INTELLIGENT SPEED ADAPTATION, RESULTS OF PRE-TEST IN PENANG, MALAYSIA

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ABSTRACT

Intelligent speed adaptation (ISA) systems are in-vehicle systems that support drivers' compliance with the speed limit. These systems have the capability of either warning drivers or limiting them from exceeding a current speed limit. GPS technology is used to adapt speed based on vehicle's position on the highway. From research conducted largely in European countries, the implementation of ISA has the potential to significantly reduce the incidence and severity of road trauma. Over the last few years there has been a growing interest in ISA, and the number of ISA research and trials are increasing worldwide. This paper presents the results from a warning system that tested the acceptance and effectiveness of an advisory ISA system in Penang, Malaysia. Statistical analyses were conducted to determine the effectiveness of the system and a questionnaire was used to determine the acceptance of the system. The results show that advisory ISA contributed to a reductions in speed. The questionnaire results revealed a significant acceptance of this system.

Keywords: Accident, Intelligent speed adaptation, Safety, Speeding, Speed management.

INTRODUCTION

Annually, about 1.2 million people die as a result of traffic crashes and almost 25 million suffer permanent disability, Peden et al. (2004). Tragically, this trend is becoming worse, with road-traffic accidents rising from the ninth most common cause of death in 1990 to the third most common cause of death expected by 2020, Murray and Lopez (1997). While many factors contribute to collisions, it is generally agreed that speed is a major factor contributing to the occurrence, and seriousness of traffic accidents (see, for instance, Graham and Garber, 1984; Blomquist, 1986; Fowles and Loeb, 1995).

The strong relationship between vehicular speed and the severity of the accident has been well documented in several studies. For example, Finch et al. (1994) declared that a mean increase in speed of 1 km/h can lead to a 3% greater risk of a crash resulting in injury and a 4–5% higher risk of a death. An additional finding was that lower speed variance is correlated with fewer accidents (See also, Salusjarvi, 1981; O'Cinneide and Murphy, 1994; Elvik and Vaa, 2004; Nilsson, 2004).

Since many drivers exceed speed limits and speed limit enforcement is still poor, a major concern for road authorities is to increase compliance with speed limits. Currently several approaches are used to prevent speeding infringements ,including, education (e.g. driving license education and campaigns), enforcement (e.g. police surveillance and speed cameras) or different types of physical measures in the traffic environment such as road humps, see e.g. Ghadiri et al., (2009).

In fact, traditional measures to reduce speed have had limited effectiveness. For example, studies have shown that police enforcement and speed cameras tend to reduce speeds only near the enforcement area and only for a short time, Teed et al. (1993). Likewise, roadway features designed to reduce speeding tend to reduce speeds in a small and limited area, Comte and Várhelyi (1997).

Recently developed in-vehicle systems based on Information and Communication Technology such as intelligent speed adaptation (ISA) are under investigation in many countries as candidate systems for improving road safety and accident rates. ISA seems to be an effective alternative and/or complement to the traditional measures.

Intelligent speed adaptation (ISA) is the generic name for an advanced in-car electronic driving aid system, and it is a one type of vehicle-based intelligent transportation systems (ITS). ISA "knows" vehicle's location and the speed limit for that location and is capable of using that information to provide feedback to the driver. This information originates from a global positioning system (GPS) and from a digital road map in which the speed limit for each link in the network has been encoded. The concept of ISA is illustrated in Figure 1, Vlassenroot et al. (2007).

Figure 1 Concept of ISA

ISA solutions can come in a range of configurations from warning systems that simply warn a speeding driver to intervening systems, which physically prevent the driver from exceeding the speed limit. A warning ISA system continuously informs the driver of the current speed limit or warns the driver with an auditory or visual signal when speeding.

Greater intervention is provided by a ISA system that physically interacts with the vehicle when the driver exceeds the speed limit. The driver can be alerted, for example, through an active gas pedal in which the reverse pressure on the accelerator pedal increases when the driver attempts to exceed the speed limit or through a device that limits the speed with no possibility of overriding (for further information see e.g. Brookhuis and De Waard, 1999; Comte, 2001; Va´rhelyi and Makinen, 2001; Regan et al., 2002).

Since the first ISA trial in Lund Sweden in 1991-1992, Persson et al. (1993) there has been a continual stream of research on ISA in various European countries, including UK (Carsten and Comte, 1997; Carsten and Fowkes, 2000; Carsten and Tate, 2000; Chorlton and Conner, 2010; Jamson et al., 2010; Chorlton et al., 2011), Denmark, (Lahrman et al., 2001; Klarborga et al., 2011), The Netherlands, Duynstee et al. (2001), Sweden, (Almqvist and Nygard, 1997; Swedish National Road Administration, 2001; Várhelyi et al., 2004; Vagverket, 2002, Adell and Va´rhelyi, 2008), Finland, Päätalo et al. (2002) Spain and Hungary, Adell et al. (2008), Belgium, Vlassenroot et al. (2007), and Turkey, Warner et al (2010).

Moreover, in the last few years there has been a growing interest in ISA, and the ISA research and trials over the world (e.g. Young and Regan, 2002; Regan et al., 2004; NSW Centre for Road Safety, 2010; Young et al., 2010). Most of these research projects have reported positive outcomes and showed that ISA can reduce general mean speeds and their variances in different road environments.

The present study is the first ISA test performed in Malaysia. This study was designed as a preliminary investigation of the effectiveness of advisory ISA for a subsequent pilot study in Malaysia. The system was evaluated in an instrumented car in which subject drove in three stages for 16 days. Subject responded to two questionnaires administered before and after the trial, which measured the subject's acceptance of the ISA system. In addition, subject's driving behavior with the ISA was analyzed.

METHOD

The experiment was organized such that the subject performed 2 trips a day for a two week period between 27th September and 12th October 2010 in real traffic conditions along an 18.5 km long test corridor in Penang, Malaysia. The test road environment consisted of a highway with regular speed limits of 50, 60 and 110 km/h (see Figure 2). To examine the effectiveness of this technology and to exclude the effects of other speed reduction measures such as speed camera and roadway features the speed limit in the segments III and exclusively for this study assumed to be 90 km/h and afterwards this limit was introduced to the device. The subject also was informed of this feature.

With a vocal message and visual warning, the ISA device informed the driver when he reached to the almost 10 km/h close by the introduced speed limit. The content of the message “danger, danger, please reduce your speed” was given by a female voice and alternatively text-projected on the device screen. This warning was continuously repeated until the driver reduced the speed to the speed boundary.

For the first five days of driving, data were recorded and the ISA was not activated and, thus, no warnings were given. For the subsequent six days warnings were activated. For the remaining five days the warning was inactivated again. For two days before the device installation, the mean speeds of the vehicle were recorded observationally by dividing distance over the travel time. This calculation was performed to determine whether is there any difference in the subject's usual driving speed occurred with and without the device.

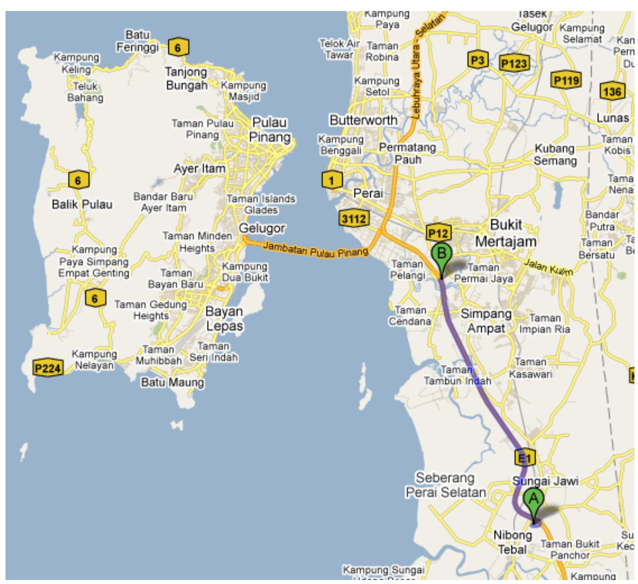

Figure 2 The test area

For this pre-test one experienced 32 years old male driver was selected. The selection criteria were possession of a driver's license for more than 5 years, having driven more than 20,000 km per annum, and an age between 25 and 60, Rook and Hogema (2005).

The subject was provided with an explanation of ISA and the specific ISA system used for the trial. Furthermore, the subject was asked to drive as he normally does. Next, he signed a form of informed consent. Preceding the trial he was asked to fill out a questionnaire concerning his attitude toward speeding, speed limits, and ISA. After the trial, a second questionnaire was administered concerning the acceptance of the system he had just experienced.

Data Collection

The collected data consisted of random spot speed registered in the device and self-reported measures. The data were logged during the trial and were downloaded to the computer after each trip. The variables were speeds of the vehicle in kilometers per hour. The self-reported measures were obtained by two different questionnaires. Numbers of questions regarding ISA from the first questionnaire were repeated in the second questionnaire to know how much the ISA influenced the driver's opinions.

Statistical Analysis

For this trial, the data were tested for the same three stages, and statistical analyses were carried out. The mean speeds were tested for the statistical differences by an analysis of variance (ANOVA). A significance level of $p < 0.05$ was used when examining whether the mean speed differed when the system was "off", "on" and again "off".

Post hoc multiple comparisons were carried out using Tukey rotation. Since differences among ISA conditions are expected the use of this not-too conservative test is justified. The independent-samples T-test was employed to assess the statistical significance of the differences in the mean speed before and during the stage I (before and after installation the device in the subject's car).

RESULT

The effect of the system on the aggregated speed from pre-test was studied through speed data from the test driver's vehicle. This study shows that the speed warning system resulted in a reduction in mean and maximum driving speeds. Table 1 shows the system effect on speeds for the three segments of the studied corridor before and after the system activation.

Independent-samples T-test revealed that statistically there was no difference between mean speed from the data recorded by the device when warning was "off" and the mean speed which has been calculated by the observer before the device installation ($p > 0.05$). It showed that the device existence didn't affect the driver's usual driving speed when the system was off.

It is hypothesized that the system will bring a reduction in speed variance since earlier studies of ISA have shown that it is especially the highest speeds that are affected. This study shows that there is a clear decrease in speed variance (see Table 1 and Table 2), and that this effect is largely due to the reduction of the highest speeds.

Table 1 The system effect on speeds for the three segments

Segments	Warning Off			Warning On			Change in		
	V	S	Vmax	V	S	Vmax	V	S	Vmax
I (50 km/h)	44.82	4.6	68.9	43.56	3.9	64.8	-1.26	-0.7	-4.1
II (60 km/h)	38.84	8.63	75.6	34.13	7.9	63.5	-4.71	-0.73	-12.1
III (110 km/h)	74.95	10.65	94.9	65.57	1.1	73.7	-9.38	-9.55	-21.2
Entire Corridor	63.67	8.04	94.9	55.02	2.94	73.7	-8.65	-5.1	-21.2

V = Mean speed, km/h.
S = Standard deviation of mean speed, km/h.
Vmax = Mean of Maximum speeds

Table 2 The system effect on speeds for the three segments in three stages

Segments	Warning Off		Warning On		Warning again Off	
	V	Vmax	V	Vmax	V	Vmax
I (50 km/h)	44.82	68.9	43.56	64.8	44.65	65
II (60 km/h)	38.84	75.6	34.13	63.5	37.94	71
III (110 km/h)	74.95	94.9	65.57	73.7	70.67	90.6
Entire Corridor	63.67	94.9	55.02	73.7	62.90	90.6

V= Mean speed km/h
Vmax = Mean of maximum driving speeds in each trip

As Table 1 shows, the mean speed was reduced by 1.26, 4.71 and 9.38 km/h when the system was "on". Furthermore, the mean of maximum driving speeds was decreased by 4.1, 12.1 and 21.2 km/h for each segment. It is worth mentioning here that even though the speed increased when the systems were removed it did not go back to same level. For example, mean speed in the entire corridor was reduced by 8.65 km/h when the system was “on” and it was increased by 7.88 km/h when warning was “off” again, but it did not return to the original level, see Table 2, Figure 3 and Figure 4. For all segments ISA brought about a statistically significant ($p < 0.05$) reduction in mean and maximum speed.

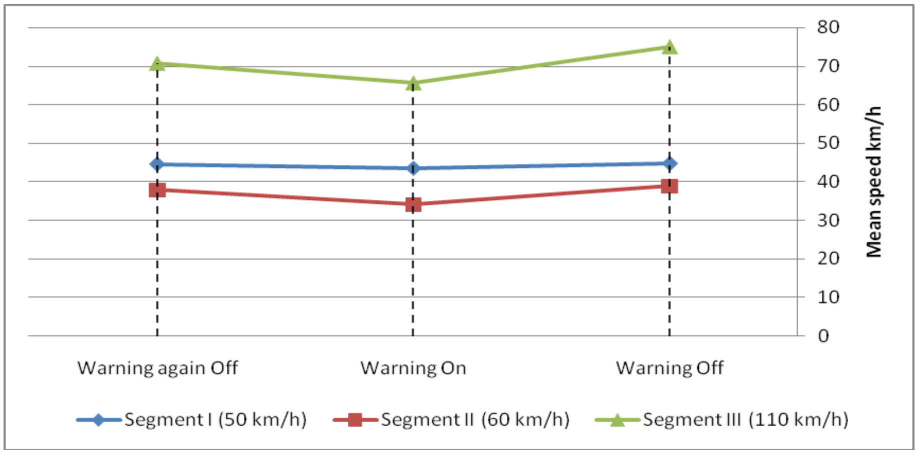

Figure 3 Mean speed of the test car when driving in three stages (warning "off", "on" and again "off") on different segments of the trial area

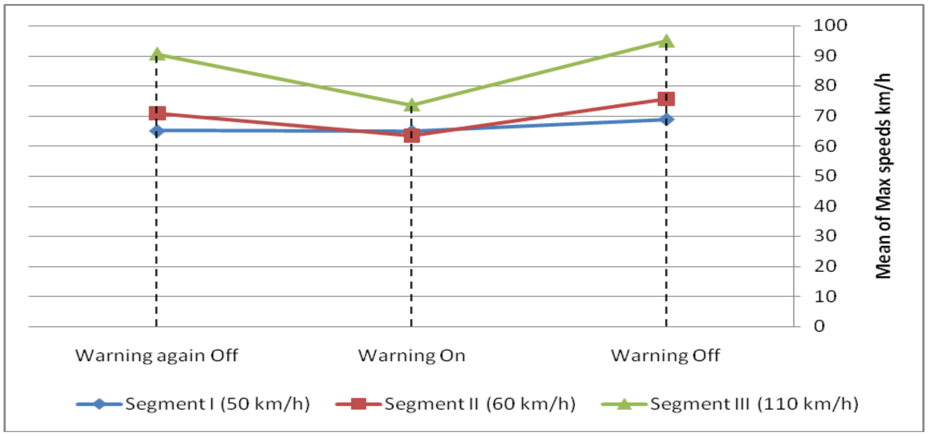

Figure 4 Mean of Max speeds of the test car when driving in three stages (warning "off", "on" and again "off") on different segments of the trial area

The mean and maximum speeds were analyzed for three stages and as is shown in both Figure 5 and Figure 6 the system had a large initial effect, but the effect decreased somewhat in the stage three when the warning was inactivated off. This situation is more obvious in the segment III where the high speeds were occurred.

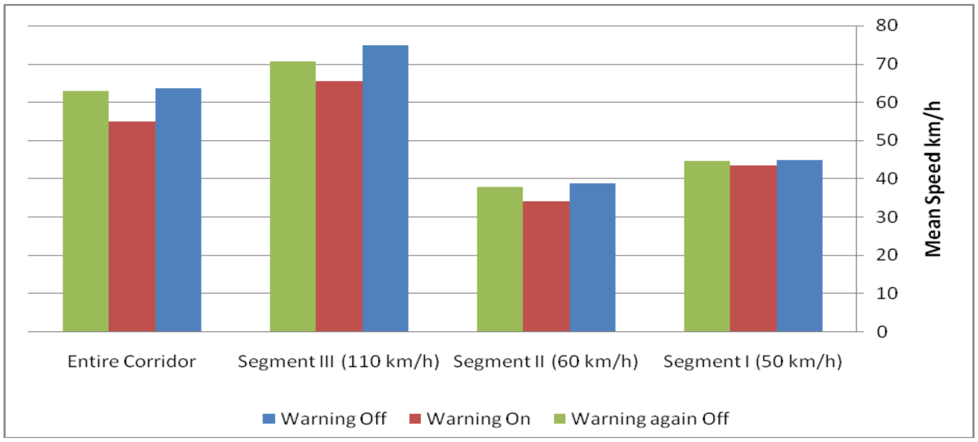

Figure 5 Speed Level of the test car on the different segments of Corridor during the three observation stages

Analysis of variance and post hoc multiple comparisons revealed that although there were significant differences between mean and mean of maximum speeds in stage 1 (warning “off”), stage 2 (warning “on”) and stage 3(warning again “off”) ($p<0.05$), the difference between stage 1 and stage 3 was not statistically significant in confidence interval 0.05, ($p>0.05$). This result indicates that when the system was inactivated, the driver returned to his habitual behavior.

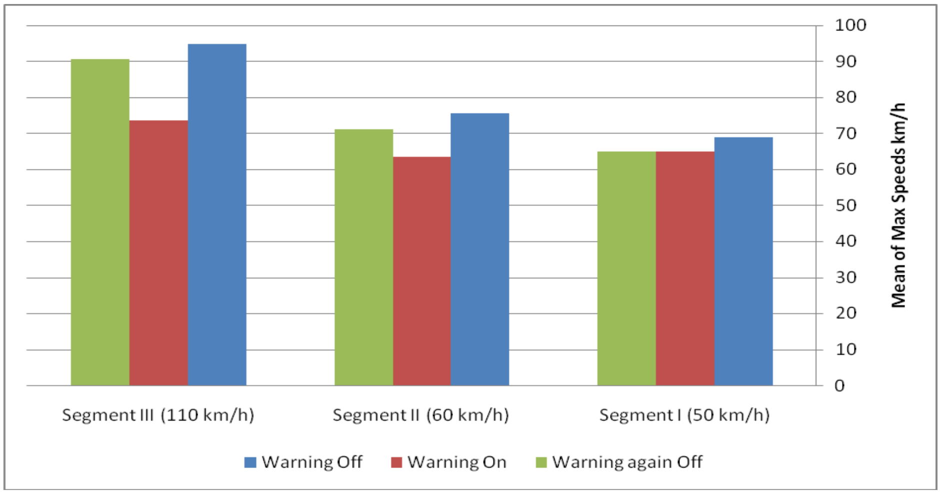

Figure 6 Speed Level of the test car on the different segments of Corridor during the three observation stages

For the faster segment (110 km/h) the results show a stronger effect of the ISA on driver's behavior and speed reduction. There are few statistically significant changes for segments with lower speed limits. This is most likely due the mean speed in the before situation was somewhat already below the speed limit, and thus the number of occasions when the system was "on" was probably very low. However, mean speeds decreased with the system and then increased again somewhat after the warning was inactivated.

The effect of the systems was regarded positively by the subject, as the subject mentioned that this system helped him to adjust his driving speed according to the speed boundary, and he is willing to buy this system. From the first questionnaire subject was not really optimistic about the positive effect of this system but post questionnaire indicated that his answer to the effectiveness of ISA on his driving behavior became "very effective" whilst it was "somewhat effective" in the earlier one. Also, the answer of subject to the questions regarding the system effectiveness on stress reduction during driving, and probability of accident reduction by using this system became "very effective" in the second questionnaire instead of "somewhat effective" in the first one.

DISCUSSION

Performing ISA trials on actual highway in real traffic situations can help test the affect of ISA on driving behavior with respect to speeding and in a high speed environment. The free-driving speed is defined as the speed that subjects freely chooses without being influenced by any other traffic. As noted in the methodology, particularly in this study the speed boundary in the device for segment III was decreased to 90 km/h to find the real and actual effect of ISA and to diminish the effects of other speed measures on the test area (e.g. speed camera, road features, etc.).

Further benefit of this boundary would be considering the driver's behavior, whilst potentially he was able to drive faster according to the actual posted speed limit of the road.

The results of the logged data revealed that system had an effect on driving speed. Using the vocal warning system, the mean speed decreased on all the analyzed road segments. The largest effects of the ISA systems were found at the highest speeds. Also, the travel time was generally believed to increase when using the systems as the mean speed decreases. These results correspond to earlier findings of the effects of ISA on speeds (see e.g. Brookhuis and de Waard, 1997; Carsten and Fowkes, 2000; Lahrmann et al., 2001; Regan et al., 2004; Várhelyi et al., 2004, Adell et al., 2008).

The drivers' experiences of using the systems in terms of emotional state and acceptance were elicited by questionnaires. The subject felt there was a reduction in his driving speeds. The driver indicated that a larger speed reduction will happen if all cars have the system. He also felt increased safety and a lower risk of being fined for speeding, but that travel time had increased.

The subject had a positive attitude to the concept of the tested ISA systems, and the systems was considered ''good'', ''effective'', "useful", ''assisting" and ''raising alertness and stress". In spite of this the acceptance of the warning system seemed to be high. The driver was more positive to having this system in his car in the future, and expressed a willingness to pay for the system. The driver's willingness to have the system in his car and the choice between the physical interfere and warning system showed a higher acceptance of the warning-system instead of physical intervening system.

CONCLUSIONS

This paper considers advisory ISA systems in preliminary test study in Penang- Malaysia. This system was tested and evaluated by a male driver. The main aim of this study was to consider the effect of ISA system in terms of driving speed, driver acceptance and to explore the trial procedure to perform main pilot trial study in that area in Malaysia.

The system effect on speed behavior was studied through speed data from the test driver's vehicle, and study concluded that the speed warning system had brought a reduction in mean and maximum driving speeds. Driver's attitude towards this system improved after the trial, and it had a good effect on subject's driving behavior when the system was activated. Furthermore, after removal the device function as the mean and maximum driving speed increased, it showed the necessity of lasting attendance of the system in the vehicle.

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