FIELD TRIALS WITH IN-CAR SPEED LIMITER

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SUMMARY

Effects of an in-car speed limiter were investigated in three European countries, the Netherlands, Spain and Sweden representing different regions and driving cultures. The study was carried out in urban and surrounding areas. Most of the European speed limit categories, ranging from 30 km/h to 120 km/h were included. The effects of the limiter were greatest in free driving conditions outside platoons. However, the effects of the limiter were also seen in congested traffic, even though milder than in free driving. The effects were greatest in suppressing momentary high speeds, and consequently the variation of speeds was clearly reduced by the limiter. Some negative behavioural effects were also found. These were usually slightly higher number of short time-headways and the increased frustration and stress caused by the limiter. The acceptance of the limiter increased somewhat after trying it out. However, clearly less than half of the drivers would take the limiter voluntarily in their cars. The majority of the subjects accepted the speed limiter as a driver operated system.

1 OBJECTIVE

Within the framework of the EU-financed project MASTER (MAnaging Speeds of Traffic on European Roads), field trials with an instrumented car were carried out in real traffic in three European countries, the Netherlands, Spain and Sweden in order to evaluate the effects of in-car speed limiters on driver behaviour. More specifically, the objectives of the field experiment were to investigate its effects, in addition to speed behaviour, also on interaction with other road users, to evaluate driver acceptance and to reveal possible national and region specific differences.

2 INTRODUCTION

It goes without saying that excessive speed is one of the greatest safety problems in modern transport systems. Numerous measures ranging from constructive changes to the use of information and education have been resorted to over the years. Still, it seems that the control of speed is one of the most difficult areas in transport safety today. It is not because of the lack of means to restrict excessive speeds, rather it is the lack of will to engage in measures that will solve the problem.

During the past few years ATT (Advanced Transport Telematics) solutions to suppress speeds by in-vehicle speed limiters have been tried out both in simulator and field conditions. Tentative experiences have shown the potential of speed limiters.

The speed limiter used in this experiment is an active gas pedal providing drivers with counter-force, whenever they try to exceed the pre-set speed limit. The pedal resistance
is sufficient to remind drivers of the speed limit, and the extra effort required to go faster is sufficient to deter them from speeding. The performance of the vehicle is not affected at speed levels below the pre-set maximum speed. When the speed of the vehicle is approaching the pre-set limit, the counter-force of the accelerator gradually increases. The speed limiter also restricts the engine’s fuel injection, when the vehicle reaches the actual speed limit. In order to not cut abruptly the acceleration, when the speed level reaches the pre-set limit and to have a smooth transition to the limited mode, the device allows the speed to exceed the limit initially, but the accelerator can not be depressed until the speed of the car decreases below the pre-set speed limit. The engine brake is often enough to suppress the speed. However, when driving downhill, or if the driver depresses the clutch pedal, the car can maintain a higher speed for a while by rolling freely. In the tests the speed limiter had continuously one of several speed limit channels activated.

Earlier field trials in urban environments showed that speeds were lower with the speed limiter switched on when travelling on links between intersections and slightly higher when turning at intersections. Moreover, there was a slight tendency to compensate for the low speeds on stretches by driving faster through intersections, as well as there was a slight increase in incorrect behaviour towards other road users at intersections (Persson, et al, 1993).

Distinct speed reductions and changed speed distributions were recorded also on an experiment, where the subjects were travelling on the sections of a test route with relatively high speeds (e.g. arterial roads). In this study, however, the observations of driver behaviour indicated improved interactions with other road-users (Almqvist & Nygård 1997).

In a simulator experiment the effects of speed limiters on time-headways, gap acceptance and traffic violations were studied in urban areas (Comte, 1996). Safety benefits were observed in terms of lower speeds, longer time-headways and fewer traffic light violations. However, compensatory behaviour was found in the form of riskier gap acceptance and delayed braking behaviour. When driving with the speed limiter switched on, drivers reported improved driving performance and less physical effort, but increased frustration and time pressure, on the other hand.

Drivers’ opinions on the speed limiting devices vary a lot. Generally, it seems that, the less freedom the drivers are given by the device in speed choice, the less acceptance the device will gain. On the other hand, automatic speed limiting devices have a general support from the driving public in certain limited conditions such as driving in urban areas, on slippery roads and in poor visibility conditions (Dahlstedt, 1994; Várhelyi, 1995).

### 3 METHOD

Three different test areas making a cross section of Europe were selected: 1) Northern Europe, Sweden, Lund region; 1) Western Europe: in the Netherlands the so called Randstad area; and 3) Southern Europe: Spain, Barcelona region. All the test areas have their characteristic features typical for the part of Europe in question. Moreover, it is assumed that these areas represent also different traffic cultures and driving styles implied by differences in accident statistics among other things.

The main principle of the experiment was to carry it out in a natural settings as follows:
- Measurements were conducted in real traffic by an instrumented vehicle,
- the process of monitoring and recording behaviour was unobtrusive and
- no experiment leader was present in the car.
The experiment was carried out by using an instrumented car equipped with a speed limiter (Rathmayer & Mäkinen 1995). The speed limiter was automatically triggered by transmitters attached to speed limit signs. The instrumented car was equipped with a forward looking video camera and several transducers conveying information of driver behaviour. All the instrumentation were hidden in the car. Driving of the whole test route was recorded. The analysis of the data was mainly limited to pre-selected test sections which made up a representative sample of the test route.

Unobtrusiveness means that the instruments/transducers were hidden, and the drivers were not aware of their presence. Neither was the exact objective of the task revealed to the subjects until after the tests. The instruction was given in the way that “approaches” the truth but it is not the whole truth. This applies especially to measuring driver behaviour. The subjects are told, that they will be interviewed after the drives to question their opinions/attitudes etc. towards the speed limiter with the implication this being the only monitoring carried out.

The subjects, 20-24 per country, served as their own controls. The order of driving was balanced in such a way that every other subject drove first with the limiter switched off and then with the limiter switched on. For the other driver the order was reversed (the so called ABBA-design). By doing this, the effects of biasing variables such as getting used to the test route or to the car can be spread evenly across the situations.

The subjects, female and male drivers from 25 to 55 years of age possessing a driving licence for at least five years were selected from the driver population as a random sample. The distributions by sex and age were balanced for the Swedish test drivers, while young male drivers were over-represented among the Spanish subjects. The subjects were given instructions with essentially the same content in each country. They were instructed to test drive the car equipped with a speed limiter. Then, they were told, that their impressions and opinions in terms of driving the car equipped with the speed limiter will be questioned. Consequently, they were asked to fill in an interview form before and after each test drive. Then, the subject was shown the route on the map and the controls of the car. They were asked to drive as they usually drive along the test route, and in case they lose their way, they were asked to try to get back to the route on the shortest way. After the test drives the subjects were revealed, that their driving was recorded by a computer and by a video camera. Their permission was asked for using the data for research purposes only. All the subjects agreed.

The length of the test routes was 20 - 30 km consisting of urban street network, rural roads and motorway stretches. Different speed limits typical for urban (30, 50 and 60 km/h) and inter-urban roads (70 - 120 km/h) were included, such as: The Netherlands: 30, 50, 80 and 120 km/h; Spain: 30, 40, 50, 60, 90 and 120 km/h; Sweden: 30; 50; 70; 90; 110 km/h. The three test routes included in the trials were different in terms of their traffic volumes: When traffic in the Lund area was fairly calm - excluding the city centre, the conditions in Soesterberg, the Netherlands were different. The Western part of the Netherlands is densely populated with only a few opportunities for driving alone. Sabadell in Spain is practically a part of Barcelona metropolitan area which makes traffic very intense, and there are only a few chances for driving outside platoons.

The independent variables were the condition (speed limiter on/off) and the between subject factors such as country (where the tests were carried out), sex and age (25-34, 35-44 and 45-55). The dependent variables were 1) Speed, 2) limiter interference, (frequency and time), 3) travel time, 4) time-headways in car following situations, 5) giving way (yield) behaviour, 6) driver workload and 7) opinions.
4 RESULTS

4.1 Speed

The results indicated that the subjects having a possibility to choose their speeds freely, the difference between the limiter-off and the limiter-on conditions was greatest - as might be expected. The differences between the two conditions were momentarily really great, even up to 40 km/h. There, where traffic was congested, the effects were smallest. On all types of urban roads (with 30, 40, 50 and 60 km/h speed limits) the effects of the limiter were clearly seen. The test site and the associated speed level caused by heavy traffic seemed to explain limiter effects more than the country. There were sites in all countries, where the speed level was originally low in 50 km/h areas, and the limiter effects were consequently small. On the other hand, in areas where the overall speed level was high, also the limiter effects were fairly great, typically ranging from 5 km/h to 10 km/h speed decrease in normal driving conditions and even more in free driving conditions. Single momentary mean speeds were suppressed at some points even more (Figure 1).

Outside urban areas, there were statistically significant effects only on 70 km/h roads in Sweden. There were no significant effects found on the other rural roads with 80 km/h and 90 km/h speed limits. Traffic on these roads was heavy preventing drivers from exceeding the posted limits. However, the limiter eliminated effectively the momentary high speeds even on these roads. The motorway stretches were surrounding urban areas and consequently rather busy. For this reason, the overall mean speeds remained clearly under the posted limit, and the limiter had in most cases only a moderate effect on the mean travel speeds. However, also on these roads the momentary high speeds were at some points reduced by 10 to 15 km/h.

![Figure 1. Mean speeds by the limiter-on and limiter-off condition in a 50 km/h street in Soesterberg area, the Netherlands (All = normal driving conditions; Free = driving unobstructed). A section including four intersections.](image)

The results indicate generally, that when the subjects could choose their speeds freely, the difference between the limiter-off and the limiter-on conditions was greatest, 5 km/h on average (Figure 2). The differences between the two conditions were momentarily
really great, even up to 40 km/h. In congested traffic ("All"- conditions, Figure 3) the effects were smaller.

The speed limiter also decreased the variation of speeds clearly thus reducing sudden decelerations, and implying, that the limiter equipped cars in greater volumes have a potential for making traffic flow smoother.

Figure 2. Mean travel speeds on stretches by the limiter-on and the limiter-off condition as a function of speed limit. Free driving conditions.

Figure 3. Mean travel speeds on stretches by the limiter-on and the limiter-off condition as a function of speed limit. All = normal driving conditions.

Approaches to roundabouts, intersections and curves were also affected by the limiter causing somewhat smoother approaches in terms of deceleration.

Turns were made somewhat faster, when driving free, no matter whether the limiter was switched on or off. It is to be pointed out, however, that usually the differences between various situations were small. This study does not lend a clear support to the earlier observations, that turning speeds are higher when driving with the limiter on. The speeds in
turns in the limiter-on conditions were more often lower compared to limiter-off conditions. However, the differences were not significant.

4.2 Limiter interferences

The recorded number of the limiter interferences by driver shows, that practically every subject exceeded the posted limit at some point - some drivers always when possible and the others only occasionally. It seems however, that there is a general need for the limiter judging also from the limiter interference frequencies. The duration of the interference also shows great differences. At some sites and for some drivers the duration of limiter interference lasts only a few percent of the driving time, while at some other sites, in favourable driving conditions and for some drivers the limiter is working more than half of the travel time. Usually, in free driving conditions the role of the interference function of the limiter was accentuated - as might be expected.

4.3 Travel time

When assessing the effects of the speed limiter on travel time, it is at first to be pointed out that the results apply only to conditions where travelling took place with only one limiter equipped car. It was found that travel times increased by between 2.5% and 8.9% depending on the country. The difference in the combined data of the three countries were statistically significant (p<0.05). However, generalising the results concerning changes in travel time to situations, where speed limiters are in wide use is difficult, since traffic flow parameters in those conditions are not known.

4.4 Time-headways

Possible behavioural adaptation effects caused by the speed limiter were studied by observing car-following behaviour and giving way behaviour. The results revealed that time-gaps in car following situations increased slightly in the speed interval between 30 and 50 km/h indicating that following behaviour became safer when driving with the speed limiter switched on with a less tendency for short time-headways.

4.5 Giving way behaviour

Behavioural observations did not show any negative effects in terms of incorrect giving-way behaviour towards other road-users. The proportion of pedestrians, cyclists and the cars, that were yielded priority were not affected by driving with the speed limiter switched on compared to the off-conditions.

4.6 Driver workload

A subjective measurement of the test drivers’ workload with the help of RTLX method (Byers et al, 1989) showed a significant increase in one of the six reported workload aspects, namely in frustration level, when driving with the speed limiter switched on compared to driving without. The change in this aspect of workload, however, may be expected, when first driving with a new equipment which interferes with the normal driving behaviour.

4.7 Driver opinions

There are some indications that the acceptance of the speed limiter increased after trying it out in the field conditions. Comparing the answers on questions before and after the test drives it can be seen that before trying out the speed limiter 18% of the subjects
pointed out “a device in the vehicle preventing the driver from exceeding the speed limit” as the best method to improve compliance with the speed limit. After the test drives 30% thought that speed limiters should be mandatory in all cars and 59% thought that such a system should be self operated, whereas only 10% were completely against the idea of equipping all cars with speed limiters.

When the subjects were asked, would they voluntarily install a speed limiter in their own car, in Spain the majority (70%) answered no, in Sweden the majority (62%) answered yes. In the Netherlands it was even between yes and no answers. The most frequent comment was that “one must be able to accelerate in emergency situations” and the most frequent “emergency situation” was overtaking (11 drivers). This comment was given equally in all three countries. The second most frequent comment was that the speed limiter would be “useful/ideal” when all vehicles are equipped (9 drivers). This comment was usually given in connection with the feeling of “strain you are under due to the pressure of knowing that the rest of vehicles aren’t using it”. The third most common comment was that, the speed limiter is a good idea/works best (but only) within built-up areas”.

4.8 National differences

The free speed levels were highest in Spain and consequently, the greatest limiter effects were recorded there. However, majority of the subjects were young male drivers in Spain. This possibly explains the tendency to higher speeds in Spain compared to the other two countries. The greatest changes of the limiter’s speed suppressing effects were recorded in 40 km/h zones in Sabadell, Spain just outside the most congested central area. There the maximum mean speeds approached 80 km/h and single speed observations were even higher. In the limiter-on conditions the situation was dramatically different.

The proportion of interventions by the speed limiter on roads with 50 km/h speed limit was highest in the Netherlands (20%) followed by Sweden (15%) and lowest in Spain (8%) F(2,329)=13.7; p<0.001. On rural roads, the highest proportion of interference was in Sweden (20%), followed by the Netherlands (11%) and the lowest in Spain (4%). There were several long congested sections in Spain. On motorways there was no difference in the proportion of interference between the countries.

There are some differences between the interview answers in the different countries which should be interpreted with caution, since young male drivers – who generally have more negative attitudes on speed management - are over-represented among the Spanish subjects.

Dutch drivers reported more significant increase in frustration level, when driving with the speed limiter switched on than the subjects in the other two countries. Test drivers in the Netherlands were relatively more often (23%) against the idea of automatic speed limiting than in the other two countries. On the other hand, here, a significantly larger group (59%) agree entirely with the idea of automatic speed limiting in poor visibility conditions than in the other two countries. While the majority of Spanish test drivers (60%) told, that the speed limiter affected their patience negatively, the opinions in the two other countries were more neutral. In Spain the majority (70%) answered that, they would not install a speed limiter in their cars, and in Sweden the majority (62%) answered yes. In the Netherlands it was even between yes and no answers. While in Spain the overwhelming majority (80%) agreed partly or entirely with the idea of automatic speed limiting in darkness, the majority were doubtful or disagreed entirely in the other two countries.
5 CONCLUSIONS

The results of this study are best generalizable to conditions when travelling in metropolitan areas, close to urban areas and inside towns and cities. There were hardly any conditions in which drivers could drive longer periods of time choosing their travel speed freely. On the other hand, a great deal of travelling in Europe takes place in conditions comparable to this experiment. The speed limiter had a significant speed suppressing effect on roads with speed limits ranging from 30 to 70 km/h. On the other hand, no significant changes could be shown on 80 - 90 km/h roads and on motorways, which might be due to the heavy traffic, or the speed level below the prevailing speed limit on these stretches.

The indicators of the positive effects of the speed limiter were as follows:
• large speed reductions in free driving conditions (smaller effects in dense traffic),
• decreased speed variance,
• approach speeds at roundabouts, intersections and curves became smoother,
• increased time-gaps in the speed interval 30-50 km/h, indicating a safer following behaviour,
• increased acceptance after having driven with the limiter.

The indicators of the negative effects of the speed limiter were as follows:
• shorter time-headways on rural roads, especially on the roads with speed limits ranging from 70 to 90 km/h which indicates a less safe following behaviour,
• increased travel time,
• increased frustration and stress, less patience.

However, the results of the trial should be interpreted as short term effects. Drivers need time to get used to the equipment, and the time available for the test drives was limited to 30-40 minutes per driver per condition.

Automatic speed limiting via in-car equipment is promising within built-up areas. Very little data, however, is still available on driving in rural conditions where the highest speeds are. The acceptance of the system is the highest there (besides, in built-up areas the opinion of the residents should also be taken into consideration).

Further research should be directed towards the long-term effects of speed limiters and experiments with greater number of vehicles having a speed limiter installed.

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