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Preliminary results from the Danish Intelligent Speed Adaptation Project Pay As You Speed

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Abstract: The driving behaviour of participants in the Danish Intelligent Speed Adaptation (ISA) project 'Pay as You Speed' (PAYS) is described. The project is the first ISA project based on Pay as You Drive principles. Thus, the ISA equipment both notifies the driver that he/she is speeding ('information') and applies penalty points which decrease the driver's chance of a potential 30% discount on the cost of his/her automobile insurance ('incentive'). The results presented are based on the first 38 of 180 participants. The key result is that the combination of 'information' and 'incentive' almost eliminated speeding on rural roads while significant reductions in speeding were found also for urban roads and to some extent motorways. On roads with speed limits of 50, 80 and 110 km/h the proportion of distance travelled when speeding was reduced significantly. No significant results were found for motorways with speed limits of 130 km/h. In a future paper the final results from 'PAYS' will be presented.

1 Introduction

In 2001 Europe's grim road accident statistics indicated more than 40 000 fatalities, which forced the European Commission to set a target of reducing the number of road fatalities in Europe by 50% by 2010 [1]. Nevertheless, in 2005, 41 000 people were killed and 1.7 million were severely injured on Europe's roads. To achieve the goal that was set, more has to be done to prevent accidents from occurring. Intelligent Speed Adaptation (ISA) and other Intelligent Transport Systems will certainly be a central tool for reaching this goal [2].

ISA is a general term for systems that compare the speed of a car with the speed limit at the car's location. In most new ISA systems, the geospatial position of a car is used to compare the car's current position and speed with a digital road map, which includes the local speed limits. If the speed limit is exceeded, the ISA equipment issues a response. There are various forms of response; it can consist of a visual and/or audible warning in real time, registration of the speed limit violation in an on-board car computer, resistance to further speeding built into the accelerator and speeding made impossible. The different ISA systems can be categorised as informative, advisory, recording or intervening systems [3].

In the last decade, many ISA projects in several European countries and in Australia have shown the potential of ISA. The large-scale Swedish trials in Borlänge, Lidköping, Lund and Umeå during the period 1999–2002 involved almost 5000 cars. One of the main results was an average speed reduction of 3–4 km/h [4].

The first ISA project in Denmark was with informative and advisory ISA and was called INFATI. It was conducted at Aalborg University from 1998 to 2001. The actual speed limit was shown on a display,

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while the advisory system had a female voice stating the speed limit and the sentence 'You are driving too fast' every 6 s if speeding. The project consisted of only 24 drivers tested for 6 weeks, but the results from INFATI were promising. A speed reduction of up to 5–6 km/h was reported. Compared with other ISA projects, the INFATI project took place in both urban and rural areas. The largest reduction in speed was found in the rural areas, where speed limit compliance was smaller [5]. The results are remarkable considering that the majority of severe accidents and fatalities happen in rural areas [6].

In the Australian TAC Safecar project, which was carried out from 2002 to 2004 in the Melbourne area, a reduction of up to 2.7 km/h was found for the 85th percentile speed. Moreover, speeding by more than 5 km/h was reduced by up to 57% [7].

Further, a recent Swedish ISA project carried out from 2003 to 2005 in Stockholm, Sweden, indicated some promising results. For a speed limit of 30 km/h, no reduction in speed was registered. On roads with speed limits of 50–110 km/h, a reduction of 1.1–2.0 km/h was reported. In general, driving speed was distributed closer to the speed limit when driving with ISA [8]. A field trial carried out in Belgium showed a reduction of up to 2.5 km/h for the 85th percentile speed [9]. Finally, ISA trials carried out in the UK [2] and the Netherlands [10] have shown promising results. In general, the ISA projects conducted to date have shown that ISA is effective in reducing speed and, in particular, on roads with high speed limits.

1.1 Pay As You Speed project

A fundamental hypothesis in many of the ISA projects carried out to date has been that motorists would like to comply with speed limits, but find that, in practice, complying with speed limits can be difficult in a modern, comfortable car. Therefore the purpose of ISA is to support the motorist in choosing the proper speed. The assumption is that speeding will be avoided, as drivers who receive such support will no longer speed. Many ISA experiments have shown support for the hypothesis; speed falls and the users say that they are pleased to have ISA in their vehicles. However, despite the general effectiveness of ISA and users' support of the system, there has not, until recently, been a breakthrough for ISA in the commercial market. There is much to indicate that more than goodwill is needed before drivers voluntarily invest in ISA. How can we reward drivers, who drive with ISA? In this project the effect of bonus on the insurance rate to ISA drivers is studied.

Therefore it has been desired to select a group for this study, which has been under-represented in most ISA projects. Other studies have also indicated that the drivers who need ISA the most are less willing to have it [11]. Young drivers are under-represented in most ISA projects [12]. Moreover, it is well known that young drivers aged 18–28 years have a high accident risk. They are less likely to adhere to speed limits and they are less experienced. In Denmark, statistical studies have shown that this group has up to seven times higher traffic accident risk than drivers in their parents' generation [13]. Finally, young car owners also pay a high insurance rate on their car. Hence, young car owners aged 18–28 years have been targeted to serve as participants in this study.

The young drivers' high accident risk and their resistance to voluntary ISA formed the overall hypotheses for the project: a speeding-dependant bonus on the insurance premium will get young car drivers to accept ISA in their car and such an ISA system will reduce their speeding. We call the principle Pay As You Speed (PAYS) with reference to the term Pay As You Drive which is often used about car insurance, where the premium is calculated depending upon vehicle usage, particularly distance travelled.

The PAYS project is based on experiences from the INFATI project and consists of three parts. The first part involved creating a digital speed map of 22 000 km of road covering the County of North Jutland in Denmark. The second part involved the development of Global Position System (GPS)-based ISA equipment, with high reliability. The third part involved recruitment of up to 300 car owners aged between 18 and 28 to take part in a 3 year study of which the first 6 months would be driven under special conditions to test the effectiveness of incentive and informative forms of ISA. For participating in the study, drivers were offered a 30% discount on their car insurance premiums. However, were the drivers to speed, then the amount of discount received would be reduced in accordance with the degree and length of the speeding.

After an initial 'baseline period' (no ISA), participants were assigned randomly into one of four ISA groups: 'incentive' only, 'information' only, 'combination' (i.e. incentive and information), and 'no treatment' (i.e. the 'control' group). The latter group continued as in the 'baseline period'. Participants' speeding performance during the treatment period was compared with their performance in the 'baseline period'. The results presented in this paper derive from 38 participants only and on data collected during the first 3 months of the project period. Hence, the results are preliminary. The low number of participants in this study is caused by a slower recruitment than expected.

The following three hypotheses guided the analyses presented in the current paper:

1. It is expected that 'incentive ISA' reduces the proportion of speeding and the speed variation.

2. It is expected that 'informative ISA' reduces the proportion of speeding and the speed variation.

3. It is also expected that the combination of 'incentive ISA' and 'informative ISA' is more efficient than each of them.

2 Methods

2.1 Equipment

The ISA1 equipment ['On Board Unit' (OBU)] used in the current project obtains the car's position from a GPS receiver. In the OBU, the position is matched to the speed map and the actual vehicle speed is compared with the speed limit of the location. The actual speed limit is shown on a display, which is positioned in front of the driver. It is shown when the ignition is turned on. If the car exceeds the speed limit by more than 5 km/h, the driver receives a verbal warning. The warning is repeated every 6 s until the speed is back below the speed limit +5 km/h. The third and subsequent warnings result in penalty points. The number of penalty points increases gradually, so a small violation results in fewer penalty points than does a serious and dangerous violation. The size of the speed violation which activates the ISA is selected because most Danish road users drive close to the speed limit, but not necessarily below it. So, if we had made a system that reacted as soon as the speed limit was met, the participants would have felt pressure too often from the cars driving behind them. Also, the Danish rules for speeding fines incorporate these principles. No fine is received if speeding is less than 10% of the limit +3 km/h.

Once every second the OBU generates a GPS-based position including the speed limit, actual speed, position and quality of the map matching. This is called the 'one second log'. These data are transferred during the night via general packet radio service (GPRS) to a database for storage for research purpose, while the penalty points are reported to the participants on a webpage immediately after the end of each trip.

Every 6 months, penalty points are calculated for each participant. If the participant has earned no penalty points, the participant receives a 30% discount on his/her car insurance rates. Each penalty point deducts 7 Euro cents from this discount. No matter what the number of penalty points, the insurance rate can never be higher than it was before the driver participated in the ISA project. For more information about the project design, see Lahrmann *et al.* [14].

2.2 Participants

In this article, the participants' performance in the 'baseline period' is compared with the next 1.5 months (subsequently named 'ISA period'). In all 38 participants, 11 women and 27 men, aged 18–28 years, were included in this study. The 38 participants were the first of 180, so the results are preliminary. There are nine participants in the 'information' group, ten in the 'incentive' group, ten in the 'combination' group and nine in the 'control' group. These four groups are described in the next section.

2.3 Research design

In PAYS, the participants have the equipment in their cars for 3 years in total. However, to determine the effect of the equipment, a 1.5 month 'baseline period' in the initial project period is recorded. During this time, the participants drive with the display and the voice message switched off, so their 'normal' driving is recorded. In the next 4.5 months the participants are randomly assigned to one of four different groups (as shown in Table 1).

By comparing the driving performance in these four groups with driving during the 'baseline period', the effect of 'incentive', 'information', the 'combination' of these and the 'control' group can be measured. During the remaining 2.5 years, all the participants drive in the 'combination' mode. Comparisons between the four groups in the 'ISA period' are based on differences between the 'baseline' and 'ISA period' for each person.

2.4 Procedures

2.4.1 Data: This study is based on the 'one second log'. Data are recalculated, so it is suitable to do mileage-based studies. Effect from ISA in the first 1.5 months of the 'ISA period' will be compared with the driving in the 'baseline period'. In these 3 months, the 38 participants drove approximately 158 000 km in total, the majority of which was distributed across the following road types:

- Roads with a 50 km/h speed limit, which is the normal speed limit in urban areas (subsequently named '50 km roads' etc.),

- Roads with an 80 km/h speed limit, which is the normal speed limit in rural areas and

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Table 1 Four groups

		Incentive	
		−	+
information	−	control group: the participant receives neither information nor warnings or penalty points and continues like in the first one and a half months	incentive group: the display and the voice message are switched off and no information or warnings are given. The participant gets penalty points if speeding
	+	information group: the display and the voice message are connected and information and warnings are given. Speeding gives no penalty points	combination group: the participant receives information and warnings and gets penalty points if speeding

- Roads with a 110/130 km/h speed limit, which are the normal speed limits on motorways.

In all, 87% of the 158 000 km were driven on these roads, and hence the following results are based on mileage on roads with these speed limits. The remaining 13% mileage is not analysed further, since the number of kilometres on roads with the remaining speed limits is low and the results might be too uncertain.

The participants' behaviour is registered by 12 million GPS positions in total. This amount of data corresponds to approximately 1 h of driving per participant each day.

2.4.2 Analysing data: All results concerning speeding are based on mileage and not the time span. Time used is primarily useful when average speed and travel time are studied. When studying speeding, the use of time can result in bias, since a large violation of the speed limit will be underestimated compared with a minor one [9].

Because ISA gives warnings and any penalty points if the speed limit is exceeded by more than 5 km/h, the proportion of distance travelled above this speed is compared. Moreover, research has shown that the amount of speed variation influences the accident rate. The more the variation of speed the more are the accidents [15]. A reduced speed variation therefore indicates that the ISA equipment can reduce the number of accidents more than just related to the reduction of speed. To avoid blurring data and to avoid bias from congestion and idling, these results are based on the mileage where speed is higher than the speed limit minus a fixed proportion of kilometres per hour. On 50 and 80 km roads, it is −15 km/h; on 110 km roads it is −20 km/h and on 130 km roads it is −30 km/h. For example, for roads with a 50 km/h speed limit all mileage which is carried out with more than 35 km/h is included. These outcomes are here denoted as 'mean free flow speed' (MFFS; see Table 2).

This definition of free flow is not without controversy. We have contacted many scientists studying ISA-related subjects via the International Working Group on Speed Control (IWGOSC) mailing list. IWGOSC is a world-wide group of experts regarding ISA and related objectives. Some define free flow as all speeds above 15 km/h, whereas others suggest that free flow is all data when speed is above 50 km/h on motorways. In the Australian TAC SafeCar Project, the cars were equipped with a 'following distance warning' (FDW) system and hence they could sort out data if the vehicle in front was closer than 3 s [7]. A fourth suggestion was to remove all mileage during rush hours. However, our cars are not equipped with FDW and if we remove all mileage during rush hours, the amount of data collected will be low and hence too uncertain.

To calculate MFFS the average speed for all speed included as mentioned above is used. This definition of MFFS is a trade-off between two considerations. 1) Because of the fact that more the data, all things being equally result in more reliable results, as much data as possible are required. 2) Driving data from speeds far less the speed limit are of no relevance when

Table 2 Speeds for each speed limit, which is included in MFFS

Speed limit	50 km/h	80 km/h	110 km/h	130 km/h
Mean free flow speed	>35 km/h	>65 km/h	>90 km/h	>100 km/h

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measuring ISA based on average speeds and should be avoided. Therefore we decided to use the above-mentioned limits of speed when defining MFFS.

2.4.3 Statistical analyses: To study the effects of 'incentive' and 'information' on the proportion of distance travelled with speeding above 5 km/h, for each speed limit we examine the difference between this variable in the 'ISA period' and the 'baseline period' (Section 3.1). Some participants did not attain any mileage in some of the speed limit classes. Hence, for some speed limits, the number of observed differences is <38.

Up to 38 differences are divided into four groups corresponding to the four combinations of incentive and information in the 'ISA period'. Let $i = 0,1$ correspond to no incentive or incentive and $j = 0,1$ to no information or information. The 'control' group then, for example, corresponds to $i = 0$ and $j = 0$. For the difference d_{ijk} for the kth person in the ijth group, we employ a two-way analysis of variance model

$$d_{ijk} = \begin{cases} m + e_{ijk}, & i = 0, j = 0 \\ m + a + e_{ijk}, & i = 1, j = 0 \\ m + b + e_{ijk}, & i = 0, j = 1 \\ m + a + b + c + e_{ijk}, & i = 1, j = 1 \end{cases}$$

In this formula, m is the mean difference for the 'control' group, e_{ijk} a normally distributed noise term and c an interaction parameter. If c is zero, the effects of 'incentive' and 'information' are additive and given by a and b, respectively. That is, in the absence of an interaction the expected difference between the 'combination' and the 'control' groups is $a + b$. A priori, one might expect $m = 0$.

In some cases the assumption of normally distributed noise was violated by the presence of outlying observations. To study the influence of such observations, we also did analyses excluding these observations but obtained qualitatively same results regarding the significance of model terms.

In addition to the proportion of distance travelled with speeding above 5 km/h, we consider MFFS and the standard deviation of 'free flow speed' computed as follows. For each person the MFFS is obtained by weighting each MFFS value with the proportion of the mileage travelled at this speed. Similarly, we compute a mean squared deviation (FFSD) for each person by weighting the squared distances between the MFFS values and the MFFS with the proportions of mileages for the speed values. The standard deviation FFSD is the square root of the mean-squared deviations.

The statistical analyses for MFFS and FFSD proceed exactly as for the proportion of mileage with speeding using a two-way analysis of variance for person-specific differences concerning these variables.

3 Results

3.1 Proportion of distance travelled while speeding

Table 3 shows the proportion of distance travelled at a speed exceeding the speed limit by more than 5 km/h in the four groups 'incentive', 'information', 'combination' and 'control' in the 'baseline' and 'ISA periods'.

It appears that the largest effect of ISA is found on rural roads with a speed limit of 80 km/h and to some extent on motorways with a speed limit of 110 km/h and on urban 50 km roads. As mentioned earlier, experience from the INFATI project showed that people have a higher acceptance of urban speed limits than rural, thus, the greater effect on 80 and 110 km roads can be explained. Also, questionnaires completed by young Danish automobile owners have shown that they have the lowest acceptance of speed limits of 80 km/h and a higher acceptance of the speed limits on both urban roads and partly on motorways [12]. Furthermore, it is likely that a large proportion of drivers consider 130 km/h to be fast enough. The differences between the four groups in the baseline period may be due to random variation since the results are based on a short time span and a small number of persons.

When comparing the four modes, it appears that the effect of 'incentive' in this first phase of the trial is less than from 'information', with a reduction in speeding by 4% on 50 km roads and 5% on 80 km roads. On 110 km roads, the reduction is 9% and on 130 km roads it is 3%. For participants receiving 'information' without 'incentive', the reductions are 5, 14, 18 and 1% for the four road types. When given both 'incentive' and 'information', the results are even better on 50 and 80 km roads: 11, 26, 14 and 4% for 50, 80, 110 and 130 km roads, respectively. For participants in the 'control' group the reductions is 2 and 3% for the 50 and 130 km roads, respectively, whereas increases of 5 and 16% are recorded on 80 and 110 km roads. This increased proportion of distance travelled with speeding above 5 km/h for the 'control' group will be discussed later. However, a similar but not significant trend is also found in the Australian TAC Safecar project [7].

To study more incisively the effects of incentive and information, two-way analyses of variances were fitted to person-specific differences between the proportion of

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Table 3 Proportion of distance travelled exceeding the speed limit by more than 5 km/h

		Speed limit							
		50 km/h		80 km/h		110 km/h		130 km/h	
		%	Change, %	%	Change, %	%	Change, %	%	Change, %
incentive	baseline	9	−4	19	−4	23	−9	7	−3
	ISA	5		15		14		4	
information	baseline	8	−5	18	−14	24	−18	2	−1
	ISA	3		4		5		1	
combination	baseline	13	−11	29	−26	16	−14	4	−4
	ISA	2		2		2		0	
control	baseline	16	−2	29	5	14	16	7	−3
	ISA	15		34		30		4	

distance travelled with speeding above 5 km/h in the 'baseline period' and the 'ISA period' (Section 2.4.3). For all speed limits, the interaction terms were not significant, so that the effects of 'incentive' and 'information' are additive. Table 4 includes the estimated effects *a* and *b* of 'incentive' and 'information' along with *P*-values (in parentheses) for the significance of these effects. Also the estimated mean difference *m* for the 'control' group is given.

The estimated effects of 'information' are in general a bit bigger than the estimated effects of 'incentive', indicating that 'information' is the most important factor for reducing speed. The effect of 'information' is significant at the 5% significance level except for 130 km roads, whereas 'incentive' is significant only for 80 and 110 km roads. Since the effects of 'incentive' and 'information' both lead to reduced speeding, the 'combination' of these effects is significant except for 130 km roads. One should expect a zero mean difference *m* between the 'ISA' and the 'baseline period' for the 'control' group. This parameter is, however, significantly different from zero for 80 km/h roads where the *P*-value, 3.7%, is just below the 5% significance level.

3.2 Speed variation and MFFS

Table 5 shows MFFS and free flow speed standard deviation FFSD (Section 3.3) obtained by merging the data for all the persons within each of the groups. Hence the proportion of distance travelled used to calculate the MFFS and FFSD values are those given in Figs. 1–4.

On 50 km roads, only minor changes in MFFS are found for the 'incentive' and 'information' groups. The effect on 80 km roads is also limited for the 'incentive' group and slightly larger with 2.5 km/h for the 'information' group. For the 'combination' group, a reduction by 2.8 and 5.4 km/h, respectively, on 50 and 80 km roads is observed, whereas the 'control' group hardly changes on urban 50 km roads and increases the speed by 2.2 km/h on rural 80 km roads. On 110 km roads, a small reduction is observed for the 'incentive' group and a larger reduction, 3.1 km/h, for the 'information' group. The 'combination' group barely changes, whereas a smaller increase of 2.3 km/h is observed for the 'control' group. On 130 km roads, no clear effect is found and the changes here are probably based on random behaviour.

Table 4 Estimated effects of 'information' and 'incentive' on proportion of distance travelled with speeding more than 5 km/h and estimated mean difference for 'control' group

	Speed limit			
	50 km/h	80 km/h	110 km/h	130 km/h
incentive	−4.2 (0.053)	−12.9 (0.006)	−13.1 (0.013)	−0.6 (0.971)
information	−6.0 (0.007)	−16.7 (0.001)	−14.7 (0.006)	−2.2 (0.207)
control	1.8 (0.333)	8.47 (0.037)	7.9 (0.095)	0.6 (0.715)

Table 5 MFFS (km/h) and FFSD for 'baseline' and 'ISA' for the four groups

		Speed limit							
		50 km/h		80 km/h		110 km/h		130 km/h	
		MFFS	FFSD	MFFS	FFSD	MFFS	FFSD	MFFS	FFSD
incentive	baseline	47.1	7.5	80.3	8.4	111.0	9.0	121.1	10.6
	ISA	46.4	7.0	79.4	8.3	109.7	7.5	122.0	8.9
information	baseline	47.1	7.3	81.1	10.1	110.3	8.9	120.4	7.1
	ISA	46.3	5.9	78.6	6.3	107.2	6.1	120.7	7.3
combination	baseline	49.1	9.0	83.4	10.7	107.4	9.0	116.9	10.1
	ISA	46.3	6.1	78.0	5.3	107.2	6.4	117.2	8.9
control	baseline	49.9	9.0	83.6	10.3	110.0	7.8	119.9	10.5
	ISA	49.7	8.6	85.9	12.4	112.3	9.3	121.8	8.2

According to the two-way analysis of variance for person-specific MFFS differences, there is no interaction effect between 'incentive' and 'information'. The estimated effects of 'incentive' and 'information' on MFFS and the mean difference for the 'control' group are shown in Table 6, with *P*-values in parentheses. The estimated effects of 'information' were again a bit bigger than those for 'incentive' and all the effects were significantly different from zero at the 5% significance level except for 130 km roads. As in Section 3.1, the mean difference for the 'control' group was somewhat counter intuitively significantly different from zero for 80 km/h roads.

Speed variation FFSD indicates the range of speed on a road. If it is small, it means that most of the traffic is driving at almost similar speeds. On 50 km roads, only larger reductions for standard deviation are found for the 'information' and the 'combination' groups, with 1.4 and 2.9 km/h, respectively. On 80 km roads, the effect is even bigger for the two groups, with 3.8 and 5.4 km/h, respectively, whereas an increased FFSD is found for the 'control' group. On 110 km roads the same trend is found even if the difference between the 'information' and the 'combination' is limited. On 130 km roads no clear and obvious changes are found.

Turning to the two-way analysis of variance, the interaction effect for 'information' and 'incentive' was insignificant also for FFSD. Table 7 shows estimated effects of 'information' and 'incentive' and estimated mean difference in the 'control' group as well as *P*-values in parentheses. The estimated effects of 'information' and 'incentive' are all negative, corresponding to reduced FFSD. However, the 'incentive' effects were only significant at the 5% level for 80 km roads, whereas the 'information' effect is significant both for 50 and 80 km roads. Again the mean difference for the 'control' group is significantly different from zero only for 80 km/h roads.

Figs. 1–4 show the proportions of 'free flow speed' distance travelled at each speed value. On 50 km roads (Fig. 1), the proportion of distance travelled above the speed limit +5 km/h is minimal for the 'combination' but barely bigger for the 'incentive' and the 'information' groups. For the 'control' group, the proportion is higher. The variation differs only slightly between the 'information' and 'combination' groups with an FFSD of 5.9 and 6.1 km/h, respectively. The FFSD is slightly bigger for the 'incentive' group and is biggest for the 'control' group. The lower variation for the 'information' group and the 'combination' groups is mostly caused by high speeds, which have disappeared.

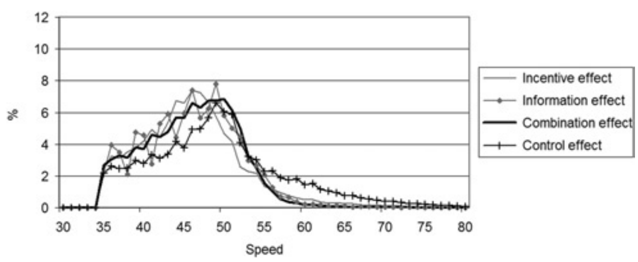

Figure 1 *Speed distribution on 50 km roads in the 'ISA period' for the four groups based on MFFS*

The speed distributions for 80 km roads are shown in Fig. 2. The variation differs somewhat between the 'information' and 'combination' groups with an FFSD of 6.3 and 5.3 km/h, respectively. The FFSD is somewhat bigger for the 'incentive' group and biggest for the 'control' group, with an FFSD of 8.3 and

12.4 km/h, respectively, and hence the speed distribution for the 'control' group is more than twice as big as for the 'combination' group. The reduced speed variation on 80 km roads for the 'combination' and to some extent for the 'information' group is also caused by infinitesimal speeding. It seems also that there is a reduction in the amount of low speeds. No explanation is found for this, but it might be because the participants are using the ISA equipment as a kind of semi-automated cruise control. This is also the suggestion in the Australian and the Swedish ISA projects, where the same trend was found [7, 16].

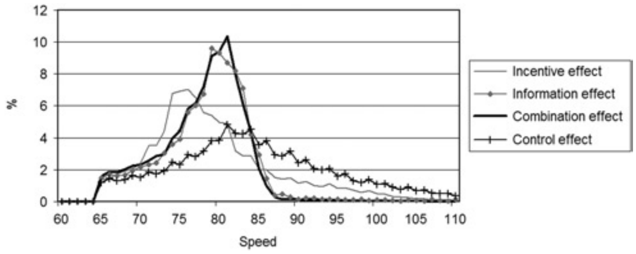

Figure 2 *Speed distribution on 80 km roads in the 'ISA period' for the four groups based on MFFS*

The same trend is found for the 110 km roads. The variation differs a bit between 'information' and 'combination', with an FFSD of 6.1 and 6.4 km/h, respectively. The FFSD is somewhat bigger for the 'incentive' group and biggest for the 'control' group, with an FFSD of 7.5 and 9.3 km/h, respectively (Fig. 3).

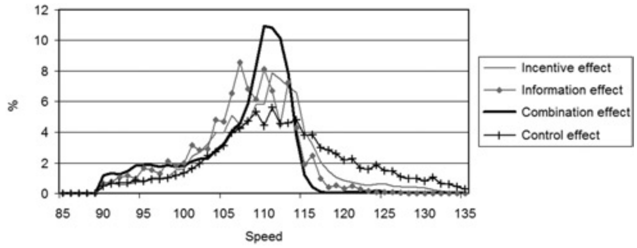

Figure 3 *Speed distribution on 110 km roads in the 'ISA period' for the four groups based on MFFS*

On 130 km roads the results are not as clear. The variations for the 'incentive' and 'combination' groups are equal with an FFSD of 8.9 km/h, whereas the 'free flow standard deviation' for the 'information' group is lower (7.3 km/h) and the 'control' group is in between with 8.2 km/h (Fig. 4).

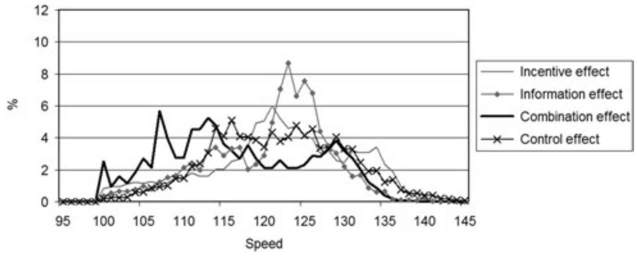

Figure 4 *Speed distribution on 130 km roads in the 'ISA period' for the four groups based on MFFS*

The study of the speed variation curves and the 'free flow standard deviation' for the four groups shows that the combination of 'information' and 'incentive' gives a

Table 6 Estimated effects of information and incentive on MFFS and estimated mean difference for 'control' group

	Speed limit			
	50 km/h	80 km/h	110 km/h	130 km/h
incentive	−1.2 (0.029)	−3.6 (0.007)	−2.9 (0.041)	−0.1 (0.933)
information	−1.7 (0.000)	−4.2 (0.002)	−3.3 (0.019)	−0.5 (0.701)
control	0.7 (0.156)	3.2 (0.006)	2.1 (0.107)	1.5 (0.249)

Table 7 Estimated effects of information and incentive on FFSD and estimated mean difference for 'control' group

	Speed limit			
	50 km/h	80 km/h	110 km/h	130 km/h
incentive	−0.7 (0.086)	−3.9 (0.003)	−1.2 (0.350)	0.8 (0.347)
information	−1.3 (0.002)	−3.1 (0.015)	−1.6 (0.199)	−0.5 (0.529)
control	0.4 (0.234)	3.2 (0.005)	0.7 (0.563)	−0.4 (0.635)

smaller speed variation on 80 km roads than each of them separately – a decrease which, with reference to the literature, will improve traffic safety for drivers [15]. On 50 and 110 km roads, 'information' seems to have almost the same effect as the 'combination' and no clear effect from ISA is found on 130 km roads.

4 Conclusion and discussion

The aim of the study presented in this paper was to test whether a form of ISA based on Pay as You Drive principles is effective in reducing speed in the Danish County of North Jutland. Although 180 participants, in total, are taking part in the study, the results given in the current paper are based on the data of 38 participants only, who are aged 18–28 years old. Therefore the results presented in the current paper should be treated as a preliminary.

To determine the effectiveness of the ISA equipment, participants drove a vehicle for 1.5 months in the absence of ISA ('baseline period') while certain information regarding their driving performance was recorded. Performance in the 'baseline period' was compared with drivers' performance in the next 1.5 months. This period was called the 'ISA period'. In the 'ISA period', participants were exposed randomly to one of four different ISA conditions: 'information' only, 'incentive' only, 'combination' (information and incentive) or no treatment ('control' group). By comparing the driving behaviour of the four groups with their driving during the 'baseline period', the effects of the 'incentive', the 'information' and the 'combined' forms of the ISA system on driving behaviour could be determined.

The key findings were as follows. The effect, relative to the baseline, of the 'incentive' ISA system was less than that of the 'information' ISA system. With the 'incentive' system, a reduction of 4% on 50 km roads and of 5% on 80 km roads was found in the proportion of distance travelled by more than 5 km/h above the speed limit. On 110 km roads, the reduction was 9% and on 130 km roads it was 3%. With respect to the 'information' system, the reductions on 50, 80, 110 and 130 km roads were 5, 14, 18 and 1%, respectively. The only results to attain statistical significance for the 'incentive' system were those for the 80 and 110 km roads, whereas for the 'information' system, the results were significant for the 50 km roads as well.

On the 50 km roads, the preliminary data showed that, relative to the baseline, the proportion of distance travelled by more than 5 km/h above the speed limit when driving in the 'combination' mode dropped from 13 to 2%, whereas on rural 80 km roads a reduction from 29 to 2% was revealed. On 110 km motorways, a reduction from 16 to 2% was found. All reported results regarding the 'combination' ISA condition were statistically significant. Moreover, the 'incentive' and 'informative' ISA forms in 'combination' resulted in greater reductions in speeding than did either the 'incentive' and 'informative' forms of ISA individually. For participants in the 'control' group the reductions in the proportion of distance travelled by more than 5 km/h above the speed limit were 2 and 3% for the 50 and 130 km roads, respectively, while increases of 5 and 16% were recorded on 80 and 110 km roads. Only the result for the 80 km roads was found to be statistically significant.

In addition, the participants who received the 'combination' of 'information' and 'incentive' showed a reduction, relative to the baseline, in their 'MFFS' by 2.8 km/h on urban 50 km roads and 5.4 km/h on rural 80 km roads. On motorways, however, the effect was infinitesimal with respect to 'MFFS'.

The results seem quite clear and substantial for the 'combination' group. Both the 'incentive' and the 'information' groups had minor, but also promising results. The participants in the 'control' group showed, for some speed zones, an increase in their general speed during the 'ISA period' relative to the baseline. Other than random variance, the most likely explanation for this result is that the 'control' group in the beginning was aware of the equipment, and that this awareness decreased as time passed. If this tendency were found to last throughout the remaining 4.5 months of the study, then it can be concluded that the effect from the ISA-equipment, and hence the recorded results, are even more substantial than noted.

One might expect that the effect from the 'incentive' form of ISA would be larger than that from the 'information' form of ISA since the driver might, over time, become used to the warnings but not the insurance penalty. Nevertheless, this pattern might change later in the project period once the drivers in the 'incentive' group have had more exposure to the system and therefore have become more aware of the impact, potential or real, of speeding on their insurance premium.

These preliminary results from the first ISA project based on Pay as You Drive principles are very promising. Consistent with the first two hypotheses, these early results show that both 'information' and, to some extent, economic 'incentive' forms of ISA are effective in reducing participants' speeding. In line with the third hypothesis, the results also show that the 'combination' of these modes gives the largest

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reduction in speeding and that the effect from incentive and 'information' are additive. Besides this, speeding by more than 5 km/h is almost eliminated among drivers in the 'combination' group. Moreover, it seems that the PAYS concept has the greatest effect on 80 km roads, where speeding is almost eliminated. Finally, the speed variation on rural 80 km roads is reduced by approximately one half.

During the remaining phases of the study, the focus will be on a number of topics. More research will be carried out based on all participants' behaviour and hence more reliable results may occur. Besides this, it will be studied whether the effect of 'incentive' ISA increases with time and whether the effect of 'information' ISA decreases over time. The long-term effect of ISA will be studied because after 6 months, that is, when all participants are driving in the 'combination mode', it will be determined if the results continue to be as positive as the preliminary ones or whether any disregards to the ISA system occur. Finally, any changes in attitude to traffic-related issues in general and more specific speeding among the participants will be studied, to recognise if the effect on the participants' attitude remains over time. The latter is based on two questionnaires sent to each participant, one in the initial 'baseline period' and the other approximately 5 months later.

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Spar på Farten - opbygning og vedligeholdelse af hastighedskortet

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Abstract

Spar på Farten er et Nordjysk INFATI projekt (Intelligent FartTilpasning). Projektet er baseret på et princip om, at i jo mindre grad hastighedsgrænsen overskrides, jo mere sparer den enkelte forsøgsdeltager på sin bilforsikring. Når overskridelse af hastighedsgrænsen skal gøres op i penge, er det meget vigtigt, at overskridelserne er baseret på korrekte hastighedsgrænser. Derfor er vedligeholdelse af projektets hastighedskort af vital betydning. Det udviklede hastighedskort er planlagt til at være delt mellem kommunerne i Nordjylland og projektet. På trods af det, har det vist sig, at opdateringerne fra kommunerne har været begrænsede og at kun 46 % af kommunerne har indrapporteret ændringer til hastighedskortet. Dermed har kommunernes involvering i projektet ikke været en garanti for et opdateret hastighedskort.

Keywords

Dansk: Intelligente Transportsystemer, Intelligent Farttilpasning, digitale hastighedskort, vedligeholdelse, map matching

English: Intelligent Transport Systems, Intelligent Speed Adaptation, digital speed map, maintenance, map matching

Baggrund

Forskningsprojektet *Spar på Farten* er en videreførelse af *INFATI*-projektet (Intelligent Speed Adaptation, forkortet til ISA på engelsk), som Trafikforskningsgruppen ved Institut for Samfundsudvikling og Planlægning på Aalborg Universitet gennemførte i 1998-2001. Projektet *Spar på Farten* er et forsøg i det gamle Nordjyllands Amt og målgruppen er primært unge førere, dvs. aldersgruppen 18-28 år. Det er projektets overordnede formål at afprøve, om økonomiske incitamenter i form af præmienedsættelser på bilforsikringen ved overholdelse af hastighedsgrænserne kan tilskynde målgruppen til at køre langsommere og dermed reducere gruppens meget høje uheldsfrekvens.

Forskningsprojektet begyndte i 2004 og vil fortsætte indtil 2010. De første 2½ år er nu overstået og projektets hardware og software er udviklet, og de første deltagere har kørt med udstyret i godt ét år. I de næste tre år skal op til ca. 300 forsøgspersoner ud at køre med udstyret. I den periode indsamles data og de vil - sammen med hele projektet - løbende blive evalueret.

Spar på Farten er et samarbejde mellem Aalborg Universitet, Nordjyllands Amt, det private elektronikfirma M-Tech samt forsikringsselskabet Topdanmark. Endvidere har Færdselsstyrelsen under Transport- og Energiministeriet bidraget med væsentlige økonomiske tilskud til projektet.

En kort projektpræsentation

Udstyret

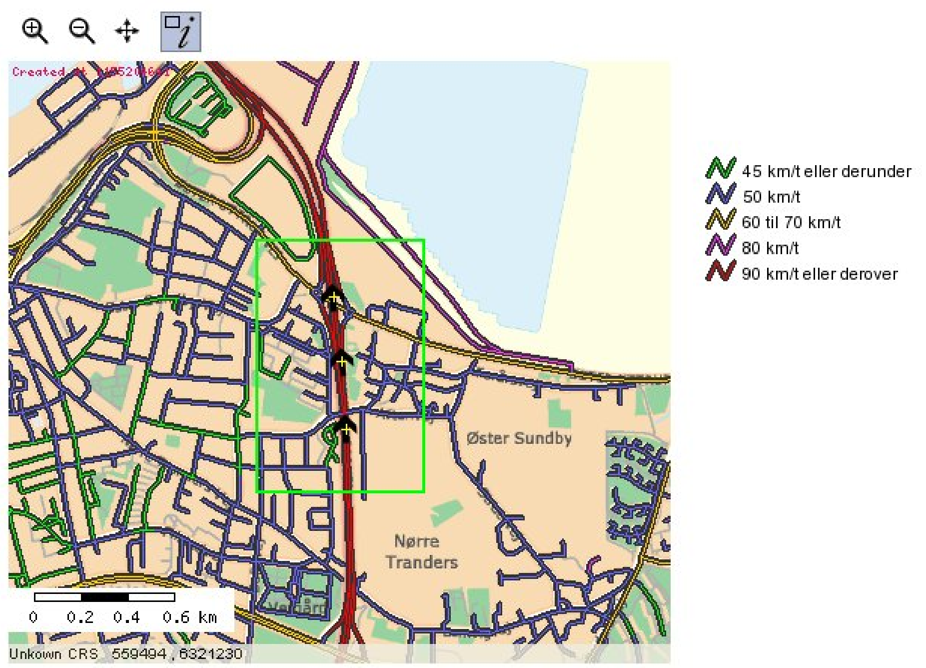
For at minde føreren af bilen om en eventuel hastighedsoverskridelse, monteres der i bilen tre mindre enheder [1]:

- En lille computer, der indeholder en GPS-modtager, en GSM-telefon, et digitalt vejkort med hastighedsgrænser i hele Nordjylland samt software, der kan guide føreren
- Et display med en lille højttaler
- En GPS-antenne

Figur 1. Display med højttaler.

GPS-modtageren fortæller hvert sekund computeren, hvor bilen er. Computeren beregner hvilken vej bilen befinder sig på (map matching), og hvilken hastighedsgrænse, vejen har. I displayet vises hastighedsgrænsen. Se figur 1. Overskrides grænsen med mere end 5 km/t, vil en kvindestemme hver 6. sekund minde føreren om overskridelsen, og føreren vil få strafpoint fra og med det 3. strafpoint. Hvor mange strafpoint, advarslen koster, graderes efter, hvor mange procent overskridelsen er på. I den nederste linie til venstre i displayet ses det totale antal strafpoint, der er registreret i indeværende 6 måneders periode. Til højre i nederste linie ses det antal strafpoint, der er registreret på den aktuelle tur. Umiddelbart efter en afsluttet tur indrapporteres overskridelser (og uregelmæssigheder) til en server. Kort efter kan deltageren gå på Nettet og orientere sig om sine overskridelser. Deltageren har mulighed for at påklage evt. forkerte strafpoint via projektets hotline.

Figur 2 viser et screen dump fra webserveren, hvor tre overskridelser er markeret på motorvejen i nordgående retning i Aalborg. Yderligere information vedrørende overskridelserne ses under kortet.



Hastighedsoverskridelser

Hastighedsgrænse	Bilens Hastighed	Antal point	Dato og tid	Overskridelse nr.	Tur nr.
90	103	1	13.07.06 kl. 17:45:31	73	46
90	102	1	13.07.06 kl. 17:45:41	74	46
90	102	1	13.07.06 kl. 17:45:51	75	46

Figur 2. Screen dump fra webserveren.

De første testkørere fik installeret udstyret i maj 2006. Siden er udstyret installeret løbende i takt med rekrutteringen. I juli 2007 kørte ca. 100 biler med udstyret.

Selve forsøget

I *Spar på Farten* kører deltagerne med udstyret i i alt tre år. For at måle effekten af udstyret, køres de første 1½ måned som en førperiode, hvor højttaler og display er slået fra, mens kørselsadfærden registreres, så deltagernes "normale" adfærd i trafikken registreres. I de næste 4½ måned fordeles deltagerne tilfældigt i fire grupper, hvor der køres under forskellige vilkår. Vilkårene i de fire grupper fremgår af figur 3.

		Incitament -	Incitament +
Information	-	**Kontrolgruppe** Deltagerne modtager hverken information, advarsler eller strafpoint og fortsætter som i de første 1½ måneder.	**Incitamentgruppe** Displayet og højttaleren er slået fra og der gives hverken information eller advarsler. Deltageren modtager dog strafpoint, hvis der køres for stærkt.
Information	+	**Informationgruppe** Displayet og højttaleren er slået til og information samt advarsler gives. Overskridelse af hastighedsgrænsen giver ingen strafpoint.	**Kombinationgruppe** Deltageren modtager både information og advarsler og modtager strafpoint, hvis der køres for stærkt.

Figur 3. De fire grupper.

Ved at sammenligne kørselsadfærden i de fire grupper med adfærden i førperioden kan effekten af henholdsvis incitament, information og kombinationen af disse måles. I de resterende 2 ½ år kører alle deltagerne som i kombinationsgruppen. De foreløbige resultater skal ikke uddybes nærmere her, men det kan kort nævnes, at udstyret stort set eliminerer kørsel med en hastighedsoverskridelse større end fem km/t på veje med en hastighedsgrænse på 80 km/t. For flere resultater se i øvrigt Agerholm et al. 2007 [1].

På grund af projektets udformning er et præcist og opdateret hastighedskort meget vigtigt. Hvis der er fejl, modtager deltagerne forkerte advarsler og endnu værre, måske får de ikke det økonomiske incitament, som de er berettet til.

Opbygning af hastighedskortet

Et hastighedskort kunne i sin simpleste form se ud som et vejmidtetema med en hastighed som attributdata. Det vil i langt de fleste tilfælde være ganske fornuftigt. Men der vil dog være enkelte steder, hvor to hastigheder pr. vejstrækning vil være nødvendig. Enkelte steder, f.eks. før nogle kryds, er der forskellige hastigheder i vejens to retninger, idet hastigheden her nedsættes et stykke før krydset for igen at ophæves straks efter krydset. Det er altså nødvendigt med to hastigheder pr. vejstrækning. Desuden er der forskellige hastighedsgrænser afhængigt af trafikanttype såsom lastbiler og biler med trailere. Endvidere er der også tidsmæssige ændrede hastighedsgrænser såsom i forbindelse med vejarbejde, samt i nogle sommerhusområder, hvor hastighedsgrænsen er sænket i sommerperioden.

For at få et pålideligt hastighedskort, hvor opdateringsprocedurerne og kommunikationen af opdateringerne bliver overkommelige, blev det besluttet, at hastighedskortet skal indeholde:

- Vejmidter (Northing og Easting koordinater)
- To hastigheder (en hver vej)
- Vejkode

Her tages ikke højde for vejarbejder samt sæsonændringer af hastighedsgrænsen. Se figur 4 for et eksempel på hvad hastighedskortet skal indeholde.

N-koordinat	E-koordinat	Hast. med	Hast. mod	Vejkode
6320151.29	553160.08	15	15	0
6320173.65	553150.59	15	15	0
6351293.70	615888.62	50	30	8250219
6351294.05	615906.44	50	30	8250219
6351293.73	615921.68	50	30	8250219

Figur 4. Et eksempel på indhold af hastighedskortet.

Indsamling af data

Baseret på erfaringerne fra det tidligere INFATI-projekt var vi klare over de problemer, indsamling af vejmidter med skiltet hastighed kunne give. Umiddelbart skulle man tro, at man blot kontakter de relevante vejmyndigheder og beder om et vejmidtetema med skiltede hastigheder og vejkode. Det er dog ikke muligt i dag.

Det har vist sig, at kun få af kommunerne har styr på hastighedsgrænserne. For amts- og statsveje, der har langt de færreste hastighedsgrænser, kan man få nogen hjælp i Vejsektorens Informationssystem (VIS), men vejmidtetemaet findes heller ikke her i en acceptabel kvalitet. I forbindelse med udviklingen af hastighedskortet havde Spar på Farten et tæt samarbejde med det tidligere Nordjyllands Amt og har derigennem fået adgang til KMS´s vejmidtetema. Det har imidlertid også vist sig at være noget mangelfuldt. F.eks. tager det på grund af KMS´s opdateringsprocedurer sommetider næsten to år fra en nye vej åbner, til den findes i vejmidtetemaet [2].

På baggrund af ovenstående forhold var status:

- Vi har fået et vejmidtetema, men dele af det kan være flere år gammelt
- Hastighederne måtte vi selv indsamle

Strategi for lagring af data

Der er principielt to måder til at få oprettet et vejmidtetema med hastigheder:

1. Hastighederne gemmes som attributter i den nyeste version af KMS' vejmidtetema
2. Der oprettes en skiltedatabase for hele Nordjylland, og der udvikles et stykke software, der automatisk kan opdatere et vejmidtetema med hastigheder

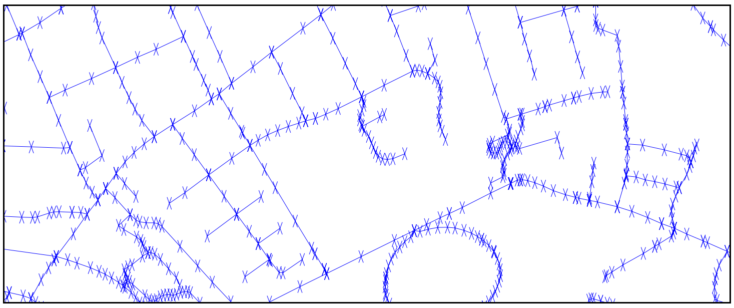
Metode 1 ser umiddelbart tillokkende ud. Men så er vi tilbage til samme strategi som Navteq og TeleAtlas benytter. Det vil sige, at projektet *Spar på Farten* selv skal vedligeholde vejmidtetemaet, f.eks. ved at finde ændringerne mellem det nye og gamle vejmidtetema leveret af KMS, opdatere vejmidtetemaet med de fundne ændringer og derefter påsætte attributter på de nye/ændrede veje. Ikke at det vil være en umulig opgave, men vi vurderede på det tidspunkt, at metode 2 vil gøre opdateringerne enklere.

Metoden beskrevet under punkt 2 tillader, at projektet får nye vejmidtetemaer fra KMS, hver gang de kommer med en 'ny' version af vejmidtetemaet (ca. 3 gange om året). Derefter kan hastighederne så automatisk generes, og ændringer til kortet er parat til at sende til bilerne næsten uden manuel indgriben.

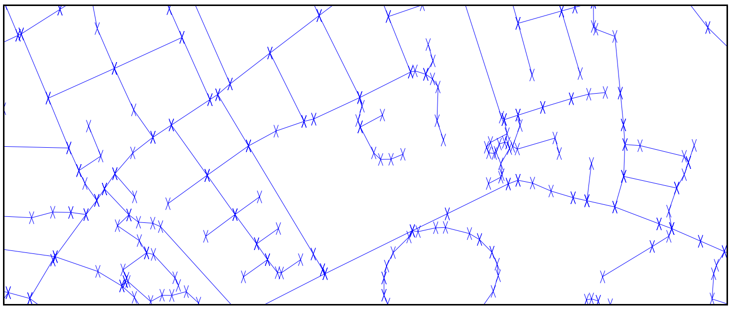
Ved at vælge metode 2 fik vi altså to databaser (vejmidter og skilte) og et stykke software, der automatisk kan opdatere vejmidterne med hastigheder.

Vejmidtedatabase

KMS' vejmidter for hele Danmark består af ca. 8.000.000 punkter. I Nordjylland er der knap 1.000.000 punkter. Reduceres punktantallet for vejmidterne, så punkter med pilhøjde under 2 meter slettes, reduceres antallet af punkter i Nordjylland til ca. 425.000. Se figur 5 og 6.



Figur 5. Vejmidter med knækpunkter markeret. Uden reduktion i punktantal.



Figur 6. Vejmidter med knækpunkter markeret. Med reduktion i punktantal. Pilhøjde min. 2 meter.

Skiltedatabase

For at få metode 2 til at virke nogenlunde smertefrit, var det nødvendigt at opbygge en skiltedatabase med følgende indhold: *Skiltetype*, *N*, *E* og *Retning*. Retningen er retningen på den vej, skiltet skal snappes ned på.

Til indsamling af data til denne opgave blev der udviklet et specialtastatur med én knap pr. hastighedsskilt. Se figur 7. Tastaturet er bygget sammen med en GPS-enhed. GPS-enheden registrerer en koordinat hvert sekund, som blev lagret på et multimediekort. Blev tastaturet rørt, blev en tastaturregistrering udløst bestående af: *ID for tast* (skiltetype) og *antal millisekunder* siden sidste GPS-registrering. Denne registrering blev lagret 'mellem' to GPS-registreringer.

Figur 7. Specialudviklet skiltetastatur.

To biler blev hver udrustet med tastatur og to studerende. Tilsammen skulle de gennemkøre de nordjyske veje, ca. 22.000 km i alt, Det tog fire uger og i alt 5.600 skilte blev registreret. Før det hele blev sat i gang, blev der mailet/ringet til alle 27 kommuner i Nordjylland for at høre, om de skulle ligge inde med materiale om hastighedsskilte/ hastighedsbegrænsninger i kommunen. Det lykkedes at få materiale fra en del af kommunerne. I alt blev der registreret ca. 90 Mb (koordinater hvert sekund + 'skiltene'). Ud fra disse registreringer er skiltedatabasen opbygget med *Skiltetype*, *N*, *E* og *Retning.* Et eksempel på en skiltedatabase fremgår af figur 8.

Skiltetype	N-koordinat	E-koordinat	Skilteretning
Lokal 60	6363122.95	587587.63	71
Byzone	6317451.38	549476.70	119

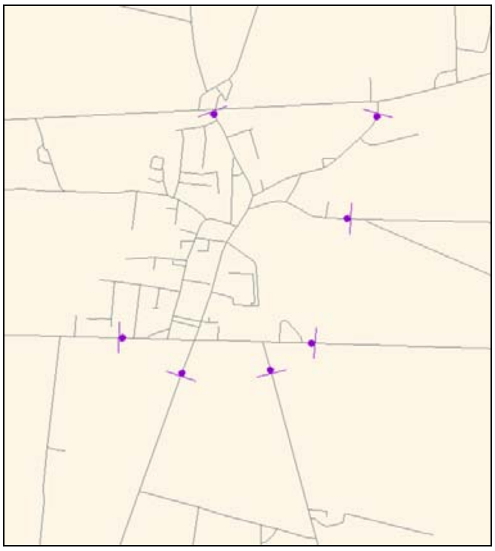
Figur 8. Eksempel på skiltedatabase.

Software til generering af hastighedskortet

Først snappes skiltepunkterne ind på vejene. Det snappede punkt bygges ind i vejmidten, og vejmidten deles i to objekter, et på hver side af det nye punkt, så der opstår en form for knudepunkt i skiltepunktet. Da der nemt kan ligge flere veje inden for en rimelig afstand fra skiltet, vægtes vejene i forhold til afstanden mellem skilt og vej og i forhold til retningsdifferencen mellem skilt og vej. Retningen får størst vægt, idet et skilt ofte står tættere på en tværvej end på den vej, som skiltet 'tilhører'. En stor vægt for retningsdifferensen bevirker et korrekt snap.
Nu skulle man tro, at der nu kun manglede:

- at pålægge 80 på hele vejnettet
- at finde *zonerne* og pålægge vejene inden for zonen med den skiltede hastighed og
- at pålægge vejene de *lokale* hastigheder (60 km/t, 70 km/t mm)

Det har imidlertid vist sig, at zonerne kun i ganske få tilfælde er lukkede. Se figur 9 for et eksempel. Pålagde man f.eks. 50 km/t i byzone, fandt programmet en vej ud af zonen, hvor der manglede et byzoneskilt. Og så havde hele Nordjylland 50 km/t på alle veje. Kun ca. 20 bysamfund ud af de ca. 350 var lukkede. Altså manglede der minimum 330 byzoneskilte!

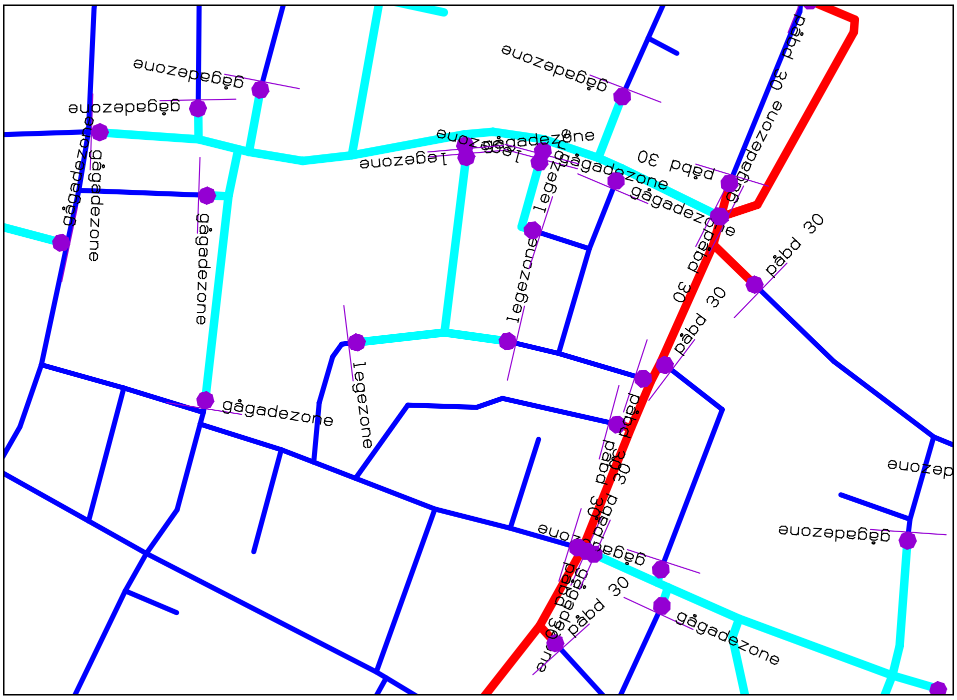

Figur 9. Byzone, der ikke lukker.

Forklaringen herpå er sparsommelighed. Byzoneskiltet på en lille grusvej med en trafikbelastning på et par biler om dagen er ofte sparet væk. Heller ikke motorvejene er én zone. Der eksisterer ikke 'motorvej ophør' på afkørselsramperne.

Vi havde også en ide om, at der skulle påføres en lokal hastighed indtil 'lokal hastighed ophør', eller indtil vejen endte blindt. Men rigtig mange steder kommer der ikke et 'lokal ophør' skilt. Det vil sige, den lokale hastighed fortsætter, indtil vejen ender blindt. Dette er ganske fremherskende i sommerhusområder. En vilkårlig grundejerforening med respekt for sig selv investerer f.eks. i et 20 km/t skilt, og placerer det på den mest trafikerede indfaldsvej til området. Da disse hastighedsskilte ofte kun er opsat i den ene retning, bliver de sjældent ophævet.

I et knudepunkt kan der i nogle tilfælde være tvivl om, ad hvilken vej påsætningen af hastighed skal fortsætte. F.eks. kan der i en Y-forgrening være tvivl, om hastigheden skal fortsætte til højre eller til venstre, fordi kortet ikke indeholder information om vigepligt i kryds. Den lokale hastighed påsættes, således at retningsændringen i knudepunktet er mindst mulig. Er dette ikke tilfældet, altså at den lokale hastighed fortsætter ad den vej, der har den mindste retningsændring, er der manuelt indsat et fiktivt skilt, der fortæller programmet, at den lokale hastighed ikke skal fortsætte ad 'denne' vej. 'Prøv den næstmindste retningsændring'. Der er således bygget rigtig mange skilte ind manuelt, for at lukke zoner (herunder motorveje), for at ophæve lokale hastighedsgrænser og for at tvinge lokale hastighedsgrænser den 'rette' vej. Derudover er der bygget en hel del 'ensretningsskilte' ind i skiltedatabasen. Disse skilte er bygget ind i rundkørsler, på vejstrækninger med midterrabat, og ved ensrettede veje.

I alt er der i dag ca. 8.600 punkter i skiltedatabasen. Den manuelle opdatering af skiltedatabasen med fiktive skilte, har været et større arbejde end forventet. Bl.a. er der udviklet software, der kan hjælpe med at finde de zoneområder, der ikke vil lukke, og de lokale hastigheder, der aldrig 'ophører'. Teknisk set er skiltedatabasen i dag korrekt. Alle zoner lukker. Ingen lokale hastigheder 'er for lange'. Dog kan det forekomme, at hastighederne på vejene ikke er korrekte, specielt i sommerhusområder, hvor de registrerede skilte er 'opdateret' med mange fiktive skilte, og beskriver de hastigheder, man forventer intensionen med den sparsomme skiltning har været. Se figur 10 for et eksempel på hvordan hastighedszoner afgrænses.



Figur 10. Screen dump fra den udviklede software til generering af hastighedskortet.

Opdatering i bilerne

Hele kortværket i bilerne er opdelt i små filer på 3·3 kilometer plus ca. 150 meter overlap mellem filerne. Ved ændringer i vejmidter og hastigheder sendes kun de kvadrater, der er berørt af ændringerne, til alle biler. Dermed formindskes omkostningerne ved opdateringerne.

Opdateringen af kortene i bilerne foregår ca. to gange om året. Der anvendes den til en hver tid nyeste version af vejmidterne fra KMS. Derudover foretages der opdateringer ved ændringer af hastigheder (nye/ændrede/slettede skilte) på de mere betydende veje. Fra den webbaserede skiltedatabase foretages et udtræk af de ændringer af hastighedsskiltene, der er sket siden sidste opdatering. Efter opdatering af skiltedatabasen påsættes hastighederne automatisk på den sidste nye version af KMS' vejmidtetema. Det nye vejmidtetema med hastigheder samt skilte sendes ligeledes til et webkort, der bruges til opdatering og det kort, der viser deltagernes strafpoint.

Vedligeholdelse af hastighedskortet

Erfaringer fra andre digitale kort

I forbindelse med opbygning og ikke mindst vedligeholdelse af digitale kort har der flere steder i såvel Danmark som i udlandet kunnet konstateres problemer. Herunder følger en kort gennemgang af nogle af de erfaringer, der er gjort.

I Norge blev en fælles digital vejdatabase gældende for kommunerne og staten oprettet i 1999. Fire år senere havde en stor del af kommunerne endnu ikke bidraget til databasen [3]. Også engelske og hollandske statslige notater beskriver vedligeholdelsen af et hastighedskort som en af de største udfordringer ifm. et eventuelt ISA-projekt [4],[5]. Tillige blev et nyligt afsluttet svensk ISA-projekt forsinket ét år, primært pga. problemer med hastighedskortet [6].

De private udbydere, som er blevet kontaktet ifm. denne undersøgelse, har også konstateret at opdateringer fra myndighederne alene ikke er tilstrækkeligt til en tilfredsstillende kortkvalitet. Krak baserer deres kort på DAV (Dansk adresse- og vejdatabase), hvorfra de modtager en årlig opdatering. Desuden kontaktes vejmyndigheder på alle niveauer ad hoc. Der er ingen standardprocedurer for disse kontakter, men de foretages, når der opnås kendskab til nye projekter osv. Endelig modtager Krak en stor mængde feedback fra bruger af deres kort, som efterfølgende verificeres af vejmyndighederne [7]. De Gule Sider baserer deres kort på opdateringer fra Kort & Matrikelstyrelsen og feedback fra deres brugere [8].

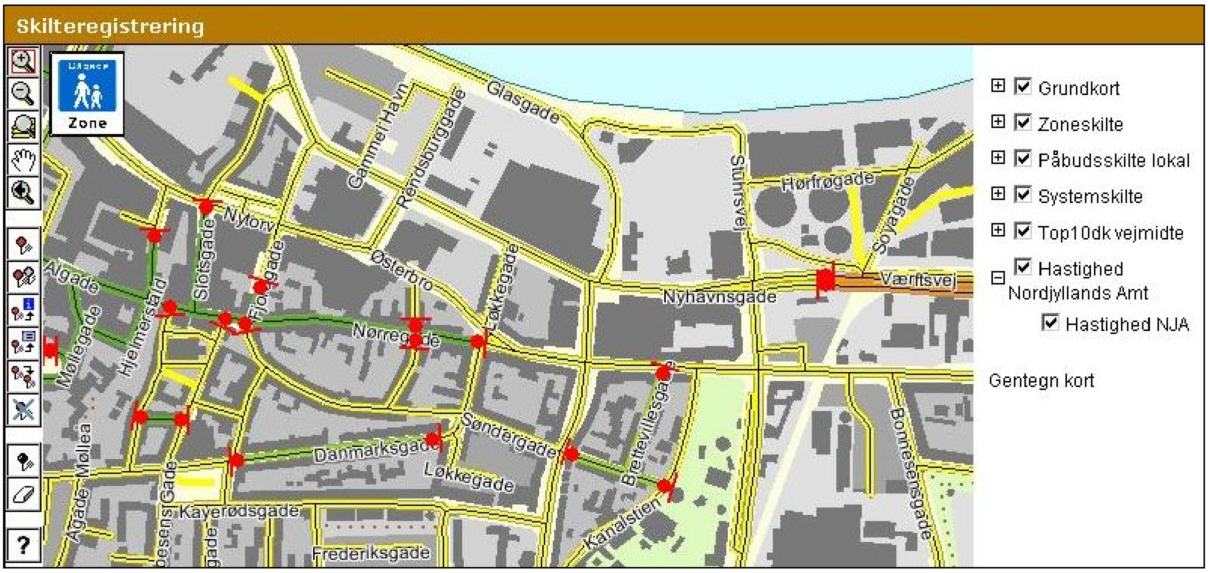
En af de store internationale kortudbydere, Teleatlas, baserer sit digitale kort på et udtræk fra DAV fra starten af 1990erne. Med dette som udgangspunkt bruges en del markmedarbejdere samt brugernes feedback til opdateringer. Dette suppleres med oplysninger fra kommunerne og Vejdirektoratet. Endvidere er mobile mapping ved at blive en vigtig del af opdateringsproceduren. Hovedvejene gennemkøres og registreres én gang årligt og de mindre veje hvert fjerde år. Der anvendes ikke nye opdateringer fra DAV. [9]

Vedligeholdelse af Spar på Farten kortet

Grundlæggende er der to tilgange, når et digitalt hastighedskort skal vedligeholdes. 1; Med udgangspunkt i et givent hastighedstema foretages løbende opdateringer i den takt der opnås kendskab til ændringerne. Det er en administrativ nem metode, men ulempen er, at kortet "vokser" fra de officielle kort, som vejmyndighederne bruger. 2; Et hastighedskort lavet og vedligeholdt med feedback fra de berørte vejmyndigheder. Denne metode er sværere at administrere, men i teorien skulle hastighedskortet altid være opdateret, da vejmyndighederne selv skulle være interesserede i det. I forventning om at få det mest præcise hastighedskort, er tilgang 2 valgt til *Spar på Farten*.

Vedligeholdelsen af hastighedskortet i *Spar på Farten* består af to kilder. Den ene er feedback fra deltagerne. Det foregår normalt via e-mail og efterfølgende verificeres det ved at kontakte den relevante vejmyndighed og/eller besøge lokaliteten. Den anden er løbende opdatering fra vejmyndighederne, så man sammen med dem altid har et opdateret hastighedskort. Den førstnævnte er nem at administrere, men må forventes at have bias, da deltagerne kun sjældent indberetter om for høje hastighedsgrænser. Den anden skulle i teorien give et kort, der altid er opdateret og korrekt, men som det beskrives herunder, har erfaringerne været noget blandede på dette område.

En webapplikation der gør det nemt at opdatere ændrede hastighedsskilte og -grænser blev udviklet som en del af *Spar på Farten*. Her kan kommunerne gå ind og oprette/ændre/slette hastighedsskilte og dermed dels hjælpe Spar på Farten og dels altid have et fuldt opdateret hastighedskort til rådighed. Et screen dump af webapplikationen fremgår af figur 11.



Figur 11. Screen dump af webapplikationen, hvor der er muligt at ændre hastighedsskiltene.

Stort set alle 27 kommuner i det gamle Nordjyllands Amt lovede at opdatere hastighedskortet løbende, når der skete ændringer på deres vejnet. En god del af kommunerne har da også bidraget med opdateringer, mens andre har været mindre entusiastiske. Siden Spar på Farten startede, er kommunerne blevet kontaktet flere gange for at få dem til at forpligte sig til at bidrage til vedligeholdelsen af hastighedskortet.

Kommunernes kendskab til Spar på Farten

I efteråret 2004 blev alle kommunerne besøgt af et medlem af projektet og blev introduceret til førnævnte webapplikation. Besøget blev gentaget primo 2005, hvor kommunerne igen blev opfordret til at indsende opdateringer. Erfaringerne var, at en mindre del af kommunerne ikke kunne afsætte ressourcer til opdateringen, samt at nogle var usikre på IT og derfor ikke ville anvende webapplikationen. På baggrund af dette besøg opnåedes følgende erfaringer:

- Ca. 15 % af kommunerne havde fravalgt opdateringerne pga. manglende ressourcer.
- Ca. halvdelen var meget interesserede og hjælpsomme omkring hastighedskortet.
- Ca ⅓ havde aldrig prøvet webapplikationen.
- Ca. ⅓ havde prøvet webapplikationen men aldrig brugt den.
- Den sidste ⅓ brugte webapplikationen når der var opdateringer.
- Der var en tendens til, at de større kommuner var lidt bedre til at bruge webapplikationen.

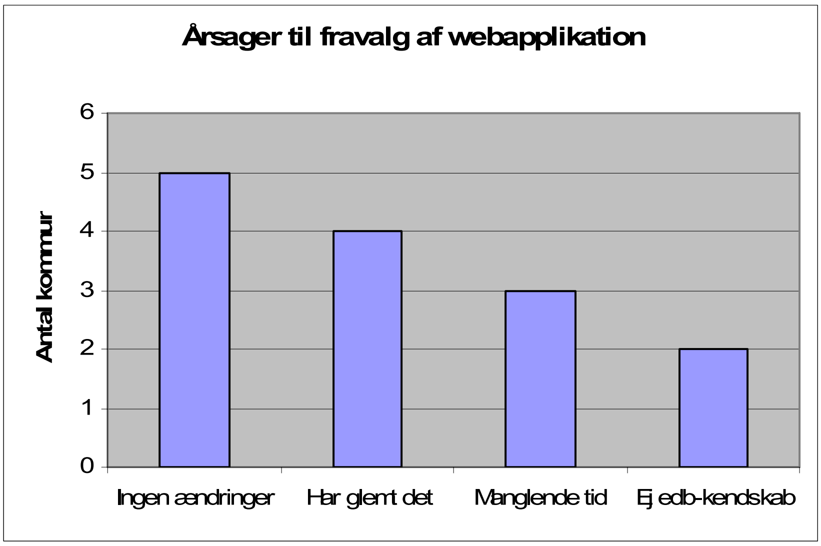
I september 2006 blev 26 positivt indstillede kommuner kontaktet via telefon for at høre om deres brug af webapplikationen. Her blev der spurgt ind til: Brug af webapplikationen, brugervenlighed, eventuelle opdateringsprocedurer, årsager til fravalg af applikationen, samt hvordan hastighedsgrænserne bliver registreret i de enkelte kommuner. Dette blev suppleret med et spørgsmål omkring deres vurdering af indsatsen når kommunalreformen er faldet på plads.

I to kommuner arbejdede kontaktpersonen ikke længere ved kommunen, mens arbejdsområdet i to andre kommuner var overdraget til en kollega. Kendskab til projektet og webapplikationen var dog ikke overdraget. Størsteparten af de kontaktede kommuner var meget positive, mens en enkel kontaktperson var utilfreds med projektet og opdateringsproceduren.

Brug af Webapplikationen

Siden sidste besøg primo 2005 havde 54 % ikke brugt webapplikationen. 46 % havde besøgt applikationen, men kun 38 % havde foretaget opdateringer.

Det betyder, at der ikke er kommet opdateringer fra kommuner, der administrerede 4.000 km ud af 7.800 km kommunevej i Nordjyllands Amt. Årsagerne hertil fremgår af figur 12.



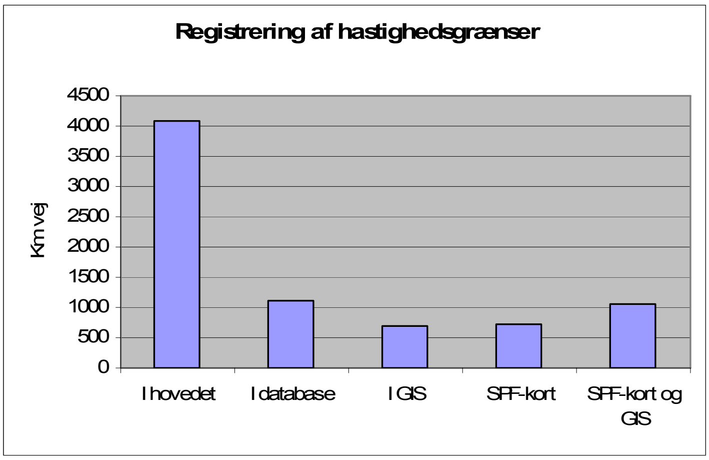
Figur 12. Årsager til manglende brug af webapplikationen.

28 % af kommunerne sagde, at de havde glemt webapplikationen. 21 % sagde at de ikke havde tid til opdateringerne, mens kun 14 % sagde, at manglende IT-kendskab var årsagen. De sidste 37 % sagde, at der ikke havde været ændringer i hastighedsgrænserne i perioden. Omkring sidstnævnte gruppe må det siges, at perioden var temmelig lang, ca. 1½ år, men at der internt i projektgruppen er registreret flere ændringer i disse kommuner, som den kontaktede medarbejder åbenbart ikke havde kendskab til eller havde glemt.

Problemet med manglende IT kendskab er blevet reduceret siden 2005, hvilket må betragtes som i tråd med den generelle udvikling i samfundet. Hvorvidt manglende tid eller uændrede hastigheder kan forklare, at webapplikationen var blevet gemt, er uklart, men den nyligt overståede kommunalreform har formodentligt trukket i negativ retning.

Hvordan registrerer kommunerne deres hastighedsgrænser

Før kommunalreformen var de nordjyske kommuner ansvarlige for ca. 7.800 km kommuneveje, hvilket svarer til ca. 85 % af de offentligt administrerede veje i amtet. Figur 13 viser hvordan hastighedsgrænserne administreres.



Figur 13. Administration af hastighedsgrænserne på det kommunale vejnet.

I de fleste små kommuner findes intet centralt register, og de ansvarlige personer har hastighedsgrænserne i hovedet[1]. Hvis der er tvivl om en hastighedsgrænse besøges lokaliteten. Enkelte af kommunerne supplerer dette med brug af Spar på Farten webapplikationen som opslagsværk - hvilket jo var en af hovedideerne med kortet. I de fleste større kommuner er der i en central database med hastighedsgrænserne. For enkelte af disse er det kun dele af deres vejnet, der i en database, f.eks. hovedbyens veje. Andre styrer hastighedsgrænserne i et GIS-tema. Endelig supplerer en enkel af kommunerne deres GIS-tema med opslag i Spar på Farten kortet.

Dermed findes der intet register over hastighedsgrænsen for 53 % af kommunevejene og kun 23 % eller ca. 1.800 km har registreringerne i et GIS-tema og dermed tilgængeligt på et kort. Baseret på disse erfaringer, må det siges, at der er lang vej før et opdateret digitalt hastighedskort findes for alle kommunerne i det nordjyske.

Fremtidige procedurer

Det fremgår ovenfor, at vedligeholdelsen af hastighedskortet ikke har fungeret så godt som forventet. Mange kommuner har ikke haft ressourcer til opdateringen, der derfor må betragtes som mangelfuld. Der er dog næppe tvivl om, at den nyligt overståede kommunalreform har forværret

[1] De fleste hastighedsgrænser er selvfølgeligt blevet godkendt af det lokale politi på et tidspunkt og må derfor være beskrevet i et notat. Det er imidlertid ikke noget der anvendes efterfølgende, og det fungerer derfor ikke som et register, der kan slås op i.

ressourcesituationen. Et andet forhold er kommunestørrelsen. I små kommuner er det tekniske personale få og har derfor en meget bred vifte af opgaver hvor imellem en lille opgave som vedligeholdelse af hastighedskortet måske forsvinder. Med de nye større kommuner med mere specialiserede medarbejdere forudså en del af de adspurgte kommuner, at et bedre vedligeholdelsesniveau for det digitale hastighedskort kunne forventes.

Konklusion og diskussion

Vores erfaringer med hastighedskortet i Spar på Farten viser, at det er relativt enkelt og økonomisk overkommeligt at oprette et digitalt hastighedskort over Nordjylland. Den virkelige udfordring er at vedligeholde kortet. Vi fik udviklet en brugervenlig webapplikation, som alle vejadministratorerne kan bruge. Vi lavede en frivillig opdateringsprocedure - vi havde ikke andre muligheder. Vi forsøgte at overbevise kommunerne om vigtigheden af opdateringerne og de fordele, som kommunerne selv kan få ud af arbejdet. Vi må konstatere, at kun en mindre del af kommunerne leverer en troværdig opdatering til hastighedskortet. Vores konklusion er derfor, at man ikke kan få et hastighedskort af tilstrækkelig høj kvalitet, hvis det skal baseres på frivillig vedligeholdelse hos kommunerne.

§ 10 i Lov om offentlige veje siger at det påhviler vejbestyrelserne at holde deres offentlige veje i den stand, som trafikkens art og størrelse kræver. Vores anbefaling er, at der laves en ændring i denne lov, så det også bliver obligatorisk at lave og vedligeholde et digitalt hastighedskort, der skal være tilgængelige for offentligheden. Det er den eneste måde, hvorpå man kan få et digitalt hastighedskort af tilstrækkelig kvalitet. Dette er i tråd med Færdselssikkerhedskommissionens Handlingsplan [10].

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Intelligent Speed Adaptation in Company Vehicles

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Abstract — **This paper describes an Intelligent Speed Adaptation project for company vehicles. The Intelligent Speed Adaptation function in the project is both information and incentive, which means that the Intelligent Speed Adaptation equipment gives a warning as well as penalty points if the driver is speeding. Each month the driver with that month's fewest points wins an award. The paper presents results concerning speed attitude on the first three of a planned 12 months test period. In all 26 vehicles and 51 drivers from six companies participate in the project. The key result is that speeding is reduced from 18.7% to 7.4% on urban roads with a speed limit of 50 km/h while it is reduced from 18.9% to 4.7% on rural roads with a speed limit of 80 km/h.**

I. Introduction

TRAFFIC is one of the factors in the industrial world that costs most fatalities to say nothing of the millions of injured persons. Even though the number of fatalities in Europe has been reduced by some 17% from 2001 to 2005 more than 40,000 fatalities happened every year on the European roads and the European Union is still a big step from the goal of less than 25,000 fatalities before 2010 [1]. There are several groups of road users, who contribute especially negatively regarding traffic safety e.g. bicycle riders, moped riders, youngsters and drivers of commercial vehicles. In many countries - also Denmark - commercial vehicles have a bad reputation among other road users due to their speed behaviour, and in addition they are notably over-represented in traffic accidents. The commercial vehicles are often bigger than the average cars, and when accidents happen the accidents are more severe [2]. These differences result in nearly 30% more fatalities and seriously injured than for passenger cars [3].

So, reducing the number of fatalities regarding commercial vehicles in traffic is an important issue in the road safety work and Intelligent Transport Systems and especially Intelligent Speed Adaptation (ISA) seems to be an efficient measure [4].

ISA means systems which compare the speed of a car with the speed limit on the location. In most new ISA projects the geospatial position of a car compares its current position and speed with a digital road map which includes the speed limit, and the equipment responds if the speed limit is exceeded. There are various forms of response if speeding: the response can be visual and/or auditory. Another possibility is to log every speed limit violation on an on-board computer. Finally, the accelerator pedal can give resistance or even make it impossible to speed. These different types of ISA systems can be categorized as informative, advisory, recording or intervening systems [5].

In the last decade a number of ISA field trials in several European countries and in Australia have shown the potential of ISA. The results differ depending on the ISA equipment, the test area and if there is a sort of incentive involved in the systems. The large-scale Swedish trials in Borlänge, Lidköping, Lund and Umeå during the period 1999-2002 have involved approximately 5,000 cars and the main result was an average speed reduction of 3 to 4 km/h [6].

In the Australian TAC Safecar project, which was carried out in the Melbourne area from 2002 to 2004, a reduction by up to 2.7 km/h was found for the 85 percentile speed. Furthermore, speeding by more than 5 km/h was reduced by up to 57% [7].

Moreover, field trials in Belgium [8], United Kingdom [4], the Netherlands [9] and Denmark [10] have shown promising results.

In addition, an ongoing Danish ISA project, "*Pay as You Speed*" has shown the possibilities with ISA. In this project the driving behaviour is directly connected to a discount on the car's insurance rate - the less speeding the less insurance rate. The first results show that speeding by more than 5 km/h is reduced from 16% to 3% on urban roads and from 28% to 2% on rural roads. [11], [12], [13].

A few ISA projects are carried out with commercial vehicles.

In Stockholm, Sweden an ISA project with 20 public cars and in all 130 test persons was carried out 2003-2005. The highest impacts were found for rural roads with a speed reduction of up to 2 km/h. On motorways the impact was less and no impact was found on roads with 30 km/h speed limit [14].

A Belgian ISA trial with both private and commercial vehicles was carried out in City of Ghent. In all 17 commercial vehicles were involved in this study, most of

[1] Submitted March 25, 2008

them from the local authorities and public transportation. No separate results were given for the commercial ones. However, a reduction of up to 2.5 km/h was found for the 85% percentile speed for all cars [8].

In addition a Swedish trial with 16 buses was made in Gothenburg in 2002 to 2003. Even though most of the participating drivers found it essential to observe the speed limits, they were rather negative to ISA. No driving results were published [15].

So far ISA in commercial vehicles has shown significant results regarding speed, but the drivers' attitudes are quite negative. Until now no ISA projects have tested the impact on commercial drivers from different kinds of incentive.

Therefore, in this paper the ISA impact on professional drivers from combining information about speeding with incentive in the form of a competition to get the fewest logged speed violations is presented.

II. Methods

A. Project specification

The current project which is carried out in cooperation between Vejle Municipality and Aalborg University is in general based on the same technology as in the *Pay as You Speed* project [12]. However, there are some differences and a brief description of the equipment follows here.

In the vehicle there is an "On Board Unit" (OBU) which consists of:

- GPS/GPRS unit with a memory card where the digital map with the speed limits are stored. It is placed under the dashboard.
- Display and loudspeaker placed in the air nozzle, the display shows the speed limit and penalty points – See below.
- GPS antenna, placed behind the rear-view mirror
- A "key reader" which can read the drivers key ID.

Fig. 1 shows a flow chart for the ISA.

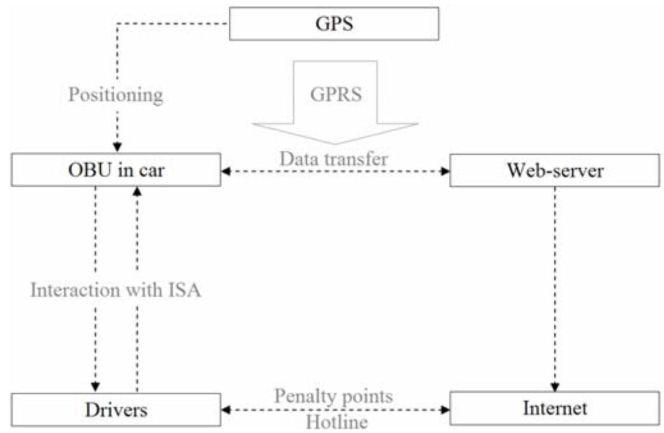
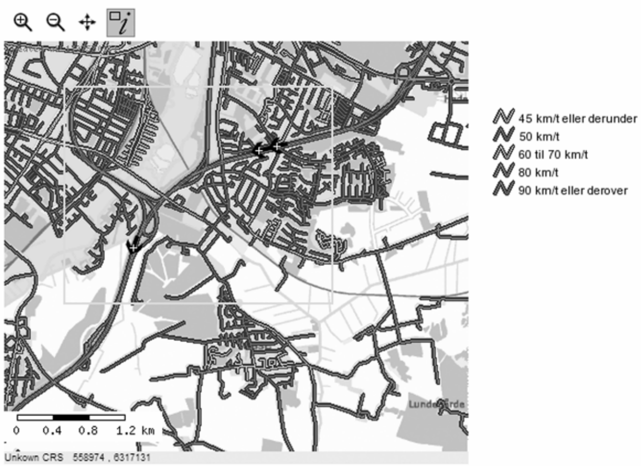


Fig. 1. The flow in the ISA.

The GPS receiver in the OBU calculates a position every second. This position is matched onto the speed map; the speed limit from the map is shown in the display and compared with the car's speed. If the speed limit is exceeded by more than 5 km/h, the OBU gives the driver a verbal warning with a female voice as e.g.; *"50 – you are driving too fast*". The warning will be repeated every sixth second until the speed is below the speed limit + 5 km/h. The third and subsequent warnings give penalty points. The number of penalty points per warning depends progressively on the degree of speeding so a small violation does not give as many penalty points as a large one. The participating drivers have access to a web based map which shows all penalty points immediately after the trip has ended. Here it is possible to check if the OBU has calculated the right speed limit and position. A hotline can be contacted for removing incorrect penalty points. Fig. 2 shows the map with penalty points.



Hastighedsoverskridelser

Hastighedsgrænse	Bilens Hastighed	Antal point	Dato og tid	Overskridelse nr.	Tur nr.
110	126	1	05.10.06 kl. 08:27:46	690	494
110	119	1	05.10.06 kl. 08:27:52	691	494
110	119	1	05.10.06 kl. 08:28:50	692	494

Fig. 2. The map with penalty points.

The penalty points are shown on the display and summarized for each driver, and once a month the driver with fewest points wins an award sponsored by the local municipality. Each participating company has the opportunity to supply this award or give an award to the “best” driver in the company, if so desired. The drivers have access to a webpage which shows the number of penalty points per driver, but only names from the driver’s own company are shown while the other drivers are anonymous. The webpage also shows the results for each firm in total.

Each driver has a personal key ID which must be shortly in contact with the display when initiating a trip. Fig. 3 shows the ISA equipment.

Fig. 3. The ISA equipment consisting of the display in the air nozzle (above) and the On Board Unit (below).

This ISA project involves 26 commercial cars and a total of 51 drivers in one year. The cars were equipped with the hardware in the spring of 2007. The cars are planned to drive with the equipment for one year. In the first 1½ months after installation the display was turned off and no warnings were given. However, the OBU also in this period logs all speeding. In this way the period is a baseline period where the normal behaviour in each vehicle is registered. After the baseline period the displays are turned on in the rest of the test period.

In this article the impact from ISA in the first 1½ months “baseline period” with the ISA equipment turned off will be compared with the first 1½ months with active ISA equipment, subsequently named the “effect period”.

Six companies are participating in this project. Four of them are small/medium companies; one is the local post office and the last is the road office in the local municipality. In the four small/medium companies each participating car has been driven most of the time by the same driver. This means that the driving registered for the single car is almost similar to what is registered for the single driver. In the large company in all 28 drivers are using five cars. In the road office seven drivers use five cars. Table I shows the distribution of drivers and vehicles in the participating companies.

TABLE I
PARTICIPATING CARS AND DRIVERS IN THE SIX COMPANIES.

	No. of participating vehicles	No. of participating drivers
Small medium enterprise	5	5
Small medium enterprise	5	5
Small medium enterprise	5	5
Small medium enterprise	1	1
Municipality	5	7
Large company	5	28
Total	26	51

After activating the ISA equipment, the number of penalty points and the mileage is calculated every month and compared for each driver. The driver with the lowest number of penalty points per driven 1,000 km receives a reward.

During the same procedure any systematic avoidance of using the key ID is monitored and a warning is sent to the manager in the company.

Besides this study on behaviour a study on the participating drivers' attitudes to ISA and traffic behaviour in general will be carried out. Here data will be collected via a web based questionnaire which all participating drivers have been asked to fill in. One questionnaire was sent out during the "baseline period" while the next will be sent out late in the project period. With these questionnaires it will be tested if participating in the ISA project will change the drivers' attitudes to ISA and the attitude to traffic related questions in general and especially speeding.

III. DATA AND RESEARCH PROCEDURES

A. *Experimental set-up*

In the "baseline period" and the first 1½ months with the ISA equipment turned on, the "effect period", the 26 participating cars have driven approximately 88,000 km in total, of which the majority is distributed on the following road types:

- Roads with a 50 km/h speed limit, which is the normal speed limit in urban areas (subsequently named as 50 km roads etc.),
- Roads with a 70 km/h speed limit, which is the speed limit on a few large city roads,
- Roads with an 80 km/h speed limit, which is the normal speed limit in rural areas,
- Roads with a 110 km/h speed limit, which is the lowest normal speed limit on motorways and the speed limit on motorways in the study area and
- Roads with a 130 km/h speed limit, which is the speed limit on motorways in less trafficked areas.

In all, 94% of the 88,000 km are driven on these roads, and hence the results are based on mileage on roads with these speed limits. The mileage distributed on all speed limits is shown in table II.

TABLE II
MILEAGE DISTRIBUTED ON SPEED LIMITS.

	Mileage (km)	
Speed limit (km/h)	Baseline period	Effect period
30	206	199
40	554	602
50	12,092	10,700
60	781	575
70	3,377	2,951
80	22,886	19,648
90	1,318	1,318
110	2,684	3,836
130	1,958	2,053
Total	45,855	41,881

The participants' behaviour is registered by 9.9 million GPS positions in all. This number of data corresponds to approximately 1.6 hours of driving per participating vehicle each weekday.

B. *Research procedure*

When studying speeding, the use of time can result in a systematic bias, since a large violation of a speed limit on a given distance will be underestimated because the higher the speed is, the less time will be spent on this distance. Hence, a small violation close to the speed limit will result in a longer time of speeding than does a large violation on the same distance. Therefore, all results are based on mileage and not on the time span.

The ISA equipment in this project starts to give warnings every 6th second if the speed limit is exceeded by more than 5 km/h, and after two warnings also penalty points. The speed limit plus 5 km/h is selected because most Danish road users are driving close to the speed limit, but not necessarily below it. If the system was designed to react already on the speed limit, it was assessed that the participants would often feel pressure from the cars behind them. Also the Danish rules concerning speeding are included in this assessment: Fines are only received if speeding is exceeding the limit by more than 10% + 3 km/h. Therefore the part of speeding above the speed limit + 5km/h will be compared in this study.

The behaviour of the cars is studied in the “baseline period” and in the “effect period” by comparing the proportion of the mileage that has been driven at more than 5 km/h faster than the speed limit in the two periods.

To handle that there are more than one driver per vehicle, the drivers must use a key ID. The frequency of the drivers’ use of the key ID is studied to see if they forget to use the key ID, maybe especially when they are busy. To test this, the part of speeding using the key ID will be compared with the part of speeding not using it.

Since speeds far below the limit can not be influenced by ISA, these speeds are sorted out of the data when calculating “mean free flow speed” (MFFS) and speed variation. There is no indisputable definition of “free flow speed”. A number of scientists working with ISA related subjects have been contacted via “the International Working Group On Speed Control” (IWGOSC) mailing list and a large number of suggestions have been made. One suggests all speeds above 15 km/h while others suggest that free flow is all data when speed is above 50 km/h on motorways. In the Australian TAC SafeCar Project the vehicles had a following distance warning (FDW) system and hence they could deselect data if the car in front was closer than three seconds [7]. A fourth suggestion was to remove all mileage during the rush hours. However, the vehicles in this ISA project are not equipped with FDW and if all mileage in the rush hours is removed, the number of data will be low and hence assessed as too uncertain. Consequently, we have decided the following limits of speed when defining “free flow speed”. On 50, 70 and 80 km roads, it is minus 15 km; on 110 km roads it is minus 20 km/h and on 130 km roads it is minus 30 km/h. The definition of “free flow speed” here is a trade-off between two considerations; 1: As much data as possible and hence the results may be the most reliable and 2: Avoid data far below the speed limit and thus of no relevance when measuring ISA. See table III.

The standard deviation indicates the range of speed on a road. If it is small it means that most of the traffic is driving at an almost similar speed. Investigations have shown that a decrease in the standard deviation will improve the traffic safety [16]. The standard deviation (FFSD) is here calculated on “free flow speed”.

TABLE III

SPEEDS FOR EACH SPEED LIMIT, WHICH IS INCLUDED IN “FREE FLOW SPEED”.

Speed limit	50 km/h	70 km/h	80 km/h	110 km/h	130 km/h
Free flow speed	>35 km/h	>55 km/h	>65 km/h	>90 km/h	>100 km/h

Finally, the impact from ISA on transportation time will be studied. It is essential that any increase in transportation time is calculated because most companies are very aware of the expenses regarding transportation including downtime, and they might reject to participate in an ISA project if it results in too large or unknown increases in transportation time. The change in transportation time is calculated on “free flow speed” for the same reasons as mentioned concerning MFFS.

C. *Statistical analyses*

In Section IV a paired t-test is used to study differences between e.g. the “baseline period” and the “effect period” for various variables. Regarding e.g. proportion of mileage with speeding we compute for each car the difference between this variable in the “effect period” and the “baseline period”. This leaves up to 26 observed differences and we then apply a standard t-test to test whether the theoretical mean of these differences is significantly different from zero. Note for some speed limit classes, some cars did not attain any mileage. Hence, for some speed limit classes the number of observed differences is lower than 26.

The MFFS shows the impact of ISA on speeds close to or above the speed limit. For each car we compute a MFFS by weighting each MFFS value with the proportion of the mileage travelled at this speed. Similarly we compute a mean squared deviation (variance) by weighting the squared distances between the free flow speed values and the MFFS with the proportions of mileages for the speed values. The standard deviation FFSD for each car is the square root of these mean squared deviations. The quantity FFSD is of interest as it measures the homogeneity of the driving pattern.

The MFFS and FFSD for one of the cars with just one driver differ markedly from the values for the other cars. In the effect period for e.g. on 50 km roads, this driver’s MFFS is 11.7 standard deviations above the mean of the remaining cars' MFFS. In the baseline period this driver’s behaviour does not differ from the other cars. This pattern is repeated for FFSD and is consistent for all speed limits. It thus appears that the driver is intentionally obstructing the ISA experiment by deliberately driving faster in the effect period. In the analyses below we omit this driver and briefly comment on the results obtained if the driver is included.

IV. Results

A. Part of speeding

Table IV shows the % of the mileage with a speed exceeding the speed limit by more than 5 km/h.

TABLE IV.
PERCENTAGE OF MILEAGE OVER THE SPEED LIMIT + 5 KM/H.

	Speed limit (km/h)				
	50	70	80	110	130
Baseline period	18.7	15.2	18.9	25.5	5.0
Effect period	7.4	5.1	4.7	6.6	1.3
Reduction	11.3	10.1	14.2	18.9	3.7
p-value	0.000	0.000	0.000	0.016	0.290

There has been an impact on the participants' speed on all roads. The largest impact has been on 80 rural roads and 110 motorways and the smallest on 50 and 70 urban roads and 130 motorways. The speeding percentage has in general been at the same level on urban and rural roads in the baseline period. This is different compared to results from two other Danish ISA projects. In these projects the violations in the baseline period were much higher in rural areas than in urban areas. Opposed to this, the impact from ISA in these projects was highest on rural 80 km roads which fits better with the present results [10] [11], [13]. On 130 km roads, the impact is infinitesimal and the amount of speeding is probably low since a majority of the drivers find that 130 km/h is fast enough and hence speeding is unnecessary. This indicates that drivers in company cars in general have a worse attitude than the private car owners to speeding in urban areas and hence more accidents which also is found in the literature [2], [3]. On urban 50 km roads, the speeding is more than halved from 18.7% to 7.4% but the relative impact is higher on 70 km roads: from 15.2% to 5.1%. On rural 80 km roads, the impact is a reduction from 18.9% to 4.3% and on 110 km motorways from 25.5% to 6.6%. On 130 km motorways, the speeding is reduced from 5.0 % to 1.3 %. All reductions expect for 130 km roads are statistically significant at the 5% significance level according to the paired t-tests, cf. III C.

B. Use of key ID

In the effect period the participating drivers were asked to use a personal key ID. However, some of them refused to use the key ID while other used it from time to time. The mileage with or without used key ID in the effect period can be seen in table V.

TABLE V
MILEAGE WITH/WITHOUT USING KEY ID.

	Baseline period	Effect period	
Speed limit (km/h)		Without key ID	With key ID
30	206 km	33 km	165 km
40	554 km	143 km	459 km
50	11,805 km	2,977 km	7,610 km
60	735 km	121 km	433 km
70	3,150 km	783 km	2,067 km
80	21,290 km	4,204 km	15,002 km
90	1,260 km	272 km	1,030 km
110	2,638 km	207 km	3,607 km
130	1,915 km	69 km	1,978 km
Total	43,554 km	8,808 km	32,351 km

In total 79% of the mileage has been carried out while using a key ID. Especially when driving on 110 and 130 km roads the proportion of key ID use has been high with 95% and 96%, respectively. This proportion should have been near to 100% and therefore the monthly study of each driver's use of key ID has been reported to the reluctant drivers' leaders. Even though there is a monitoring of the key ID use some of the drivers are averse to using it.

A big difference in the drivers' use of key ID is found. In some cars the key ID is always used and in other cars the drivers often forget to use the key ID. Table VI shows the number of cars in different percentage intervals for mileages driven with key ID.

TABLE VI
NUMBER OF COMPANY CARS DISTRIBUTED ON THE PROPORTION OF MILEAGE WHEN USING KEY ID

Proportion mileage with key ID	0-25%	26-50%	51-75%	76-100%
Number of cars	7	1	0	18

The drivers in most cars use the key IDs in the majority of the mileage. The impact from using key ID can be seen on table VII.

TABLE VII
PERCENTAGE OF MILEAGE OVER THE SPEED LIMIT + 5 KM/H DEPENDING ON USE OF KEY ID.

	Speed limit (km/h)				
	50	70	80	110	130
Baseline (No key available)	18.7	15.2	18.9	25.5	5.0

Effect, without Key	13.6	9.7	11.0	3.0	0.3
Effect, with Key	4.2	2.9	2.5	6.9	1.4
p-value	0.014	0.009	0.056	0.403	0.500

When not using the Key ID the drivers were speeding more than when using it, but still the speeding was less than in the "baseline period". So based on these first results, it is found that even without incentive (penalty points on the drivers key ID) the information part of the system has an impact on speed behaviour, in accordance with findings in other ISA projects [7], [8].

Except on 130 km roads, the use of key ID seems to reduce speeding more than informative ISA alone. However, only on 50 and 70 km roads the extra reductions based on use of key ID are significant at the 5% significance level. The insignificant results for 110 and 130 km roads may be explained by lack of data, only 3 and 2 difference observations were available for these speed limits.

C. *Mean free flow speed*

The MFFS shows the impact from ISA on speeds close to or above the speed limit. In table VIII the MFFS and the FFSD are compared for the different speed limits.

TABLE VIII
MFFS AND FFSD IN THE BASELINE AND EFFECT PERIODS.

Speed limit (km/h)		Baseline	Effect	Reduction	p-value
50	MFFS	50.5	47.9	2.6	0.000
	FFSD	10.0	9.5	0.5	0.000
70	MFFS	69.6	66.4	3.2	0.000
	FFSD	9.4	8.3	1.2	0.000
80	MFFS	82.2	76.8	5.4	0.000
	FFSD	11.4	9.6	1.8	0.000
110	MFFS	113.5	107.4	6.2	0.002
	FFSD	15.2	8.3	6.9	0.023
130	MFFS	120.2	121.0	-0.8	0.941
	FFSD	10.4	9.1	1.3	0.654

Not surprisingly, the same trends as mentioned above can be found when studying MFFS. The biggest reduction 5 – 7 km/h is found on 110 motorways and on 80 roads, on urban roads the reduction is between 2 and 4 km/h. On 130 motorways, there has been an increase in speed of nearly 1 km/h. The results are very similar to the primary results in the *Pay As You Drive* project [11].

The FFSD is reduced on all road types, from 0,5 km/h on 50 km roads and up to 7 km/h on 110 km motorways. As the reduction in percentages speeding and the free flow speed a reduction in the FFSD also indicates better traffic safety.

Except on 130 km roads all the reductions in MFFS and FFSD are significant at the 5% significance level according to paired t-tests. If the differences for the obstinate driver are included in the statistical analyses the observed reductions are still positive, but not significant anymore (except at speed limit 80 km/h) since the data for this driver both inflates the variance and leads to smaller observed reductions.

D. *Transportation time*

The increase in transportation time is very low. In average each participating car has used 11:51 minutes more per week for transportation which can reasonably be related to the ISA system. According to Danish socio-economic estimations an hour of wasted time for a commercial car is priced as 35 € [17]. Hence, the weekly expenses regarding increased transportation time per vehicle is 6.9 €. As a supplementing comment to this result it must be remembered, that some 40% of the transportation among the participating cars has been carried out with speeds lower than 'free flow speed' and hence of no relevance for ISA.

V. DISCUSSION

In this study the drivers are under influence from two factors – an information influenced through the female voice *"50 – you are driving too fast*" and an incentive influence through the penalty points. If it is presumed that when driving without key ID the drivers are not under influence from the incentive "penalty points" this primary study has shown that both influences give a significant impact. It will be exciting to see the development in the remaining part of the 12 month test period. Will the total effect increase or decrease over time? Will the mileages without key ID increase or decrease and what will the effect be on the speed? Will the speed increase or decrease over time when the drivers get used to the ISA equipment? And what about the effect of the incentive – the penalty points? Will the drivers get used to the penalty points? And how will the companies handle the penalty points: will they give awards to their driver with the smallest number of penalty points or will they punish the driver with most speeding – or maybe do nothing and leave the "job" to be solved in a social process between the drivers when they are discussing their penalty points over the lunch table?

VI. CONCLUSION

The aim of this study of ISA in company cars is to test the combination of incentive and information. It is shown that ISA has a significant impact on the drivers speed. These primary data show that the percentage of mileages with speeding on 50 urban roads is reduced from 18.7% to 7.4% and on 70 roads from 15.2% to 5.1%. On roads with higher speed limits the impact is even bigger. On rural 80 km roads, a reduction from 18.9% to 4.7% is found, while it is the biggest on 110 km motorways where mileages with speeding is reduced by 19.3% from 25.5 to 6.6%. On 130 motorways, only a minor part of the mileage was with speeding in the baseline period but still the speeding has decreased in the effect period.

It has also been shown that the use of the key ID improves impact from ISA. It indicates that incentive supplies information alone and that the combination is better than informative ISA solely. The percentage of mileages with speeding on 50 km urban roads is reduced to 13.6% without using key ID while it is as low as 4.2% when using key ID. The results on 70 km roads are 9.7% and 2.9% while they are 11.0% and 2.5% on 80 km roads. On 110 and 130 km motorways some small increases are observed when using key ID. The impacts from using key ID are significant for 50 and 70 km roads while the results for the remaining roads are insignificant.

Moreover, the data shows that "mean free flow speed" and "free flow standard deviation" have been reduced significantly because of ISA. Impact has been most marked on rural roads and motorways with a 110 km/h speed limit, while also clear impacts are found for urban roads. Again the results indicate that ISA has limited impact on 130 km roads - most likely because most road users find a 130 km speed limit high enough - an attitude, which is also found in the other Danish ISA project "*Pay as You Speed*".

The main results are statistically significant but they are only based on the first 1½ months with activated ISA equipment, and so far it seems that the drivers improve their behaviour regarding speed.

Based on these primary data it has been calculated that the average increase in transportation time with regard to the ISA system is as low as 9:51 minutes per vehicle per week. According to Danish socio-economic estimations the weekly expenses regarding increased transportation time per vehicle is 6.9 €.

VII. Acknowledgments

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HOW INTELLIGENT SPEED ADAPTATION AFFECTS COMPANY DRIVERS' ATTITUDES TO TRAFFIC RELATED ISSUES

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ABSTRACT

A Danish Intelligent Speed Adaptation trial with company cars was concluded in November 2008. It included 26 cars and 51 non-voluntary drivers. Results presented here are regarding attitudes to behaviour in traffic and to Intelligent Speed Adaptation. In general the trial has increased the drivers' awareness of speed limits but hardly changed the drivers' attitude to what constitutes dangerous behaviour in traffic. Further, ISA was assessed as more positive for company cars than for private cars. Moreover, respondents from this trial were more aware of risk in traffic than were young drivers in another Danish Intelligent Speed Adaptation trial.

KEYWORDS

Intelligent Speed Adaptation, Driving speed, Attitudes, Traffic, Road Safety, Attitudes, Traffic Safety, White van driving

BACKGROUND

Road safety is one of the world's main causes of loss of years of life. In 2004 it was estimated that more than 1.2 million people died because of poor road safety [1]. The European Commission has set an ambitious goal to mitigate this problem. The goal is a reduction of road fatalities by 50% in 2010 compared to the situation in 2001. Nevertheless, in 2005 only a reduction of 17% was reached and it became clear that new tools must be introduced to reach the goal. In this context, Intelligent Transport Systems (ITS) and especially Intelligent Speed Adaptation (ISA) could be key tools in reaching the goal [2]. ISA means equipment in a car which compares the current speed with the current speed limit and gives feedback to the driver if speeding. Various forms of response can be given if speeding occurs: There may be a visual and/or auditory response in case of violations, and/or a display may show the speed limit. Additionally, violations can be logged on an on-board computer. Finally, the accelerator pedal may give resistance (heavy accelerator pedal) or even make it impossible to violate speed limits (hard accelerator pedal). These different types of ISA systems can be categorized as informative, advisory, recording, or intervening systems [2].

Commercial drivers have a poor reputation among other road users due to their behaviour, and are notably over-represented in traffic accidents. A new Danish study has e.g. concluded that commercial drivers are approx. 125% more exposed to road fatalities or severe injuries than are drivers in private cars [3]. Moreover, many companies have recently formulated policies regarding safety, environment, etc. Consequently, ISA could be a suitable solution for the companies to fulfil their stated goals.

In a number of countries, ISA trials with company cars have been carried out in the last decade with significant results. The Australian *TAC Safecar* project, which was carried out from 2003 to 2005, included 15 company cars and 23 voluntary participating drivers. This involved an advisory and intervening ISA system which consisted of a display showing the speed limit if speeding and a heavy accelerator pedal if speeding continued. The main results were a reduction by up to 2.7 km/h for the 85 percentile speed, and driving time with speeding by more than 5 km/h was reduced by up to 57% [4]. Also, in Stockholm, Sweden an ISA project with 20 public cars and a total of 130 drivers was carried out from 2003 to 2005. The highest effect here was found for rural roads with a speed reduction of up to 2 km/h. On motorways the effect was smaller. This trial involved an intervening ISA system with a heavy accelerator pedal [5]. Further a Belgian ISA trial with both private and commercial vehicles was carried out in the City of Ghent. 14 company cars were involved in this study. No separate results were given for company cars. However, a reduction of up to 2.5 km/h was found for the 85% percentile speed for all cars. The ISA system used in the trial was similar to the one used in Sweden [6]. So far ISA in company cars has shown significant results.

An ISA trial with incentives for company drivers

In the Danish ISA trial *ISA Commercial* (ISA C), ISA was tested with non-voluntary company drivers. In addition to an informative and advisory function, the ISA system had an incentive function based on recording ISA, which consisted of penalty points if a driver violated the speed limit. In this paper the non-voluntary professional drivers' attitude to ISA and road safety topics in general are studied.

ISA C was carried out in cooperation between Vejle Municipality and Aalborg University and included 26 company cars and 51 drivers in total. The cars belonged in six companies with 1-5 vehicles in each company. In most companies, the participation was decided after discussions among the drivers, who were mainly positive towards the trial beforehand. In one company, the decision was taken without involvement of the drivers, who were of course less positive towards the trial. The trial was finalized in November 2008. It was generally based on the same technology as in the *Pay As You Speed* ISA trial (PAYS) [7]. However, there were some differences, and a brief description of the ISA system follows here.

In each car an "On Board Unit" (OBU) was installed. It consisted of:

- A GPS/GPRS unit with a memory card on which the digital speed map was stored,
- a display with a loudspeaker. The display showed the speed limit and any penalty points. The loudspeaker was used for verbal warnings in case of speeding, and
- a 'key reader' which could read the drivers' unique key ID and hence distinguish between several drivers' behaviour in the same car.

Based on a GPS signal the position was matched onto the speed limit map. This limit was shown in the display and compared with the car's speed. If the speed limit was exceeded by more than 5 km/h, the driver received a verbal warning in a female voice such as e.g.; *'50 – you are driving too fast'*. The warnings were repeated every sixth second until the speed was reduced to under the speed limit + 5 km/h. The third and subsequent warnings were associated with penalty points. The number of penalty points per warning depended progressively on the level of speeding. Moreover, each driver had access to a web page which showed all received penalty points.

During the first 1.5 months, the ISA equipment was inactive albeit collecting 'normal' behaviour among the drivers - a 'baseline period'. After this, ISA was activated. The number of received penalty points per driver was summarized and compared with the driven distance once a month. The driver with the fewest penalty points per driven distance was announced as the driver of the month and received a small present worth app. 40 €. After approx. 12 months with ISA activated, the trial stopped and the 10 drivers with virtually no penalty points received a GPS navigator for their private car as a reward. Data collected during the trial consisted of a recording of the driving for each driver based on GPS data. Also, the drivers' attitudes to traffic related issues were collected by two web-based questionnaires.

Recorded driving data from the full trial period have not yet been analysed completely. However, preliminary results based on the behaviour in the 'baseline period' compared with the behaviour in the first 1.5 months with ISA activated have shown remarkable results (see table 1) [8].

Table 1. The proportion of the driven distance at more than 5 km/h above the speed limit

	Speed limit (km/h)				
	50	70	80	110	130
Baseline period	18.7%	15.2%	18.9%	25.5%	5.0%
ISA activated	7.4%	5.1%	4.7%	6.6%	1.3%
Reduction	11.3%	10.1%	14.2%	18.9%	3.7%
p-value	0.000	0.000	0.000	0.016	0.290

Based on these data, speeding was reduced significantly on all analysed road types except on motorways with a 130 km/h speed limit where almost no speeding occurred anyway.

The effect from ISA was significant, but how did the drivers review their experiences with the system, and what were their attitudes to behaviour in traffic generally? Moreover, how has ISA affected these attitudes? The large-scale Swedish trials in which private car owners participated concluded that a substantial part of the drivers would like to keep the ISA equipment after the end of the trial and that they became more positive towards ISA in general [9]. In the TAC Safecar trial, increased discontent with the system was indicated [10].

METHODS

Research design data and statistical analyses

Data were extracted from two web-based questionnaires. One questionnaire was filled in during the 'baseline period', while the other was filled in when the drivers had driven with ISA activated for approx. one year. These are subsequently mentioned as 'baseline' and

‘ISA’, respectively. Although the drivers were forced to participate in the trial because ISA was installed in their company car, the questionnaires were filled in voluntarily. The two questionnaires were almost identical, so any effect from ISA would be measurable. In total, 51 drivers were equipped with a key ID, and 40 of them filled in the first questionnaire (baseline). The number of respondents in the second questionnaire was too low after the first deadline, and a small reward was subsequently offered to all respondents to increase the number. However, the second questionnaire was only filled in by 23 drivers (ISA). Of these 23, two were ‘new’ and had not filled in the first one. Consequently, the analyses made here consist of feedback from 21 drivers. Four of them were women. These drivers are subsequently denoted as ‘respondents’.

The questions used in this trial were very similar to the ones used in the PAYS trial. Therefore, it is possible to compare results from ISA C with the ones from PAYS where suitable. Results from PAYS are only shown in figures if they differ markedly from the ISA C results. In addition, it is notable that the groups of questions used are similar to the ones used in most new ISA trials [11]. The first questionnaire included a number of background questions such as age, gender, education and car use. Also, questions related to driving style, attitudes to driving style, safe driving, driving speed, speed limits, and risky traffic behaviour were included. Further, any differences between driving behaviour in private and in company cars were expounded. Moreover, the drivers were asked about their attitudes to a number of ISA systems, including the one they tried in ISA C. The questionnaires were sent to the respondents by e-mail. Each questionnaire took 15 to 20 minutes to fill in and consisted of some 90 to 125 questions, depending on some answers which resulted in additional questions. To keep the results from the trial short and clear and to deal with the limited space available, only selected results are presented here. Moreover, regarding a number of topics, the respondents were asked about their behaviour in both private and company cars. In many cases, the results were almost similar for the two types of vehicles. Therefore, results regarding driving in private cars are only included in a few cases. Using the advantages of web-based questionnaires, the respondents were provided with a continuous scale without visible values for indication of their attitudes to most of the questions. These scales have a hidden scale and were made as two types: one ranging from -200 to +200 in bipolar questions in terms of how much respondents agreed or disagreed with a statement, and one ranging from 0 to 400 depending on e.g. how often they speed (see Figure 1).

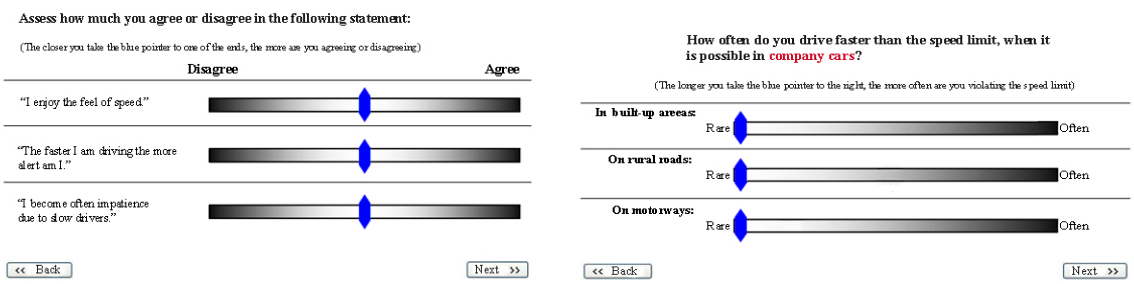

Figure 1. Examples of the two types of questions

A paired t-test was used to study differences between the baseline and ISA for various variables. Regarding e.g. the respondents’ attitudes to speeding in built-up areas, the differences for each respondent in the ‘baseline’ and ‘ISA’ were calculated. This resulted in up to 21 observed differences, and then a standard t-test was applied to test whether the theoretical mean of these differences was significantly different from zero. P-values below 0.05 are assessed to be of statistical significance, while p-values between 0.05 and 0.10 are assessed as likely to be of statistical significance.

RESULTS

Personal data

The participating respondents were between 24 and 61 years old when the trial started. The mean age was 44. 76% had one or several children. All had obtained their driving licence before they were 21, so most of them were experienced drivers. Their assessed driving in company cars differs widely, from 600 km to 34,800 km per year, and some 75% of the drivers answered that they drove between 10,000 and 15,000 km per year.

Attitude to and occurrence of speeding

The drivers' attitudes to risk in traffic depending on the road types in 'baseline' and 'ISA' are shown in Figure 2. Results marked with an oval indicate that the change is of statistical/likely to be of statistical significance.

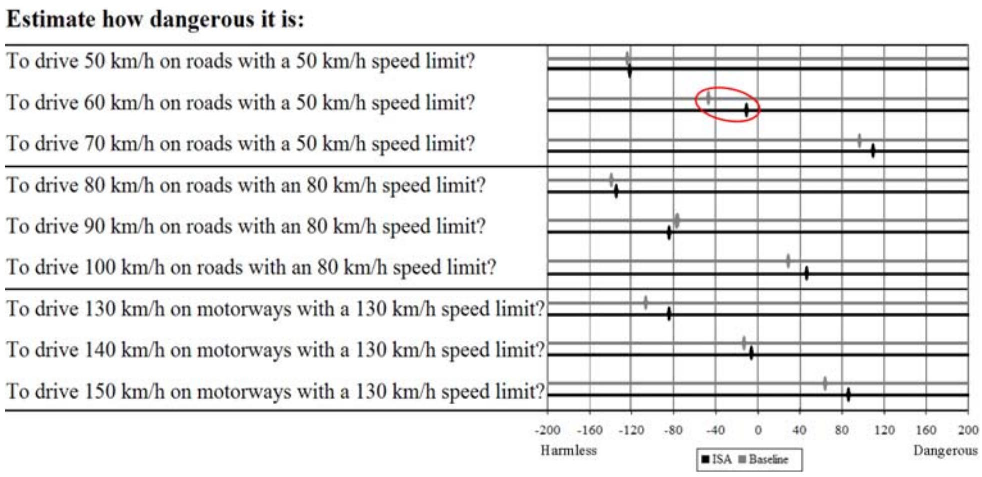

Figure 2. Respondents' attitudes to speed and risk on different road types

The Danish speed limit in built-up areas is 50 km/h, in rural areas it is 80 km/h, and on motorways it is 130 km/h, unless other speed limits are stated locally. In general the respondents found that increased speed results in higher danger. However, regardless of road type, they found a 10 km/h violation of the speed limit harmless rather than dangerous. Serious speeding by 20 km/h was assessed as somewhat dangerous, most dangerous on roads in built-up areas, and least dangerous on roads in rural areas. The only significant change due to ISA was regarding moderate speeding (10 km/h) on roads in built-up areas (p=0.041). These attitudes corresponded well with the attitude among voluntary participants in other Danish ISA trials as well as with Danish drivers who had never participated in an ISA trial [11,12]. In the TAC Safecar trial speed violations by 10 km/h were assessed as dangerous while the ones by 20 km/h were assessed as very dangerous [10]. In general the Australian participants found that speeding is more dangerous than did the Danish participants. The lowest acceptance of posted speed limits was for the rural roads. This result is alarming, because this is where the majority of severe road accidents occur in Denmark [13]. The respondents were also asked about their preferred speed limits on roads in built-up areas, roads in rural areas, and on motorways. Based on the mean results, these were approx. 50, 86, and 125 km/h for the three road types, respectively (not shown). So their feeling of danger corresponds well with the respondents' proposed speed limits. They assessed the limit in built-up areas as suitable, while it should be increased somewhat on rural roads and reduced to a similar extent on motorways. These results are somewhat identical with the ones found in the Belgian trial, where the respondents stated that they speeded the most on rural road and less in urban roads. Moreover, they felt that the speed limits in general were acceptable [14].

The respondents assessed that they speed quite rarely regardless of if they were driving in built-up areas, rural areas, or on motorways. In private cars the respondents stated that they speed least on roads in built-up areas, while they speed the least on motorways when driving company cars. No changes in attitudes due to the activation of ISA were significant. The discrepancy with the results in Figure 2 may be because small violations of a speed limit might not perceived as 'real' speeding in the results in Figure 3.

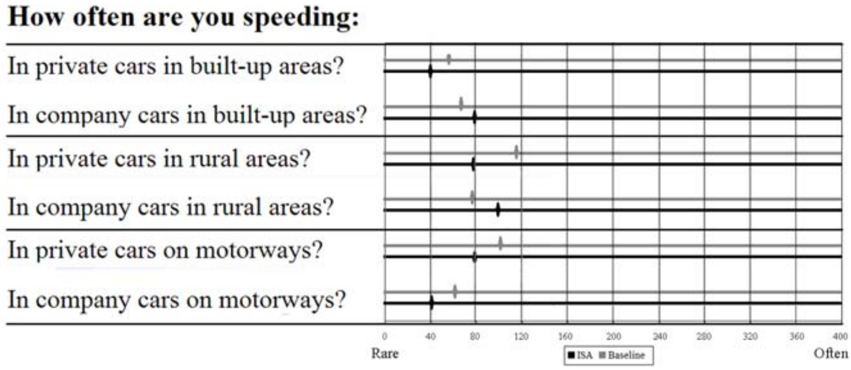

Figure 3. Respondents' assessment of how often they speed in company cars and private cars, respectively

Attitudes to different types of and reasons for risk related behaviour

The two most important reasons for speeding appear in Table 2. Both in the baseline and ISA period it was lack of awareness of the speed and a desire to follow the flow of traffic. Pressure from others cars was in the baseline a minor reason for speeding, but with ISA the proportion increased as expected. Intention to speed is more rarely as reasons for speeding and did not change. The awareness of the speed limits decreased from baseline to ISA. One can wonder about this result, because the respondents in the ISA period got continuous information about the speed limit contrary to in the baseline period where they only had information from the speed limit signs placed on the road. Finally their urge to speed dropped from baseline to ISA. It was probably because in the ISA period they knew that that speeding was not possible without getting penalty points. However, none of these changes were of statistical significance. In the TAC Safecar trial, the respondent stated that the most important reasons for speeding were lack of awareness of the speed and unawareness regarding the speed limit. A desire about to follow the traffic was only rare the case [10].

Table 2. Respondents' two most important reasons for speeding

	Baseline	ISA
	Proportion	
I wish to follow the traffic.	62%	57%
I am not aware of my speed.	67%	52%
I feel pressure from other cars.	14%	29%
I intend to speed.	19%	19%
I am not aware of speed limit.	19%	38%
I feel an urge to speed.	19%	5%

The reasons for speeding were several, and so were the various risk-related activities. Figure 4 shows respondents' attitudes to risky behaviour.

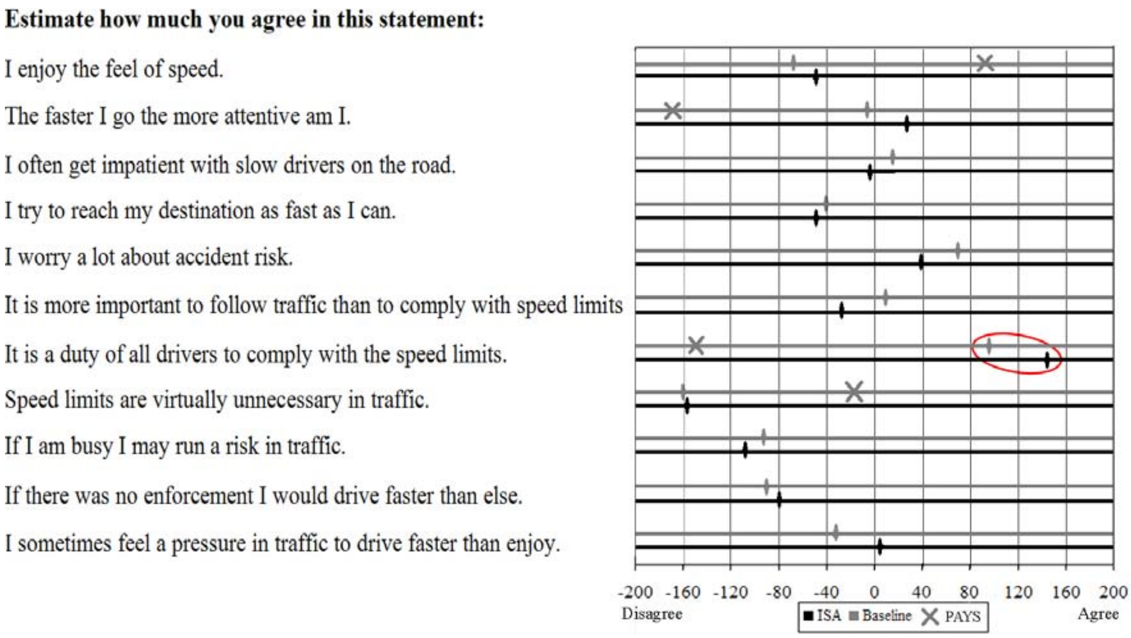

Figure 4. Respondents' attitudes to a various statements regarding risky behaviour

Respondents generally disagreed with the following statements:

- enjoying the feeling of speed,
- lack of enforcement would make them speed more,
- if busy they were prepared to take risks,
- they try to reach their destinations as soon as possible, and
- speed limits are unnecessary in traffic.

Respondents neither agreed nor disagreed on the following issues:

- feeling of pressure from the car behind,
- it is more important to follow the traffic than the speed limits,
- they would often become impatient due to slow drivers, and

- increased speed results in increased awareness.

Respondents agreed with these statements:

- they worried much about the risk of accidents, and
- it is a duty of all drivers to comply with speed limits.

When these results are compared with the ones found in other ISA trials, there are some noticeable differences. The respondents in ISA C stated that speed did not result in enjoyment. The drivers in the Belgian ISA trial were also disagreeing in this statement, while the drivers in PAYS stated the opposite [11,14]. On the other hand, the ISA C respondents were almost neutral regarding higher speeds resulting in higher awareness, while PAYS showed significant disagreement with this statement. Also differences were found regarding the necessity of speed limits and the duty to comply with them, which the ISA C drivers found much more important than, did the PAYS drivers. Furthermore, ISA C resulted in a significant increased agreement on this statement (p=0.012), so it seems that their safety awareness has increased somewhat. The reasons for these noticeable differences are probably that the PAYS drivers were younger, less experienced and somewhat blind to risks related to speeding. These characteristics are well known for young drivers and could explain some of their high over-representation in the accidents statistics.

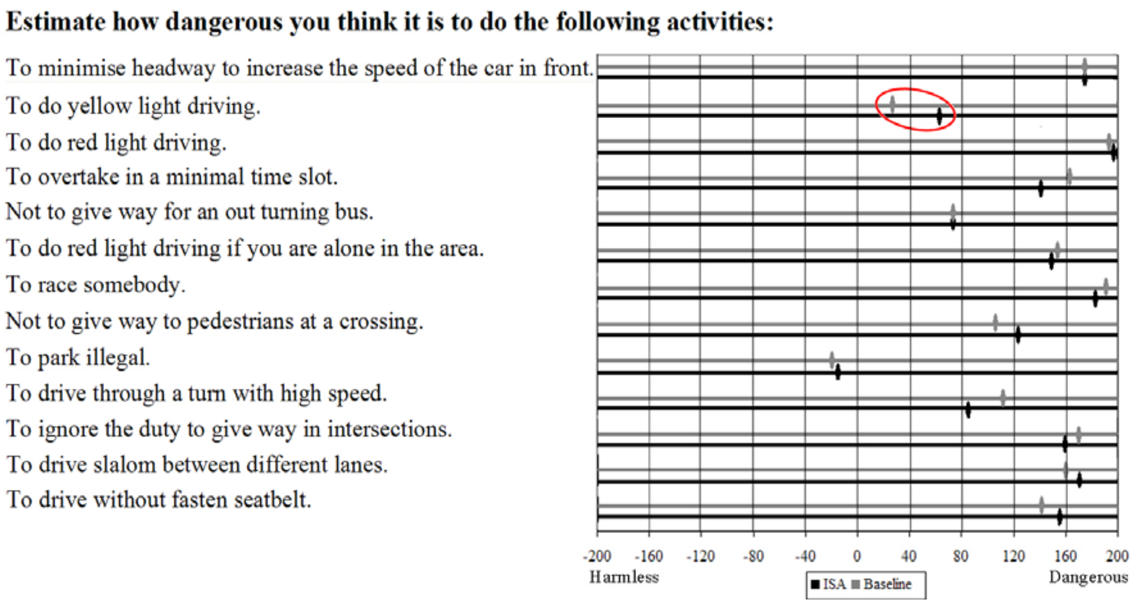

Figure 5. Respondents' estimated level of danger in connection with activities in traffic

Moreover, the respondents have answered questions about how dangerous a number of risk-related activities in road traffic are (see Figure 5). A hypothesis could be that ISA would have increased respondents' risk awareness. However, this is not supported by the feedback from respondents. In general, respondents' assessed danger of risk-related activities only changed minimally after the introduction of ISA. Only yellow-light driving tended to change significantly towards a more dangerous assessment (p=0.0849). Therefore, it can be concluded that ISA C did not change respondents' view of what constitutes dangerous behaviour in traffic.

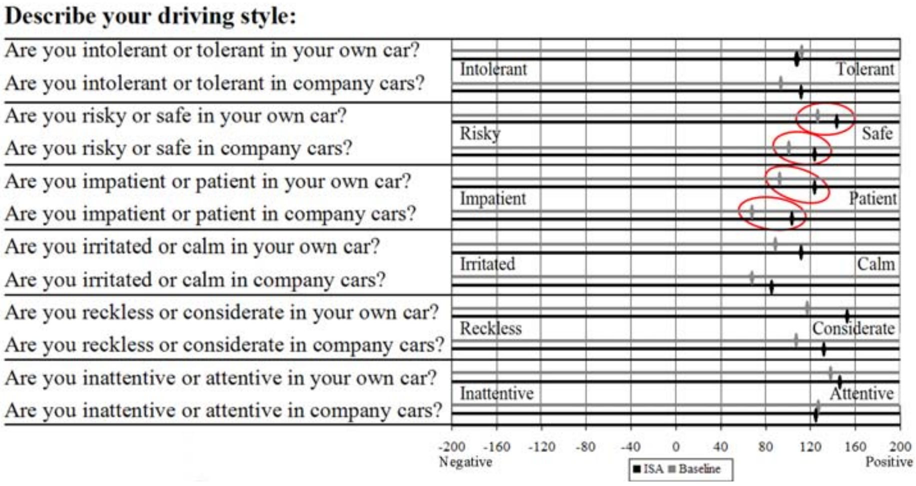

Figure 6. Respondents' assessment of their behaviour in company and private cars, respectively

As shown in Figure 6, respondents stated that their driving behaviour was positive rather than negative. Based on the summarised values for each respondent, ISA resulted in significantly better behaviour (p=0.0142), but also significant changes regarding other statements are found. Patience increased for private and for company cars (p=0.0065 and p=0.0167, respectively). Also, drivers' behaviour became safer with ISA (p=0.0203 and p=0.0395, respectively). Further, consideration and calmness in private cars were likely to increase significantly (p=0.0638 and p=0.0934, respectively). In general, the results correspond well with the PAYS results. However, the respondents in ISA C stated that they were slightly more tolerant and calm than did the ones in PAYS - maybe due to the higher age group in ISA C. Another thing that appears from these data is that for all objectives, partly with the exception of 'Tolerant' vs. 'Intolerant', the respondent stated that their behaviour was more negative when driving in company car than in private car. This points towards the same problems regarding safety and company cars as stated in the first section.

Attitudes to ISA

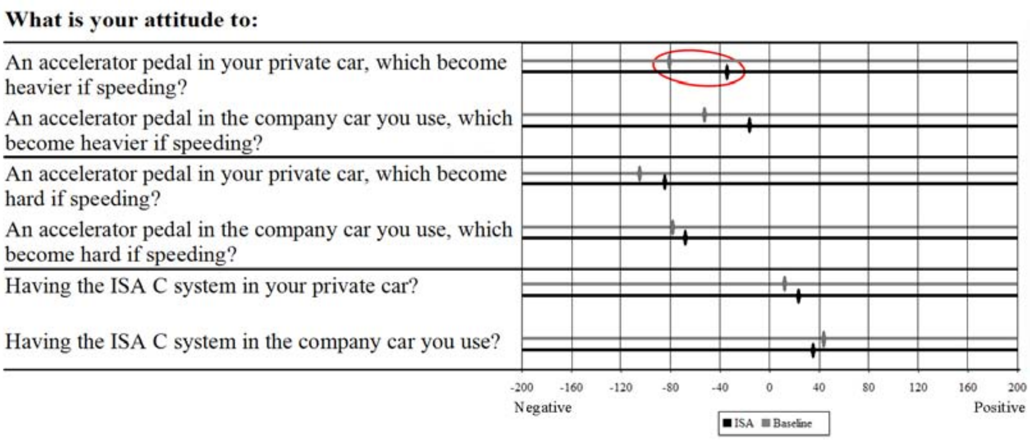

Figure 7. Respondents' attitude to different ISA systems in company cars and private cars, respectively

Respondents' attitudes to different ISA systems appear in Figure 7. When asked about their attitude to ISA equipment in general, and to the ISA C equipment in particular, they were cautiously positive towards driving with the ISA C equipment both in private and company cars. Respondents' attitudes to the heavy and hard accelerator pedal were, despite a decrease in negativity during the trial, generally rather negative. As regards a heavy accelerator pedal, the changes towards a more positive attitude tended to be significant for private cars, while it almost tended to be so for company cars (p=0.0901 and p=0.1278, respectively). These results correspond reasonably well to the results from PAYS. What is also noteworthy is that the respondents were in general slightly more positive towards ISA in company cars than in their private cars, irrespective of the type of ISA. It is also noteworthy that the respondents in general were slightly more positive towards ISA in company cars than in private cars, irrespective of the type of ISA. It also corresponds well to the respondents' assessment that their attitudes when driving in company cars were slightly more negative than when driving in private cars. These results show both a bigger need and a bigger acceptance of ISA in company cars than they do in private cars. In Belgium, it was found that commercial drivers were slightly negative to ISA (heavy accelerator pedal) while the private drivers were clear positive [14]. In ISA C the drivers were also mainly negative, but they were less negative regarding ISA in commercial vehicles. Moreover in the Australian trial, the respondent stated that they were positive to a heavy accelerator pedal while they were negative to a hard one [10].

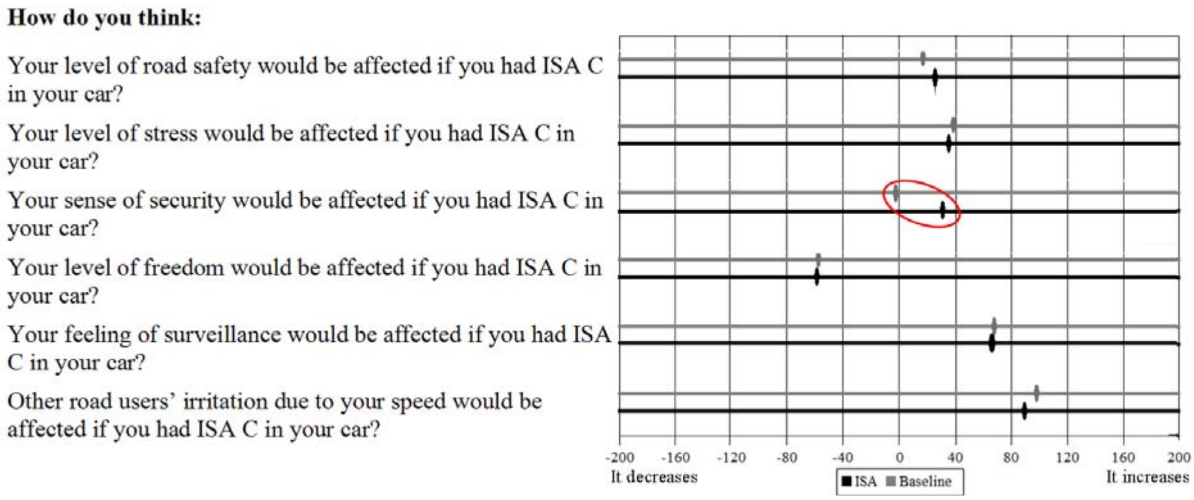

Figure 8. Respondents' attitude to the ISA C equipment

Respondents' attitudes to how the ISA C system would affect their driving experience are expanded in Figure 8. In ISA C the level of safety due to ISA was assessed as slightly positive and almost stable from before to after trying ISA while in the Swedish trials it decreased substantial after ISA was tried [9]. Both irritation from other road users due to ISA and the expected feeling of surveillance were assessed as increased due to ISA. Freedom on the road was assessed as reduced due to ISA, while the sense of security was assessed as slightly positive. The level of stress remained unchanged due to ISA. In the TAC Safecar trial, the large-scale Swedish trial and a Swedish trial with commercial vehicles the level of stress or irritation was assessed a good deal bigger due to ISA [5,9,10]. It hardly changed in ISA C. The sense of security while driving was significantly higher after activation of ISA ($p=0.0254$). It is also noticeable that except regarding the feeling of freedom while driving, attitudes to the ISA C system were positive rather than negative. The same result was found in the TAC Safecar trial, but here the respondents became markedly less satisfied with ISA after the trial [10]. Opposite to this, driver attitudes in ISA C under ISA conditions did neither differ significantly from the ones found in PAYS nor from the ones in baseline.

DISCUSSION, SUMMARY, AND CONCLUSION

One might perhaps question if the respondents are representative of the average company car driver. However, it is known that not all the drivers were keen on participating but were obliged to do so. Furthermore, one could ask if there is bias among the respondents towards the most positive part of the drivers in the participant companies. Probably, there is such a bias, but the small reward to respondents of the second questionnaire raised the respondent rate and has resulted in more mostly 'negative' respondents than else. However, irrespective of whether or not there is bias, it is reasonable to assume that any bias is significantly lower than for other ISA trials based on voluntary participation. Results from the Danish ISA trial PAYS have e.g. shown that voluntarily participating drivers sped less and were more positive to ISA beforehand than the average driver [11].

ISA C with 26 vehicles and 51 drivers in total was carried out in 2007 to 2008, and the results in this paper are concerned the drivers' attitude to ISA and road safety-related issues in general. The drivers were non-voluntary and some of them were negative towards ISA. In addition to informative and advisory functions, ISA was supplied with an incentive function consisting of penalty points if speeding occurred. Data collected during the trial consist of driving data based on GPS data and two web-based questionnaires regarding drivers' attitudes to traffic-related issues.

ISA seems to have resulted in increased awareness of danger associated with speeding, but it has only changed significantly as regards roads in built-up areas. This result corresponds well with a high acceptance of speed limits here. It was also stated that ISA did not result in significant changes in the reasons for speeding even though pressure from other cars increased and the urge to speed decreased. However, the attitude to complying with speed limits increased significantly among the respondents. On the other hand, except as regards yellow-light driving, ISA did not change drivers' awareness of danger in risky situations. Moreover, when respondents were asked about their own driving style, they assessed it as safer after trying ISA, but they also stated that their behaviour was better in their private car than in their company car. Acceptance of ISA changed only slightly but was, however, regarded quite positively. In general, the acceptance of ISA in company cars was higher than in private cars. ISA also resulted in a feeling of a higher sense of security, while safety, stress, other road users' irritation, and freedom hardly differed from the expected levels. Also, if comparing the results found in ISA C with the Danish PAYS trial involving young car owners, it is evident that the respondents in ISA C were markedly less keen on speeding and more aware of the danger in traffic than were the young. In general the drivers in ISA C were somewhat in between the drivers in PAYS who were rather risky in their attitudes, and the respondents in other trials. It might be so, because the participants in ISA C were older than in PAYS and not all were voluntary participating opposite to participants in the other trials.

Overall, ISA C has increased drivers' awareness of speed limits but has not significantly changed drivers' attitude to dangerous behaviour in traffic. Moreover, ISA was assessed as more positive for company cars than for private cars.

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