LAVIA – AN EVALUATION OF THE POTENTIAL SAFETY BENEFITS OF THE FRENCH INTELLIGENT SPEED ADAPTATION PROJECT

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Abstract : This paper presents the potential safety benefits of the experimental French LAVIA Intelligent Speed Adaptation system, according to road network and system mode, based on observed driving speeds, distributions of crash severity and crash injury risk. Results are given for car frontal and side impacts that together, represent 80% of all serious and fatal injuries in France. Of the three system modes tested (advisory, driver select, mandatory), our results suggest that driver select would most significantly reduce serious injuries and death. We estimate this 100% utilization of cars equipped with this type of speed adaptation system would decrease injury rates by 6% to 16% over existing conditions depending on the type of crash (frontal or side) and road environment considered. Some limitations associated with the analysis are also identified.

LAVIA is the acronym for Limiteur s'Adaptant à la VItesse Autorisée, a French Intelligent Speed Adaptation (ISA) project that was set up towards the end of 1999. At the time, 1998 French national road safety statistics recorded 8437 road related deaths, a figure which had shown virtually no positive evolution since 1994. Detailed analysis of the contributory factors involved in fatal road crashes highlighted the time-honoured crash and injury causation mechanisms – alcohol, speed and seatbelts. Of the three, excessive speed (over and above the posted speed limit) was a contributory factor in half of all fatal crashes

Inappropriate behaviour such as excessive speeding can be dealt with either by legislative or driver-incentive programmes. The first of these two solutions involves the introduction of new legislation and/or the enforcement of existing laws. This is the domain of Public Authorities and will not be discussed in detail here. Alternatively, incentive schemes can involve the implementation of speed related driver assistance systems, categorised according to their voluntary or mandatory character and the degree of autonomy proposed to or imposed on the driver. The LAVIA project set out to address several possible combinations of these two factors.

The generic term Intelligent Speed Adaptation (ISA) encompasses a wide range of different technologies aimed at improving road safety by reducing traffic speed and homogenising traffic flow, within the limit of posted speed limits. "Fixed speed limit" systems inform the vehicle of the posted speed limit whereas "variable speed limit" systems take into account certain locations on the road network where a speed below the posted limit is desirable, such as sharp curves, pedestrian crossings or crash black spots. Taken one step further, speed limit systems may also take into account weather and traffic flow conditions. These systems are known as "dynamic speed limit" systems and benefit from real time updates for a specific location.

The different ISA systems are generally characterised by the degree of freedom of choice given to the driver in moderating his or her speed. Speed limit technologies may be **advisory** (informing drivers of the current speed limit and speed limit changes), **voluntary** (allowing the driver to decide whether or not to implement speed limitation) or **mandatory** (imposing the current speed limit). The information supplied may be provided by way of the road infrastructure (and associated equipment), may be acquired autonomously by the vehicle or may be based on an interaction between the infrastructure and the vehicle.

Even the most basic of these systems should be considered as a very useful driver aid, helping the driver to stay within the posted speed limit, avoiding "unnecessary" speeding fines through inattention, modelling driver behaviour through the long term reduction of speeds and reducing driver workload by limiting visual speedometer controls. Vehicle-based ISA systems should not be confused with internal systems. These latter systems rely upon the driver entering the desired travel speed, which is then maintained by cruise control or set as a maximum value by automatic speed regulators. Although these systems will not be discussed in detail here, it should be noted that the engine management technologies that they employ are a vital component of ISA systems.

PREVIOUS STUDIES

In France, the earliest study regularly cited is that of Malaterre and Saad (1984) who tested vehicles equipped with two different ISA systems. The first system (System A) comprised a control panel placed near the steering wheel with fixed speed limit controls. Once the vehicle reached the selected speed limit, the accelerator pedal became stiffer, but this hard point could be overridden if necessary. This was the equivalent of a "mandatory" system described above. The second system (System B) involved a lever, which the driver used to set a given driving speed, beyond which the accelerator pedal had no effect. A kick down system enabled the vehicle to override the chosen speed for as long as the pedal stayed depressed. Releasing the pedal brought the vehicle back to the chosen speed. This was the equivalent of a voluntary system of speed control. Tables 1 and 2 show how subjects used the two systems, according to the posted speed limit and the chosen driving speed.

Table 1. System A speed limits and speed settings by Malaterre and Saad (1984)

Speed limit	System use imposed			System use on voluntary basis		
	Correct speed	Excessive speed	Non-use	Correct speed	Excessive speed	Non-use
45	50%	8%	42%		7%	93%
60	72%		25%	11%	32%	57%
80	81%	2%	17%	7%	35%	58%
90	96%		4%	42%	33%	29%

Table 2. System B speed limits and speed settings by Malaterre and Saad (1984)

Speed limit	System use imposed			System use on voluntary basis		
	Correct speed	Excess speed	Non-use	Correct speed	Excess speed	Non-use
60	25%	68%	7%	13%	63%	34%
80	26%	71%	3%	4%	63%	33%
90	73%	25%	2%	28%	37%	35%
100	8%	88%	4%	6%	61%	33%
110	88%	4%	8%	49%	21%	30%
130	87%	8%	5%	50%	17%	33%

System use had a greater effect on correct speed driving when imposed by the test protocol. The mandatory System A showed better correct speed driving results than the voluntary System B. However, none of the subjects was favourable to the installation of such a system in their own vehicle.

University of Leeds Study

In 1997, British researchers at the University of Leeds and the Motor Industry Research Association began a major 3-year ISA project called External Vehicle Speed Control (EVSC). This project combined both field tests using ISA equipped vehicles on the road and simulator tests.

The overall results from the field test and the simulator study showed that during the second drive of the field test, voluntary system use was between 54 % and 78% on urban roads, between 40% and 55% on two-lane rural roads and 31% on motorways. The test drivers declared a feeling of frustration and vulnerability because other vehicles were not equipped with ISA. They concluded that mandatory ISA should not be recommended until the number of equipped vehicles increases.

The EVSC study also made predictions about the potential reduction in all injury and severe and fatal injury crashes, based on the conclusions of previous studies. Accordingly, for each 1 km/h change in mean speed, the corresponding change in crash risk is 3% (Finch et al., 1994). This estimate was used for the advisory ISA system. As in Finch et al., the change in crashes was capped at 25%. For the mandatory ISA system, the ESVC study applied a transformed speed distribution, cutting off all speeds above the speed limit and used a formula derived from West and Dunn (1971) for the relationship between speed variance and risk, namely $\mathbf{y = 0.0139.x^2 + 0.010x}$ where y is relative risk and x is the speed difference of a vehicle from mean speed (mph).

The calculations for the effect of ISA on fatal and on fatal and serious crashes were made using Nilsson's power model. The EVSC results are given in Table 3.

Table 3. Best estimates of crash savings by ISA type and by severity. (ESVC 2000)

System Type	Speed Limit Type	Best estimate of *Injury Crash* reduction	Best estimate of *Fatal and Serious Crash* reduction	Best estimate of *Fatal Crash* reduction
Advisory	Fixed	10%	14%	18%
	Variable	10%	14%	19%
	Dynamic	13%	18%	24%
Driver Select	Fixed	10%	15%	19%
	Variable	11%	16%	20%
	Dynamic	18%	26%	32%
Mandatory	Fixed	20%	29%	37%
	Variable	22%	31%	39%
	Dynamic	36%	48%	59%

According to Table 3, best estimates of fatal crash reductions vary from 18% with an advisory fixed speed limit type ISA system to 59% with a mandatory, dynamic system.

Netherlands Study

From 1999 to 2000, the Dutch Ministry of Transport ran a mandatory ISA field test in the city of Tilburg using 20 passenger cars and a bus (Loon et al. 2001). The test zone contained 30, 50 and 80km/h speed limits. Table 4 below shows the effect of mandatory ISA use on speed values.

Table 4. 95 percentile speed values for all test zone road sections. All differences are significant (95%). ISA Tilburg (1999-2000)

Speed limit (km/h)	Unrestricted v95 (km/h)	ISA v95 (km/h)	Difference v95 (km/h)
30	44.4	28.9	-6.7
50	57.0	47.3	-9.7
80	77.9	75.1	-2.8

The LAVIA System

The LAVIA (ISA) system involved a vehicle-based fixed speed limit system with different advisory, voluntary and mandatory modes. The system architecture comprised:

- A GPS receiver combined with a gyrometer and an odometer was used to determine the vehicle's exact location.
- The GPS coordinates were then compared to an onboard digital map, using matching techniques to identify the road section on which the vehicle was driving.
- The LAVIA calculator then retrieved the posted speed limit from a pre-recorded speed database.

If the vehicle's travel speed was above the posted speed limit, a signal was sent to the engine management system to limit the fuel supply until the posted speed limit was reached. The LAVIA system did not apply the vehicle's brakes. This system was installed in 2 cars for the trial phase and then a further 20 vehicles for the field test. As well as the equipment listed above, the vehicles were equipped with a visual display of the current speed limit. The system had 4 modes:

- <u>Neutral</u>, the system was deactivated;
- <u>Informative</u>, where the current speed limit was displayed and included an auditory warning of speeding;
- <u>Driver activated</u> where the driver was free to activate and deactivate the limiter at will; and
- <u>Mandatory</u> where the limiter automatically came into operation when the speed limit was reached

In both the "activated" modes, a kick down function enabled the driver to temporarily override the system, which automatically came back into operation when the speed dropped back below the speed limit.

Data were collected on travel speeds in 3 different ways during the field trial.

- Active: Vehicle data was collected in this zone and compared with the onboard speed limit database. Speed limit information or enforcement was applied when the ISA system was switched on.
- Observation: Vehicle data was collected but no speed limit data was available.
- Neutral: Beyond the active and observation areas, no vehicle data was collected.

During the field test, the vehicles were given to 92 households for an 8 week period (2 weeks per LAVIA system mode). Driver behaviour and their acceptance of the system were examined through questionnaires, interviews and the analysis of the data collected from the vehicles.

Drivers were recruited in the LAVIA zone according to a quota sampling design. They had to have a driving licence, a car in the household and a good health. The sampling procedure and the study design are perfectly in line with the French Huriet-Sérusclat law which imposes ethic and deontological rules whenever an experiment is conducted with healthy volunteers for medical or para-medical aims.

Households drove a total number of 15.911 trips for a total number of 130.000 kilometres, more or less evenly distributed among the LAVIA modes. The average trip length and duration is 8,3 kms and 14 minutes. Drivers were 50 % males and 50 % females; 31 % were less than 30 years old, 25 % between 30 and 39, 31 % between 40 and 49 and 13 % above 50 years old.

In-car data (such as speed and acceleration) was recorded every half a second with a data recorder especially conceived and produced for the study. Data was controlled and missing or irregular data (less than 5 %) was left apart.

The LAVIA project comprised four main aims. First, to assess drivers' attitudes towards and representations of ISA, second, to examine any behavioural changes brought about by ISA use, third, to study the acceptance of ISA according to the system mode and traffic environment, and finally, to analyse the potential safety benefits of the system. Only the last aim of the LAVIA project is addressed in this paper.

Study Objective

This paper looks at the potential safety benefits of the different LAVIA modes, using the data collected during the field test from drivers using the neutral, informative and driver and mandatory activated modes in the active test zone. All other information collected was used for the project's other aims. The potential safety benefit is defined as the number of seriously or fatally injured vehicle occupants who could be saved if all vehicles were equipped with such a system. The authors accept that the definition and methodology have certain limits, which will be addressed at the end of the paper.

METHOD

The potential safety benefits were estimated by simulating a hypothetical traffic environment in which all passenger cars are equipped with the LAVIA system. The simulation involved 4 steps. First, to estimate injury risk as a function of impact severity, second, to establish the relationship between impact severity and the travel speed of injury crash involved vehicles that would be observed following LAVIA deployment, third, constituting the distribution of the travel speeds of injury crash involved vehicles using the real travel speed distributions from the LAVIA field tests, and finally, calculating the potential benefits of the LAVIA system using these data.

Injury Risk and Impact Severity

Figure 1 represents the relationship between a vehicle impact severity indicator (such as Delta V, Equivalent Energy Speed, collision speed…) and injury severity risk (using for example the Abbreviated Injury Scale from 0 – unhurt to 6 – fatally injured). Crash investigators working at LAB and CEESAR collect data from vehicles involved in real world crashes. The black curve in Figure 1 is created empirically from this data and symbolises passenger cars involved in frontal and side impact injury risk.

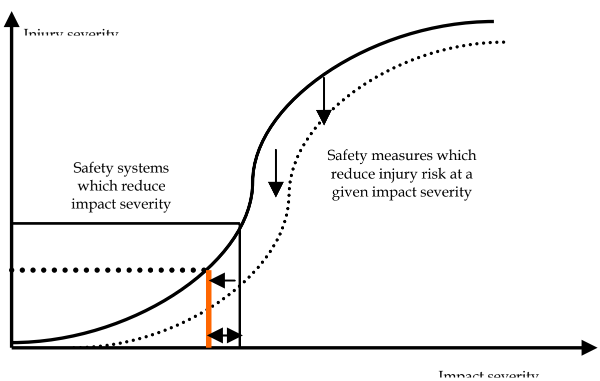

Figure 1. Relationship between a vehicle impact severity indicator and injury severity risk.

As noted earlier, frontal impacts are responsible for approximately 50% of all fatal car crashes (60% for serious injury crashes). The figures for side impact are 30% and 20% respectively. The simulation presented in this paper thus represents roughly 80% of all crash related injuries.

Safety systems can have one of two possible impacts on injury risk. At a given impact speed, the risk of sustaining injuries of a given severity can be reduced (translation from the black to the dotted curve). This is typically true of passive safety systems which do not play a role in crash avoidance, but only in injury mitigation (air bags, seat belt pretensioners, etc). Alternatively, the system may intervene in the pre-crash phase, reducing impact speed and consequently injury risk (reduced impact severity on the same curve). This is the case with active safety systems such as ABS, ESC (Electronic Stability Control) and in the present situation – LAVIA.

In order to estimate the potential safety gain of the LAVIA system, the impact severity distribution was calculated that would be observed if all vehicles were equipped with the system (for a given mode) and then this was compared with the impact severity distribution for the neutral mode (i.e. the current distribution). The safety gain for each mode is obtained by subtracting the average risk for that mode from the average risk of the neutral mode. Table 5 below is a hypothetical example of how this safety gain is calculated. Figures are not real, just hypothesized to make the calculation of the safety benefits understandable.

Column 1 shows the impact severity indicator classes (i.e. the energy equivalent speed, EES), Column 2 shows the risk of serious injury (MAIS 3 and above) for each EES class, and Column 3 the current EES distribution. Columns 4 to 6 show the EES distributions per mode that would be observed if all vehicles were equipped with a LAVIA system.

The table shows that the hypothetical AIS3+ average injury risk is 40.5% (the sum of the injury risks multiplied by the EES distributions) for the neutral mode. The same risk is 29% for the mandatory activated mode. The safety gain would thus be (40.5-29)/40.5=28% which is to say that the mandatory activated mode would reduce the risk of being seriously injured by 28%.

Table 5.Hypothetical safety gain calculation

EES classes (km/h)	MAIS 3+ injury risk	Neutral	Informative	Driver activated	Mand. activated
0-20	10 %	10 %	10 %	20 %	20 %
20-30	20%	20%	20%	20%	30%
30-40	30%	30%	30%	30%	30%
40-50	50 %	20 %	20 %	20 %	10 %
50-60	70 %	10 %	10 %	10 %	10 %
60-70	90 %	5 %	10 %	0 %	0 %
>70	100%	5 %	0 %	0%	0 %
Average risk		40.5 %	40 %	32 %	29 %

Relation between EES distribution and travel speed of crashed involved vehicles

In establishing the relationship between impact severity and travel speed of the crash involved vehicles in casualty crashes if all vehicles were equipped with a LAVIA system, there was a need for EES distributions for crash involved vehicles (frontal and side impact) equipped with a LAVIA-type system. Such information is obviously not available at this time. However, EES distributions for non LAVIA cars involved in crashes are available for crash involved vehicles in three European countries, namely France, Germany and the United Kingdom. This information is collected through in-depth crash investigations carried out in these countries.

We must therefore estimate the EES distributions that would be observed if all vehicles were equipped with LAVIA (per mode). This is achieved by comparing the travel speed classes observed in real world injury crashes and the EES distributions for frontal and side impact. This empirical comparison has not yet been reduced to an algebraic function (research currently in progress) and can be expressed in the form of a Table 6, based on the in depth crash investigations carried out by the LAB in France and by the Universities of Hannover and Dresden in Germany (German In-Depth Accident Studies data).

Table 6: Travel speed and EES distributions in real world crashes

Travel speed / EES	0-20	20-30	30-40	40-50	>50	Total
0-20	X_1 %	X_2 %	X_3 %	X_4 %	X_5 %	100%
20-30	Y_1 %	Y_2 %	Y_3 %	Y_4 %	Y_5 %	100%
30-40	Z_1 %	Z_2 %	Z_3 %	Z_4 %	Z_5 %	100%
40-50	T_1 %	T_2 %	T_3 %	T_4 %	T_5 %	100%
50-60	U_1 %	U_2 %	U_3 %	U_4 %	U_5 %	100%
>60	V_1 %	V_2 %	V_3 %	V_4 %	V_5 %	100%

While it is now possible to calculate of the travel speed distributions and EES values for crash involved vehicles using the travel speed distributions for frontal and side impacts, the travel speed distributions for crash involved vehicles equipped with LAVIA (per mode) are still not available. This can be derived using the Bayes theorem (Bayes edited by Price, 1763) that is expressed as:

$$P(V_i / A) = \frac{P(A / V_i) * P(V_i)}{P(A)} \quad (1)$$

Where: P(Vi/A) is the probability that a vehicle has a pre-crash travel speed of Vi. Combining all possible P(Vi/A) gives the distribution of travel speeds of crash involved vehicles;

P(A/Vi) is the probability of being involved in an injury crash at travel speed Vi; and

P(A) is the probability of being involved in an injury crash.

P(Vi) is the probability of driving at speed Vi in traffic.

This theorem can also be expressed by

$$P(Vi / A) = \frac{RR_{i-ref} * P(Vi)}{\sum_j RR_{j-ref} * P(V_j)} \quad (2)$$

In this form, RRi-ref is the relative risk of injury crash involvement for a given speed Vi, compared to a reference speed (chosen arbitrarily). This RRi-ref is taken from Nilsson's formula, as revisited by Elvik et al. (2004). In other words, the probability of being at the pre-crash travel speed Vi (P(Vi)/A) depends on the probability of being at travel speed Vi (P(Vi)) in the traffic. This second probability is given by the travel speed distributions obtained through the LAVIA field tests.

Speed Distributions (i.e. P(Vi))

For the purposes of this study, the data were grouped by LAVIA mode and by road network (urban, inter-urban and motorway). These are shown in Figures 2 to 4 below.

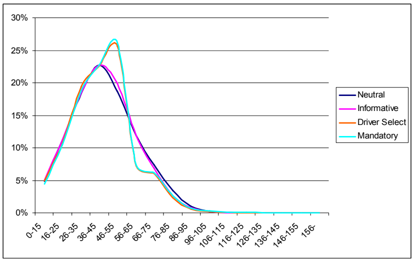

Fig 2: Urban travel speed distributions

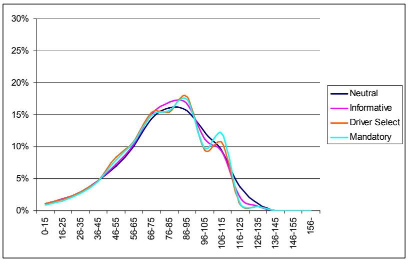

Fig 3: Inter urban travel speed distributions

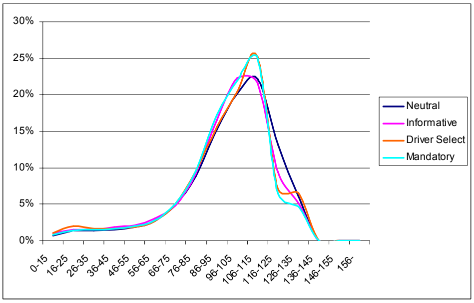

Fig 4: Motorway travel speed distributions

Speed distributions are very similar if we consider the neutral and the informative modes, with however a slight shift towards lower speeds for the informative mode. Speed distributions for driver select and mandatory modes are highly modified with higher frequencies around the speed limit values and less excessive speeds.

RESULTS

We observed a reduction of overall (mean speed over all network types) mean speed of 0,8 km/h (or 7% of the average level of speeding), from neutral to informative mode; a drop of 2 km/h, i.e. 23 % from neutral to mandatory; and a drop of 1.4 km/h i.e. 13% from neutral to mandatory. Highest reductions in speeding take place on the interurban and motorways networks.

As noted earlier, the potential safety benefits were estimated using a simulated traffic environment in which all passenger cars were equipped with the LAVIA system. The simulation process involved estimating injury risk as a function of impact severity, deriving the travel speed of all injury crashed vehicles, assuming the total vehicle fleet was fitted with the LAVIA system and then estimating the likely travel speed distribution of vehicles that crashed using the speed distributions observed from the LAVIA sample in the field. From these, the potential benefits of the LAVIA system could then be calculated.

In computing the safety benefits of the LAVIA system, the estimated EES distributions (per impact type) associated with the travel speed distributions of crash involved vehicles, for each LAVIA mode and for each road network type. By multiplying these distributions by the risk of sustaining serious (MAIS 3+) or fatal (MAIS 6) injuries for each type of impact (frontal and side), it was possible to calculate the safety gains for a given road network, impact type and LAVIA mode.

Table 7 presents the results of the safety gain estimation calculations. The LAVIA mode “neutral” is used as a reference. A 5% reduction shown in the MAIS 6 column means that 5% of all car occupants fatalities could be avoided if all vehicles were equipped with a LAVIA system, for the specific mode shown and a given road network (the neutral mode being the reference for each network and impact type).

Because of the in-depth crash data available, these estimations are only valid for crashes involving passenger vehicles in which an occupant is seriously or fatally injured in a frontal or side impact (i.e 40% of all serious injuries and 50% of all fatalities). The safety benefits for other road user and other car crash types are still to be estimated. Confidence intervals for the estimations given above cannot be calculated until the relationship between EES and pre-crash travel speed has been modelled algebraically. This work is currently underway.

Table 7: LAVIA safety gain estimation calculations

Network Type	LAVIA mode	Frontal impact		Side impact	
		MAIS 3+	MAIS 6+	MAIS 3+	MAIS 6+
Urban	Neutral	ref	ref	ref	ref
	Informative	4%	4%	3%	4%
	Driver activated	11%	14%	1%	3%
	Mandatory	9%	11%	0%	na
Inter urban	Neutral	ref	ref	ref	ref
	Informative	2%	5%	0%	7%
	Driver activated	3%	8%	9%	17%
	Mandatory	2%	8%	8%	6%
Motorway	Neutral	ref	ref	ref	ref
	Informative	3%	7%	na	4%
	Driver activated	6%	13%	5%	16%
	Mandatory	5%	13%	4%	16%

The results show that for the most part, the driver-activated mode of operation excelled in terms of reducing serious injury and death from speed-related crashes. This varied from between 6 and 16 percent depending on the type of crash (frontal or side) and the road environment. Interestingly, though, the estimated benefit in the mandatory mode is also substantial. While there were still some injury reductions in the informative mode among the motorists studied, they were less likely to benefit with just feedback of their travel speed.

The 'driver activation' seems to have a higher effect than the mandatory mode, which is unexpected. Actually, we have observed in the experiment data that the driver generally chooses to activate the LAVIA and therefore this mode is very close to the mandatory mode. But the LAVIA experiment imposed to all drivers to use the LAVIA system in the same sequence, starting with the neutral mode, then the informative, the driver activation and finally the mandatory mode. This could have generated a bias in the experiment since the driver gets more familiar with the car and the system at the end of the 8 weeks. The percentage of override by the kick down increased with time, that can explain higher speeds in the mandatory mode than in the driver activation one. This could have ended up with an overestimation of the effect of the driver selection mode.

Benefits were generally higher in terms of reduced fatalities (MAIS6+) than for serious injuries (MAIS3+). This was particularly so for side impact crashes, although the trend was consistent also in frontal crashes. Indeed, the results overall show that the benefits of the LAVIA system when applied to the total vehicle fleet in France would be more substantial in side impacts. This is not surprising, given the superior capabilities of vehicle structure to absorb impact forces in frontal collisions.

Some benefit calculations, especially for side crashes, were not robust since the size of accident data in our databases was not sufficiently high to simulate, for a specific area, a specific impact and a specific LAVIA mode, the shifts in table 6 due to a LAVIA mode. Consequently, we do not publish these unstable results (not available, na in table 7).

DISCUSSION

This paper presents the results of an analysis of the potential safety benefits of the French LAVIA system for passenger car occupants, according to road network type and system mode, based on observed driving speeds, observed distributions of crash severity, observed distributions of travel speeds before the crash for crashed vehicles and injury risk curves. Results are given for frontal and side impacts in France, which comprise 80% of all fatal and serious injury car crashes in this country.

Many of the previous studies (eg; Malaterre and Saad, 1984; Loon et al, 2001; Duynstee and Katteler, 2001; Hjälmdahl, 2003) focussed on measuring the effects of ISA in terms of speed reductions and user acceptance of this technology. The ESVC reported by Carsten and Tate (2000) is the most famous example of a study addressing the safety benefits of ISA in terms of lives and serious injuries potentially saveable. Biding et al. 2002 also reported a potential benefit of ISA systems for reducing the accident risk by 10% to 15 %. But these kind of studies are quite rare. Therefore, this study adds considerably to our knowledge on the likely safety benefits of a new technology.

The benefits reported by Carsten and Tate (2000) suggest significant reductions in fatal and serious injuries for cars fitted with ISA technology compared to the benefits calculated here as shown in Table 8 below.

Table 8: comparison of benefits between results obtained in this analysis and those reported by Carson & Tate (200)

Network Type	Injury Severy	Carson & Tate (2000)	LAVIA system
Advisory	Fatal	18-24%	4-7%
	Serious Injury	14-18%	0-3%
Driver select	Fatal	19-32%	3-17%
	Serious Injury	15-26%	1-11%
Mandatory	Fatal	37-59%	8-16%
	Serious Injury	29-48%	0-9%

There are several reasons why these benefits differ to the degree they do across the two studies in Table 8.

First, the analysis here only examined the benefits of ISA in frontal and side impacts for car crashes whereas those computed by ESVC were for all crashes. In terms of effectiveness it might explain the discrepancies between the results (actually this would hold true only if the effectiveness of ISA is higher on other types of crashes non studied here).

Second, our analysis relies on data collected in 2005 just after an exceptional decrease in fatalities in 2003 and 2004 in France. Actually, the national statistics show a 20 % decrease in injury accidents and a 30 % decrease in road deaths from 2002 to 2005. Such a decrease has only been seen twice before in France; in 1974, after the generalized introduction of speed limits and compulsory seat belt use and, to a lesser extent, in 1978, with the introduction of a law allowing preventive alcohol testing of car drivers. Road safety watchdogs in France impute this reduction to 3 main groups of factors:

- The declaration by the head of state on the 14th July 2002 that road safety was now a national issue.

- Unprecedented media coverage of road safety following this declaration and reinforced from September 2002 with the organization of a national road safety congress.

- The preparation of the 12th June 2003 road safety law, which is predominantly repressive (harsher fines and prison sentences for serious infractions, probative driving license for young drivers, etc.).

These elements contributed to a short-term increase in road safety awareness, an increase in traffic policing (+15% for alcohol testing and more speed controls in 2003), a dramatic increase in seat belt use (Seat belt use by car front occupants is now 97 % in rural areas and 90 % in urban areas compared to 95 % and 80 % respectively in 2002), and finally to a reduction of driving speeds (exceeding speed limits by 10 km/h decreased from 35 % to 25 %) and alcohol consumption when driving. The main reason for this speed reduction (and thus fatalities reduction) is the progressive introduction of hundreds of automatic speed cameras from 2003 on.

This reduction in speed due to speed cameras may explain that a technology supposed to reduce speeds further has a lower effectiveness if speed is already reduced by other means.

Third, the study design and calculation methods were quite different between the two studies. The ESVC study was based on a simulator experiment and a field test with only one vehicle equipped with the ISA system whereas the LAVIA field test was conducted at a larger scale with 22 equipped vehicles and a one-year trial. The ISA systems were a bit different but the basics were similar. On the other hand, the safety benefits calculation is very different. The ESVC study relies on statistical formulae linking the average speed to the fatalities or injuries rate. Our analysis also uses such a relation. But the study mainly relies on the use of real-world accident in-depth data (distribution of travel speed before crash and distribution of violence of impact, injury risk curves) and on travel speed distributions in traffic collected from the trial. Furthermore, we used distributions instead of means, which is supposed to be more accurate.

The question to which other new vehicle safety technology might influence these results is difficult to answer. There have been a number of other new safety technologies introduced in current model vehicles such as Electronic Stability Control (ESC) and Electronic Brake Assist (EBA) to name a few. These technologies also have potential to reduce fatal and serious injuries and hence may influence the benefits estimated here. Conversely, ISA may well influence the benefits of other technologies by invoking slower travel speeds. This warrants further research.

Limitations

A study of this kind is valuable as it helps to focus attention on the potential value in introducing new safety technology in future cars and optimise the benefits to society of their introduction. Nevertheless, there are a number of limitations in these benefit studies that need to be stated.

- That kind of studies always rely on a series of implicit and explicit assumptions that can eventually be questionable. In our case, we tried to reduce the number of assumptions. The main point to be taken into consideration concerns the use of LAVIA equipped vehicles in a non-ISA environment. The speed profiles were obtained during the field trial phase where the test vehicles were surrounded by vehicles that were not equipped with similar systems. We assumed it did not cause too much bias and considered that the speed distributions of LAVIA cars would be the distribution of all cars thanks to a 100% penetration of LAVIA in the car fleet.

- We certainly assessed a kind of 'potential short term effect' of LAVIA. Even though the households drove the vehicles for 8 weeks, they did not really learn how to use the systems as they would have on a regular basis in the long term. For example, the experiment showed that the drivers tend to use the kick down more and more as time passes by. The speed effect could then be reduced in a longer term and consequently the safety benefits too. It would mean that, in that case, the safety benefits that we calculated would be overestimated. This 'long term' effect is very difficult to reproduce in field trials and is now a subject of considerable interest in Europe.

- As for the data used, if, in any case, we are confident in the calculation of the injury risk curves and in the speed data collection in the LAVIA trial, we must say that the non algebraic relation between the travel speed before crash distribution and the violence of impact distribution must be turned towards a more rigorous mathematical relation. We do not know whether this leads to an overestimation or a underestimation of the safety benefits. This work is currently under way.

- This method, partly based on the use of injury curves for car occupants leaves apart the calculation of the safety benefits for other kind of users, particularly the vulnerable road users such as pedal cyclists, powered two-wheelers and pedestrians. Insufficient accident in-depth data for these users are the main explanation. But the general method also applies to them and could be equally used in case of in-depth data availability.

- It is generally argued that this method only looks into injury mitigation and ignores accident avoidance because the benefits are calculated with the help of injury curves, which is commonly used for the evaluation of passive safety measures whereas ISA is a preventive safety system. This remark would be actually true if we had not used the Nilsson (up dated by Elvik et al.) parameter in formulae (2). This parameter actually takes into account the accident avoidance and the injury mitigation effect altogether. It then prevents this study to be considered as taking only one effect and putting the avoidance apart.

CONCLUSION

This study addresses the potential safety benefits of ISA systems. A large scale experiment has be conducted in France from 2001 to 2006 in order to collect and analyze data about LAVIA usability, usage, acceptance, techniques, feasibility and potential benefits. This paper is therefore addressing part of the whole project.

The results of the French experiment show that the LAVIA systems are able to bring potential safety benefits, the benefits being higher if the system is selected by the driver or mandatory, compared to simple information. The maximum potential reduction in fatalities reaches 17 % of the current number of car occupant fatalities in France, depending on the type of crash (frontal or side) and the road environment.

LAVIA could then by no doubt produce safety gains because it reduces overall the driving mean speed and the speed variance. Its technical feasibility and reliability is demonstrated, its ergonomics is understood and generally properly used. The informative mode is the most accepted one whereas the drivers are more reluctant to use the mandatory mode which brings constraints in some driving situation.

Unfortunately the LAVIA project did not address the effectiveness of the current speed limiters which are now well implemented in the French car fleet. Above 30 % of the new French registered cars are equipped with those limiters that allow the driver to choose himself the speed limit. In the absence of this evaluation, it is difficult to argue about the additional effectiveness that ISA systems bring compared to these manual limiters. Common sense says it should be positive but it has not been demonstrated yet.

What the LAVIA project did not address too is the economic (business model) and the legal aspects of the systems. Research should now concentrate on these aspects as they should precede a plan to implement these systems on the roads.

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REFERENCES

Bayes, T (1763) An Essay towards solving a Problem in the Doctrine of Chances. ommunicatedby Mr. Price, in a letter to John Canton, M. A. andF. R. S.

Biding T. and Lind G. (2002) Intelligent Speed Adaptation (ISA), Results of large-scale trials in Borlänge, Lidköping, Lund and Umeå during the period 1999-2002. Vägverket Publication 2002:89E

Carsten O. and Tate F., External Vehicle Speed Control Deliverable D17. Final report: Integration. July 2000.

Comte S. (1998). Evaluation of in-car speed limiters: Simulator Study. MASTER project, working paper R 3.2.1.

Ehrlich J. Le projet français de limiteur de vitesse adaptatif. LIVIC (LCPC-INRETS).

Elvik R., Christensen P. and Amundsen A. (2004). Speed and road accidents. An evaluation of the power model. TOI Report 740/2004.

Finch et al (1994). Speed, speed limits and accidents. Transport Research Laboratory, Project Report 58.

Hjälmdahl M. (2003). Who needs ISA anyway? An ISA system's safety effectiveness for different driver types, Proceedings of the 16th ICTCT workshop safety impact of new technology, Soesterberg, The Netherlands

Kloeden C. et al. (1997). Travelling Speed and the Risk of Crash Involvement. NHMRC Road Accident Research Unit, University of Adelaide.

Kraay J. (2002). The Netherlands traffic and transport plan; Road safety with a special focus on speed behaviour. ICTC workshop Nagoya.

Loon et al. (2001) Intelligent Speed Adaptation (ISA): A successful test in the Netherlands. Canadian Multidisciplinary Road Safety Conference XII; June 10-13, 2001; London, Ontario.

Malaterre G. and Saad F. (1984) Contribution à l'analyse du contrôle de la vitesse par le conducteur: Evaluation de deux limiteurs. Cahier d'Etude n° 62, ONSER.

Munden J. (1967). The relationship between a driver's speed and his accident rate. Road Research Laboratory, Report LR 88, Crowthorne, Berkshire.

National Highway Traffic Safety Administration (NHTSA) (1989). Report to Congress on the effects of the 65 mph speed limit through 1988. US National Highway Traffic Safety Administration.

Nilsson G. (1981). The effects of speed limits on traffic accidents in Sweden. In: Proceedings of the international symposium on the effects of speed limits on traffic accidents and fuel consumption, 6-8 October 1981, Dublin. Organisation for Economic Co-operation and Development OECD, Paris.

Peltola H. and Anttila V. (2005) Recording ISA - experience from Finland ICTCT Workshop, Helsinki

Solomon D. (1964). Accidents on main rural highways related to speed, driver and vehicle. Washington, DC: US Department of Commerce and Bureau of Public Roads.

Taylor M., Baruya A. and Kennedy J. (2002). The relationship between speed and accidents on rural single-carriageway roads. TRL Report TRL511.

Várhelyi A., and Mäkinen T. (1998). Evaluation of in-car speed limiters: Field Study. MASTER project, working paper R 3.2.2.

West L. and Dunn J. (1971). Accidents, speed deviation and speed limits. Traffic Engineering, 41 (10).

Wilson T. and Greensmith J. (1983). Multivariate analysis of the relationship between drivometer variables and drivers' accident, sex and exposure status. Human Factors, 25(3), 303-312.