Lund influenced the speed level or time headways in the city. The speed at critical spots, i.e. intersections and zebra crossings was measured with radar gun and on stretches with pneumatic tubes. In connection with tub-measurements of speeds also time headways between vehicles were measured. Control measurements were carried out in another city of the same size; Helsingborg.

Observations of red light violations

The aim of the study was to observe if drivers of ISA cars differ from non ISA drivers concerning red light violation and if the large scale use of ISA in Lund could give system effects (i.e. the share of vehicles violating red light changes) through influence from the vehicles equipped with ISA. Possible effects from ISA would also be separated from other factors. Control measurements were carried out in the city of Helsingborg in order to keep underlying factors under control. The study was designed as a before/after study with

control. Vehicles arriving at the traffic light after the green/amber change and under the red phase were registered manually of observers in the field and the share of cars violating red was calculated.

Interaction studies

The aim of the interaction study was to analyse indirect effects of the ISA system in situations where the prevailing speed is lower than the speed limit, and where ISA drivers have to negotiate on priority with other road users. The situation selected for study by analysing video-recordings was the priority of pedestrians when meeting ISA respective other cars at a pedestrian crossing.

Accidents

The aim of the accident study was to find out whether test drivers' accident history differed from the "average" Swedish drivers', and to follow up on any accident that would occur involving an ISA-car, and to find out whether that accident might have any kind of relation to the use of the ISA-equipment.

RESULTS

Some of the data analyses are still under processing at the time when this paper is written, therefore some of the results are preliminary (marked when appropriate), however, most of the results are based on completed analyses.

Attitudes, experiences, acceptance

Attitudes among the public in Lund

The results from the baseline questionnaire to the public showed that road safety is the most important of the presented aspects when driving in urban areas, followed by travel time, travel costs and the environment. There seems to be a strong interest for traffic safety issues and a consciousness that speed has an important role for traffic safety. All respondents agree with the statement that there is a strong relationship between speed and the risk of accidents and that the number of accidents would decrease if everybody kept the speed limit. Women regard road safety higher than men and so do elderly compared to young people. Men are to a greater extent of the opinion that it is more important to follow the general tempo in traffic than to keep the speed limits than women. Most of the respondents consider the current speed limit of 50 kph in urban areas appropriate while the 30 km/h limit is considered too low. The respondents judge their own compliance with the speed limit in urban areas as generally good and especially good for streets with 30 m/h speed limit. The most efficient measures to increase road safety according to the respondents are: 1) more pedestrian and cycling lanes, 2) more visible presence of the police in traffic, 3) grade-separated junctions. Measures, judged as least efficient, are more traffic rules and lower general speed limits.

Attitudes and acceptance among test drivers

There are good prerequisites for the acceptance of the active accelerator pedal in general:

- The test drivers generally think that ISA systems are efficient for increasing traffic safety.
- It was emphasized that the risk of being caught for speeding within the test area decreased significantly. The test drivers thought that it became easier to comply with the 30, 50 and 70 km/h speed limits.

- 40 % of the test drivers thought that the best thing with the active accelerator pedal in the car was that they did not have to keep in mind what the actual speed limit was.
- At the same time the test drivers regarded themselves as compliant with regulations ("more compliant than the others") which in some way would make ISA superfluous.

The prerequisites for the acceptance of ISA are less good at individuals with a negative initial attitude to the active accelerator pedal:

- They feel to be more in the way for others in traffic, they feel more frustrated for being a hindrance for others.
- They experience a larger time pressure, stress and less driving pleasure and they feel that it is more laborious to drive with the active accelerator pedal than without.
- They agree to a less extent with the statement that the active accelerator pedal should be mandatory in built-up areas and they agree to a less extent with the statement that there should be a law that all cars should be equipped with an active accelerator pedal than persons with positive initial attitude.

The test drivers revealed that it became a habit to them to comply with the speed limit and their speed decreased. After a long-time use of ISA they think that they need to accelerate and brake less and they look less often at the speedometer. They let their foot "rest" relatively often on the counterforce of the accelerator pedal, even as some of them, mostly elderly drivers, try to drive in such way that the active accelerator pedal would not be activated.

According to the drivers' own statement it happens some times that they continue to exceed the speed limit, even after the accelerator pedal has given a counterforce, i.e. they use the "kick down" function. This is said to occur significantly more often towards the end of the trial. Young and initially negative drivers continue to exceed the speed limit to a larger extent than older and initially positive drivers. Individuals with initially negative attitude to the active accelerator pedal have a tendency to make more frequent use of the "kick down" function than initially positive drivers. On the other hand there is no direct indication on occurrence of compensatory behaviour in low speed situations.

The test drivers estimate that they lowered their speed on stretches with 30, 50 and 70 km/h speed limit also outside the test area, even though not to the same extent than within the test area. This is an indication of a positive behaviour transfer. They estimated their speed unchanged on roads with 90 and 110 km/h speed limit outside the test area. According to the test drivers their compliance with traffic rules has improved. They stated that their attention to speed limit signs decreased within the test area, while it increased outside the test area. They stated that their attention to incidents along the road side and their showing consideration for bicyclists and pedestrians increased. They believe that their distance keeping to the vehicle ahead improved too.

They said that they did not choose another way to avoid the 30 km/h streets within the test area. But they believed that travel times increased (which is not supported by the results from data logging in their cars). Fuel consumption was estimated to be unchanged.

The test drivers' experience of being controlled and their wish to switch off the active accelerator pedal increased with time. They felt larger time pressure, being in the way for others in traffic and more frustrated. Their willingness to pay for keeping the ISA system in their car decreased by about 20 % from the beginning of their driving with the system to about 90 EUROS on average at the end of the trial. One reason to this may be the frequent problems with the technology. 47 % of the test drivers stated that they had to visit the workshop where the ISA was installed because of system brake down.

Those test drivers who did not experience any problems with the technology did not experience it frustrating or laborious to drive with the system. They stated that it was easier to comply with the speed limits and experienced that they became better drivers and thought that their subjective safety increased to a larger extent than those who experienced problems with the technology. Those test drivers who did not experience any problems with the technology was the group of individuals who gave highest attractiveness to the active accelerator pedal.

Log-book comments of test drivers

Technical problems with the equipment in some way disturbed the possibility to assess the ISA system in an unbiased way. Such problems made more test persons than "necessary" leave the experiment. What was written in the diary shows that some press by other car drivers is felt, that risk compensation and delegation of responsibility can be identified to a certain degree, and that phenomena of behaviour generalisation can be observed, as well, but the latter mainly in its positive form. The test drivers also express their general feeling that their driving style has become more relaxed, and that they are more conscious of both speed limits and speed problems.

In-depth interviews with test drivers

The majority of the interviewed believe that measures to control vehicle speeds are necessary and that society should sponsor such activities; measures of ISA-type are considered adequate in this respect; further research on ISA is considered important; improvements of ones own behaviour due to ISA are reported by part of the interviewed persons, some of them could not identify any changes, but nobody stated that his/her behaviour had deteriorated. It became clear that technical problems have the potential to disturb practical acceptance, so that the principle of ISA is considered positive but it is added that in practice the equipment will have to function better technically speaking in order to deploy its positive effects.

Passengers' experience on ISA vehicles

Passengers of ISA equipped vehicles did not experience the ISA system as disturbing. Bus passengers were not aware of that the ISA system was functioning on the bus they travelled with, and did not notice any effect, either positive or negative. Taxi passengers were more aware of the system – maybe the taxi driver spoke to them about the system when he gave them the questionnaire. Those taxi passengers who indicated some difference between the ISA equipped and "ordinary" taxis experienced the difference as positive concerning comfort, speed and traffic safety.

Pedestrians' experience

The conclusion of the analysis is that we could not detect any effects on pedestrians with regard to traffic climate and interaction (neither negative nor positive) due to the fact that 284 cars were equipped with ISA in Lund. There were no signs that the hypotheses that had been underlined several times during earlier studies and projects, namely that ISA could lead to a deterioration of the communication between drivers of equipped cars and pedestrians, is valid in any respect.

Effects on driver behaviour

The results from speed measurement in field revealed that no general changes in the speed level could be shown either in Lund or in Helsingborg. Similarly, when it comes to time headways, no changes could be shown either in Lund or in Helsingborg. The conclusion from the study is that no system-effects considering speeds or time head ways could be shown of the fact that 284 ISA vehicles were circulating in traffic in Lund for a period of 5-11 months.

The results from observation of red light violation showed a general tendency with increasing share of cars violating red light both in Lund and in Helsingborg. The increase was of the same order, near one percent in both cities. The number of cars equipped with ISA passing the observed approaches during the observation periods was so little that it was not possible to do a comparative analysis between ISA and non ISA vehicles. The conclusion was that the study could not show any system effects on red light violation of the fact that ISA vehicles were circulating in traffic in Lund.

Observations of interactions with other road users in field showed that ISA car drivers' behaviour when meeting pedestrians at a pedestrian crossing generally did not differ from other car drivers' behaviour. It means that they did not give priority to pedestrians more often, in spite of their somewhat lower speed. This also means that the drivers of ISA cars did not compensate in these situations for not being able to drive over the speed limit. The drivers of Lund city buses with ISA system did not give priority to pedestrians at a pedestrian crossing as frequently as drivers of non-ISA buses. The difference is not significant, only a tendency, but indicates that bus drivers who have to keep the time table, try to compensate for not being able to drive over the speed limit, by higher speeds in low speed situations.

The results from in-car observations of test driver behaviour showed that the test drivers' priority giving to pedestrians improved, as well as distance keeping to the car ahead, while speed adaptation before hinder deteriorated slightly.

The analyses of logged data in the test drivers' own cars (before activating the ISA) indicate that the speed limit is exceeded to a large extent. An overview of the percentage of speeding cars on different stretches in the road network before (without ISA) and after (with ISA) is presented in figure 1 and 2. A preliminary comparison between the speeds of "normal drivers" measured in field and speeds of the test cars in the before situation showed that these did not differ from each other. In the after period the test cars' speeds on average decreased by 1.6 km/h while the average speed of the "public" was unchanged. Travel speeds (reflecting travel times) did not change significantly. The average travel speed for the whole test vehicle population (stops included) was 34.2 km/h before and 34.4 km/h with ISA.

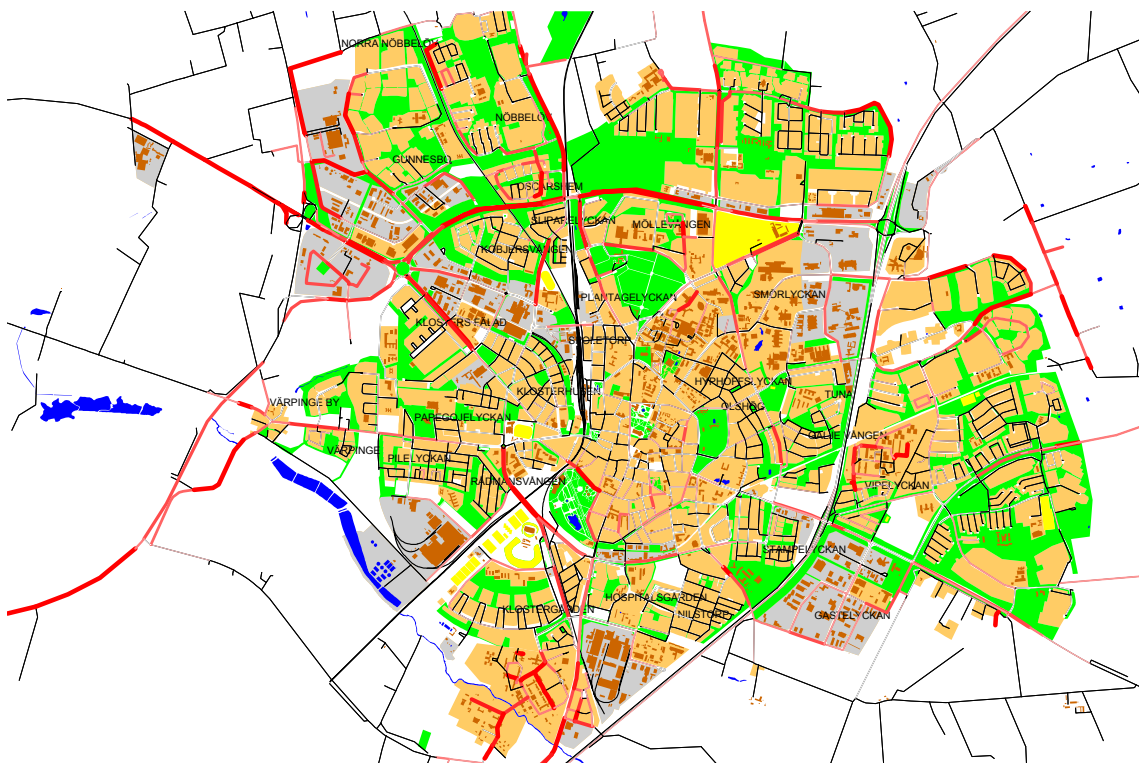


Figure 1. Percentage of test cars driving over the speed limit – Before

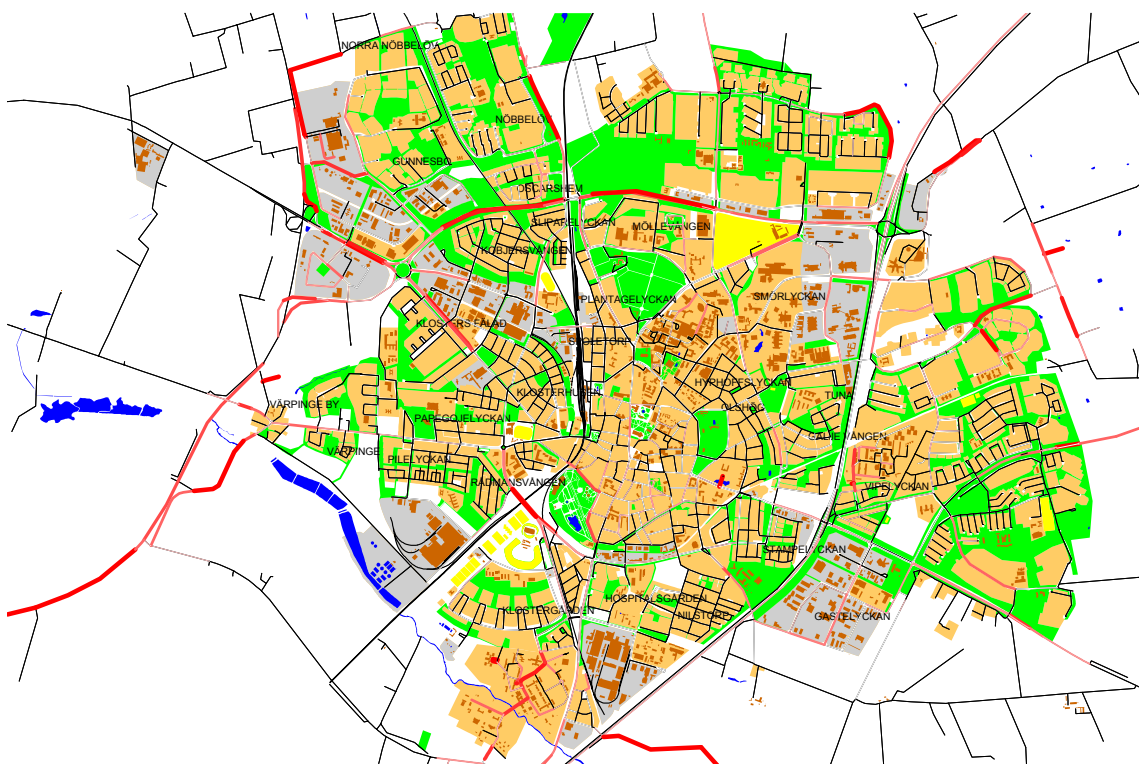


Figure 2. Percentage of test cars driving over the speed limit – with ISA

Preliminary results on speeds on links show that mean speeds at mid-block sections on main streets decreased statistically significantly ($p < 0.05$), on average by 2.0 km/h. An example of a profile of mean speeds before, one month after and 5-11 months after the activating the ISA system is shown in figure 3. No compensatory behaviour in form of higher speeds when approaching intersections and turning at intersections could be found.

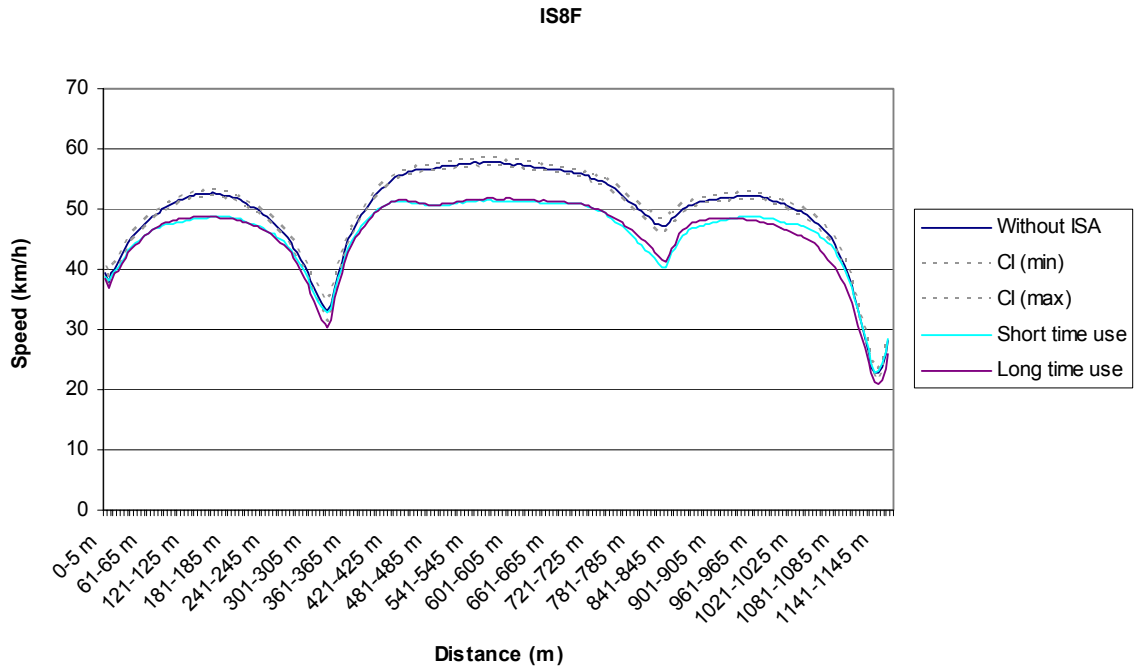


Figure 3. Profile of mean speeds on a main street before, one month after and 5-11 months after the activating the ISA.

The accident study revealed that it was not possible to identify any general change of the accident trend in Lund. It was therefore concluded that there was no sign of a system effect due to the use of 284 ISA-vehicles in Lund. ISA had nothing to do with the accidents that occurred with ISA-equipped cars, i.e. we could not identify any negative effects on accidents due to ISA.

CONCLUSIONS

The results from the evaluation studies revealed that drivers' speed behaviour improved and at this stage practically no negative compensatory effects could be found. Compliance with the speed limits increased both according to the test drivers' own statements and objective measurements.

The test drivers generally think that the active accelerator pedal is efficient for increasing traffic safety and experience it as a support in car driving. However those who would need it mostly are most negative to the idea.

It became clear that technical problems have the potential to disturb practical acceptance, so that the principle of ISA is considered positive but it is added that in practice the equipment will have to function better technically speaking in order to deploy its positive effects. Before further research work is carried out, therefore, the equipment will have to be further improved, so that it works perfectly when test persons use it in the field. The problem at the moment is that perfect functioning will probably only be possible if the number of car makes or car types is reduced to just two or three where one can feel sure that everything works in a way that people are used to when they drive a modern car.

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