ABSTRACT

The French Ministry of Transport launched a significant program of experimentation and evaluation in order to better appreciate the effects of the intelligent speed adaptation system in terms of acceptance by the drivers and effects on their driving behaviours.

The LAVIA (Limiteur s’Adaptant à la VItesse Autorisée) will be tested according to three variants : advisory, voluntary limited and mandatory limited.

After a first evaluation that will be carried out on two prototypes and a reduced panel of voluntary drivers, the experiment will be extended to a hundred drivers to which vehicles for a daily use will be entrusted.

Technical tests are currently carried out to verify LAVIA functionalities, digital map and speed limits data base consistency and data acquisition operation. Validation methodology and first results on these tests are presented in this paper.

INTRODUCTION

Inadequate speed limit compliance

Accident analysts both in France and abroad all agree that speed both causes accidents and increases their severity.

Accidents that involve a single vehicle or a single vehicle and a pedestrian account for 35% of injury accidents and 45% of fatal accidents in France. In many cases they are caused by unsuitable speed.

In built-up areas, 70% of pedestrians who are hit by a vehicle travelling at over 50 km/h are killed. 80% of them would survive if the vehicle were travelling at 30 km/h at the time of the impact.

In spite of this, speed limit compliance is poor. More than 60% of drivers do not comply with speed limits on urban roads or trunk roads. However the worst situation is when a trunk road passes through a village. Here 80% of drivers break the speed limit.

Reacting to excessive speeds

Initial driver training, repeated awareness campaigns, surveillance and sanction are all necessary, but they are not enough reduce driving speeds significantly.
New technology and the technical advances made by cars manufacturers and equipment suppliers mean that vehicles can now be fitted with systems that can help the driver to comply with speed limits and also provide genuine driving comfort.

**From manual speed limiting devices to LAVIA**

In the early year 2000, the first manual speed limiting devices appeared as an accessory on French cars. This system means that a driver can be certain of not exceeding a pre-selected speed. Above this speed the accelerator is deactivated. The system can nevertheless be switched off in an emergency by pressing hard once on the accelerator (this is known as “kick-down”).

It is a short step to move from this to a system which automatically sets the vehicle’s highest speed at the speed limit in force at the location. Technical advances have made this transition possible. The resulting device is the LAVIA (equivalent of foreign ISA), from the French acronym for “Speed limiter that adapts to the speed limit”.

**HOW DOES LAVIA WORK**

LAVIA is based on the following principle:

- Using GPS and a number of in-vehicle sensors (an odometer and a gyrometer, the vehicle knows its position at all times (Figure 1-A).

- The position is processed by an on-board navigation system that contains a digital map of the region in which the vehicle travels. By applying appropriate techniques the navigation system can determine which road the vehicle is on at any moment (Figure 1-B).

Once the road has been identified, the on-board computer can find the speed limit on the road by consulting an on-board speed data base that contains the speed limits on all the roads or streets in the region where LAVIA is in operation (Figure 1-C).

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![Figure 1 – LAVIA technical principle](image-url)
PROJECT’S AIMS

These are:
- to test the system in operation and its acceptability to users, which means that the system must have several modes of operation so behaviours and assessments can be compared under more or less constraining conditions of use;
- to evaluate changes in individual behaviours, and in particular to measure any speed reductions that result or any divergences from the speed limit in force;
- to measure its effectiveness in terms of individual risk and also to detect and evaluate any adverse effects (e.g. conflict analysis, reductions in headways, loss of vigilance as a result of drivers placing too much trust in the system);
- to conduct simulation in order to evaluate overall collective safety impacts using models supplied with data collected during the trial;
- to estimate how appropriate the technical solution is. This is not, however, a priority for the project as the solution applied in the trial is not necessarily the one which will be used in the event of large scale deployment;
- to evaluate complementarities between this trial and those conducted abroad [1].

SYSTEM EVALUATION

Apart from the technical choices, which may always be changed as a consequence of advancing technology, the principal concerns relate to the ergonomics of the system, its acceptability to drivers and how it influences behaviours [2].

System to be evaluated

Three operating modes will be tested:
- an advisory mode where the speed limit is displayed blinking on the dashboard as soon as the driver exceeds the speed limit,
- a voluntary active mode in which throttle is under control of the LAVIA such as speed limit cannot be exceeded, but the driver can enable or disable the system at any time,
- and a mandatory active mode that has the same functionalities as the previous one, but without possibility of disabling the system.

In both active modes the “kick-down” can be used to disable temporarily the system by pressing the accelerator pedal beyond a stiffening point, and it will be enabled again as soon as the vehicle speed returns below the speed limits.

From ergonomic point of view, it should be pointed out that there is no haptic effect on the accelerator pedal unless when the “kick-down” point is reached.

Step 1 : The pre-evaluation phase using prototypes

Firstly, a pre-evaluation of the system will be led on two prototypes with a reduced population of drivers accompanied by psychologist. During the ride, driving context and driver behaviour are collected by observers or recorded by means of a data acquisition system and a digital multi-channel video recorder. Afterwards, video records will be replayed in the presence of the driver who will be induced to react on his own behaviour.

Step 2 : Middle scale evaluation on a vehicle’s fleet

The second stage will involve roughly a hundred drivers who will each be lent a LAVIA-equipped car for eight weeks. They will use this vehicle instead of their usual car for daily trips (both work-related and leisure).
Firstly, the vehicle will be used normally, and it will not be possible to activate LAVIA. This period will be used to observe and better understand the driver’s habits, and will also allow the driver to become used to the vehicle.

Next, the drivers will use the system in informative mode. In this mode the system uses a visual display to inform the driver of the speed limit in force at the location and whether the vehicle is exceeding it.

The voluntary active and the mandatory active modes will then be tested successively; in the first of these the driver can decide to disable the system while in the second it operates on a permanent basis (except in the event of kick-down).

During this step, a wide variety of driving parameters is recorded in order to feed a database that will be processed with different kind of algorithms [3] such as to characterize the usage of the system, the driver’s behaviour, the effect of LAVIA on speed reduction etc.

**A trial zone in the Departement of Yvelines**

A large trial zone has been selected (Figure 2). It was important for this to be adequately representative. To achieve this, there had to be a sufficiently wide range of speeds, the area had to be large enough to include some whole trips (for example from home to work) and traffic conditions needed to be sufficiently varied, with congestion and free-flow occurring at certain times or certain locations.

The zone includes the communes of Saint Quentin en Yvelines, Versailles, Vélizy, Villacoublay, Le Chesnay and the main roads and expressways leading to the western gates of the city (Porte de Saint-Cloud, Porte de Sèvres).

The trial site also includes the La Défense ring road and two roads that link this to the rest of the zone (not shown in the maps below).
TECHNICAL ASPECTS

Vehicle instrumentation
Two kinds of acquisition [4] system equip prototypes vehicles (Figure 4): a video digital recorder (SRD VIDEO) and a data acquisition system (SRD DATA). It should be pointed out that fleet’s vehicles that are currently under construction will be equipped only by the latter.

Digital video recorder
The on-board video digital recorder is designed to record simultaneously images from 3 video cameras that look on forward and backward scenes and driver’s face. Images are recorded at a rate of 25 images/sec with a resolution of 720X576. As system autonomy specification was about 3 hours, MPEG2 coding was required such as data files doesn’t exceed a hard disk storage capacity of 40 Gbytes.

An off-board station allows to replay video records simultaneously on three screens. The replay software offers almost all functions that exist on a standard analogue video recorder.

Data acquisition system
This system is fully invisible for the driver. All information recorded is provided by a specific CAN bus that is interfaced through a gateway to the vehicle CAN or VAN bus.

Numerous parameters are recorded at a frequency rate of 480 ms. Among them one can find : time stamp, type of trip, video time-code, actual speed, speed limit, accelerator pedal position, brake pedal state, kick-down counter, LAVIA on/off state, state of head lights, windscreen wiper and indicator, vehicle’s position etc.

A time-code provided by the video recorder is also recorded. It allows matting of data into images on the video replay workstation.

Based of an average vehicle usage of three hours per days, the storage autonomy required is 8 weeks. Thanks to data compression, a flash memory of 192 Mbytes was sufficient and consequently data transfer occurs only at the end of an experiment for one driver.

However, in order to reduce the risk of data loss, reports resulting of auto diagnostic are transmitted via GSM at the end of each trip. Thus, any failure can be fixed as soon as it is detected.
On board system architecture

The experimentation is performed using Renault Laguna II (medium/upper class market segment) and Peugeot 307 (medium class market segment) vehicle as test cars (Figure 5). Starting from vehicles equipped with a standard speed limiter, we have modified their hardware and software architecture in order to perform LAVIA functionalities.

Figure 5 – Vehicle for the experimentation (Peugeot 307 on the left and Renault Laguna 2 on the right)

In the voluntary limited mode, the LAVIA can be simply described as a standard speed limiter with a speed limit set point coming from a navigation database instead of being set by the driver.

Below the speed set point the accelerator pedal behaves as a standard one. Once the speed limit is reached no additional effort on the gas pedal will allow to exceed the speed set point.

There are many ways to get the legal speed limit information on board like vehicle–infrastructure communication systems (beacons, road marking, …) or autonomous devices (GPS + speed limits map, traffic signs recognition using cameras, …).

Due to the fact that the experimental test zone includes approximately 1000 km of various roads and the number of vehicles is small (22), we chose for cost, availability and maintainability reasons to use a GPS like device.

Hardware

We can see on the block diagram (Figure 6) that the LAVIA has five main components linked by multiplexed data buses: a standard speed limiter, a localisation device, a LAVIA controller, a HMI module and a data acquisition system including a telecommunication (GSM) unit.

![Hardware block diagram](image-url)
The standard speed limiter will take into account the speed limit issued from the LAVIA controller and will then act as usual when operating with a speed limitation coming from the driver.

The localisation device is a standard navigation system. Using GPS, gyrometer and odometer information, it determines a rough vehicle localisation which is then matched with a digital map in order to obtain an accurate localisation of the vehicle (latitude and longitude in a WGS84 format).

The LAVIA controller ensures the system management. It provides the speed limit to the vehicle, collects the vehicle location from the navigation system, informs the driver upon the system outputs and state, acquires the driver inputs and transmits the data to the data recorder.

The HMI module consists of display unit and user interface to switch on and off the system and to collect data entered by the driver for experimental purpose. The display is located on the dashboard. It displays the state of the device (on/off), the speed limit value and some warning to the driver (when speed limit is exceeded).

The driver inputs are mainly: the on/off switch of the device and his willingness to stop the experiment. For experimental purposes, the driver is requested to enter the type of trip he is planning to achieve. Other information are automatically collected for experimental purposes: who is the driver assuming that each driver uses his own key, kick down actions in order to disable temporarily the system.

The data recorder and telecommunication unit allows to collect data for 8 weeks of use. To avoid discovering after 8 weeks, that all the files are corrupted, the telecommunication unit sends after each trip a file allowing to assess the validity of the recorded data.

**Software**

The software performs 3 main tasks every 250 ms: HMI management, Speed limit determination and Acquisition and storage of experimental data. We will, hereafter, focus on the speed limit determination procedure.

The vehicle location is determined by the navigation device. It combines dead reckoning data with the GPS ones to assess the vehicle position and then matches them with a digital map in order to obtain accurate vehicle localisation coordinates (longitude and latitude in a WGS84 format). These data are then transmitted via a VAN or a CAN bus to the LAVIA controller which determines the speed limit value.

Basically, the procedure consists in searching in the speed limit database (also named lookup table or LUT) the neighbouring elements which corresponds to the vehicle coordinates and by extracting the most probable one. Due to the fact that a speed limit value is attached to each element, this algorithm allows us to get the speed limit information. This is achieved through a distance criteria.
It is necessary to add heuristic considerations to enhance the procedure. It would have been more efficient to modify a standard navigation device by adding the speed limit parameters to the digital map, but it finally appeared difficult to implement such a modification in a serial system at an affordable cost for the project. Conversely, speed limit errors are easier to fix because speed limit database is a simple lookup table implemented in flash memory when digital map format is rather more complicated and is implemented on a CD-ROM.

FIRST RESULTS FROM TECHNICAL TESTS

*Context and problem setting*

As pointed above, LAVIA speed limit is obtained from a location (GPS positioning and vehicle sensors), and an on board database linking speed limit values and graph arcs, and various algorithms matching estimated points to arcs with maximum likelihood principle. Speed layer validation task consists in verifying that observation of real road signals really corresponds to speed limits displayed on the dashboard [5].

What is aimed is to maximize drivers security during the whole test period, and to give a statistical guarantee that the contents of the database is as most as possible in appropriateness, with reality (this suitability can never reach 100% because road signals are constantly subject to changes).

Three criteria are considered:

- equality between observed value and displayed value,
- respect of time advance or delay tolerance between the moment when the signal is observed outside the car and the moment it appears on the display
- no random discontinuity

*Methodology*

The validation process concerns a large area (Figure 2: 13 communes, almost 200 sq. Km and 1000Km of roads) with various configurations, including main roads, little size roads and urban or residential streets, and as well urban zones than interurban zones.

For those reasons, considering the available time, it has been decided to process first of all pathological sites or those on which there are uncertainties, main axis, and some samples of representative zones.
The prototype vehicle drives all along the road network while simultaneously CAN bus parameters are recorded (especially speed limit, and \([Xc,Yc]\) GPS coordinates corrected by map matching) as well as observed external values, by an operator that writes them down (Figure 9).

Meanwhile, another recorder coupled to a separate GPS receiver memorize tracks (in order to prove what has been done and to replay graphically the ways when data are downloaded and processed).

This also allows to eliminate possible doubts about positioning accuracy and reception quality factor.

When data are analysed, CAN parameters files are computed by a software that automatically detects anomalies between observed speed limits and theoretical and displayed values, and then generates a file with marked problem zones (or potentially problems zones). In those files, each error point is geographically located.

The data processing produces through a map planner and viewer, specific maps of wrong zones linked with the trips characteristics, identifiers and data sorted files in an interactive document. A finer analysis then allows to distinguish 5 types of errors:

1) location system errors,
2) map matching function or navigation process errors,
3) heuristic algorithms errors inducing wrong arcs selection in the vector graph,
4) look up table errors or arcs speed limit errors,
5) observer data entry errors.

First algorithm
With the same geographical and vectorial representation than the one used on board (NAVTECH system), the \([Xc,Yc]\) coordinates of the trajectory are drawn on the screen, and visually compared to the effective track. If no difference appears, then it can't be a map matching error. Else, it might be either a sensor failure (GPS, odometer,…), or a map matching problem (this means error #2).

![Figure 10 Error points are superimposed to the map in magenta](image-url)
**Second algorithm**

It is supposed we exclude case 2. On the same way, observer data entry errors are supposed to be eliminated by a second pass allowing to check the right signals on the road.

In the CAN data recorded file, the covered arcs sequence is extracted. This sequence is displayed and superimposed to the map and compared to the existing topology. If missing or wrong arcs are detected, then the model used is not a good representation of reality, and should be modified (this case is rare). Else, the arc identifiers sequence is translated to an alphanumeric name of streets sequence (with a correspondence array). This one is compared to the effective routing. If differences exist, this means a heuristic function error (error #3). On the contrary, this means the speed limit attribute is not correct in the look up table (error #4).

**Some difficulties met**

Several little problems are encountered and can make the system work improperly. As we know, the navigation system and the arc assignment process for LAVIA are separated. Their databases too, even if the maximum has been made to make them as close as possible. In some configurations, especially those of motorways interchanges and access lanes, some assignment errors may appear, and consequently, speed limits are not reality-true.

As well, when the system doesn’t find for a specific location a possible arc in the graph, it spreads the finding process, and a wrong segment located on a parallel way (or lower or higher ways) can be assigned, even temporarily. On a theoretical point of view, it might even happen that a same arc driven through two different routings using this same common way segment, is sometimes affected to a value, sometimes to another one.

The cartographic representation used now, is based on a topological graph on which it is difficult to take in account the cases where, according to the itinerary direction, the speed attribute is different (unless separating the same path in two arcs what is not so easy). This brings ambiguity cases which are difficult to process.

Concerning mobile road works, some signals are frequently moved away, and then appear like faults. Besides, the data processing used to compare the delivered speed limit and the observed one can hide “cumulated but balanced“ errors.

But the most problematic thing is undoubtedly the important time necessary to make the itinerary reports (and records), but even much more to process and comment the data files. This is a real difficulty to validate regularly a database which has to fit constant and large evolutions (more than 15% a year).

**First results**

Several zones have been identified in which speed limits assignments were uncertain. Among cases, we could find residential zones (with road arrays) in which some access had signals, others no one (or signals indicating different speed limits). If usual traffic regulations are applied (speed limit spreading up to the end speed limit signal, or another speed limit signal, or a crossing), those zones let appear ambiguities.

We have covered those zones and found trade-off or natural solutions (in which sometimes it is better to choose the lower speed that is in this case the most prudential solution, sometimes the less restricting speed because it could be accident-proning). Nevertheless, some zones remain ambiguous (exits of roundabout).

At this moment of the validation process, most of the main roads of the experiment zone have been covered, and we just have achieved the phase in which detection of sites where displays and signals do not match together.
In urban or extra urban zones, frequent anomalies can be viewed at the neighbourhood of the road interchanges, but we also can find errors on some main roads. For the present, some occasional map matching or heuristic errors excepted, it seems that most of the cases concern differences between LUT values and observed values. A last test will be carried out: it consists in separating LUT errors from observer errors.

CONCLUSION

Two prototypes have been designed for the LAVIA project. To save costs, the choice has been made for an autonomous vehicle based on GPS, on-board sensor and digital map and lookup table. Technical tests concern mainly speed layer validation in order to localize disparities between actual speed and speed provided by the LAVIA controller and to identify reasons for this disparities. This process is a long, meticulous operation in which all cannot be processed except through a very long period, that is not realistic. Besides, at the very moment the process is achieved, several changes may have occurred between observation and recording, and outputs and conclusions. The work could be highly simplified if navigation system and LAVIA processor could operate on a single database and a unique graph matcher, limiting thus, possible error causes, and combinations of those errors. If another validation should be processed, it would be probably judicious to involve more powerful tools, allowing a dynamic interaction between a GIS and the topological on board system. However, we can already say that GPS like systems may not be efficient enough to perform speed limit application for serial car. As a matter of fact, up to 15% of a digital map database could be obsolete per year so we can conclude on the robustness of such a device based on GPS and map matching. Thus, it seems obvious that for deployment purpose, the technical solution will be a compromise between an autonomous and an infrastructure dependant system.

REFERENCES