Use of Speed Limiters in Cars for Increased Safety and a Better Environment

SVERKER ALMQVIST, CHRISTER HYDÉN, AND RALF RISSER

A major traffic safety problem exists in Europe because many road users do not comply with speed limits. Therefore, researchers at the Department of Traffic Planning and Engineering at Lund Institute of Technology in Sweden have developed a method for controlling speed at the source, that is, in the vehicle. This method involves use of a speed limiter (SL). At every change of existing speed limit, a sender emits impulses. Each vehicle is equipped with a receiver able to understand these impulses, automatically limiting the vehicle's maximum speed to the speed limit in question. This concept sounds utopic, and there is not the slightest chance of introducing an SL into road traffic unless the advantages, from safety and environmental viewpoints, clearly outweigh the possible disadvantages. Hypotheses about the SL's major impact on traffic were developed through a literature study, roundtable discussions, and self-observation studies. In addition to objective safety, these hypotheses concern security, travel time, road net capacity, energy consumption, air pollution, and noise. External test drivers are currently being chosen for behavior observations and interviews. Their attitudes concerning several safety aspects will be measured, then groups of drivers will use the SL for different lengths of time. After driving, they will be interviewed again about their attitude toward the SL and its practical use. Along with the field experiments, estimates will be made on aggregated levels. The results of these studies will be used in planning and designing a large-scale experiment that will be held as an option, unless there is a surprising change of status quo in the official attitude concerning an SL system.

In all countries of western Europe, a major traffic safety problem exists because car drivers do not comply with the speed limits set by authorities. This problem seems to be fairly independent of the type of limit (30, 50, 70, 90, 110, and 130 km/hr and those in between), and it must be viewed apart from theoretical discussions about which speed limits are adequate for different circumstances from a traffic safety perspective.

Besides simply putting up traffic signs, many methods to achieve better compliance with speed regulations have been tried, including new types of road design, humps and other hindrances, and law enforcement. These methods continue to be the ones most often used, along with arguments for better compliance with speed regulations through traffic safety campaigns. Some of these methods (e.g., speed humps) are efficient, but only locally so. At the same time they are considered to be too expensive to install in all the places they are needed. Some other methods (e.g., safety campaigns) are inefficient, or their efficiency is difficult to prove in the short term. Still another method—the use of radar pistols—is in opposition to a certain law in most European countries. This law disallows radar pistols because their use is considered to be of questionable validity in speed measurement and in the correct identification of the measured vehicle out of several vehicles.

Instead of discussing the problems with using these methods to adapt vehicle speed to existing limits, the problem has been approached from another angle. So far, little effort has been focused on the most natural solution, namely, to control the process at the source (i.e., in the vehicle). A method for accomplishing this goal is introduced in the following paragraphs.

THE SPEED LIMITER

The proposed method involves the use of a speed limiter (SL). At every change of existing speed limit, a sender emits impulses. Each vehicle is equipped with a receiver able to receive these impulses, automatically limiting the vehicle's maximum speed to the speed limit in question. This system would be automatic and obligatory.

Researchers in the Traffic Safety Group of the Department of Traffic Planning and Engineering at Lund Institute of Technology in Sweden have presented this idea to their sponsors, along with a plan for analyzing the feasibility of and the conditions for introducing SL equipment into road traffic.

It must be stressed that the focus at this stage is on built-up areas with speed limits of 30 to 70 km/hr. It is also important to stress that the system must be mandatory—that it eventually must be in operation all the time for all drivers. A guarantee that a significant majority of car drivers would be complying with speed rules would allow for a smooth introduction of the SL and would provide a real improvement. It is believed that voluntary use would not change speed behavior significantly.

The main problem in testing this method is obvious. Because such a system does not exist, it will be difficult and time-consuming to provide conditions that simulate an automatic and obligatory SL, even in limited areas. Thus, the studies presented in the following sections (i.e., studies already conducted and those planned for the near future) are theoretical and are based on answers to conditional questions

Department of Traffic Planning and Engineering, Lund Institute of Technology, University of Lund, P.O. Box 118, S-122 00 Lund, Sweden.

about options for future road traffic dealing with an entire speed-limiting system. Empirical studies are limited to detailed system aspects, such as technical reliability and functioning smoothness, as well as attitudes toward the use of speed limiters in cars.

PRECONDITIONS FOR INTRODUCTION OF AN SL

Demands to introduce an SL into road traffic will be acted on only if it can be clearly shown that the advantages, from a safety and environmental viewpoint, outweigh the disadvantages. Hence, an overall appraisal of the extent to which the SL can influence the traffic system is necessary. Following are some hypotheses about possible advantages and disadvantages of the SL.

Advantages

When drivers have difficulty judging their own speed and therefore drive faster than they intend, the SL would be of help. The speedometer does not always fulfill its function. Drivers frequently must look at other road users, the road, or other displays in the vehicle and cannot read the speedometer on these occasions.

When drivers are aware they are speeding but are doing so because they feel pressed to keep up with surrounding traffic, the SL should help them maintain the speed limit. This hypothesis is a typical one, and is of interest only in connection with the current traffic system. Obviously, if all vehicles were equipped with SLs this problem would be solved.

Sometimes, a driver's choice of speed is caused by irrational or emotional motives, for example, trying to be faster or stronger than other car drivers. In such cases, the SL can be assumed to be of help. However, the tendency to compete on the road may then find outlets other than the use of vehicle speed.

Overall, the SL will have a positive effect on safety, fuel consumption, air pollution, and noise pollution. If the SL leads to a more relaxed and smooth driving style, then the positive effects will be more pronounced.

Disadvantages

The SL limits the drivers ability to choose the vehicle's speed. This restriction in freedom of choice might lead to unwanted forms of behavior, at least in the beginning phase after introduction of the SL. As a psychological rule, compensating behavior almost always results when freedom of choice is reduced. Possible actions might include driving against red or more dominant behavior at pedestrian crossings.

Another interesting hypothesis is that the frustration that may result for drivers from a feeling of losing time would lead to even higher speeds in low-speed situations (e.g., right or left turns) where the maximum speed today is below what the SL would allow. Moreover, the possibility that problems might arise in connection with overtaking maneuvers must not be overlooked.

A significant increase in time consumption is another possible consequence of the use of an SL, assuming that drivers currently save some time by breaking certain rules.

COMPLETED STUDIES

Phase 1: Literature Study

The basic hypotheses about the SL's possible impact on car driver behavior have been guided by experts' interpretations of existing knowledge of car drivers' motives and actions (*1*). More detailed hypotheses were to be formulated in subsequent phases of the project.

Phase 2: Roundtable Discussions

A roundtable discussion is an open form of discussion that can be used to broaden knowledge of a subject not yet discussed widely. Agreements as well as contradictions among the participants are used to shed light on as many aspects of the matter as possible. Experiences with roundtable discussions (*2*) have indicated that the following advantages result from application of this method:

- Preset statements are avoided.
- Spontaneous comments are usual.
- New and independent trains of thought are more likely to be found.
- Goal setting is not based on a predetermined route choice.

Thus, increased opportunities arise for discovering aspects not previously considered.

Concerning psychological aspects, the roundtable discussions make clear that the question of acceptance, not explicitly included in the hypotheses named previously, has to be given priority (*3*). Moreover, it became more and more obvious that the aspects of technical reliability and functioning smoothness that should be considered thoroughly were precision, maneuverability, adjustability, comfort, and hamper resistance.

During the roundtable discussions, contacts were established with a German team of researchers also working on an SL project series (*4*,*5*). This group had built an SL that met the specifications for technical reliability and functioning smoothness. Of course, the SL must be manually operated at this time, and an automatic and compulsory system if far from being installed. However, an SL was purchased from Germany to allow simulation of the SL concept. In accordance with the research concept, it was then possible to start on the third phase of the project.

Phase 3: Self-Observation Studies

To begin, one car was equipped with the SL from Germany. Personnel employed at the Department of Traffic Planning and Engineering in Lund drove this car. During the trips, which they chose freely according to their needs, they used a built-in microphone to comment on unusual situations, as well as any change—positive or negative. All comments were immediately recorded on tape. In addition to these comments, expert discussions were held regularly at the department. The car was also equipped with a datalog for later recording of time, speed, and energy consumption. These studies were conducted to test the hypotheses resulting from Phases 1 and 2 to allow them to be better defined, completed, and put into operation.

The initial hypotheses are concerned with the individual drivers' acceptance of and reactions to the SL and with the effects on an aggregated level (e.g., safety, noise, and air pollution). As a main result of Phases 1–3, those hypotheses that deal with a situation in which only few cars are equipped were verbalized in more detail, as follows:

- Various degrees of resistance to the SL will disappear after an equipped car has been driven for some time (the length of time must still be established).
- Irrespective of the attitude shown before driving the equipped car, drivers will generally feel comfortable driving such a car. A systematic deterioration of attitude is not expected.
- There is a possibility that driving an SL-equipped car in today's traffic could be frustrating because the driver is pressed, or overtaken, so often.
- Drivers who want to drive slower, despite the pressure exerted by today's traffic, will find it much easier when their wishes are supported by the SL.
- On the other hand, the hurry reflected by today's traffic might influence drivers of SL-equipped cars, leading to such compensation tendencies as driving faster when turning left or right or driving against a red light.
- For drivers having a positive attitude toward lower speeds, the SL will be experienced as a support for their behavioral tendencies.
- For drivers having a negative attitude toward lower speeds, these attitudes will change for the better in the long run (as a dissonance phenomenon).
- A driver who is the only one using an SL in a fast-going traffic system might experience a kind of claustrophobia (because of being slower than others or not being able to overtake vehicles going slightly below the limit).
- No relevant safety gains for the system can be expected if only a few vehicles are SL-equipped. The safety gain for single drivers depends on their own attitudes, in response to the compensation tendencies. This effect should vanish after some time, however.
- Frustration with the SL could lead to revenge tendencies, because others cause pressure and possibly bad feelings at times. This effect should vanish after some time, as well.
- Compensation tendencies are not likely with individuals who have a positive attitude toward the SL.
- The reduction in fuel consumption and air pollution will be perceived immediately for people who have a positive attitude toward the SL. For those who initially have a negative attitude toward the SL, this advantage will be realized after some time.
- Time consumption will not be altered so significantly that usual routines will have to be changed on a large scale.
- The SL will cause smoother behavior because acceleration and deceleration will become less accentuated. The whole speed set will become slower, irrespective of attitudes toward the SL.

FUTURE STUDIES

In a previous section the reasons for the opinion that the SL must be mandatory were demonstrated. However, even if future work is basically directed toward effects within a fully equipped SL system, the transition phase to such a system might be long. Safety during this transition period might be influenced. The hypotheses just described, as well as short-term future work, must be viewed in this light.

Phase 4: Field Studies, Part 1

In Phase 4, a special test crew will be recruited. Crew members will drive the car, with and without the SL activated, simultaneously recording behavior. Additionally, time consumption, speeds, accelerations, and decelerations will be recorded automatically with help of the datalog that was calibrated in Phase 3. The driving period will be preceded by interviews to characterize the drivers' attitudes about driving, traffic safety, and traffic safety measures. The idea is to choose drivers with different attitudes toward traffic safety issues, especially toward the importance of speeds and measures to reduce speeds. After the test driving, new interviews will be conducted, focusing on reactions to the SL and changes in driver attitudes.

The tests of the hypotheses about driver behavior will be performed by specially selected drivers on a certain stretch of road in an urban area (e.g., in Malmö) and partly on the driver's usual route (e.g., the route driven to work). First, the drivers will drive these stretches a few times with the SL activated. When driving on the specially selected route, an observer will be in the car. The observer will take written notes on behavior, which cannot be covered automatically, and will ask questions about special situations that demand an explanation or interpretation of driver behavior. When driving the usual route, behavior will be recorded only by the datalog. The measurements will later be calibrated so that comparisons can be made between the before and after situations. Factors compared will include speed, acceleration, deceleration, and fuel consumption.

Primarily, these studies of behavior can be used to test hypotheses about drivers' reactions and behavior only when a few cars are equipped with SLs. The behavioral observations will be combined with detailed analyses of every recorded change in behavior and applied to whether this change will be influenced when an increased share of vehicles are equipped with SLs (including the scenario in which all cars are equipped). These analyses will be backed up with driver interviews after they have driven with an SL.

When the results of these studies give accurate enough estimates of driver reaction to the SL under given circumstances, work on the aggregated level will begin. The degree of accuracy in these estimates depends on several circumstances, of which the following are the most important:

- How well the test drivers represent the whole population,
- How well the chosen test routes represent the road network,

• Relevance of observed changes in behavior for situations in which the SL is mandatory and functions automatically, and

• Relevance of observed changes in behavior for situations in which many cars are equipped with SLs (including all being equipped and always in operation).

Of course, the accuracy of the estimates will be influenced by the size of the tests with hired drivers. However, the estimates will not become reliable until a large-scale, isolated experiment has been carried out.

Phases 5 and 6: Field Studies, Part 2; Surveys

Following are the most important hypotheses that are to be tested using the methods described:

• Normal attitudes toward speed-reducing measures are distinctly more sensible than politicians and traffic experts usually suggest.

• Among such groups as pedestrians, cyclists, the elderly, and beginning drivers, acceptance of the SL within a system frame will be high.

• In an SL system it will be easy to eliminate stress caused by the SL. Drivers will quickly get used to the SL because daily traffic will not remind them of former options (other drivers will not press and overtake).

• Stress will also be reduced because car drivers will stop trying to save time by driving fast. Such a concept has no basis in an SL system.

• Competition between drivers, and between drivers and other road users, will be reduced because one of the most important aspects of competition—namely, speed difference—is eliminated to a great extent.

• One important motive for sensationalist behavior is eliminated by eliminating speeding possibilities in an SL system. (It is hoped, however, that the optimistic hypotheses about compensatory behavior presented in the section on Phase 3 are correct.)

• Traffic in the frame of an SL system will become quieter and smoother. Fuel consumption, air pollution, and noise production will therefore decrease.

• Summing up all hypotheses about behavioral changes presented in the section on Phase 3, it is expected that safety in the SL system will be much higher than in today's system.

Phases 5 and 6 involve long-term work. Part 2 of the field studies will primarily concern a limited area or region in which a certain concentration of SL-equipped cars are in compulsory and automatic operation. Such a large-scale behavioral study will not be possible during the next 3 years, however, and the design of the study will depend on the results of Phase 4. If such a study can be carried out in 1994, some knowledge about a larger-scale functioning of an SL system will already be available. If all goes as planned, a study will be conducted in Germany by Von Winning and Krüger in which cars belonging to the federal state of Nordrhein-Westfalen and its counties will be equipped with an SL. The drivers of these cars will be instructed to use the SL in precisely defined areas. Although Von Winning and Krüger are not aiming at introducing a compulsory and automatic system in Germany, the study will come close to simulating a qualified number of car drivers in the region compulsorily using the SL in inhabited areas.

It is desired that a simulation study be conducted in Sweden. The knowledge gained from carrying out more behavior observations in different places and under different, but well-defined, conditions cannot be overestimated. Surveys, on the other hand, can be performed immediately after Phase 4, or at least earlier than large-scale field studies. It is difficult to draw valid conclusions about acceptance and other aspects of attitude from behavior observations alone. Even if those observations are done within a long-range experimental frame, they still have to be complemented with verbal data. Survey questions asked today must be of a hypothetical nature because not much is known about the characteristics of a future SL system. It is not possible to wait for results from large-scale experiments before asking questions. Sponsoring of this research will be probable only if hypotheses demonstrate that there will be sufficient acceptance of an SL system within a defined period of time by authorities, car manufacturers, and the public.

PERSPECTIVES

The most important perspectives of the prognoses will be traffic safety, travel time and traffic capacity, and environmental aspects (such as air pollution, energy consumption, and noise). Smooth functioning and technical reliability are not the subject of these prognoses because such aspects will not be problematic according to current knowledge.

Traffic Safety

Safety analyses are divided into two parts, namely, objective safety (reflected by accident risk and accident frequency) and subjective safety (perceived risks).

As long as there are no large-scale tests of an automatic and obligatory SL system, estimations of the final effects on accident risk can be done using only intermediate behavioral measures. Even this analysis may create problems. It is known, however, that changes in speeds usually are strong indicators of changes in accident risks. There are also some indications that red driving, accepted gaps, and similar behavior variables are related to accidents. Another behavior aspect that is of interest is the homogeneity in traffic, which primarily concerns any variance in speed between vehicles driving in the same direction (e.g., the frequency of overtaking maneuvers will be reduced decisively). A total homogeneity—that is, a flow without speed variance—would theoretically eliminate many accidents (especially rear-end and overtaking accidents). In general, there is likely to be a strong correlation between homogeneity and accident frequency. Also of interest is the study of how crossing pedestrians and cyclists choose gaps in the flow according to the homogeneity of vehicle speeds, as well as the safety implications of this factor.

Generally, it can be concluded that these behavioral measures are strongly linked to accident risk. Even though quantifications are partly missing, it should still be possible to make rough estimates of changes in accident risks by using behavioral measures.

The behavior types that reflect objective safety (accident risk) can be analyzed both from observations of test drivers' cars, which allow an assessment of the dangerousness of certain types of behavior (*6*) and from observations on the spot, in which traffic conflicts resulting from road-user interaction are used to indicate the existence and degree of accident risk (*7*). The former method can already be used when single cars are equipped with an SL (although system predictions must be made cautiously). The latter method will be adequate once large-scale experiments have started. In a somewhat longer perspective, it will also be possible to evaluate the total effects in a larger system with the help of accident analyses. (These analyses should, however, be supported by conflict and behavioral studies, partly to provide detailed information not possible to obtain from accident data for quite some time and partly to allow an explanation of the changes that occur.)

The self-observation studies have given some strong indications that the subjective safety of unprotected road users might increase. Drivers believed that their behavior toward pedestrians, for example, became more lenient. Such aspects can be observed to a certain extent, but questionnaire and review data will also be needed. The hired drivers should be asked about subjective safety aspects, as should drivers taking part in larger scale experiments or studies and, of course, pedestrians, cyclists, parents, residents, and so on. (Again, if asked today, many questions will be of strictly hypothetical nature.) Different groups of drivers might experience differences in safety as a consequence of the SL. For example, older and just-licensed drivers may react differently to an SL than would other drivers.

Travel Time and Traffic Capacity

Self-observation studies have initially shown that travel times are not much longer when an SL is used. It seems to be a matter of impatience if a driver wants to go faster, depending on whether the driver feels impeded by the SL. However, whether or not relevant losses of time could be a consequence of the introduction of an SL system is something that must be studied empirically. It is likely that the introductory studies of behavior, and the interviews focusing on acceptance and attitudes, will offer a good prediction of the way in which drivers will behave in traffic flows. This knowledge can then be applied to established models on the relationships between speed and gap choice and between travel time and capacity. It should then be fairly easy to predict what will happen on an aggregated level concerning these variables.

It is important to understand that these studies will not be sufficient in predicting the effects of a fully implemented SL system. It must be realized that interactions between road users in such a system might be influenced in quite a different way than when only a few cars are equipped. The effects cannot be appraised until large-scale experiments have been carried out.

Energy Consumption, Air Pollution, and Noise

Noise and air pollution are the environmental aspects that are of greatest interest. The effects of the SL on air quality can be studied when the first cars are equipped with SLs. The effects on an individual level can be studied either directly with the help of measurements of the test vehicles (e.g., an exhaust-measuring device connected to the datalog) or indirectly from knowledge of the relationship between speed and acceleration behavior and exhaust volumes. The effects on an aggregated level will be analyzed using the data from individual drivers as well as knowledge about aggregated speed data.

As explained previously, primarily the effects from few cars being equipped with SLs can be predicted. Earlier assumptions about changes of behavior following the transition from a system with few to one with many SL-equipped cars will be used. It will also be possible to make certain predictions about the effects of a fully implemented SL system. However, analogous to other aspects, it will not be possible to get reliable estimates until large-scale experiments have been carried out.

Energy consumption is closely linked to exhaust levels. The studies of energy consumption will, therefore, be planned in a similar way. Individual energy consumption will be measured directly in the test vehicles. Aggregations will be based on speed and acceleration data, including their distributions.

The noise aspect will be harder to study in the short range. It will be necessary to rely on theoretical models of the way in which noise levels are influenced by such factors as speed, acceleration, deceleration, and make of car. The possibility of aggregating is vague. A large-scale experiment is therefore important, partly because of an interesting aspect of construction in the SL that has already been acquired. This SL has an extra function that creates the possibility of decreasing the vehicle's acceleration capabilities as well as limiting the maximum speed. With the help of this function, the acceleration capabilities can be determined by choice. Thus, experiments can be performed with varying available acceleration capabilities. There is reason to believe that noise caused by powerful acceleration is common in urban areas. If so, limiting the acceleration capabilities will have a considerable effect on the noise level. This concept has yet to be examined.

CONCLUSIONS

Completed studies in this project as well as planned future research have been described. The presentation had to be kept short and unspecific in the current framework. Emphasis has been placed on describing the hypotheses and other aspects that are to be studied in the coming phases of the project, which methods could be used, and in which time perspective these phases should be done. The possibility of estimating a situation in which few cars were equipped with SLs and one in which all cars are equipped has been explored. As indicated, the need for continued research is great. It is therefore essential to proceed in a step-by-step fashion. In the first stage introspective studies were used to get a practical illumination of all aspects. The most important agenda was to revise, complete, or modify all behavioral hypotheses that had been formulated in the beginning of the project series. Changes in behavior are the ultimate indication of the way in which road users accept the SL and react to it and, thus, the consequences of the SL on safety, noise, air quality, travel time, and capacity.

After a first round of introspective studies with 10 to 15 employees of the Department of Traffic Planning and Engineering, external test drivers are now being chosen for behavior observations and interviews. Before driving, they will be asked about their attitudes toward traffic safety, traffic safety measures (especially speed-related measures), and the SL. On the basis of these interviews, the drivers will be grouped by their driving behavior and then compared. The behavior of the drivers when driving with and without the SL will be analyzed. Also, the motives behind the behavior will be considered to test the hypotheses presented in the section on Phase 3. At first, some of the drivers will drive the car for only a short time. Others will be driving for a longer time. This method will allow an analysis of how the adaption process works and whether the long-term effects are different from the short-term ones. This analysis will then be used in planning the rest of the field tests. After driving, the drivers will be interviewed again. In principle, the same questions will be asked, but some distinctions will be made when it comes to the drivers' attitudes toward the SL and the practical use of it.

Parallel with the field experiments, preparations will be made for making estimates on the aggregated level, that is, estimates for different phases within the transition phase and estimates in the fully implemented system. This work will begin with a theoretical study of models that can be used for estimating noise, air pollution, fuel consumption, capacity, travel time, and safety.

The results of these studies will be used to plan and design a large-scale experiment, which will be held as an option if evidence about the consequences of a hypothetical introduction of an SL system is not received by other means or unless there is a surprising change of status quo in the official attitude toward an SL system (e.g., in Sweden). However, it is essential that the study of attitudes toward traffic safety, safety measures, and the SL starts early. This research should include tests of hypotheses through the interviews of drivers of the experimental vehicles and through the questionnaire sent to a representative mix of people. The knowledge gained by these tests of hypotheses will be an important part of the base needed for decision making by authorities and industry.

To sum up, the next stage of research for the coming 3 years will include the following:

- Test driving with enough drivers in different situations to estimate the different effects well enough to enable large-scale testing as the next step;
- Estimates of the consequences for safety, noise, air pollution, and energy consumption using models, behavioral data, and interview data from the test driving; and
- Accumulating attitudes toward traffic safety issues, traffic safety measures in general, and the SL specifically.

The results from this stage will give a clear picture of the way in which individual drivers react to having a mandatory SL in the car. It is also considered possible to make a fairly good prediction of what will happen if the SL is introduced on a large scale, as well as actions needed to improve this knowledge.

The speed debate is intensive, and there is no indication that it will slacken in the near future. To date, the debate has focused primarily on rural roads. At the same time, the problems in built-up areas are of at least the same magnitude. There is also a lack of measures that can be expected to have a decisive influence on automobile speeds, especially in urban areas. The great potential for safety offered by the SL—according to the work done so far—means that the results from this next stage will be important for the future policies of authorities.

In the speed debate the performance of automobiles has been increasingly emphasized. Speed, acceleration, and handling abilities of modern cars, in combination with a quiet and comfortable inner environment, naturally influence the choice of speed. In this perspective it is important that car manufacturers also get as accurate a picture as possible of the qualities of the SL, how it will be accepted, and what consequences it will have for behavior, safety, noise, and energy consumption. The manufacturers can thereby adjust the production to better meet new demands that authorities, as well as consumers, might specify.

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