IMPROVER

Impact Assessment of **Ro**ad Safety Measures for **Ve**hicles and **R**oad Equipment

Final Report

Impact of cruise control on traffic safety, energy consumption and environmental pollution

Subproject 3

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Executive Summary

In this subproject, the impact of Cruise Control (CC) was analysed with respect to traffic safety, energy consumption, and environmental pollution. In order to work on this topic from a European perspective, a team of European experts in the fields of driver assistance systems, human factors, engineering and road safety contributed. The subproject was split up into six workpackages:

- **WP 3.1:** Current policy and practice for CC in the EU Member States
- **WP 3.2:** Level of usage of CC by class of vehicles in the EU
- **WP 3.3:** Identifying issues associated with use of CC
- **WP 3.4:** Estimation of the impact of CC on fuel consumption and environmental pollution
- **WP 3.5:** Impact of CC across jurisdictional boundaries
- **WP 3.6:** Recommendations for further actions at an EU level

No major safety, energy consumption or environmental pollution issues with respect to CC were discovered; however, the subproject found several areas of interest and possible concern, these are summarised below:

1. There is an overall lack of knowledge and specific research about CC, its usage and how it affects driving and fuel consumption. Generally, previous research provides a mixed message; the literature in various places shows both possible safety benefits and dis-benefits with respect to CC usage. These findings are mainly based on interview studies and on theoretical grounds but not on experimental research.
2. Market studies are not precise and information provided by several sources differs a little. As such, it is difficult to make an accurate estimation on the numbers of CC equipped vehicles, nevertheless the data available indicate that the uptake of CC is still increasing as it becomes easier and cheaper to fit.
3. Higher classes of vehicles (larger and more expensive vehicles) have higher CC fitment rates, as such types of vehicles tend to have CC fitted as standard equipment.
4. There is no national or European-wide database of vehicles and their equipment, whether that be CC or other In Vehicle Information System (IVIS) / Advanced Driver Assistance System (ADAS).
5. It will take time for Adaptive Cruise Control (ACC) to reach the same levels of market penetration as CC (despite there being more recent research undertaken on ACC compared with conventional CC). In contrast do CC, there are experimental studies on ACC showing that driving with ACC may lead to safety critical behavioural adaptations (e.g. prolonged reaction times in critical situations). On the other hand, the research on ACC reveals possible benefits of ACC on traffic safety and fuel consumption, if it is used appropriately.
6. So many external factors affect fuel consumption that it is very difficult to tell what sort of effect CC has on it. Manufacturers claim that from a technical point of view

CC has no effect on Fuel Consumption. Experimental research on driver behavioural changes due to CC is lacking.

7. CC is a comfort system and is used as such. For example, HGV drivers use it to stop their feet from getting tired. Only a small portion of all drivers use CC to avoid speeding tickets. This may change as soon as the pressure by enforcement increases.
8. Previous research shows drivers do not tend to use their CC in hazardous conditions such as snowy/wet weather on slippery road surfaces.
9. Regarding the use of CC across jurisdictional boundaries, there is legislation in Belgium that makes CC usage illegal in certain areas, such as stretches of busy motorway; although driver knowledge of such legislation might be quite poor, especially amongst foreign drivers.
10. The Belgians and the Dutch have no scientific data to back up legislation or calls for CC to be fitted as standard equipment to all vehicles. An effective enforcement of the Belgium legislation on CC is not possible for practical reasons.
11. For those drivers who use CC to avoid speeding tickets, the variability in speed limits and speed units across jurisdictional boundaries could cause difficulties.

Recommendations for EC Actions

Based on these areas, the following recommendations for actions at an EU level are proposed:

1. According to current knowledge, it is not justified to forbid CC in general. Furthermore, legislative actions to restrict the use of CC do not seem to be sensible because enforcement of this legislation is not possible for practical reasons.

2. There is no indication that it is necessary to include CC in type approval due to either safety or environmental issues.

However, it has to be noticed that studies on the effects of CC are scarce and experimental research is lacking. The existing accident data statistics do not allow for analysing the impact of CC on accident causation, but there are some hints that CC might be used inappropriately by some drivers leading to safety hazards. The more complex ACC is able to compensate for some disadvantages of CC but new hazards are created. Therefore:

3. A study be commissioned to experimentally investigate CC usage, how drivers react in certain safety critical situations and the effect of CC on fuel consumption due to driver behavioural changes. A simulator study that could assess the differences between ACC and CC would be beneficial. A selection of older and more inexperienced drivers would add further value to this research.

4. Accident Data Recorders are able to log information such as vehicle speed in the moments before an accident. For research purposes such systems should be encouraged at national and EC levels to include data on the use of any electronic

assistance systems inside the vehicle at the time of the accident such as CC and other IVIS and ADAS in order to get insight into safety issues associated with the use of CC and other (A)DAS.

5. Better driver knowledge of CC would be beneficial. For example, a defined set of instructions - like not using CC in dense traffic - should be produced and disseminated among drivers.

6. Research and development of future intelligent CC systems other than ACC and further improvements of ACC avoiding possible dis-benefits of the existing systems should be supported.

With respect to the specific legislation on CC in Belgium:

7. In some cases, greater harmonisation of national legislation regarding the use of CC in Europe, and CC signing, should be undertaken. The EC should promote such harmonisation, for example though organising a workshop of stakeholders. In particular, a common approach should be implemented by national authorities regarding the situations where CC should not be used (and how that information is displayed to drivers). For example, Belgium has certain CC restrictions (displayed via national traffic signs); on major arterial roads in Europe (e.g. the E Network or the Trans European Road Network) this may cause comprehension difficulties for non-native drivers.

Conclusions

The subproject discovered no major safety, energy consumption or environmental pollution issues with respect to CC. However several areas of possible concern were noted. Based on these areas of concern, recommendations for actions at an EU level were proposed.

It seems likely that CC will become more widespread in vehicles in the EU in future years. The work undertaken here has shown that there are many knowledge gaps and many issues of possible concern. In contrast to the more complex ACC, only little research has been done on CC.

Although ACC (that currently is far from replacing CC on the market) can help to avoid some hazards connected to CC (e.g. smaller between-vehicle distances), new hazards are created (e.g. over-reliance of the driver on the system; distraction of the driver by doing other things; driver is 'out of the loop'; over-estimation of system functions). To avoid these drawbacks of ACC, new developments are currently introduced / assessed that combine ACC with a collision warning / emergency braking function. On the basis of current knowledge, it is not possible to directly compare the effects of the three systems with respect to traffic safety, environmental pollution, and fuel consumption. But it is possible to conclude that the more complex a system is, the more promising it is on the one hand, and the more the driver is 'out of the loop' on the other hand.

Contents

1 Background

Cruise Control (CC) is a driver assistance system that automatically maintains a driving speed that has been determined by the driver. This system is deactivated as soon as the driver brakes. It is possible to drive faster than the speed set by pressing down the accelerator without deactivation of the system. CC *must not be confused* with a **speed limiter** which strictly prohibits a driver to drive faster than a fixed or driver selected speed limit.

Currently, the type approval of vehicles equipped with CC is not subject to any specific national or international regulation.

Potential benefits of CC are an enhancement of driving comfort, a voluntary compliance with speed limits, a reduction of fuel consumption and a reduction of exhaust gas emissions. On the other hand, the driver might be tempted to accept smaller between-vehicle distances because he tries to avoid braking. Furthermore, in case of emergency braking, the reaction time might be prolonged because the driver took his feet away from the pedals and / or because the driver was inattentive.

A further development of CC is **'Adaptive' or 'Intelligent Cruise Control' (ACC).** This advanced driver assistance system combines CC with an automatic maintenance of a predefined distance to the preceding vehicle. In this way, ACC is able to compensate for some disadvantages of CC. On the other hand, there may be additional risks like an over-reliance of the driver on the system and an over-estimation of the system functions. In contrast to the 'simple' CC system, a lot of research has been done to evaluate the more complex ACC system. It has to be noticed that the effects of CC might be completely different from that of ACC. Therefore, it is not possible to simply transfer the results of research on ACC to CC.

The number of vehicles equipped with CC is much greater than that of vehicles equipped with ACC. According to the DAT-Veedol-Report (2002), in 2001, 14% of the vehicle fleet and 15% of new vehicles in Germany were equipped with CC. Especially in trucks, a CC system is installed because it is believed to allow for a compliance with legal speed limits saving fuel at the same time. Currently, it is not known whether the activation of a CC system contributed to (severe) accidents because this information was not gathered in the accident statistics.

In this subproject, such issues with respect to CC were analysed with respect to traffic safety, energy consumption, and environmental pollution by different methods including literature reviews and questionnaire studies.

2 Conventional Cruise Control: A targeted review of the literature

To establish what previous work had been performed on conventional CC, a targeted review of literature was conducted.

2.1 Cruise Control Research at Monash University Accident Research Centre

A series of focus groups were undertaken with drivers aged 25-49 from rural and metropolitan areas of New South Wales, Australia. The purpose was to assess the use, acceptability and effectiveness of manual speed alerting and conventional CC devices. The study was completed in 2004 by Regan and Young.

The data collected consisted of self-reports by focus group participants. No actual evaluations of the effectiveness of CC devices were undertaken, nor were any surveys conducted to quantify the extent to which these systems are used by drivers.

Overall the participants held positive attitudes towards CC, and felt such devices were effective in helping them maintain and control their speed. Indeed, their main motivation for using it was to help avoid speeding fines. Despite this, it was found that drivers often set their speeds well above the posted speed limit. Differences in acceptability and use of these devices was, however, found between drivers in the rural and metropolitan areas - generally rural drivers were more likely to use such devices.

The focus group participants comprised drivers who either regularly used CC, or those who did not (despite it being fitted to their vehicles). The main reasons attributed to the non-use were: forgetting the system was available, finding it difficult to use, and not feeling in control of the car when using it.

The drivers who did use CC were found to regulate their use according to time of day, traffic density and types of road travelling on. For example, it was popular on quiet, straight rural roads in day-time conditions, but less used on winding or urban roads.

A targeted literature review was undertaken as part of this work. Overall, it concluded that few studies have examined the effects of conventional CC on driver behaviour. Those studies that were conducted generally found that the use of CC does not have a major adverse effect on driver behaviour and safety; indeed, a positive impact might be found for some aspects of driving, such as following distance (although there was fairly large individual variability due to driving experience, with less experienced users displaying more unsafe behaviour).

2.2 Other Studies

A targeted literature review was undertaken using the extensive databases at TRL. Search terms used included CC and Safety. Overall the review found that the majority of the published work considered types of Adaptive/Intelligent Cruise Control systems.

The most noteworthy results for conventional CC are summarised below.

Van Kampen (1996) undertook perhaps the most detailed literature review of conventional CC to date. The abstract reports:

> '*In this literature survey little evidence is found of studies primarily investigating the road safety effects of cruise control. Those effects which were examined (mainly through practical tests with and without cruise control) showed that in addition to positive effects governing individual fuel consumption, cruise control was also likely to cause positive road safety effects. This was linked to the fact that: (1) drivers would have fewer tasks to perform; (2) they would be driving at lower average speeds; and (3) that the traffic flow would be more 'stable'. On theoretical grounds, these studies anticipate a significant road safety effect following the general introduction of cruise control on motorways in the form of a 50 per cent reduction in the number of fatal accidents involving passenger cars. This dramatic effect is linked to the calculation that the widespread introduction of cruise control would slightly reduce average speeds and significantly reduce the distribution of speeds on these road types. This would result in fewer changes of lane, less overtaking and less braking, all of which would cause fewer accidents. One possible specific application of cruise control is in cars towing caravans, for which comfort and road safety are important factors'* (Van Kampen, 1996).

Gunnerhed (1988) reported an engineering risk assessment of CC that focused on the mechanical reliability of such systems. Results found that a single mechanical fault such as a bad solder joint could cause safety problems such as sudden acceleration. This means that the alleged events such as fatal accidents in Sweden attributed to sudden acceleration due to defective CC devices are possible. However, the study did not directly examine human factors / behavioural aspects of these systems.

In Austria, Christ, Smuc et al. (2000) examined the behavioural effects of conventional CC in traffic situations. When using the system, they found no evidence that drivers were driving less attentively than they would when not using CC. The study also found that CC generally had a positive effect on drivers' choice of speeds. However, similar to the Regan and Young study, there was some evidence that drivers less familiar with CC tended to set the speeds excessively high (especially on rural roads) in comparison to more experienced drivers.

2.3 User study performed by order of the Dutch Ministry of Transport

To be able to judge whether different speed regulating systems have a positive effect on achieving the policy goals of improved road safety, traffic circulation and environment, the Ministry of Transport, Public Works and Water Management (Ministerie van Verkeer en Waterstaat) decided to have a user study carried out (AVV, 2004). This user study addressed three related research questions with supporting studies.

1. Interviews with drivers of cars fitted with different in-car speed controlling systems. What is important to drivers? (qualitative: why). Thirty car drivers were interviewed in total, which included:
    - 13 about the ACC
    - 11 about a speed limiter: (6 with warning signal, 4 with hard limiters and 1 with both)

- 12 about the CC (of which 6 car drivers were also asked about the speed limiter).

2. A survey among drivers of Nissan Primera cars fitted with an ACC. How many drivers have had what experience? (quantitative: numbers). Altogether only 76 of the 137 survey forms were returned.
3. Interviews (by telephone or by completing a questionnaire by e-mail) with car dealers and sales staff provided information about what sales people think of these systems and the way in which they introduce them to their clients. Ten dealers altogether were approached by telephone and by e-mail and five took part in the study.

With regard to the results concerning CC, it was shown that there were clear differences in the driving style of the people interviewed who had a standard CC fitted. Some felt that the car rapidly accelerated to reach the set speed, while others thought the acceleration was fine. To be able to adjust to these differences in driving style, more setting choices should be offered. The danger of offering more choice, however, is that the operation of the system will become more complicated thus requiring even more time to get used to it.

CC was mainly used on motorways and major roads and to a lesser extent on 80 km/h roads. More than with the ACC, to use the CC it is important that it is quiet on the road and the driver expects to be able to cover a larger distance at the same speed. The drivers reported that the CC contributed to driving comfort.

According to those interviewed, the CC neither improves nor worsens road safety. A negative effect of the CC on driving style often mentioned was that drivers are inclined to keep the CC switched on for as long as possible, even if it results in following distances that are too short. Many drivers felt that the CC could be used to prevent (heavy) fines. Essentially the CC worked as a speed limiter for them.

3 Adaptive Cruise Control (ACC): A short literature review

Although this report is targeted at studying the effects of Conventional Cruise Control, a short review of the literature available on the more complex Adaptive Cruise Control (also known as Intelligent Cruise Control (ICC)) will be given.

This advanced driver assistance system combines CC with an automatic maintenance of a predefined distance to the preceding vehicle. So, ACC can automatically adjust a car's speed to maintain a predefined following distance. The technology uses forward-looking radar or similar sensor devices installed at the front of the vehicle to detect the speed and distance of a vehicle ahead of it. Based on this, it automatically adjusts speed in order to maintain an appropriate distance between vehicles in the same lane. It must be noticed that ACC is designed as a comfort system and not as a collision avoidance system. This means that the braking capability of ACC is limited and emergency braking must be performed by the driver. Furthermore, ACC sensors in general do not detect stationary objects.

Research about this type of technology has been increasing steadily since the early 1990's; this section summarises the research on the effects of ACC on traffic safety and environmental pollution / fuel consumption.

3.1 Safety

There are a plethora of safety studies with ACC, so the following is only a summary of some of the literature.

ACC is still not yet widespread, so the longer term safety effects of such technology is still being researched, and some studies are based on more hypothetical/ theoretical effects. For example, Chira-chavala and Yoo (1994) undertook preliminary vehicle simulation based on police accident reports and found that the use of the hypothetical ACC system could potentially reduce traffic accidents by up to 7.5%.

Slightly more recently, Van Arem et al (1996) stated:

> *"Concerning traffic safety the following results were obtained: (a) a decrease in the number of shockwaves and in the number of vehicles in a shockwave; (b) an increase in Time-To-Collisions (TTCs), especially for AICC vehicles; (c) a decrease of headways, especially on the left lane; and (d) a slight increase of the fraction of headways less than 0.5 s."*

As such, the safety effects of ACC were mixed: potentially more traffic predictability and regularity, but increases in the number in potentially hazardous vehicle headways.

Likewise, Nahm et al (1999) found positive safety effects of Intelligent Cruise Control:

> *"The effectiveness of the ICC system is estimated at about 17 percent based on computer simulations of two rear-end precrash scenarios that are distinguished by whether the following vehicle encounters a suddenly-decelerating or slow-moving lead vehicle. The ICC system has the potential to eliminate*

> *approximately 13 thousand police-reported rear-end crashes on US freeways, using 1996 national crash statistics"*

Stanton, Young & McCaulder (1997) argued that whilst there are undoubtedly some benefits associated with such systems, there are some concerns also. Their work experimentally investigated the driver's ability to reclaim control from the Adaptive Cruise Control system in a malignant scenario; it found that a third of the participants were unsuccessful in reclaiming control of the vehicle before a collision occurred. Hence in this context the system might occasionally take the driver out of the vehicle control loop.

Similarly, Nilsson (1995) found in a simulator study that drivers using ACC had more collisions when approaching a stationary queue than unsupported drivers. Rudin-Brown & Parker (2004) reported behavioural adaptation effects of drivers using ACC that lead to prolonged reaction times in safety critical situations.

Finally, Hoetink (2003) conducted an extensive literature survey of Advanced Cruise Control and road safety. The work found:

> "*Although there can be positive effects of ACC, negative effects were also found. Current ACC systems can have a favourable road safety effect if they are used on motorways outside rush hours with good visibility. An ACC advantage is that the increased comfort tires the driver less. ACC also has a moderating effect on the speed driven, and the percentage of very short headway times decreases. Moreover, driving with ACC is easy to learn and easy to use. It is worrying that the driver does not always react adequately in critical situations, or if the ACC fails. It is also, for road safety reasons, undesirable to use ACC on secondary roads and during motorway congestion. A gradual increase in the road capacity and road safety is not feasible with the current ACC systems. Drivers could be recommended to only use ACC as a support on motorways during long journeys, if one can drive calmly, and with good visibility. Public information agencies could inform the user about ACC's safe use, in which it must be emphasised that one should regularly control the system to see if it is working properly*."

So overall it can be concluded there are both safety benefits and disbenefits with regard to ACC. However, if used correctly and in appropriate situations, then the potential safety benefits may overall outweigh the negative effects.

3.2 Environmental Pollution and Fuel Consumption

Less experimental data are available about ACC and environmental pollution / fuel consumption. Many studies (e.g. Mitchell, 1993) argued that ACC should reduce pollution and fuel consumption because speed was more limited, controlled and regulated - however little empirical data was reported.

However, more recently, Bose and Ioannou (2000) found:

> *"It is shown that ICC vehicles can accurately track a lead vehicle and attenuate position errors generated by the lead vehicle during smooth transients. Furthermore, the smooth response of ICC vehicles designed for human factor considerations filters out traffic disturbances caused by rapid acceleration*

> *transients. Such ICC vehicle properties have beneficial air pollution and fuel consumption effects that are significant when the manual vehicles perform aggressive rapid acceleration manoeuvres."*

And

> *"Simulations have demonstrated that the fuel consumption and pollution levels present in manual traffic can be reduced during rapid acceleration transients by 28.5% and 1.5 to 60.6%, respectively, by the presence of 10% ICC vehicles."*

As such, the available evidence suggests there are fuel consumption / environmental pollution benefits from the use of ACC/ICC. Although more empirical data, to examine more precisely in what conditions these benefits might occur, would certainly be valuable.

4 Summarised Reports of Work Packages

To put the recommendations for actions at an EU level into context, extended summaries of the workpackages 3.1 - 3.5 are given below.

4.1 Current policy and practice

In order to establish current policy and practice for CC in the twenty-five member states, delegates from all member states were contacted and asked to fill in a questionnaire, found in Appendix A.
In this inquiry, Member States were asked for details on current policies and practices regarding CC and for their plans concerning future policies. Representatives of Member States were asked if more detailed policies were made by category of vehicle:

1 Person-cars (Small, Medium, Large (including SUVs))
2 Light-vans with a maximum of 3500 kg (empty vehicle plus loading capacity)
3 Trucks (empty vehicle plus loading capacity over 3500 kg)

4.1.1 Results

Of twenty-five EU member States contacted, 18 (72%) responded to the questionnaire. Of the seven countries for which no response was found in time to prepare this report, the language barrier posed a problem in Spain and current policy definition in the area of CC posed a problem for filling in the questionnaire in France. Appendix B contains a summary of policies relevant to CC in the responding EU member states.

Denmark, Germany and The Netherlands view CC as policy-relevant for environmental reasons. These countries see CC as one way to reduce environmental effects of vehicles in terms of reduction of fuel consumption and exhaust gas emissions. Germany and The Netherlands regard CC as an 'antiquated' technology and instead put their focus on more advanced technologies like ACC.

In Belgium, serious accidents happened involving a heavy goods vehicle (HGV) crashing into a traffic jam. This accident raised concerns about the decreased driver awareness when using CC. As a result, CC is forbidden in areas where road work is being carried out or where traffic jams are likely to happen. Specific road signs are used for that purpose on highways. It has to be noted that this legislative act was a reaction to public pressure. There was no proof that CC actually caused an accident (oral communication of a member of the Belgium Ministry of Transport).

The Finnish interviewee indicated that he was interested in securing that CC does not cause any harm to traffic safety when driving on slippery road surfaces in winter conditions. Furthermore, he is following the use of CC and if accident cases will show that CC causes some harm to traffic safety, then they are ready to consider limiting the use of CC.

4.1.2 Summary and conclusions

A survey of twenty-five EU Member States about current policy and practice resulted in eighteen responses. Seventy-two percent of the responses indicated that CC plays no role in current policy and practice. Of the 28% for which CC has policy relevance, approximately half do it for environmental reasons (reduction of fuel consumption and exhaust gas emissions) and the other half for safety reasons. The Netherlands did give an incentive system for installation or purchase of CC (tax reduction), but this tax break has since been rescinded. The Netherlands mentioned a research program on CC.

The results regarding policy provided by this work are not conclusive. Rather, they indicate that there are several possibilities for future activity with respect to CC. These are:

- Six of the EU Member States interviewed spontaneously stated that they expect the EU to take a leading role in policy development for CC. In fact, the stance taken by the Member States indicates that this holds not only for CC but other Advanced Driver Assistance Systems (ADAS) both already on the market (Advanced Cruise Control, Lane Departure Warning System) and in development at the automotive manufacturer and supplier level in the EU fifth and sixth framework projects.

- A wider context for the impact of ADAS in general, under which CC would fall, is needed. As an example, the World Forum for Harmonization of Vehicle Regulations (WP.29) of the United Nations Economic Commission for Europe (UN ECE) does not specifically address CC. CC does not affect the lighting, braking, transmission and other systems, that the WP.29 specifically addresses through its structure. Thus, CC "falls between the cracks". However, systems such as Advanced Cruise Control (ACC) would be addressed by the group for which braking regulations are made, as ACC directly affects the braking of a vehicle.

- Systematic measurement of the effects of CC on traffic safety, traffic flow, energy consumption and gas emissions are necessary in order to objectively inform the Member States. There is little quantitative evidence of CC effects at this time. Some Member States expressed interest in this information and even the desire to participate in European research on this topic. However, most Member States indicate that they have too few resources to investigate these issues individually.

4.2 Level of usage of Cruise Control

In order to establish usage by class of vehicles of CC in the EU a number of car manufacturers, suppliers and automobile associations were contacted and asked to fill in the questionnaire in Appendix C. In this questionnaire the contact person fills in the number of CCs their car company sells per year and, if available, the numbers of CCs in the following categories of vehicles:

1. Person-cars
   a. Small
   b. Middle
   c. Large (including SUVs)
2. Light-vans with a maximum of 3500 kg (empty vehicle plus loading capacity)
3. Trucks (empty vehicle plus loading capacity over 3500 kg)

Results

A list of car manufacturers, a number of car related organisations (ANWB, RDW, RAI, ACEA, CLEPA, Bosch), insurance companies (FBTO) and statistical databases (EURSTAT, CBS) were contacted. However, it was difficult to get the requested data, because of the following reasons:

- Nine replied that they did not have this kind of information (e.g. ACEA, CLEPA)
- Four contacts did not respond at all (even after a reminder).
- Four promised to send the information, but did not do so (on time).

Eight car manufacturers replied. The results received are summarised in Table 1.

Table 1: Summarised results from the level of usage questionnaire.

	Car/Truck	No. 2004	% 2004	No. last years	% last years	Increase?
A	Car	model A: 40,000 model B: 66,000	model A: 92% model B: 79%			?
B[1]	Car	39,000		137,489 (2000-2003)		yes
C	Car	Medium:120,000 Large:100,000 Vans:9,000 Total:229,000	Medium:20% Large:50% Vans:25% Total: 27%		Medium: <2000, 3% '01-'03, 8% Large: '90-'95, 5% '96-'00, 10% '01-'03, 20%	yes
D	Car	Total in Europe: 605,000 Total in world: 760,000	model A : 15% model B: 15% model C: 18% model D: 37% model E: 45% model F: 90% model G: 65% model H: 55% model I: 98% model J: 100%		2003: model A: 5% model B: 15% model C: 18% model D: 35% model E: 40% model F: 80% model G: 60% model H: 50% model I: 98% model J: 100%	yes

[1] Sold only in the Netherlands

	Car/Truck	No. 2004	% 2004	No. last years	% last years	Increase?
E	Truck		model A and B: 100% model C: 80% model D: 50%	300,000 trucks 15,000 buses (since 1988)		?
F	Truck	40,000		237,400 (1997-2004)		yes
G	Truck	model A: 61,000 model B: 6,000 model C: 7,000	model A:100% model B: 100% model C: 22%			?
H	Car	Small: 109,789 Medium:314,467 Large:103,096 Vans: 23,153				

Whilst cars can be equipped with CC by the manufacturer, CC can also be installed after a car is bought. For this reason the automotive suppliers were also approached. Unfortunately, no information was received from them or their organisations.

On basis of the data, it is reasonable to conclude that the absolute number of cars equipped with CC increases. As was seen by the numbers provided by one car manufacturer there is not only an increase of CCs in the 'large' category of cars but also in the 'medium' category. This undoubtedly also applies to other car manufacturers.

CC is quite common in trucks and buses. The data provided by one manufacturer shows that 92% of all their trucks sold in 2004 had CC installed. However, based on the data provided and the statistics available it was not possible to come up with an estimate of the number of trucks and buses currently equipped with CC.

In order to be able to provide a reasonable estimate of the number of cars, trucks and busses currently equipped with a CC in Europe, we wanted to link the number of cars and trucks sold with CC to the total number and age of cars and trucks currently driving around in Europe. With regard to this latter amount the EURSTAT database provides the amount of cars per country, but unfortunately only up until 2001 and not for every European country. In order to be able to estimate the volume of CC as a percentage of the total number of cars, figures are needed up until 2004. The figures from EURSTAT, however, do give an indication of the percentage of older cars that drove around in the total car population in 2001 and almost certainly did not have CC.

Data obtained from Statistics Netherlands showed that approximately 9.5% of the total number of cars in the Netherlands in 2003 were constructed before 1989. In 2001 about 30% were constructed before 1990. Although the periods do not exactly overlap these numbers do show that the percentage of cars constructed before 1990 (at least in the Netherlands) decreased rapidly in two years time. More new cars increase the number of cars with a CC.

<u>Summary and conclusions</u>

Only a limited number of responses were received to the initial inquiry about the number of passenger cars, trucks and busses equipped with CC currently on the road in Europe. The data that was received differed in the information it provided. Some car manufacturers do not make a distinction between different car models and others only provide the number or percentage of cars sold with CC in 2004. Based on the limited amount of responses received it is not possible to provide valid estimates of the number of cars, trucks and busses equipped with CC.

However, based on the limited number of responses received it is possible to conclude that the number of passenger cars with CC increases, not only in the ‘large’ models but also in the ‘medium’ models. Nevertheless, CC can still mainly be found in ‘upper class’ or ‘large’ passengers cars. Furthermore, CC is far more common in trucks than in passenger cars. The provided data suggest that a very high percentage of new trucks are equipped with a CC.

Short view on the market position of ACC

The number of cars / trucks equipped with ACC is much lower than those with CC. ACC is installed in a very small number of high-class vehicles only. According to an oral communication with one car manufacturer, significantly less than 10% of *high-class* vehicles they sell are equipped with ACC.

This is partially explained by the fact that CC is either a standard device or costs about 200 - 300 € as original equipment and 60 - 80 € on the aftermarket whereas ACC is not offered by all car manufacturers and costs at least 2000 € up to 3400 €. One car manufacturer offered an ACC functionality two years ago but then decided to delete this system from the choice of products because of lacking demand by the customers.

This finding of the equipment of new vehicles with ACC is in contrast to the results of a market study performed by ABI research in 2003 that predicts a penetration rate of up to 1.7% of *all* new vehicles with ACC in 2005. Given the information of the car manufacturer above, however, it can be concluded that much less than 1% of *all* new cars are equipped with ACC in 2005. This means that ACC is far from replacing CC on the market.

In the cited market study of ABI research it is mentioned how difficult it is to gather the needed information from the car manufacturers and that many assumptions and estimations had to be made. This explains why these studies often yield slightly different results.

4.3 Issues associated with use of cruise control

WP3.3 aimed at investigating the benefits and disadvantages of the use of CC as experienced by drivers. Drivers in this case are represented by the 1121 car- and truck-drivers that responded to the questionnaires that were sent out (Appendix D). Since there is no registry over vehicles that are equipped with CC not all drivers that received the questionnaire had a CC but more than 50% of the car-drivers drove cars with CC so there is a solid foundation in this study.

Results

Overall it was found that men are more in favour of the CC than women, both with regard to having a car equipped with CC and with regard to using the CC once they had it in their car. The same goes for the will to have an ACC in the car where the men are more in favour of such a system than women. Full results are given in Appendix E.

Both for cars and trucks, there are about 6-7 % of drivers that have CC in their cars but choose not to use it. The main reason for not using it is a belief that it reduces safety followed by being uninterested and not finding the system useful. For truck-drivers the belief that it increases fuel consumption is also a deterrent. What is interesting here is that some drivers state that the anticipation of increased safety and reduced fuel consumption are the main reason for using CC.

The CC is most often used on the motorways but also to a rather high degree on rural roads, especially for car-drivers. Truck-drivers do not use it on rural roads to the same extent. In general drivers tend to use the CC in good free flowing traffic conditions and not so much on urban roads, slippery roads, during peak hour and in darkness even though it does occur to some degree.

The main reason for drivers to use CC is comfort which was stated as the main reason by nearly 60 % of the car-drivers and 66 % of the truck-drivers. Avoiding speeding tickets and reduced fuel consumption had almost the same rating, 10-15 %, where avoiding speeding tickets was more often given as the main reason for drivers who do not use CC that much.

The opinions regarding the benefits and disadvantages of CC differ quite a lot within the driver population. Some drivers think that safety is increased when using CC, some think the opposite. Some drivers think that comfort is increased; again, some think the opposite and these views are reflected in both how and how much the CC is used. The drivers who think that safety is increased do often think that the comfort is increased as well and, not surprisingly, they tend to use it to a higher degree than drivers who think that safety and/or comfort is decreased. They also tend to set the CC on speeds above the speed limit to a higher degree while the drivers who don't use the CC that much use it to avoid speeding tickets to a higher degree than the drivers who use CC a lot.

The drivers were also given a description of how an ACC-system works and then asked whether they would prefer such a system before a traditional CC and in that case why/why not. Most drivers, more than 70% said that they would prefer such a system and the main reason why was that they thought that safety would increase followed by increased comfort. There were some drivers however who were not interested and this was due them finding such a system needless or that they saw a potential danger in a system taking to much control over the vehicle.

Conclusion

Overall it can be concluded that the perception of benefits and disadvantages of the use of CC are just perceptions. The respondents' views go both ways for many of the questions, both for car-drivers and professional drivers such as truck-drivers. What seems to be clear however is that most users find it to be useful as a comfort system if the circumstances are right and, since there is only a small proportion of drivers who do not use the CC due to safety issues, there does not seem to be any *major* safety issues associated with the system from the drivers' point of view. But nevertheless, it is remarkable that some drivers feel unsafe when using CC and therefore do not use the system. It should be investigated experimentally whether this subjective feeling is based on objective potential hazards of the use of the system.

It should be considered that the picture resulting from questionnaire studies might be a little bit too positive because the respondents might not be willing to tell the whole truth. For example, regularly, cases of misuse of CC and ACC especially by truck drivers are observed and punished by the motorway police (oral communication of a police officer from the German motorway police). The respective drivers have activated their CC or ACC and are involved in doing other things than driving (e.g. reading) and they sometimes put their feet away from the pedals. Unfortunately, there are no data or statistics available that could give some information about the frequency of these cases of misuse and it is not possible to separate the effects of CC and ACC.

4.4 Estimation of the impact of cruise control on fuel consumption and environmental pollution

To elaborate the effects of Cruise Control (CC) on fuel consumption and exhaust gas emissions an internet inquiry, a literature survey and on road measurements were carried out. The following sections display the results of the three chosen approaches leading to conclusions and recommendations with regard to the impact on Cruise Control on environmental aspects. Full details are given in Appendix F.

Internet inquiry

An internet inquiry delivered some hints about the effect of Cruise Control on fuel consumption and emissions. The statements given are ambivalent. The majority of citations report decreases in fuel consumption but there also might be increases due to inappropriate use of Cruise Control.

To conclude the internet inquiry one can state that Cruise Control has the potential to save fuel if it is used correctly. The amount of reduction of fuel consumption is not clear. It differs depending on the traffic situation and the behaviour of the driver. Advancements of Cruise Control using information about traffic conditions are developed promising a significant reduction of fuel consumption.

Literature review

An international literature survey including the IRRD-OECD database was carried out with regard to Cruise Control and associated environmental aspects. The results of the literature review confirm those of the internet inquiry.

As the internet inquiry the literature study does not deliver corroborated results of the impact of Cruise Control on environmental aspects. Fuel consumption and exhaust gas emissions can be changed both to higher and lower values. In many cases very special testing or simulation conditions were given so that the results are not transferable to real traffic and do not help to calculate the change of the emissions of real traffic. More studies were performed with regard to Adaptive Cruise Control (ACC) than to Cruise Control showing that for ACC the expectations on an impact on traffic smoothening and thus fuel savings are higher.

On road tests

There is very few literature and reliable data about the influence of Cruise Control on fuel consumption and emissions. In order to fill this gap on the one hand vehicle manufacturers as well as hauliers and fleet managers were asked about their experiences with the usage of Cruise Control and the impact on fuel consumption and emissions. Also the German association of freight service, logistics and disposal was included. On the other hand on road tests were performed with three passenger cars and two trucks to achieve a first impression how Cruise Control could influence the fuel consumption on different motorways. A theoretical consideration based on the statements of the vehicle manufacturers and hauliers is given, and the results of on road fuel consumption measurements are stated. On the basis of these information conclusions are drawn and recommendations are derived.

Conclusions

From a theoretical and technical point of view Cruise Control does not have any influence on fuel consumption and emissions if the vehicle is driven exactly the same way using Cruise Control and not using Cruise Control. Vehicle manufacturers also state that Cruise Control is not designed to save fuel but to enhance driving comfort. That means that any changes in fuel consumption due to Cruise Control are primarily not dependent on technical properties of the vehicle or system but on the behaviour and skills of the driver.

Cruise Control can only have an influence on fuel consumption if either the average speed changes by using it or by changing the dynamics of the trip.

Real world measurements carried out within the scope of this project with passenger cars and trucks on different motorways show ambivalent results. Smaller as well as higher fuel consumptions are observed while using Cruise Control. The changes in fuel consumption are small and not unambiguous.

Fuel consumption depends more on the experience of the driver, the traffic situation and the topography than on Cruise Control itself.

Recommendations

Based on the results of the on road measurement, on the statements of manufacturers, hauliers and associations and on the results of the literature and internet survey the following recommendations could be derived:

- Cruise Control should be used as the instructions of the vehicle manufacturers indicate. These instructions are e. g.:
    - not to use Cruise Control in dense traffic,
    - not to use Cruise Control in hilly terrain if the systems keeps the velocity without taking the topography into account,
    - to switch on Cruise Control not until the desired speed is reached by accelerating by foot if the Cruise Control systems uses full engine load for acceleration.
- Drivers should get better information about how their Cruise Control system works and when it should be used.
- To reduce fuel consumption without increasing travel time too much drivers should use Cruise Control in a way that the velocity profile is smoothened and the maximum speeds are lowered.
- The desired speed set by Cruise Control should be lower than the velocity of the speed limiter to avoid conflicts between the control strategies of both systems.
- Advancements of Cruise Control systems like Predictive Cruise Control or Intelligent Cruise Control including topographical and other information about the traffic in front of the vehicle should be supported.

- To smoothen the velocity profile without the need to use a Cruise Control system manufacturers should think about introducing an “insensitive” accelerator which either allows bigger movements of the accelerator without changing the velocity of about 80 km/h or which becomes stiffer at 80 km/h and thus serves as a rack for the drivers foot.
- Due to the ambivalent effects of Cruise Control on fuel consumption and emissions indicated by the literature and the on road measurements no legislative actions on EU level with regard to Cruise Control and environmental issues should be taken.
- Future advancements of Cruise Control should be awaited in order to check if they have a bigger potential to lower fuel consumption than the conventional Cruise Control system.

4.5 Impact of Cruise Control across jurisdictional boundaries

The aim of this workpackage was to assess the impact of cruise control across jurisdictional boundaries.

Method

To undertake this work, the following tasks were undertaken.

1. A desk based study reviewing results from WP 3.1 and 3.2, which cover the policy and practice in each member state, and the level of usage and class of vehicles in the EU.
2. A desk based task developing possible scenarios for using cruise control across jurisdictional boundaries.
3. A brainstorming session identifying any potential problems that might arise when crossing boundaries, using the review and the scenarios developed.
4. An internal report for WP 3.5. The internal report (shown in Appendix G) details in full the results of stages 1-3.

Results

Overall, the workpackage found several areas where cruise control might be a possible issue across jurisdictional boundaries. These areas included:

- *Violations and accident reporting* – the main jurisdictional issue is when travelling into areas where cruise control usage is restricted.
- *Speed limits and speed units* – differences in both these parameters across jurisdictional boundaries may exist and conflict with cruise control usage.
- *Knowledge of legislation* – there are restrictions on cruise control usage in some EU states, but some drivers may be unaware of these restrictions, especially foreign drivers.

Conclusions

There appears to be no legislation and very little guidance on CC usage. It seems to have been overshadowed by the more sophisticated Adaptive CC that was first introduced onto the market by Toyota in May, 1998.

However even though CC is sold as a comfort system this does not mean that there are not safety-critical elements to its usage. The brainstorming sessions held have produced a number of potential scenarios that appear to show important issues across jurisdictional boundaries. A number of the scenarios that were identified have the potential to cause adverse consequences across jurisdictional boundaries. The major issues identified include:

- Legislation in Belgium that makes CC usage illegal in certain areas, such as stretches of busy motorway.

- The variability in speed limits and speed units across jurisdictional boundaries, and the effect that these differences could have on CC usage.
- Knowledge of such legislation may not be widespread in the country it is enforced in, especially if it is relatively new. Further to this; foreign drivers are even less likely to be aware of such legislation or the penalties for violation.

Some States expect the EU to take a leading role in policy development for cruise control - the issues identified in this workpackage could help guide this policy.

5 Workshop Outcomes

A meeting was held at BASt in October 2005 with the partners to discuss the findings from the separate workpackages. A summary of knowledge gained from this work was produced and a list of recommended EC actions was developed.

5.1 Summary of knowledge gained from this work

CC Research

- There is a lack of knowledge and specific research about CC, its usage and how it affects driving and fuel consumption
- Market studies are not precise and information provided by several sources differs a little

CC Numbers

- It is very difficult to make an estimation on the numbers of CC equipped vehicles
- There is no national or European wide database of vehicles and their equipment, whether that be CC or other IVIS/ADAS
- Higher classes of vehicles have higher CC fitment rates as such types of vehicles tend to have CC fitted as standard equipment
- The data available indicate the fitment rate of CC to vehicles is still increasing as it becomes easier and cheaper to fit
- It will take time for Adaptive Cruise Control (ACC) to reach the same levels of market penetration as CC

Fuel Consumption

- So many external factors affect fuel consumption that it is very difficult to tell what sort of effect CC has on it
- Previous research provides evidence to both benefits and dis-benefits
- Manufacturers claim CC has no effect on fuel consumption from a technical point of view
- If there is an effect of using CC on fuel consumption this level is likely to be no bigger than 5%

Driver Knowledge

- There is a lack of driver knowledge about CC, the way it works and how it can affect fuel consumption

Cruise Control usage

- CC is a comfort system and is used as such. For example, HGV drivers use it to stop their foot from getting tired. A small portion of drivers use CC to avoid speeding tickets.

Cruise Control Legislation and Recommendations

- The Belgians and the Dutch have no scientific data to back up their legislation or calls for CC to be fitted as standard equipment to all vehicles
- There is legislation in Belgium that makes CC usage illegal in certain areas, such as stretches of busy motorway; although driver knowledge of such legislation might be quite poor, especially amongst foreign drivers

Safety

- VTI report showed that drivers do not tend to use their CC in dangerous conditions such as snowy/wet weather on slippery road surfaces, but these self-reports might be a little bit too positive.

- There are a few drivers who have CC but do not like to use it because they feel unsafe when using it.

5.2 Recommendations for EC Actions

Based on the knowledge gained from this work, the following recommendations for actions at an EU level are proposed.

- According to current knowledge, it is not justified to forbid CC in general. Furthermore, legislative actions to restrict the use of CC do not seem to be sensible because enforcement of this legislation is not possible for practical reasons.
- There is no indication that it is necessary to include CC in type approval due to either safety or environmental issues.

However, it has to be noticed that studies on the effects of CC are scarce and experimental research is lacking. The existing accident data statistics do not allow for analysing the impact of CC on accident causation, but there are some hints that CC might be used inappropriately by some drivers leading to safety hazards. The more complex ACC is able to compensate for some disadvantages of CC but new hazards are created. Therefore:

- A study be commissioned to experimentally investigate CC usage, how drivers react in certain safety critical situations and the effect of CC on fuel consumption due to driver behavioural changes. A simulator study that could assess the differences between ACC and CC would be beneficial. A selection of older and more inexperienced drivers would add further value to this research.
- Accident Data Recorders are able to log information such as vehicle speed in the moments before an accident. For research purposes such systems should be encouraged at national and EC levels to include data on the use of any electronic assistance systems inside the vehicle at the time of the accident such as CC and other IVIS and ADAS in order to get insight into safety issues associated with the use of CC and other (A)DAS.
- Better driver knowledge of CC would be beneficial. For example, a defined set of instructions - like not using CC in dense traffic - should be produced and disseminated among drivers.
- Research and development of future intelligent CC systems other than ACC and further improvements of ACC avoiding possible dis-benefits of the existing systems should be supported.

With respect to the specific legislation on CC in Belgium:

- In some cases, greater harmonisation of national legislation regarding the use of CC in Europe, and CC signing, should be undertaken. The EC should promote such harmonisation, for example though organising a workshop of stakeholders. In particular, a common approach should be implemented by national authorities regarding the situations where CC should not be used (and how that information is displayed to drivers). For example, Belgium has certain CC restrictions (displayed via national traffic signs); on major arterial roads in Europe (e.g. the E Network or the Trans European Road Network) this may cause comprehension difficulties for non-native drivers.

6 Conclusions

This subproject analysed the impact of CC with respect to traffic safety, energy consumption, and environmental pollution. A team of European experts from various branches of the field of driver assistance systems contributed.

The subproject discovered no major safety, energy consumption or environmental pollution issues with respect to CC. However several areas of possible concern were noted. Based on these areas of concern, recommendations for actions at an EU level were proposed.

It seems likely that CC will become more widespread in vehicles in the EU in future years. The work undertaken here has shown that there are many knowledge gaps and many issues of possible concern. In contrast to the more complex ACC, only little research has been done on CC.

Although ACC (that currently is far from replacing CC on the market) can help to avoid some hazards connected to CC (e.g. smaller between-vehicle distances), new hazards are created (e.g. over-reliance of the driver on the system; distraction of the driver by doing other things; driver is 'out of the loop'; over-estimation of system functions). To avoid these drawbacks of ACC, new developments are currently introduced / assessed that combine ACC with a collision warning / emergency braking function. On the basis of current knowledge, it is not possible to directly compare the effects of the three systems with respect to traffic safety, environmental pollution, and fuel consumption. But it is possible to conclude that the more complex a system is, the more promising it is on the one hand, and the more the driver is 'out of the loop' on the other hand.

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8 Annexes

Appendix A - Policy questionnaire (WP3.1)

Appendix B - Overview of Policies Relevant to Cruise Control in EU Member States (WP3.1)

Appendix C - Questionnaire for CC level of usage (WP3.2)

Appendix D - Questionnaires for car and truck drivers on issues associated with the use of CC (WP3.3)

Appendix E - Detailed description of the results of the questionnaire study on issues associated with the use of CC (WP3.3)

Appendix F - Estimation of the impact of cruise control on fuel consumption and environmental pollution (WP3.4)

Appendix G - Impact of Cruise Control across jurisdictional boundaries (WP3.5)

Appendix A: Policy questionnaire (WP3.1)

Name of contact Person: Date:
Position:
Organization:
Country:
Form of contact: Interviewer:

These questions concern *Cruise Control (CC)*. CC is a driver assistance system that automatically maintains a driving speed that has been determined by the driver. This system is deactivated as soon as the driver brakes. Currently, the type approval of vehicles equipped with Cruise Control is not subject to any specific national or international regulation.

Question 1: Is CC a relevant policy issue in your country?

Question 1a: If not, why not? (Fill in and go to Question 4)

Question 2: For what reasons is CC relevant for your country's policy?
For example, you can think of the following justifications:

Safety
Compliance with speed limits
Driver comfort
Reduction of fuel consumption
Reduction of exhaust gas emissions
Better (homogenized) traffic flow

Question 2a: Is there a distinction made among vehicle types, e.g.,
Person-cars (small, medium, large (including SUV's)
Light vans with a maximum of 3500 kg (empty vehicle plus loading capacity)
Trucks (empty vehicle plus loading capacity over 3500kg.)

Question 3: What is the current practice with respect to CC? (policy implementation)
The following are examples:

CC is forbidden, perhaps in specific areas
Subsidies, tax reduction, or insurance reduction for purchase of vehicle or retrofit with CC
Research programs on CC and its effects

Question 3a: Is there a distinction among vehicle types? (see question 2a for the categories)

Question 4: what direction will policy on CC take in the future?

Appendix B: Overview of Policies Relevant to Cruise Control in EU Member States (WP3.1)

Country	Is Cruise Control an issue in your country?		If yes, justification	If no, why not	Look to EU to formulate policy
	Yes	No			
Austria		X		CC is a comfort system	
Belgium	X		Primarily Safety: Accident caused by HGV making use of CC. Concern about possible decreased concentration of the driver due to use of CC. As a result, CC is forbidden in areas where road work is carried out or where traffic jams are likely to happen. Road signs are used to communicate this on highways. Furthermore, CC is policy-relevant for compliance with speed limits, reduction of fuel consumption, and better traffic flow.		
Cyprus		X		CC is an optional system that can be purchased for vehicles.	X
Czech Republic		X		Other more pressing safety issues face Czech Republic; low equipment level at present.	
Denmark	X		Reduction of fuel consumption and exhaust gas emissions		X
Estonia		X		No problems encountered with CC due to low equipment level of vehicles.	
Finland	X		Safety, particularly monitoring the possible negative effect on safety.		
Germany	X		Improved compliance with speed limits; improved driver comfort; reduction of fuel consumption and exhaust gas emissions; and better (homogenized) traffic flow). More advanced technologies such as ACC promoted preferentially over CC as CC is seen as an antiquated technology.		
Hungary		X		Not subject to UN ECE or EU regulation	X
Ireland		X		Limited resources to spend on this issue.	X
Italy		X		No policy necessary unless there are (safety) problems with it.	X

Latvia		X			
Luxembourg		X			X
Slovakia		X			
Slovenia		X			
Sweden		X		Speed is considered strategic area. Focus on ISA and speed alert	
The Netherlands	X		Mainly reduction of fuel consumption and gas emissions. Other justification such as safety and comfort are recognized as possible positive effects. Attention has shifted to more intelligent forms of CC (ICC/ACC).		
United Kingdom		X			

Appendix C: Questionnaire for CC level of usage (WP3.2)

Name of contact Person: Position: Organization: Country:	Date:

These questions concern *Cruise Control (CC)*. CC is a driver assistance system that automatically maintains a driving speed that has been determined by the driver. This system is deactivated as soon as the driver brakes. Currently, the type approval of vehicles equipped with Cruise Control is not subject to any specific national or international regulation.

Question 1: Do you sell CC in your car and trucks?

Question 1a: If not, why not? (Fill in and stop the questionnaire)

Question 2: Since when do you sell CC and in which countries?

Question 2a: How many CC's did you sell in 2004 and in which countries?

If possible can you make a distinction among vehicle types:
Person-cars
- small:
- medium:
- large (including SUV's)

Light vans with a maximum of 3500 kg (empty vehicle plus loading capacity):
Trucks (empty vehicle plus loading capacity over 3500kg.):

Question 3: Could you please indicate how many CC's you have sold in the past years?
Please go as far back as you can, preferably until the introduction of CC in the different countries (see question 2).

If possible can you make a distinction among vehicle types:
Person-cars
- small:
- medium:
- large (including SUV's):

Light vans with a maximum of 3500 kg (empty vehicle plus loading capacity):
Trucks (empty vehicle plus loading capacity over 3500kg.):

Appendix D: Questionnaires for car and truck drivers on issues associated with use of CC (WP 3.3)

D1: Questionnaire for Truck drivers

Dear Sir/Madam

You have been selected to answer this questionnaire in your role as a truck driver and we would like to ask you a few questions regarding you and your possible use of cruise control. The questionnaire will take approximately ten minutes to answer.

This study is carried out by VTI/VUB and is part of an European research project called IMPROVER

The IMPROVER project is a study commissioned by the European Commission (Directorate General Energy and Transport) to examine the aspects of road safety. One of the subprojects of IMPROVER is on the impact of Cruise Control on traffic safety, energy consumption, and environmental pollution.

The purpose of the questionnaire is to investigate the opinion of drivers on Cruise Control (CC) and its usage. A special focus is on safety issues, possible benefits and the need for legislation.

You are considered to provide a good representation of people with practical experience in these matters and we are very thankful for your cooperation.

When you have finished the questionnaire, please return it to VTI/VUB in the pre-paid envelope.

Thank you for your participation.

Yours

………………………………………….
Name and signature

We would like to ask you how you use your cruise control in your truck and what you think of the system?

1. Where / when do you use your CC?

		Never	Rarely	Some-times	Often	Always
a.	Motorways	☐	☐	☐	☐	☐
b.	Rural roads	☐	☐	☐	☐	☐
c.	Urban roads	☐	☐	☐	☐	☐
d.	Night time driving	☐	☐	☐	☐	☐
e.	Day time driving	☐	☐	☐	☐	☐
f.	Peak hours	☐	☐	☐	☐	☐
g.	Off-peak hours	☐	☐	☐	☐	☐
h.	Foggy weather	☐	☐	☐	☐	☐
i.	Slippery roads	☐	☐	☐	☐	☐
j.	Good weather conditions	☐	☐	☐	☐	☐

Comments? ____________________

____

If you answered Never on all the options in question 1 above, please answer question 2, otherwise go to question 3.

2. What is the reason for you not to use CC?

____

____

____

____

For "Non users", after answering question 2, please continue on question 7.

3. When using the cruise control on a motorway, what speed would you set it on according to your speedometer?

Don't use CC on motorways	Below the speed limit	On the speed limit	10 km's over the speed limit	20 km's over the speed limit	30 km's over the speed limit	More than 30 km's over the speed limit
☐	☐	☐	☐	☐	☐	☐

4. When using the cruise control on a rural road, what speed would you set it on according to your speedometer?

Don't use CC on rural roads	Below the speed limit	On the speed limit	10 km's over the speed limit	20 km's over the speed limit	30 km's over the speed limit	More than 30 km's over the speed limit
☐	☐	☐	☐	☐	☐	☐

5. When you are using your CC, how do you think the following factors are affected in general?

		Decrease a lot	Decrease some	Unchanged	Increase some	Increase a lot
a.	Traffic safety	☐	☐	☐	☐	☐
b.	Fuel consumption	☐	☐	☐	☐	☐
c.	Comfort	☐	☐	☐	☐	☐
d.	Your vigilance	☐	☐	☐	☐	☐
e.	Other? ____________	☐	☐	☐	☐	☐

____

6. What is the main reason for you to use the CC? (Tick only one box)

a. Traffic safety ☐
b. Fuel consumption ☐
c. Comfort ☐
d. Avoiding speeding tickets ☐
e. Other? ____________ ☐

____

7. Do you think that the usage of CC in/for the following environments / vehicle types / drivers is an increased or decreased safety risk compared to driving without any speed management support?

		Increased risk	Decreased risk	No difference
a.	Motorways	☐	☐	☐
b.	Rural roads	☐	☐	☐
c.	Urban roads	☐	☐	☐
d.	Night time driving	☐	☐	☐
e.	Day time driving	☐	☐	☐
f.	Peak hours	☐	☐	☐
g.	Off-peak hours	☐	☐	☐
h.	Novice drivers	☐	☐	☐
i.	Elderly drivers	☐	☐	☐
j.	Professional drivers	☐	☐	☐
k.	Trucks	☐	☐	☐
l.	Buses	☐	☐	☐
m.	Cars	☐	☐	☐
n.	Light vans	☐	☐	☐
o.	Foggy weather	☐	☐	☐
p.	Slippery roads	☐	☐	☐
q.	Good weather conditions	☐	☐	☐

Comments? ____

____

For some vehicle models there is today a new kind of cruise control available. This is called Adaptive Cruise Control (ACC) and it controls both the speed of your vehicle and the distance to the vehicle in front. An example: You are driving on a motorway with the cruise control set to 100 km/h when you are approaching a slower vehicle in front. The ACC would then automatically slow down your vehicle and instead keep a constant distance to the vehicle in front. When the vehicle in front leaves at an exit or you steer your car into the left lane the ACC would then accelerate your vehicle back to 100 km/h.

8. Compared to a traditional Cruise control, would you be more interested in having an ACC in you vehicle?

Yes ☐ No ☐ I'm not interested in either ☐

Could you please motivate your answer:

____

____

____

____

____

9. Compared to a traditional Cruise control, how do you think an ACC would affect the following factors?

a.	Traffic safety	Increased safety ☐	Decreased safety ☐	No difference ☐
b.	Fuel consumption	Increased fuel consumption ☐	Decreased fuel consumption ☐	No difference ☐
c.	Comfort	Increased comfort ☐	Decreased comfort ☐	No difference ☐
d.	Your vigilance	Increased vigilance ☐	Decreased vigilance ☐	No difference ☐

10. If you have any further comments, please write them down below.

Thank you for your participation!
Please return the questionnaire in the pre-paid envelope

D2: Questionnaire for car drivers

Dear Sir/Madam

You have been selected through a random selection from the vehicle registry and we would like to ask you a few questions regarding you and your possible use of cruise control. The questionnaire will take approximately ten minutes to answer.

This study is carried out by VTI/VUB and is part of an European research project called IMPROVER

The IMPROVER project is a study commissioned by the European Commission (Directorate General Energy and Transport) to examine the aspects of road safety. One of the subprojects of IMPROVER is on the impact of Cruise Control on traffic safety, energy consumption, and environmental pollution.

The purpose of the questionnaire is to investigate the opinion of drivers on Cruise Control (CC) and its usage. A special focus is on safety issues, possible benefits and the need for legislation.

You are considered to provide a good representation of people with practical experience in these matters and we are very thankful for your cooperation.

When you have finished the questionnaire, please return it to VTI/VUB in the pre-paid envelope.

Thank you for your participation.

Yours

………………………………………….
Name and signature

We would like to start by asking a couple of questions about you

1. What is your age in years? ___________

2. Are you male or female? Male ☐ Female ☐

3. Are you:

- ☐ A student?
- ☐ In full time employment?
- ☐ In part time employment?
- ☐ Involved in full time home duties?
- ☐ Unemployed?

4. What is the highest level of education you have so far completed?

- ☐ Elementary school (up to 15 years of age in Sweden, mandatory)
- ☐ College (16-19 years, optional)
- ☐ University studies
- ☐ Doctors degree
- ☐ Other, please specify ______________________________

5. What kind of car do you drive? ______________________ ______________ ____________

make *model* *year*

6. How many kilometres do you on average drive every year? ________000 kilometres

7. Is your car equipped with cruise control? Yes ☐ No ☐

(If you answered no please go to question 10)

Now we would like to ask you how you use your cruise control and what you think of the system?

8. Where / when do you use your CC?

		Never	Rarely	Some-times	Often	Always
a.	Motorways	☐	☐	☐	☐	☐
b.	Rural roads	☐	☐	☐	☐	☐
c.	Urban roads	☐	☐	☐	☐	☐
d.	Night time driving	☐	☐	☐	☐	☐
e.	Day time driving	☐	☐	☐	☐	☐
f.	Peak hours	☐	☐	☐	☐	☐
g.	Off-peak hours	☐	☐	☐	☐	☐
h.	Foggy weather	☐	☐	☐	☐	☐
i.	Slippery roads	☐	☐	☐	☐	☐
j.	Good weather conditions	☐	☐	☐	☐	☐
	Comments?					

If you answered Never on all the options in question 1 above, please answer question 2, otherwise go to question 3.

9. What is the reason for you not to use CC?

____

____

____

____

For “Non users”, after answering question 2, please continue on question 7.

10. When using the cruise control on a motorway, what speed would you set it on according to your speedometer?

Don't use CC on motorways	Below the speed limit	On the speed limit	10 km's over the speed limit	20 km's over the speed limit	30 km's over the speed limit	More than 30 km's over the speed limit
☐	☐	☐	☐	☐	☐	☐

11. When using the cruise control on a rural road, what speed would you set it on according to your speedometer?

Don't use CC on rural roads	Below the speed limit	On the speed limit	10 km's over the speed limit	20 km's over the speed limit	30 km's over the speed limit	More than 30 km's over the speed limit
☐	☐	☐	☐	☐	☐	☐

12. When you are using your CC, how do you think the following factors are affected in general?

		Decrease a lot	Decrease some	Unchanged	Increase some	Increase a lot
a.	Traffic safety	☐	☐	☐	☐	☐
b.	Fuel consumption	☐	☐	☐	☐	☐
c.	Comfort	☐	☐	☐	☐	☐
d.	Your vigilance	☐	☐	☐	☐	☐
e.	Other?	☐	☐	☐	☐	☐

13. What is the main reason for you to use the CC? (Tick only one box)

a.	Traffic safety	☐
b.	Fuel consumption	☐
c.	Comfort	☐
d.	Avoiding speeding tickets	☐
e.	Other?	☐

14.	Do you think that the usage of CC in/for the following environments / vehicle types / drivers is an increased or decreased safety risk compared to driving without any speed management support?			
		Increased risk	Decreased risk	No difference
a.	Motorways	☐	☐	☐
b.	Rural roads	☐	☐	☐
c.	Urban roads	☐	☐	☐
d.	Night time driving	☐	☐	☐
e.	Day time driving	☐	☐	☐
f.	Peak hours	☐	☐	☐
g.	Off-peak hours	☐	☐	☐
h.	Novice drivers	☐	☐	☐
i.	Elderly drivers	☐	☐	☐
j.	Professional drivers	☐	☐	☐
k.	Trucks	☐	☐	☐
l.	Buses	☐	☐	☐
m.	Cars	☐	☐	☐
n.	Light vans	☐	☐	☐
o.	Foggy weather	☐	☐	☐
p.	Slippery roads	☐	☐	☐
q.	Good weather conditions	☐	☐	☐
	Comments?			

For some vehicle models there is today a new kind of cruise control available. This is called Adaptive Cruise Control (ACC) and it controls both the speed of your vehicle and the distance to the vehicle in front. An example: You are driving on a motorway with the cruise control set to 110 km/h when you are approaching a slower vehicle in front. The ACC would then automatically slow down your vehicle and instead keep a constant distance to the vehicle in front. When the vehicle in front leaves at an exit or you steer your car into the left lane the ACC would then accelerate your vehicle back to 110 km/h.

15. Compared to a traditional Cruise control, would you be more interested in having an ACC in you vehicle?

Yes ☐ No ☐ I'm not interested in either ☐

Could you please motivate your answer:

16.	Compared to a traditional Cruise control, how do you think an ACC would affect the following factors?			
		Increased safety	Decreased safety	No difference
e.	Traffic safety	☐	☐	☐
		Increased fuel consumption	Decreased fuel consumption	No difference
f.	Fuel consumption	☐	☐	☐
		Increased comfort	Decreased comfort	No difference
g.	Comfort	☐	☐	☐
		Increased vigilance	Decreased vigilance	No difference
h.	Your vigilance	☐	☐	☐

17. If you have any further comments, please write them down below.

Thank you for your participation!
Please return the questionnaire in the pre-paid envelope

Appendix E: Detailed description of the results of the questionnaire study on issues associated with use of CC (WP 3.3)

Introduction

Subproject 3 of Impact Assessment of Road Safety Measures for Vehicles and Road Equipment (IMPROVER) aims to clarify the impact of Cruise Control (CC) on traffic safety, energy consumption and environmental pollution.

Cruise Control is a driver assistance system that automatically maintains a driving speed that has been determined by the driver. This system is deactivated as soon as the driver brakes. Currently, the type approval of vehicles equipped with Cruise Control is not subject to any specific national or international regulation.

Potential benefits of Cruise Control are an enhancement of driving comfort, a voluntary compliance with speed limits, a reduction of fuel consumption and a reduction of exhaust gas emissions. On the other hand, the driver might be tempted to accept smaller between-vehicle distances because he tries to avoid braking. Furthermore, in case of an emergency braking, the reaction time might be prolonged because the driver took his foot away from the pedals and / or because the driver was inattentive.

Work package 3.3 of this subproject contributed to the IMPROVER goal by a greater understanding of how, where and when the CC is being used. It has further provided information on the benefits of the system as experienced by the drivers as well as disadvantages and potential dangers of using CC. The findings of this study can be seen as a description of the present situation and is necessary as an input to WP 3.6 Recommendations for further actions on EU-level.

Aim

The aim of this study is to investigate the benefits and disadvantages of the use of cruise controls as experienced by the drivers. Drivers are here represented by car-drivers and truck-drivers

Method

A questionnaire study was undertaken to identify issues associated with the use of cruise controls (CC) and to investigate the benefits and disadvantages thereof. The survey was carried out on drivers of passenger cars and heavy vehicles in Sweden and Belgium.

In addition a web-based questionnaire study was carried out on members of the UN-ECE WP29 working group. Since the European part of the working group is somewhat small for a questionnaire it was important to have a high response rate. To ascertain this, an effort was made to contact the respondents by phone before an e-mail was sent out with a link to the web-questionnaire. Despite this the response rate was too low to carry out a meaningful analysis, only eight persons responded. Therefore no further analysis was made on that material.

Truck drivers in Belgium were selected by a random sample from a database of SAV for Flemish transport companies. 1000 questionnaires were sent out and 182 were returned which means an 18% response rate. In Sweden the procedure was similar; the largest transportation union (Transportarbetarförbundet) was contacted and they made a random sample of 1000 members. Due to an error in printing 860 questionnaires were sent out and in total 341 replies came back giving a response rate of 40%.

For cars the procedure differed somewhat between the two countries. In Sweden a random sample of 1000 vehicles from the vehicle registry was made. To ensure a reasonable amount of cars equipped with CC was included in the sample cars older than 2001 were excluded. There were a few addresses (less than 10) that were erroneous and the questionnaires were therefore returned to sender. In total 578 questionnaires came back giving a response rate of 57%.

In Belgium another approach was chosen. In order to have more direct responses for the car-drivers 140 questionnaires were sent to our personal business contacts. Of these 20 questionnaires came back which makes 14% as a rate of reply.

The questionnaires were identical for the two countries and there was one questionnaire for cars and one for trucks. However, a majority of the questions were the same for cars and trucks but for trucks it was emphasized that it was their view as truck-drivers that was of interest. Original questionnaires were made in English and then translated to Swedish and Flemish.

Analysis

For the analysis the SPSS 13.0 software was used and all the responses were included in one database. This allowed comparisons between truck-drivers and car-drivers as well as between nationalities.

In the analysis comparisons between various groups were made, especially between vehicle types (cars/trucks), nationalities (only for trucks due to the difference in sample size for cars) and sex (only for cars since truck-drivers are predominately male). All drivers were also asked how much they used CC on various roads and from this a Usage Index (UI) was calculated. The drivers were then divided into three groups (low, medium and high usage) based on how they scored on the UI.

The UI was based on three questions:
- How much do you use the CC on motorways?
- How much do you use the CC on rural roads?
- How much do you use the CC on urban roads?

The responses were graded 1 Never, 2 Rarely, 3 Sometimes, 4 Often and 5 Always. As can be seen in Figure 1 there is a small concentration of people answering "never" (3x1=3) but otherwise there is a normal distribution of answers. The cut points for three equal groups are 7 and 9 which is a logical cut point between low, medium and high usage groups, see Table 3.

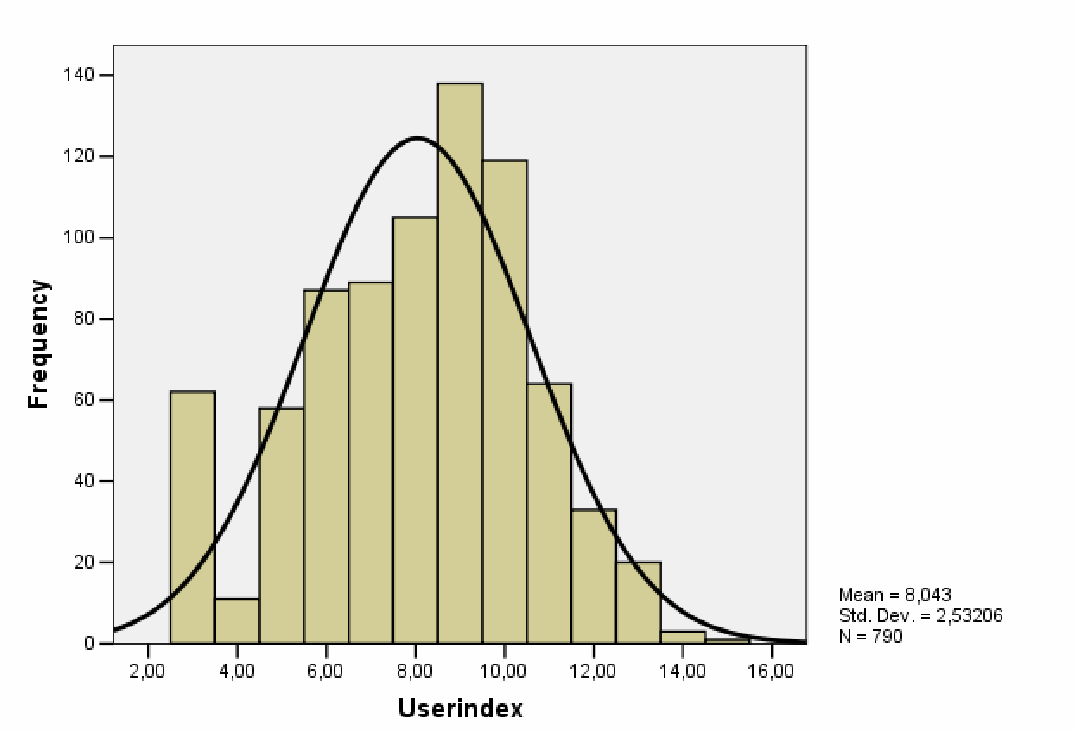

Figure 1: Histogram over how much the drivers use CC (3 denotes never and 15 denotes always)

Table 3: Cut points for user index (UI)

N	Valid	790
	Missing	331
Percentiles	33.3333	7.00
	66.6667	9.00

Comparisons between groups were carried out with t-test or ANOVA, Tukey Post Hoc at the $p<0.05$ level.

Results

Description of respondents

All in all there are 1121 respondents in this study, 523 truck-drivers and 598 car-drivers. The average age of the car-drivers is 51 years with a standard deviation of 13.6 years. Of the car-drivers there are 53.7% men and they are slightly older than women (52.7 years compared to 49.4 years for women).

Of the car-drivers there are 52% that have got a CC in their car and there is a great difference between men and women. For men 65.3% of them drive cars equipped with CC while only 36.9 of women do so, see Table 4.

Table 4: The percentage of men and women among the car-drivers with CC-equipped vehicles.

Sex * CC_in_car? Crosstabulation

			CC_in_car?		
			Yes	No	Total
Sex	Men	Count	201	107	308
		% within Sex	65,3%	34,7%	100,0%
	Woman	Count	100	171	271
		% within Sex	36,9%	63,1%	100,0%
Total		Count	301	278	579
		% within Sex	52,0%	48,0%	100,0%

Among the car-drivers there are 6.7% of the drivers that have a car equipped with CC but never use it and for the truck-drivers the figure is 7.6%. Here there is a difference between men and women as well: there are 2.9% of the men that have a CC in their car but never use it which can be compared with 18.5% for women.

The reasons for not using CC even though having one in the car was answered by 32 car-drivers. The question was designed as an open question where the respondent self could formulate his or her motivation for not using the CC. It should be noted here that the majority of the answers came from Swedish drivers since only three Belgian truck-drivers motivated why they did not use their CC. The answers could be categorized into three groups where the first group can be labelled as "Being uninterested in the system". Examples of comments from this group are "I don't feel like it" or "I never cared to try it out". The second group consists of drivers who feel unsafe when using the system, examples of comments are: "I feel safer when accelerating myself", "I have heard about accidents with CC's", "I think it's safer when I use the gas pedal" and "I am more prepared to brake when not using CC". The third group consists of drivers who do not find the system useful or suitable, examples of comments are: "Cannot be used in urban traffic", "I drive only on smaller roads", "Not suitable", "Not useful".

For truck-drivers 21 respondents commented on why they did not use their CC. The same groups as for car-drivers can be found but with the addition of a group that thinks that fuel consumption is increased and therefore do not use CC. Examples of comments are "More economical to drive without" and "Demands more fuel".

It is not really useful to count frequencies for open comments from 32 respective 21 drivers but a rough estimation gives that "unsafe" is the most dominant reason for car-drivers to not use their CC followed by "not interested" and "not useful", see Figure 2. For truck-drivers the group that thinks the CC is unsafe is the most dominant with more than 50% followed by "increased fuel consumption", "not useful" and "uninterested in using the system" in that order, see Figure 3.

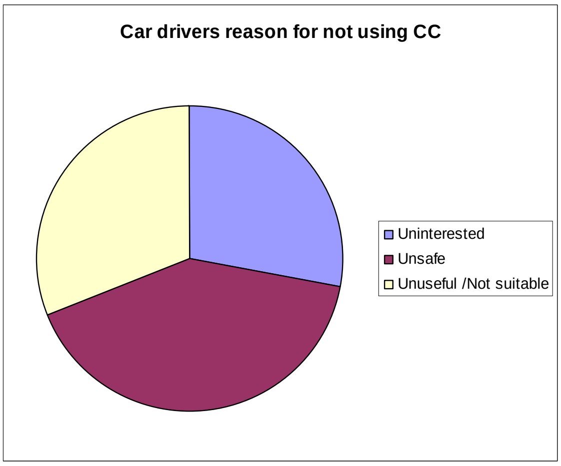

Figure 2: Car-drivers reason for not using their CC

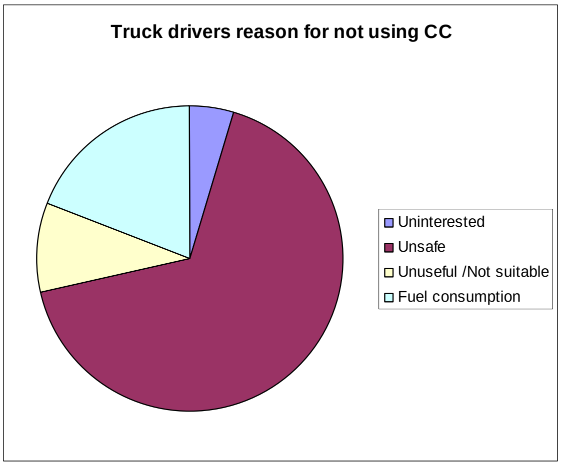

Figure 3: Truck-drivers reason for not using their CC

Overall women use the CC to a lesser extent then men. A comparison of how men and women are distributed with regard to UI shows that more than half of the male population in this survey is high UI drivers while the female population is more evenly distributed, see Table 5.

Table 5: The proportion of low, medium and high UI car-drivers for men and women

Sex		Use index			Total
		Low use	Medium use	High use	
Men	Count	39	53	103	195
	% within Sex	20.0%	27.2%	52.8%	100.0%
Women	Count	40	26	38	104
	% within Sex	38.5%	25.0%	36.5%	100.0%

All the results below are based on the answers of drivers that use the CC

On how and where the CC is used

A traditional CC is to its nature best suited to use under free flowing conditions where the drivers can keep an even speed and the CC can support them in this task. This is clearly shown in where the respondents use the CC. Both car and truck drivers use CC the most on motorways and to some degree on rural roads (lesser so for the trucks) but on urban roads, in peak hours, in fog and on slippery roads they tend to use it less, see Table 6. Overall women use CC less then men for all roads and situations. There are some differences ($p<0.05$) here between nationalities; the Belgian truck-drivers use it much less on rural roads than the Swedish drivers. They also use it less on slippery roads and in fog, on the other hand they use it somewhat more on urban roads and they use it more in peak traffic, see Table 6. These effects are most likely due to the different driving environments in the two countries.

Table 6: How much the drivers use CC on various roads and scenarios on a scale from 1=Never to 5=Always, 3 denotes sometimes.

	Vehicle type	N	Mean	Std. Deviation
Motorway	Car	315	3.69	1.178
	Truck	498	4.00	1.137
Rural roads	Car	315	3.11	1.234
	Truck	498	2.80	1.391
Urban roads	Car	306	1.36	.777
	Truck	493	1.24	.642
Night time	Car	306	2.70	1.255
	Truck	494	3.33	1.277
Day time	Car	308	3.37	1.112
	Truck	488	3.68	1.110
Peak hour	Car	306	1.39	.827
	Truck	492	1.41	.821
Off Peak	Car	305	3.18	1.196
	Truck	482	3.23	1.271
Fog	Car	307	1.47	.825
	Truck	493	1.51	.894
Slippery roads	Car	292	1.43	.845
	Truck	491	1.34	.748
Good weather	Car	292	3.52	1.135
	Truck	483	3.82	1.087

For car-drivers it was found that the amount of usage of CC is correlated to what speed they set it on. The effect is not significant on motorways ($p=0.81$) but the drivers with low UI score an average value of 2.53, i.e. between "On the speed limit" and "10 km/h above the speed limit" while drivers with medium and high UI score 2.84 and 2.75, i.e. closer to the "10 km/h above the speed limit". For rural roads this effect is even more visible even though the actual difference is quite small. In Figure 4 below it can be seen how the UI correlates with the set speed of the CC and the difference is significant on the $p<0.05$ level.

Overall for the car-drivers there are 42.7 % of the drivers who claim they set the CC at or below the speed limit (2.1% below, 40.6 at the speed limit). There are also 1.4 % of the drivers who don't use CC at all on the motorways. This means that a majority of the drivers set their CC's at speeds above the speed limit on motorways. For rural roads almost 60% set the CC at or below the speed limit and there are also 7% of the drivers who do not use CC at all, but there are still 33% who set the CC at speeds higher than the speed limit.

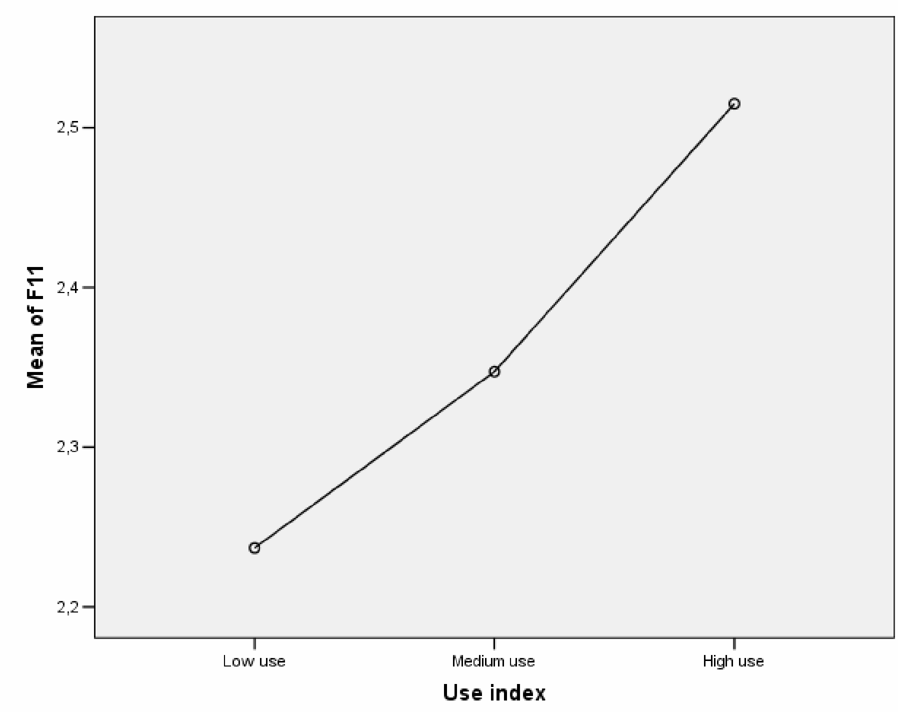

Figure 4: Average value for the drivers' set speed of the CC depending on level of usage on rural roads (2=At the speed limit, 3=10 km/h above the speed limit).

A comparison between men and women shows that men set the CC on a higher speed than women, both on motorways and on rural roads.

For truck-drivers the UI did not have the same effect on the speed they set their CC on as for cars. All groups state that they put the CC on the speed limit (as a group average value), both on the motorways and on the rural roads. There are however approximately 13% of the drivers who state that they put the CC 10 km/h above the speed limit on motorways and another 2% that claim even higher speeds. For rural roads the figures are 70% on the speed limit, 6 % for 10 km/h above the speed limit and another 0.5 % for even higher speeds. There are also 24% that claim they never use CC on rural roads which can be compared to 0.9% for the motorways.

A comparison between Swedish and Belgian truck-drivers show that they are very similar, no difference could be found, not even on the $p<0.1$ level.

The effect the use of CC has on safety, fuel consumption, comfort and vigilance as rated by the drivers.

In the questionnaire the drivers rated how they thought that the use of CC effects traffic safety, fuel consumption, comfort and vigilance and here some interesting differences between groups could be found.

Drivers with a high UI believed that the use of CC would increase safety while drivers with a low UI thought it would decrease. Drivers with a medium UI were closest to the "unchanged" score, see Table 7. Similarly there was a difference between groups with regard to vigilance. Even though all groups believed that vigilance did increase when driving with CC the medium and high UI drivers scored much higher than the low UI drivers (3.58 for low UI compared to 4.09 and 4.18 for the medium and high UI drivers respectively). There was also a difference in how the groups rated comfort where the high UI drivers considered comfort to increase (2.40) the low UI drivers thought it was unchanged (3.00).

A comparison between men and women did not show any difference for the car-drivers.

Table 7: The relation between Use Index and the rated safety effect of CC for car-drivers. (The score 3 denotes "Unchanged")

Use index	N	Subset for alpha = .05		
		1*	2	3
Low use	54	2.61		
Medium use	79		2.89	
High use	138			3.31
Sig.		1.000	1.000	1.000

*Means for groups in homogeneous subsets are displayed.

For truck-drivers the results are very similar to the results for car-drivers. The drivers with high UI believe that the safety is increased when using CC while the low UI drivers think it will decrease and the medium UI drivers are close to the "unchanged", Table 8

Table 8: The relation between Use Index and the rated safety effect of CC for truck-drivers. (The score 3 denotes "Unchanged")

Use index	N	Subset for alpha = .05		
		1*	2	3
Low use	102	2.62		
Medium use	107		2.89	
High use	226			3.15
Sig.		1.000	1.000	1.000

*Means for groups in homogeneous subsets are displayed.

The medium and high UI truck-drivers also believe that the comfort is increased to a higher degree than the low UI drivers and they also believe that vigilance is increased. In this respect truck-drivers and car-drivers are very similar, see Table 9.

Table 9: The relation between Use Index and the rated vigilance when using CC for truck-drivers. (The score 3 denotes "Unchanged")

Use index	N	Subset for alpha = .05		
		1*	2	3
Low use	102	2.73		
Medium use	107		2.95	
High use	226			3.20
Sig.		1.000	1.000	1.000

*Means for groups in homogeneous subsets are displayed.

A comparison between the two countries shows that there are no differences for the rating of vigilance, comfort and safety between the two countries. The variable that does differ and differs a lot is the perception of how fuel consumption is affected; the

Belgian drivers think that it is reduced (1.95), Swedish drivers also think it is reduced but not to the same degree (2.72).

Reasons for using CC

The respondents got to answer what was the main reason for using the CC. They got four alternatives to chose from, traffic safety, fuel consumption, comfort and avoiding speeding tickets. There was also one option to tick “Other” and in their own words state the main reason. Of these options they could only select one. The by far most common reason for car-drivers to use the CC is comfort which was chosen by 59% of all car-drivers. The second most common reason was avoiding speeding tickets with 17.9% followed by reducing fuel consumption 13.9% and traffic safety 7.2%. There were only 2% that chose the “Other” option.

In Figure 5 below the reason for using the CC is presented for the three levels of UI and there are some differences even though they are small. Traffic safety as the main reason is increasing with the level of usage which goes well in line with the findings above where it was clear that the low UI drivers thought safety decreased while high UI drivers thought it increased. Also in line with the findings above the low UI drivers use CC as a mean to avoid speeding tickets to a higher degree than the high UI drivers. Since the high UI drivers often set the CC to speeds above the speed limit it does not help them to avoid speeding tickets.

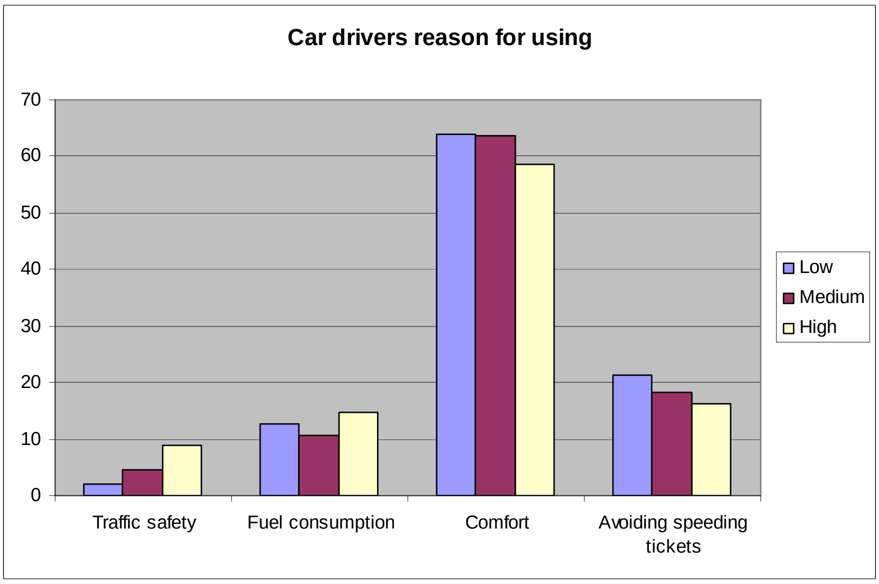

Figure 5: The main reason for using CC for the different UI groups.

For truck-drivers the difference between UI is not that clear as for car-drivers. Comfort is the most dominant reason for using CC with 66.0% followed by reduced fuel consumption on 16.0%, avoiding speeding tickets 11.7%, traffic safety 3.6% and other 2.6%. For “traffic safety” and “reduced fuel consumption” there is no difference between the groups but the low UI drivers rates reduced fuel consumption as the main reason to a higher degree than the high UI drivers and for comfort it is the opposite relation. In Figure 6 below the main reason for truck-drivers to use the CC is displayed separated according to UI.

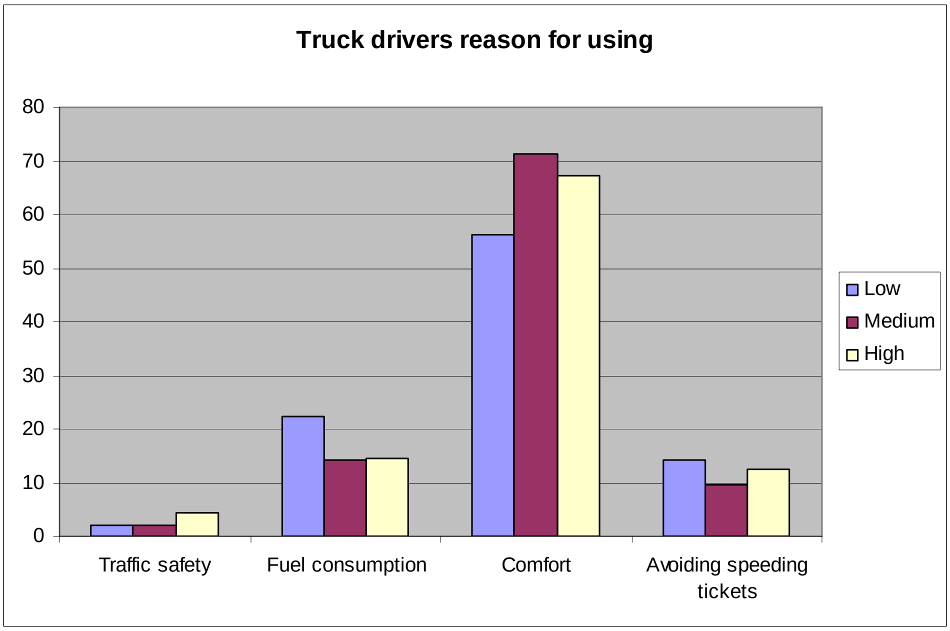

Figure 6: The main reason for using CC for the different user groups.

Drivers' view on Adaptive Cruise Control (ACC)

In the questionnaire the drivers were presented a description of an ACC and how it works and they had to decide whether they would be more interested in having that in their vehicle compared to a traditional CC. A majority of the drivers are more interested in having an ACC than a traditional CC in their vehicle. The proportion of drivers saying yes is more than 70 % for both car and truck-drivers. Some 20% said that they are less interested in this type of equipment and about 5% say that they are not interested in any of the systems.

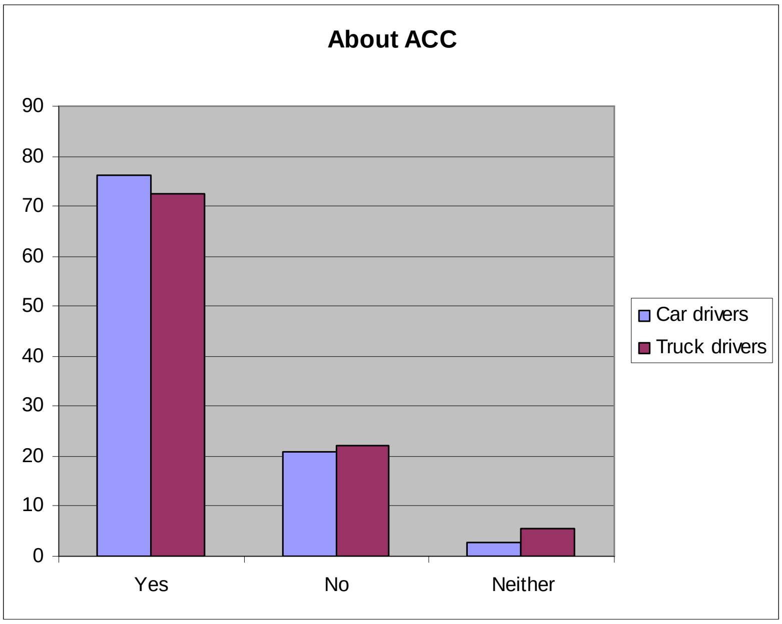

Figure 7: Car and truck-drivers preferences for ACC compared to traditional CC

The question on ACC was designed as an open question where the respondents themselves could motivate why they would/would not prefer an ACC. There were 183 comments from the car-drivers and 226 from the truck-drivers and their comments on why they would prefer an adaptive cruise control rather than a traditional were categorised in three groups. The first and most common group dealt with increased traffic safety and examples of comments are “It would feel safe to have a proper distance automatically”, “Sounds like a good idea. I think it will increase safety” and “Increased safety when approaching a slower vehicle”. The second group deals with increased comfort and examples of comments are “Then I wouldn’t have to disconnect it so often”, “It would increase comfort even more” and “Makes handling the CC easier”. The third group can be categorised as people who like new technology and examples of comments are “Sounds great”, “Wow!” and “I want that in my next car”, see Figure 8.

For the drivers negative to the ACC system the respondents can be divided into two groups where the first group deals with mistrust in technology and where they don’t want the system to take over. Examples of comments for this group are “I want to decide for myself”, “It’s important to keep the distance yourself, it will keep you alert”, “There is a risk in trusting the system too much“ and “I think it will make you trust the system too much and relax and lose your alertness”. The second group thinks that such a system is needless and comments are “I don’t need any more costs for functions that I don’t use” and “It works fine as it is”, see Figure 8.

For the truck-drivers the same groups and comments can be found but with the difference that there is a third group who do not want the ACC and the motivation is that it will increase fuel consumption, see Figure 8.

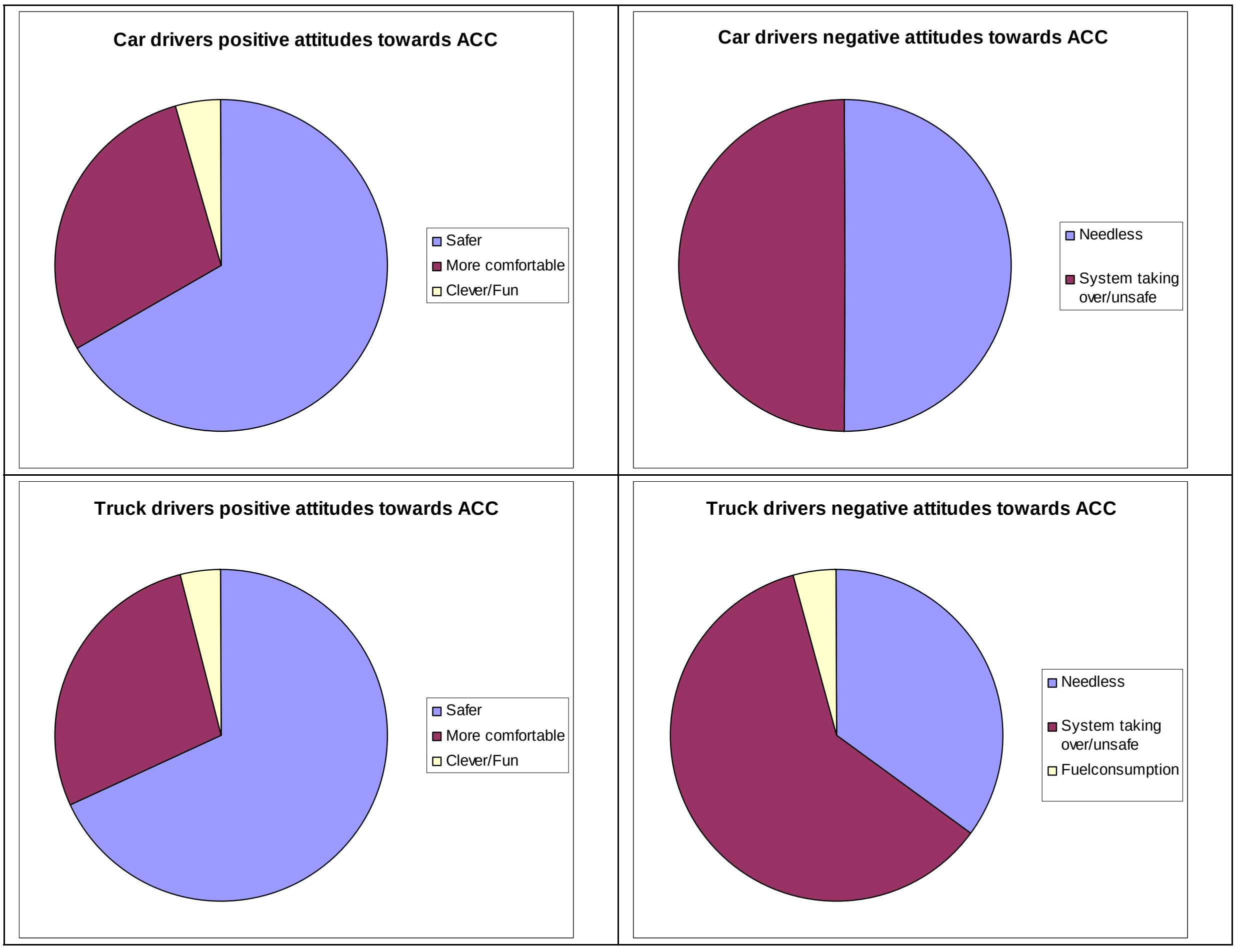

Figure 8: Car and truck-drivers' motivation for being for or against ACC

There is a small difference between men and women where men are more in favour of the ACC (74.1% for men compared to 68.8% for women) while women to a higher degree do not want any of the systems (8.3% for women compared to 4.1% for men).

Summary and conclusions

This study aimed at investigating the benefits and disadvantages of the use of CC as experienced by drivers. Drivers in this case are represented by the 1121 car- and truck-drivers that responded to the questionnaire that was sent out. Since there is no registry over vehicles that is equipped with CC not all drivers that received the questionnaire had a CC but more than 50% of the car-drivers drove cars with CC so there is a solid foundation in this study.

Overall it was found that men are more in favour of the CC than women, both with regard to having a car equipped with CC and with regard to using the CC once they had it in their car. The same goes for the will to have an ACC in the car where the men are more in favour of such a system than women.

There are about 6-7 % of the drivers, both for cars and for trucks, that have a CC in their cars but choose not to use it. The main reason for not using it is a belief that it reduces safety followed by being uninterested and not finding the system useful. For truck-drivers the belief that it increases fuel consumption is also a deterrent. What is interesting here is that some drivers state that the anticipation of increased safety and reduced fuel consumption are the main reason for using CC.

The CC is most often used on the motorways but also to a rather high degree on rural roads, especially for car-drivers. Truck-drivers do not use it on rural roads to the same extent. In general drivers tend to use the CC in good free flowing traffic conditions and not so much on urban roads, slippery roads, during peak hour and in darkness even though it does occur to some degree.

The main reason for drivers to use CC is comfort which was stated as the main reason by nearly 60 % of the car-drivers and 66 % of the truck-drivers. Avoiding speeding tickets and reduced fuel consumption had almost the same rating, 10-15 %, where avoiding speeding tickets was more often given as the main reason for drivers who do not use CC that much.

The opinions regarding the benefits and disadvantages of CC differ quite a lot within the driver population. Some drivers think that safety is increased when using CC, some think the opposite, some drivers think that comfort is increased, some think the opposite and this is reflected in how and how much the CC is used. The drivers who think that safety is increased do often think that the comfort is increased as well and, not surprisingly, they tend to use it to a higher degree than drivers who think that safety and/or comfort is decreased. They also tend to set the CC on speeds above the speed limit to a higher degree while the drivers who don't use the CC that much use it to avoid speeding tickets to a higher degree than the drivers who use CC a lot.

The drivers were also given a description of how an ACC-system works and then asked whether they would prefer such a system before a traditional CC and in that case why/why not. Most drivers, more than 70% said that they would prefer such a system and the main reason why was that they thought that safety would increase followed by increased comfort. There were some drivers however who were not interested and this was due them finding such a system needless or that they saw a potential danger in a system taking to much control over the vehicle.

Overall it can be concluded that the perception of benefits and disadvantages of the use of CC is just perceptions. The respondents' views go both ways for many of the questions, both for car-drivers and professional drivers such as truck-drivers. What seems to be clear however is that most users find it to be useful as a comfort system if the circumstances are right and, since there is only a small proportion of drivers who do not use the CC due to safety issues, there does not seem to be any major safety issues associated with the system from the drivers point of view.

Appendix F: Estimation of the impact of cruise control on fuel consumption and environmental pollution (WP3.4)

To elaborate effects of Cruise Control on fuel consumption and exhaust gas emissions an internet inquiry, a literature survey and on road measurements were carried out. The following sections display the results of the three chosen approaches leading to conclusions and recommendations with regard to the impact on Cruise Control on environmental aspects.

Internet inquiry

An internet inquiry delivered some hints about the effect of Cruise Control on fuel consumption and emissions. The statements given are ambivalent. The majority of citations report decreases in fuel consumption but there also might be increases due to inappropriate use of Cruise Control.

SWOV [1] for example reports about positive effects governing individual fuel consumption.

An advertisement [2] for a Cruise Control system states that depending on traffic conditions fuel savings of up to 10 % were possible.

The journal WasteAge [3] talks about 6 % improvement of fuel consumption comparing Cruise Control versus no Cruise Control.

Volvo [4] points out that, used incorrectly, cruise control could actually lead to increased fuel consumption. One should avoid using it when driving in hilly terrain or in dense traffic. In these cases the driver can far better anticipate when to release the accelerator. Also setting the cruising speed at the value of the speed limiter may lead to an increase in fuel consumption. To safe fuel the advice is given to use Cruise Control when driving in top gear and on flat roads. The acceleration process should be carried out by the driver and the selected speed should be a little bit lower than the speed limiter allows.

Instructions about fuel-efficient driving [5], [6] include the recommendation to use Cruise Control on long stretches of highway driving. The rationale for saving fuel is maintaining a steady speed respectively reducing excess gas pedal activity.

The Canadian Office of Energy Efficiency [7] reports effects of Cruise Control in both directions. Many drivers would save fuel by using cruise control to maintain a constant speed on the highway. In certain circumstances, however, skilled driving could be more fuel efficient than using Cruise Control. In hilly terrain, for example, it would be more fuel efficient to let the speed drop going uphill and build it up again going down the other side.

Within the DaimlerChrysler Environmental Report 2004 [8] an advancement system of Cruise Control called "Predictive Cruise Control" is described. This system not only maintains a preset speed but also regulates the engine by assessing driving conditions ahead and adjusting speed accordingly using topographical data. It is pointed out that Predictive Cruise control can bring fuel savings of two percent or more.

Also Bose and Ioannou [9] report environmental benefits of an "Intelligent Cruise Control" (ICC) which uses a forward looking radar. For special driving conditions (rapid and smooth accelerations) following a lead vehicle fuel consumption and exhaust gas emissions were measured. Using emission and traffic modelling they calculated the benefits of having one vehicle equipped wit ICC in a line of manually operated vehicles. Depending on the driving situation the authors partially calculate tremendous savings in fuel consumption and emissions of CO, NO_x and HC.

To conclude the internet inquiry one can state that Cruise Control has the potential to save fuel if it is used correctly. The amount of reduction of fuel consumption is not clear. It differs depending on the traffic situation. Advancements of Cruise Control using information about traffic conditions are developed promising a significant reduction of fuel consumption.

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[5] "Fuel-efficient Driving", eartheasy.com/live_fuel_efficient_driving.htm

[6] "Green Driving Tips", www.tripnet.org/GreenDrivingTips.pdf

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Literature survey

An international literature survey including the IRRD-OECD database yielded the following results with regard to Cruise Control (CC) and associated environmental aspects. The cognitions were sorted in results concerning pure Cruise Control, Adaptive Cruise Control (ACC) which includes a distance control and Intelligent Cruise Control (ICC) which means any further development of the Cruise Control systems.

<u>CC</u>

In 1982 CC was announced to be a future improvement to reduce fuel consumption of heavy commercial vehicles [10]. Trucks equipped with CC should accelerate economically and maintain their velocity for longer periods at levels at which fuel consumption is low.

A literature survey concerning road safety effects of a general introduction of CC showed positive effects governing individual fuel consumption due to the facts that drivers would be driving at lower average speeds and the flow of traffic would be more stable [11]. In an experiment forty motor cars were tested in traffic, twenty of them equipped with CC and twenty without CC. It was reported that for the vehicles with CC fuel consumption was 4 -10% lower than for the others.

In 1999 Franck announced a fuel-saving potential when driver assistance systems like CC and Distronic (an ACC System) communicate with each other [12]. Vehicles could reduce fuel consumption by driving in line. In experiments with trucks equipped with an Electronic Draw-Bar savings up to 15 % were established.

ACC

Naab reported that ACC would be a way to smooth traffic flow. Therefore fuel consumption and emissions would be reduced by using ACC [13].

In the course of the projects “FORFAHRT” and “ACC im Ballungsraum” the influence of ACC systems on the fuel consumption in urban areas was analysed [14], [22]. On the basis of data measured in real traffic a simulation with the program PELOPS was arranged. It was stated that the real effect of an ACC system on the fuel consumption strongly depends on the behaviour of the driver. It was shown that ACC vehicles smoothen the traffic flow so that strong accelerations are prevented with positive effects on fuel consumption even for those vehicles which are not equipped with ACC. Dependent on the position of the vehicle in a string of other vehicles and dependent on the equipment rate of vehicles with ACC fuel savings of about 5 % were reported.

A model has been developed to estimate the influence of Advanced Driver Assistance Systems (ADAS) on network efficiency and the environment [15]. As an example an ACC system was regarded in an urban network. It was shown that the impact of ACC systems can be significant in the improvement of the traffic parameters for high system penetration levels and peak period traffic conditions.

The environmental effects of ACC vehicles in a highway traffic (versus highway traffic without ACC vehicles) were evaluated in [16, 17] for two traffic situations, namely smooth and rapid acceleration. Simulations have been performed using a string of 10 vehicles with an ACC vehicle in the fourth position (Table 10). The results of the simulation model were validated in experiments with three real vehicles (ACC vehicle in the 2^{nd} position, Table 11). It was shown, that ACC vehicles reduce the fuel consumption and the emissions due to the facts that ACC vehicles

- can attenuate position errors generated by the lead vehicle during smooth accelerations,
- act as a filter, leading to smoother traffic flow in case of rapid acceleration by the lead vehicle.

It is not clear why there are differences in the savings of fuel and CO_2.

Table 10: Percentage savings in pollution emission and fuel consumption for traffic including vehicles with ACC versus traffic without ACC (simulation results) [16].

	Savings with ACC vs. without ACC	
	Smooth Acceleration	**Rapid Acceleration**
CO	18.4 %	60.6 %
CO_2	8.1 %	19.8 %
NO_X	13.1 %	1.5 %
HC	15.5 %	55.4 %
fuel	8.5 %	28.5 %

Table 11: Percentage savings in pollution emission and fuel consumption for traffic including vehicles with ACC versus traffic without ACC (experiment and simulation results) [16].

	Savings with ACC vs. without ACC			
	Smooth Acceleration		**Rapid Acceleration**	
	experi-ment	**simulation**	**experi-ment**	**simulation**
CO	1.2 %	0.8 %	19.2 %	12.3 %
CO_2	0.4 %	0.2 %	3.4%	3.3 %
NO_X	1.6 %	1.3 %	25.7 %	19.2 %
HC	0.8 %	0.4 %	9.8 %	6.6 %
fuel	0.4 %	0.2 %	3.6 %	3.4 %

The effects of lane changes on fuel consumption and pollution levels in mixed manual and ACC traffic were examined in [18]. It was shown, that ACC vehicles have a beneficial effect in case of disturbances that are due to lane cut-ins and lane exiting.

In [19] two Adaptive Cruise Control systems were designed based on driver comfort, safety, vehicle following performance, environmental and traffic flow characteristics considerations. The first system (ACC1) was a conventional ACC with separate speed tracking and vehicle following. The advanced system (ACC2) combined the task of speed tracking and vehicle following. The latter system was able to attenuate oscillations in the speed response of the preceding vehicle and was able to reject disturbances. It was shown that this system provides better fuel economy and emission results than the conventional system. The results were obtained using a simulation model. Table 12 shows the changes in environmental performance of a string of 10 vehicles with the ACC vehicle in the 2^{nd} position for high acceleration manoeuvres and high acceleration manoeuvres with oscillations of the lead vehicle.

Table 12: Comparison of two ACC systems with regard to their impact on environmental pollution [19].

Improvement of environmental performance due to ACC2 compared with ACC1	high acceleration manoeuvre	high acceleration manoeuvre with oscillations
fuel	17.5 %	23.5 %
CO	53.9 %	55.5 %
HC	48.4 %	52.6 %
NO_x	36.8 %	42.2 %

The effects of heavy-duty trucks equipped with four different ACC systems on environment and traffic flow characteristics were examined in [20]. It has been shown, that trucks in principle smoothen traffic disturbances even if they are not equipped with ACC. If the inter-vehicle spacing is too large, the beneficial effects on fuel consumption and pollution may be eliminated because of possible cut-ins from neighbouring lanes. Some negative effects of trucks in traffic flow can be reduced by ACC systems. A new ACC design, developed under this project, was shown to have better filtering properties than existing ones with beneficial effects on fuel consumption and emissions.

ICC

In the Intelligent Traffic Systems (ITS) project a number of different computer simulation programs are integrated in one model with a holistic view [21]. In a case study an ICC combined with a beacon system, which delivered infrastructure data like traffic intensity or reference speed was examined. On a microscopic level which was applied on a simulated road section the following trends were presented:

- A penetration level of 40%, with respect to 20%, yields a decrease of fuel consumption and of most exhaust gas emissions.
- An ICC target headway of 1.5 s, with respect to 1.0 s, yields an increase of fuel consumption and of exhaust gas emissions.
- A beacon distance of 500 m, with respect to 1000 m, yields an increase of fuel consumption and of all exhaust gas emissions.

On a macroscopic level, representing a road network, it was found that ICC increases the emissions and the fuel consumption.

Résumé

As the internet inquiry the literature study does not deliver corroborated results of the impact of Cruise Control on environmental aspects. Fuel consumption and exhaust gas emissions can be changed both to higher and lower values. In many cases very special testing or simulation conditions were given so that the results are not transferable to real traffic and do not help to calculate the change of the emissions of real traffic. More studies were performed with regard to ACC than to Cruise Control showing that for ACC the expectations on an impact on traffic smoothening and thus fuel saving are higher.

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On road tests

Introduction

There is very few literature and reliable data about the influence of Cruise Control on fuel consumption and emissions. In order to fill this gap on the one hand vehicle manufacturers as well as hauliers and fleet managers were asked about their experiences with the usage of Cruise Control and the impact on fuel consumption and emissions. Also the German association of freight service, logistics and disposal was included. On the other hand on road tests were performed with three passenger cars and two trucks to achieve a first impression how Cruise Control could influence the fuel consumption on different motorways. In the following first a theoretical consideration based on the statements of the vehicle manufacturers and hauliers is given. Second the results of on road fuel consumption measurements are stated. On the basis of these information conclusions are drawn and recommendations are derived.

Theoretical approach

For the fuel consumption of vehicles with combustion engine the following general relations are valid. Due to the air resistance fuel consumption increases with increasing speed if the vehicle is operated stationary in the highest gear on a flat road. The second important factor for fuel consumption is the amount of accelerations included in the ride. Having the same average velocity a ride with a higher share of dynamics will lead to more fuel consumption than a ride with little changes in velocity.

So Cruise Control will have an influence on fuel consumption if either the average speed changes by using it or by changing the dynamics of the trip.

From the technical point of view Cruise Control does not have any influence on fuel consumption and emissions if the vehicle is driven exactly the same way using Cruise Control and not using Cruise Control. In other words: If a driver manages it to treat his throttle control respectively the Cruise Control system in such a way that the velocity profile (velocity over time) is the same for both cases no change in fuel consumption or emissions will occur.

That means that any changes in fuel consumption due to Cruise Control are not dependent on technical properties of the vehicle or system but on the behaviour and skills of the driver.

The change in the behaviour of the driver can lead to both increase or decrease of fuel consumption due to the usage of Cruise Control. Intelligent usage of the accelerator will lead to disadvantages for Cruise Control, inattentive and nervous driving will result in benefits for Cruise Control. Vehicle manufacturers recommend to use Cruise Control only if it is possible to drive anticipatory. That might be e.g. on a flat road or during nighttime with low traffic density. If the traffic is dense or the track is hilly Cruise Control should not be used. The reasons for these recommendations are as follows: If there are less traffic and a plane road it is hard for the driver to keep the accelerator pedal constantly in the same position to drive a certain velocity. Due to inattention of the driver the velocity will oscillate around the desired value. Here a Cruise Control system will be able to keep a constant velocity much better. In dense traffic a Cruise Control would have to be switched on and off very often so that the uniformity of the ride suffers. A driver would be able to adapt the vehicle speed much better and smoother by his own foot and not using Cruise Control. Also in hilly terrain or on winding roads there are advantages for manually controlling vehicle speed. The driver can anticipate the topography and adjust the speed early. That means to gather momentum before an ascending slope is reached and to reduce speed before the top of a hill is reached. Cruise Control would always try to maintain the speed set without considering ambient conditions which leads to higher fuel consumption.

The resume function of Cruise Control can be used to accelerate again to the desired speed after the system has been deactivated by braking. In this phase fuel consumption depends on the value of the acceleration. If the driver accelerates stronger than the Cruise Control he will need more fuel and vice versa. Also in this case the effect does not depend on the technical properties of Cruise Control.

Especially for trucks it is recommended not to set the speed of the Cruise Control at the same value of the speed limiter. This might lead to confusion between the two control loops of the systems and thus to higher fuel consumption.

Some truck driver training departments recommend setting the vehicle speed of the Cruise Control much lower than the value of the speed limiter. This of course leads to reductions in fuel consumption. But they are not an effect of Cruise Control but result from the change in vehicle speed. Driving slower without Cruise Control would lead to the same result.

As a measure to avoid the effect of dynamic accelerator movements due to a driver's "nervous right foot" it was suggested to introduce an active accelerator pedal. This device should allow to accelerate as usual until the maximum desired speed of about 80 km/h is reached. Then it should become stiffer so that it can serve as a resting position for the foot. Slowing down would be possible by lifting the foot, accelerating by kicking down the pedal. Thus the active accelerator could take over the function of a Cruise Control system while at the same time keeping the driver in the loop.

With regard to exhaust gas emissions only very few differences are expected if Cruise Control is used or not used. To fulfil the standards all newer passenger cars are equipped with exhaust gas after-treatment systems which are able to eliminate the majority of HC (hydrocarbons), CO (carbon monoxide) and NO_x (nitrogen oxides). Since most passenger car Cruise Control systems accelerate with an air/fuel ratio of $\lambda = 1$ while resuming the selected speed no changes in the amount of pollutants should arise. Also for trucks there should be no relevant change in emissions. If the truck is loaded accelerations would have to take place using full engine load no matter if the acceleration is done manually or by Cruise Control.

Vehicle manufacturers state that they are carrying out research to improve Cruise Control and Adaptive Cruise Control. Under the name "Predictive Cruise Control" a system is developed which not only maintains a preset speed but also regulates the engine by assessing driving conditions ahead and adjusting speed accordingly using topographical data. Predictive Cruise Control can thus bring fuel savings by avoiding unnecessary accelerations due to driver's limited foresight.

On road measurements

To confirm the statements with regard to the impact of Cruise Control on fuel consumption some measurements were carried out on the road to give a first impression how Cruise Control could influence fuel consumption.

In order to achieve representative results a measurement programme would have to be performed including a lot of vehicle types and various drivers driving several thousand kilometres in different traffic situations so that enough data for statistics were collected. But within this study these efforts were not possible. The results of the on road measurements therefore only can give a hint which effects Cruise Control could have on fuel consumption and they are not representative.

Two passenger cars, one passenger car with trailer and two truck-semitrailer combinations were driven on two different motorways. Each vehicle was run about 1000 km with and 1000 km without Cruise Control. Each vehicle was driven only by one driver. For the passenger cars the track was divided into one flat motorway with tree lanes and another motorway with hilly topography and a mix of two and three lanes. For one truck a third motorway with three lanes and mixed topography was included. The drivers were instructed to keep a definite speed as well as possible with and without Cruise Control (see Table 13). On the hilly motorway it was forbidden to adapt the vehicle speed to the topography. Speed limits due to e. g. road works were followed by driving 5 km/h more, according to the speed indicator, than the signs said. During the test runs with Cruise Control the drivers should use it as often as possible. In longer sections with speed limits the Cruise Control was set to the lower speed value. The velocity profiles of the test runs were recorded by GPS.

Table 13: Dedicated speeds for the test runs according to the speed indicators of the vehicles.

vehicle	**dedicated speed**
passenger car	130 km/h
passenger car with trailer	85 km/h
truck with semi trailer	85 km/h

The estimation of fuel consumption was done by measuring the amount which had to be refuelled into the tank after the test run. A correction of changes of the volumes due to temperature variation was performed.

To consider external or ambient influencing factors like different traffic conditions or weather at different test runs a second vehicle always accompanied the test as a reference. Thus it passes through the same conditions as the first vehicle. Except for the car-trailer tests this second vehicle was identical to the first one. Also the second vehicle had to follow the same instructions as the first one but it was never operated with Cruise Control. The fuel consumption of the second vehicle was measured as well. By this means it is possible to normalise the fuel consumption of the first vehicle to the reference so that only the effects of Cruise Control remain and side effects are eliminated.

Table 14 shows a list of the vehicles incorporated in the test runs.

Table 14: Vehicles used for the measurements of fuel consumption.

passenger car 1	DaimlerChrysler E-Class, Diesel, automatic transmission, power: 110 kW, model year: 2004, curb weight: 1810 kg
passenger car 2	DaimlerChrysler C-Class, Diesel, automatic transmission, power: 110 kW, model year: 2005, curb weight: 1565 kg
passenger car with trailer	Audi 90, spark ignition, manual gearbox, power: 100 kW, model year: 1989, curb weight: 1170 kg; with double-axle trailer, weight (loaded): 0,94 t
truck with semitrailer 1	DaimlerChrysler Actros MB 1841 LS 4x2 Megaspace with Krone semitrailer, semiautomatic transmission, power: 300 kW, model year 2004, total weight: 37,5 t
truck with semitrailer 2	MAN TGA 18.413 XXL 04 with Krone semitrailer, automatic transmission, power: 301 kW, model year: 2004, total weight: 37,5 t

In the following figures the results of the measurements of fuel consumption with and without Cruise Control are presented. All values are normalised to the reference vehicle. The baseline of 100 is given by the test runs without Cruise Control.

Figure 9 shows the results of the measurements with the two passenger cars and the passenger car with trailer. It is distinguished between the two different motorways on which the test runs were performed. The figure displays the normalised fuel consumption so that the value of 100 gives the fuel consumption for drives without Cruise Control.

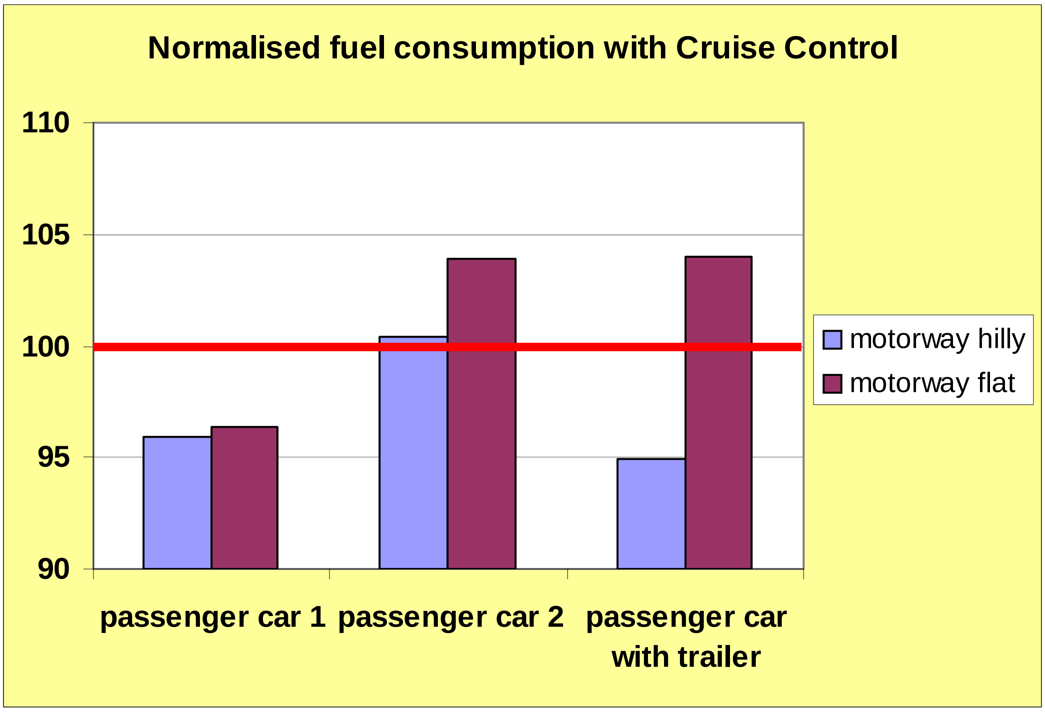

Figure 9: Normalised change in fuel consumption due to the usage of Cruise Control in passenger cars. The line at a value of 100 represents the measurements without Cruise Control.

The results of the measurements show that small decreases as well as small increases in fuel consumption can be observed. The maximum of the deviations was about 5 %. Passenger car 1 had less fuel consumption while driven with Cruise Control on both motorways. Passenger car 2 had a higher fuel consumption only on the flat motorway. For the passenger car with trailer changes in both directions were measured: On the hilly road fuel was saved with Cruise Control and on the flat road more fuel was consumed. So there is no clear tendency for the impact of Cruise Control. With the theoretical background given above this kind of result could be expected since the drivers were instructed to behave in principle the same driving with or without Cruise Control.

Nevertheless the measurements yielded small but ambivalent effects although the drivers were told to drive the same velocity with and without Cruise Control as far as traffic conditions allowed it and although the results are normalised to the reference vehicle. There is no obvious explanation for the reasons why fuel consumption has increased respectively decreased in the certain cases but several aspects could be responsible for it.

First there is an estimated error of about 3 % due to inaccuracies in the measurements especially in determining the used amount of fuel by refuelling. So the results achieved are only slightly above the margin of error.

Although the instructions for the drivers had been clear there might have been small changes in driving behaviour while using Cruise Control which also could be influenced by different ambient conditions. Also the driving style of the driver of the reference vehicle might be subject to variations between different test runs so that the result is influenced.

Besides that the responses of the test vehicle and the reference vehicle to different traffic situations might not be identical although the same vehicle types are used.

It was only possible to perform the measurements with one driver, three vehicles and with a limited track length so that averaging over a lot of measurements was not feasible.

Also the velocity profiles that were recorded did not show specific reasons for the results of the measurements. In some cases different average speeds were measured for runs with and without Cruise Control due to changes in traffic conditions. In spite of normalising to the reference vehicle this could have an impact on the calculated fuel consumptions.

Nevertheless the velocity profiles can help to get insight in the changes in driving behaviour while using Cruise Control. Figure 10 shows the velocity profiles (velocity over distance covered) of a section of a test run with passenger car 1 on a flat motorway with and without Cruise Control. The desired speed was 130 km/h. With Cruise Control the curve is much smoother and there are long phases during which the velocity was constant. Also a speed limit of 120 km/h is visible. Without Cruise Control the driver has difficulties to maintain a constant speed. It oscillates around the desired value. This behaviour is one of the reasons that Cruise Control can have positive effects on fuel consumption on a flat road with less traffic.

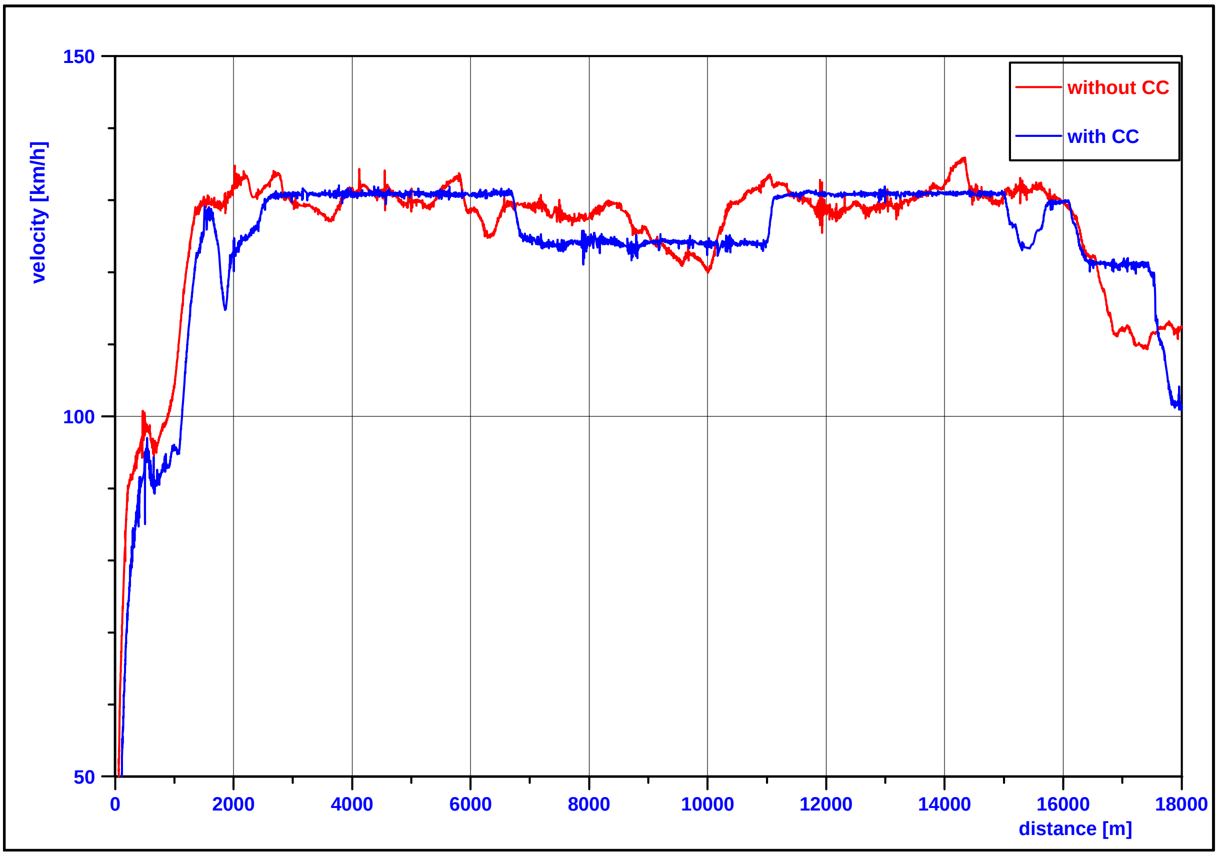

Figure 10: Velocity profiles of a section of a test run with passenger car 1 on a flat motorway with and without Cruise Control.

In the following figure 11 the results of the measurements with trucks are presented. The trucks were loaded to a total weight of 37.5t. All values are normalised to the reference vehicle. The figure again displays the normalised fuel consumption so that the value of 100 gives the fuel consumption for drives without Cruise Control. It is distinguished between three different motorways on which the test runs were performed. Truck 1 was driven only on a flat motorway, truck 2 was driven on motorways with hilly, flat and mixed topography.

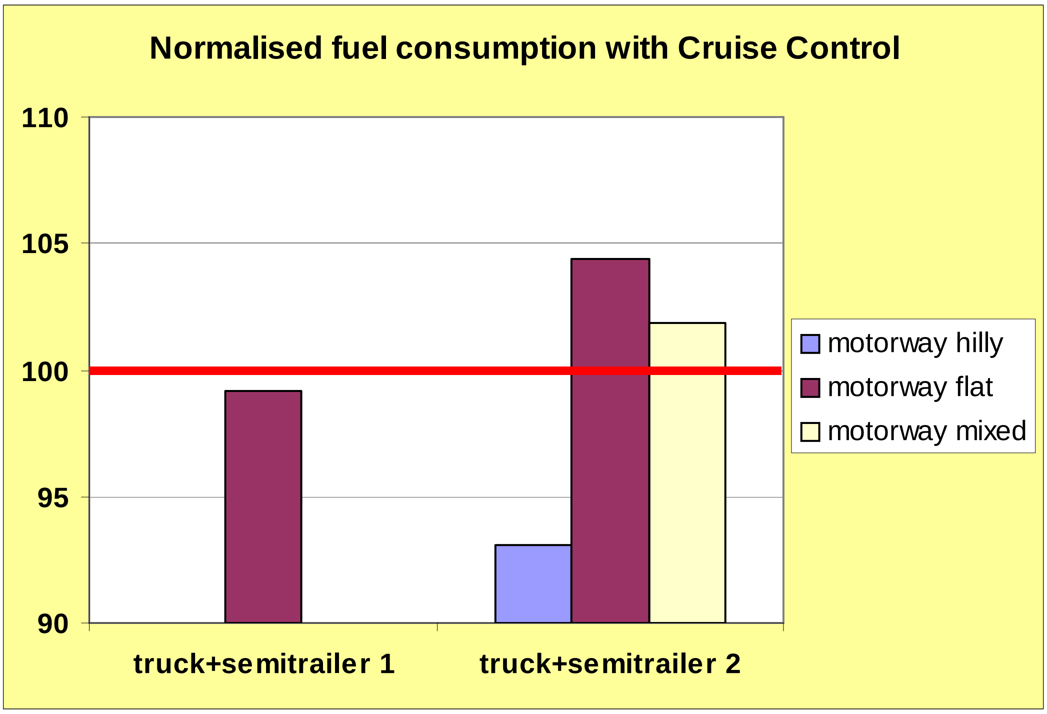

Figure 11: Normalised change in fuel consumption due to the usage of Cruise Control in trucks. The line at a value of 100 represents the measurements without Cruise Control.

The results of the measurements show that small decreases as well as small increases in fuel consumption can be observed. The maximum of the deviations on the motorways with flat and mixed topography was about 4 %. Only the measurement with truck 2 on the hilly motorway yielded a significantly lower fuel consumption with Cruise Control of about 7 %. This effect was not only caused by the Cruise Control system but also by the automatic gearbox of truck 2. With operating Cruise Control the velocity of the vehicle was not kept constant on steep slopes. Cruise Control allowed the engine speed to decrease to smallest values without forcing the automatic transmission to gear down so that the velocity was significantly lower than the desired speed. Without Cruise Control the driver kept the desired velocity by kick-down of the accelerator forcing a gear change. So there was a fuel saving effect while using Cruise Control which was in fact to be traced back to a change in velocity. If it is common to couple gear shift strategies of automatic transmissions to the use of Cruise Control by the manufacturers could not be elicited.

So also for the trucks there is no clear tendency for the impact of Cruise Control. With the theoretical background given above this result could be expected since the drivers were instructed to behave in principle the same driving with or without Cruise

Control and especially for trucks the velocity is always slightly above 80 km/h driving on the right lane and changes in the velocity are small.

With regard to the inaccurateness and errors of the measurements the same aspects as for the passenger cars are valid for the trucks.

Conclusions

From a theoretical and technical point of view Cruise Control does not have any influence on fuel consumption and emissions if the vehicle is driven exactly the same way using Cruise Control and not using Cruise Control. Vehicle manufacturers also state that Cruise Control is not designed to save fuel but to enhance driving comfort. That means that any changes in fuel consumption due to Cruise Control are primarily not dependent on technical properties of the vehicle or system but on the behaviour and skills of the driver.

Cruise Control can only have an influence on fuel consumption if either the average speed changes by using it or by changing the dynamics of the trip.

Real world measurements carried out within the scope of this project with passenger cars and trucks on different motorways show ambivalent results. Smaller as well as higher fuel consumptions are observed while using Cruise Control. The changes in fuel consumption are small and not unambiguous.

Fuel consumption depends more on the experience of the driver, the traffic situation and the topography than on Cruise Control itself.

Recommendations

Based on the results of the on road measurement, on the statements of manufacturers, hauliers and associations and on the results of the literature and internet survey the following recommendations could be derived:

- Cruise Control should be used as the instructions of the vehicle manufacturers indicate. These instructions are e. g.:
    - not to use Cruise Control in dense traffic,
    - not to use Cruise Control in hilly terrain if the systems keeps the velocity without taking the topography into account,
    - to switch on Cruise Control not until the desired speed is reached by accelerating by foot if the Cruise Control systems uses full engine load for acceleration.
- Drivers should get better information about how their Cruise Control system works and when it should be used.
- To reduce fuel consumption without increasing travel time too much drivers should use Cruise Control in a way that the velocity profile is smoothened and the maximum speeds are lowered.
- The desired speed set by Cruise Control should be lower than the velocity of the speed limiter to avoid conflicts between the control strategies of both systems.

- Advancements of Cruise Control systems like Predictive Cruise Control or Intelligent Cruise Control including topographical and other information about the traffic in front of the vehicle should be supported.
- To smoothen the velocity profile without the need to use a Cruise Control system manufacturers should think about introducing an “insensitive” accelerator which either allows bigger movements of the accelerator without changing the velocity of about 80 km/h or which becomes stiffer at 80 km/h and thus serves as a rack for the drivers foot.

⇒ Due to the ambivalent effects of Cruise Control on fuel consumption and emissions indicated by the literature and the on road measurements no legislative actions on EU level with regard to Cruise Control and environmental issues should be taken.

⇒ Future advancements of Cruise Control should be awaited to check if they have a bigger potential to lower fuel consumption than the conventional Cruise Control system.

Appendix G: Impact of Cruise Control across jurisdictional boundaries (WP3.5)

Executive Summary

The aim of this WP was to assess the impact of cruise control across jurisdictional boundaries. To achieve this, the following tasks were undertaken.

1. A desk based study reviewing results from WP 3.1 and 3.2, which cover the policy and practice in each member state, and the level of usage and class of vehicles in the EU.
2. A desk based task developing possible scenarios for using cruise control across jurisdictional boundaries.
3. A brainstorming session identifying any potential problems that might arise when crossing boundaries, using the review and the scenarios developed.
4. An internal report for WP 3.5. The internal report (this appendix) details in full the results of stages 1-3.

Overall, the Workpackage found several areas where cruise control might be a possible issue across jurisdictional boundaries. These areas included:

- *Violations and accident reporting* – the main jurisdictional issue is when travelling into areas where cruise control usage is restricted.
- *Speed limits and speed units* – differences in both these parameters across jurisdictional boundaries may exist and conflict with cruise control usage.
- *Knowledge of legislation* – there are restrictions on cruise control usage in some EU states, but some drivers may be unaware of these restrictions, especially foreign drivers.

The implications of these findings are discussed in the Conclusions section at the end of this document.

Overview of Methodology

The work process for WP 3.5 is shown in schematic form in Figure 12 below. Each stage will be described in turn, and then overall conclusions will be made.

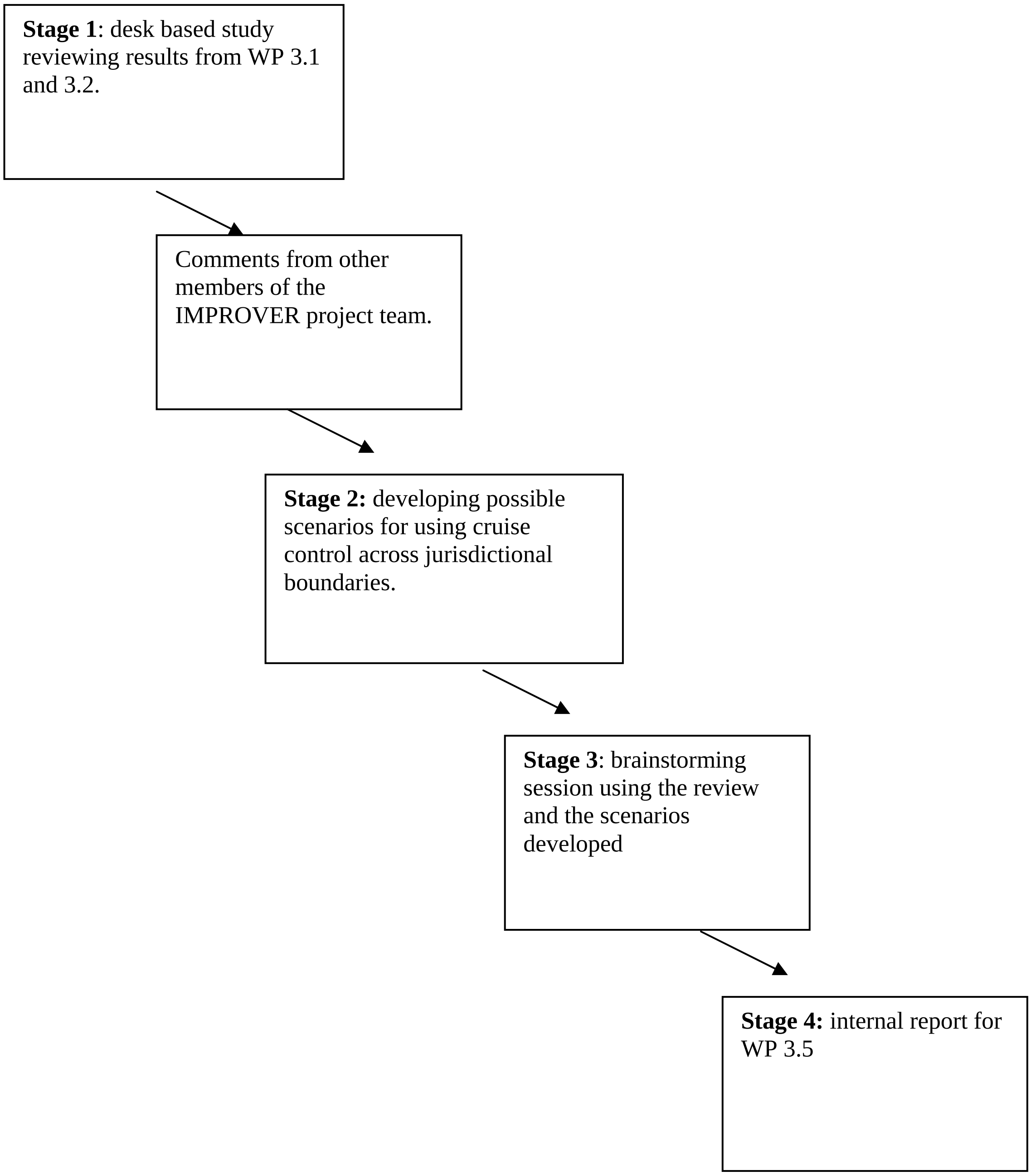

Figure 12: Structure of WP 3.5

Stage 1: Desk based study

Stage 1 was a desk based study reviewing results from WP 3.1 and 3.2, which cover the policy and practice in each member state, and the level of usage and class of vehicles in the EU.

Three members of the project staff from TRL, with substantial traffic safety experience, conducted this review. Before the review, each read the results of WP 3.1-2, and undertook limited consultation with colleagues abroad and within TRL where necessary (for example with vehicle engineering colleagues).

The aim was to uncover the possible benefits and disbenefits of cruise control in a variety of EU traffic environments, and to ascertain if these are compatible with current EU policies and practice.

Results

Jurisdictional Boundaries

Before the body of this report could be developed it was necessary to define the meaning of jurisdictional boundaries in relation to cruise control. A number of jurisdictional boundaries were highlighted which were:

- Country boundaries
- Road types – motorways vs. lower category roads
- Weather conditions – for example France has a lower speed limit on some roads when it’s raining.
- Day and time of the week – peak time (“rush hour”)
- Differences in units of speed
- Areas of road works or other abnormal traffic situations

TNO Report – Cruise Control and policy/level of usage (WP 3.1 & 3.2)

The previous workpackages of the TNO report highlighted a number of issues related to the policy and level of usage of cruise control. At present there are no specific national or international regulations to the type approval of vehicles fitted with cruise control. The majority of the 16 countries that responded declared that they had no current policy on the issue of cruise control, 7 of these were “new states”. For the 5 countries (all “old states”) that stated that cruise control was a policy issue, none stated that they differentiated between vehicle classes. However six of the EU member states expressed that they expect the EU to take a leading role in policy development for cruise control.

Table 15 below summarises the countries that stated that cruise control was a policy issue and their reasoning for this.

Table 15: Cruise control as a policy issue, by country

Country	Reasoning for cruise control as a policy issue
Belgium	Policy relevant for safety reasons. Due to serious accidents, Belgium was concerned about the decreased driver awareness when using cruise control. As a consequence of this cruise control is forbidden in areas where traffic jams are likely and where road works are being carried out.
Finland	Policy relevant for safety reasons. Finland is ready to consider restricting cruise control if accidents cases show a link to cruise control.
Netherlands	The Netherlands reports an incentive scheme for installation or purchase of cruise control in the form of a tax reduction. However this has since been withdrawn.

Information search

As part of this work package a targeted literature search was performed regarding selected aspects of cruise control across jurisdictional boundaries. These included classifications of cruise control, standards regarding cruise control and insurance and training information.

Classification of cruise control

Cruise control is neither an IVIS (In Vehicle Information System) nor ADAS (Advanced Driving Assistance System) system so it appears that it falls between the cracks regarding policy issues, as described in WP 3.2. It is most accurately defined as a driver assistance system (DAS). Cruise control is predominantly a system that aids driver comfort rather than a system that improves the driver's ability or assists the driver's reactions in hazardous circumstances.

Current regulations in regard for cruise control

<u>ISO Standards and International Regulations</u>

There appears to be currently no standards available for cruise control; however, there is ISO 15622:2002 Transport information and control systems – Adaptive cruise control systems – performance requirements and tests procedures.

<u>Construction and Use Regulations</u>

Input was sought from vehicle engineers within TRL; they confirmed that the UK construction and use regulations seemingly make no direct mention of cruise control in terms of its impact across jurisdictional boundaries.

Insurance costs of CC

A number of UK major insurers were contacted regarding the issue of post purchase (not factory fitted) cruise control. The purpose of this was to ascertain whether cruise control had an effect on insurance quotes and the nature and reasoning of this effect.

The responses received were mixed. However all the responses stated that cruise control was added to the quote as a modification to the car. Certain responses stated that cruise control would not have an effect on the policy premium. However, in other cases, it would cause a 7% rise in the premium quoted. The only reasoning given for this was that it was a modification from the manufacturer's specification for the car. As such, it does not in itself seem to be an issue across jurisdictional boundaries.

Cross-border enforcement

(VERA/VERA 2)

VERA 2 (Video Enforcement for Road Authorities) addresses the enforcement of road traffic laws across the EU Member States' borders. The EC funded 5th Framework Research Programme (VERA 2) has developed a possible legal framework for cross-border enforcement in the field of road safety. The results of the VERA 2 project coupled with the February 2005 Framework Decision adopted by the Council of the European Union, now gives each Member States the authority to enforce financial penalties for a range of different offences across national borders.

Cross-border enforcement

The European Commission has adopted a recommendation on the enforcement of traffic law which includes requirements on cross-border aspects. The major obstacle that was found was the minimal harmonisation between traffic enforcement law in Europe. Specifically there were differences in penalty points systems and different levels of financial penalty for the same offence.

In summary, cross-border enforcement is becoming more regulated across Europe. However, at present, there is a lack of specific standards or regulations for cruise control; although there might be an opportunity to develop standards to be applied within the current EU cross-border enforcement policy.

Stage 2: Desk based task developing scenarios for using cruise control across jurisdictional boundaries

Stage 1 results were sent to all IMPROVER partners for comment. Following this, a desk based task developing possible scenarios for using cruise control across jurisdictional boundaries was completed.

This task involved the three members of the project staff from TRL. Members of the TRL project staff developed scenarios based on professional experience, supported by targeted literature reviews and consultations with colleagues.

These scenarios were designed to consider issues associated with the impact of cruise control on traffic safety – covering issues of driver, environment, vehicle and various policies of different member states.

Results

Table 16 shows the 10 scenarios developed. These 10 scenarios were then used in stage 3.

Table 16: Scenarios developed.

	Scenario
1	Differences in Reporting and Investigation of Violations and Accidents
2	Different Training Issues
3	Different Levels of Cruise Control Usage
4	Differences in Speed Limits and Speed Units (kph/mph)
5	Different Rules on Vehicle Following
6	Differences in Vehicle Inspections
7	Different Insurance Requirements
8	Different Policies on Emissions and Other Environmental Considerations
9	Differences in Cruise Control Licensing: *a) Licence status* *b) Impairment*
10	Differences in Knowledge of Legislation *a) Within a country* *b) Between countries*

Stage 3: Brainstorming session identifying any potential problems that might arise when crossing boundaries

Following Stage 2, a brainstorming session was completed, identifying any potential problems that might arise when crossing boundaries, using the Stage 1 review and the scenarios developed in Stage 2.

As with Stages 1 and 2, three members of the project staff from TRL, with substantial traffic safety experience, conducted this session. The aim was to identify any possible problems that might arise when crossing boundaries.

Results: Cruise Control Scenarios

Ten scenarios to assess the impact of cruise control across jurisdictional boundaries were developed by the project team at TRL. Thereafter, three members of the project team ran two brainstorming sessions to develop implication from to these scenarios.

1. Violations/Accident Reporting and Investigation Differences

Violations

Traffic violations such as speeding ticket issuing may be different across different member states. Previously there was no definitive way of issuing speeding tickets to owners of vehicle from other EU countries, but as reported in the EU project VERA 2 this should shortly change.

Accidents

Differences in traffic accident reporting do exist between different Member States (where jams/queues are likely). For example, in the UK a police officer must fill in a STATS19 form at the scene of an accident to record accident details. However, there is no section of this form to indicate whether Cruise Control had been in use at the time of the accident unless the police officer makes note of this in a section for comments.

However, in Belgium, where Cruise Control is illegal in roadwork locations and on busy stretches of motorway, there may be more stringent checks on whether Cruise Control had been in use at the time of the accident. Motorists can face on the spot fines for use of Cruise Control in illegal areas and punishment is the same as for a violation of any other traffic sign. Areas are shown by a crossed circle over the words 'cruise control'.

As such, the main jurisdictional issue in these scenarios is when travelling into areas where cruise control is restricted (i.e. parts of Belgium).

2. Different Training Issues
There seem to be no formal training requirements in any country in the use of Cruise Control; ***and as such, there are no jurisdictional issues in this scenario.***

3. Different Levels of Cruise Control Usage
As seen in WP 3.2, between member states there are different levels of Cruise Control in vehicles and different levels of use. Also, as described in the overall project literature review, the use of Cruise Control can influence driver behaviour. If someone from another country is driving in one area of high usage, the differing traffic environment may have negative safety consequences.

As such, possible differences across some jurisdictional boundaries may exist with this scenario.

4. Differences in Speed Limits and Speed Units (kph/mph)

Speed Limits

Issues may arise when crossing from one country to another. The Vienna Convention (1968) states that "*Domestic legislation shall establish speed limits for all roads*". If a driver had Cruise Control set and passes into another country they may not remember or realise that there may be a need to re-set their Cruise Control to a new speed. For example Belgium has lower motorway speed limits than France or Germany yet a driver can cross between the countries without having to stop at any form of border control.

Speed Units

Issues may arise when crossing between countries that use different speed units. For example a driver may have set Cruise Control in the UK (including Northern Ireland) to 70mph but when arriving in the Republic of Ireland which uses metric unit signing may re-set the Cruise Control for the same speed not realising that the speed units have changed.

As such, possible differences across some jurisdictional boundaries may exist with differences in speed limits and speed units.

5. Different rules on vehicle following
Vehicle following rules in the EU are generally advisory unless the driving is judged to be dangerous by the police. The Vienna Convention advises that the driver of a vehicle must keep a "*sufficient distance*" behind another vehicle, so that a collision can be avoided. However, as seen in the project literature review, Cruise Control use may make drivers less willing to brake, to avoid having to re-set their cruise control. Because of this it may be likely that headway distances used by drivers with Cruise Control might be shorter.

As such, possible differences across some jurisdictional boundaries may indirectly exist with this scenario.

6. Vehicle Inspections

In the UK, vehicles over three years old must undergo a certificate of roadworthiness (MOT) test every year whereby the vehicle undergoes an inspection of its fitness to be on the road. However, such a test does not make any assessment of Cruise Control. Issues may arise if such a fitted system was faulty; if the system was then used whilst abroad and it malfunctioned causing an accident this may have legal implications.

As such, some possible differences across some jurisdictional boundaries may exist with this scenario. However there will only be a difference if some countries do make an inspection of Cruise Control.

7. Insurance Requirements

In the UK it was found that there is no requirement to state whether Cruise Control is fitted to a vehicle when insuring it, unless it has been fitted after purchase (whereby it is classed as a modification also pushing up the cost of the policy).

However, whilst this is acceptable in the UK, it is possible that other EU countries might be different regarding insurance.

A further examination of insurance requirements throughout EU states would be required to assess if this is an issue across jurisdictional boundaries.

8. Emissions and Restrictions

At the end of 2003 the Netherlands were proposing that all new cars within the 15-nation EU were fitted with cruise control as a way of reducing emissions and saving fuel. The Dutch claimed a 10% reduction in fuel usage and substantially less CO_2 emissions.

This issue is investigated in WP 3.4; however, it is not an issue across jurisdictional boundaries

9. Cruise Control Licensing

Licence Status

As far as the project team are aware there are no requirements on drivers to achieve a certain type of EU licence before use of Cruise Control is allowed. For example, learner drivers in the UK are not restricted from using it.

Impairment

One area where use of Cruise Control may be restricted is for drivers with functional restrictions or a cognitive impairment. Indeed the Vienna Convention states that for drivers where the validity of a permit is made in accordance with the holder utilising certain devices. The permit is not recognised if the devices are not worn whilst driving.

A further examination of different EU restrictions of driving due to physical or cognitive impairments is required to assess if this is an issue across jurisdictional boundaries

10. Knowledge of Legislation

Within a country

With only certain sections of the Belgium motorway network subject to Cruise Control restrictions even members of the population within one country maybe unaware of any restrictions on Cruise Control usage.

Between countries

With Belgium being the only country in Europe to restrict the use of Cruise Control it is not unreasonable to judge that many other European drivers may not be aware of this and use Cruise Control in prohibited areas (as they largely rely on traffic signing to inform drivers).

As such, where there are some restrictions in some EU states then some drivers may not have full knowledge of these restrictions, especially those drivers from abroad. Hence, some possible differences across some jurisdictional boundaries may exist with this scenario.

Conclusions

There appears to be no legislation and very little guidance on cruise control usage. It seems to have been overshadowed by the more sophisticated adaptive cruise control that was first introduced onto the market by Toyota in May, 1998. However even though cruise control is sold as a comfort system this does not mean that there are not safety-critical elements to its usage. The brainstorming sessions held at TRL have produced a number of potential scenarios that appear to show important issues across jurisdictional boundaries. Further investigative work, beyond the scope of this project, is needed to understand the full implications of some of the scenarios (e.g. vehicle inspection, insurance requirements and licensing requirements) across jurisdictional boundaries.

A number of the scenarios that were identified have the potential to cause adverse consequences across jurisdictional boundaries. The major issues identified include:

- Legislation in Belgium that makes cruise control usage illegal in certain areas, such as stretches of busy motorway;
- The variability in speed limits and speed units across jurisdictional boundaries, and the effect that these differences could have on cruise control usage.
- Knowledge of such legislation may not be widespread in the country it is enforced in, especially if it is relatively new. Further to this; foreign drivers are even less likely to be aware of such legislation or the penalties for violation.

The identification of issues related to cruise control across jurisdictional boundaries is important, but not fully a useful end in itself. Some states expressed that they expect the EU to take a leading role in policy development for cruise control - the issues identified here could help guide this policy.