TØI report 1304/2014

Truls Vaa
Terje Assum
Rune Elvik

Institute of Transport Economics
Norwegian Centre for Transport Research

Driver support systems:

Estimating road safety effects at varying levels of implementation

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Author(s): Truls Vaa, Terje Assum, Rune Elvik

Forfattere: Truls Vaa, Terje Assum, Rune Elvik

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Summary:

The Norwegian Public Roads Administration has asked for estimates of selected driver support systems with a potential to reduce the number of fatalities. The driver support systems considered were: Intelligent Speed Adaptation (ISA), maximum speed governor, Alcolock, seat-belt lock, sleep/fatigue warning system, programmable electronic ignition lock (“Smartcard”), adaptive cruise control (ACC), and electronic stability control (ESC). Estimates of lives saved are for the most part based on in-depth investigations of fatal accidents that may have been prevented if respective systems had been activated. The most effective is ISA with an estimated 41 lives saved per year in Norway, the least effective system is a maximum speed governor with an estimate of 8 lives saved per year. Estimates of lives saved for the other seven systems vary between 14.9 and 37.5 lives saved per year.

Sammendrag:

Vegdirektoratet (VD) ønsket beregninger av førerstøttesystemer som kan bidra å redusere antall drepte i trafikken. Prosjektet tok for seg følgende systemer: Intelligent fartstilpasning (ISA), toppfartssperre, alkolås, bilbeltelås, varsling av sovning/tretthet, programmering av elektronisk nøkkel (”Smartcard”), adaptiv cruisekontroll/automatisert nedbremsing (ACC), og elektronisk stabilitetskontroll (ESC). For de fleste av disse benyttes anslag som er basert på studier av dødsulykker og medvirkende årsaker som systemene antas å kunne ha virket på. Det mest effektive er ISA med et anslag på 41 sparte liv pr år i Norge, det minst effektive er toppfartssperre med 8 sparte liv pr år. For de øvrige systemene varierer anslagene mellom14,9 og 37,5 sparte liv pr år.

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Institute of Transport Economics
Gaustadalleen 21, 0349 Oslo, Norway
Telefon 22 57 38 00 - www.toi.no

Transportøkonomisk Institutt
Gaustadalleen 21, 0349 Oslo
Telefon 22 57 38 00 - www.toi.no

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Preface

The Norwegian Public Roads Administration commissioned a research project at the Institute of Transport Economics, designed to estimate the effects on traffic fatalities of driver support systems. Driver support systems are part of the large set of technologies referred to as Intelligent Transport Systems (ITS). The road safety effects of such systems has been discussed for more than 20 years, but there are few evaluations based on accident data in real traffic. Electronic stability control is an exception; for this system there are many evaluations based on accident data. For most systems, however, evaluations of their likely safety effects are based on "ex ante" analyses, i.e. analyses performed before the systems are introduced in real traffic on a large scale. Many of the ex-ante evaluation studies are based on in-depth studies of fatal accidents, in which factors that contributed to the accidents have been identified.

The objective of the study presented in this report is to estimate the number of traffic fatalities that can be prevented at different levels of deployment of different driver support systems. The two most important of the systems are intelligent speed adaptation (ISA) and alcohol ignition interlock. However, the study also included top speed governor, seat belt interlock, fatigue monitoring and warning, electronic, programmable ignition key (Smartcard), adaptive cruise control, automatic braking, and electronic stability control. In addition to these systems, the Public Roads Administration wanted an assessment of the effects of changes in behaviour associated with eco-driving.

Initially the project was reported in Norwegian (TØI report 1202/2012).

The contact person in the Public Roads Administration was Vibeke Grimstad. Senior research psychologist Truls Vaa was project manager at the Institute of Transport Economics and principal author of the report. Rune Elvik wrote the section dealing with ISA and top speed governor. Terje Assum wrote the section dealing with alcohol ignition interlock. Truls Vaa wrote the rest of the report. Chief research officer Torkel Bjørnskau has been responsible for quality control of the report.

This report is a translation of the Norwegian report from 2012 with some minor adjustments. The translation is financed by the Public Roads Administration, with Torbjørn Tronsmoen as contact person. Rune Elvik has been project manager for the translation at TØI. Truls Vaa, Rune Elvik and Terje Assum have translated the part they were responsible for in the Norwegian report. Trude Rømming have prepared the report for publication in electronic form.

Oslo, March 2014
Institute of Transport Economics

Gunnar Lindberg	*Torkel Bjørnskau*
Managing director	Chief research officer

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Institute of Transport Economics
Norwegian Centre for Transport Research

Summary:

Driver support systems: Estimating road safety effects at varying levels of implementation

TØI Report 1304/2014
Authors: Truls Vaa, Terje Assum, Rune Elvik
Oslo 2014, 63 pages

The report considers the following driver support systems regarding their potentials to reduce the number of fatalities: Intelligent Speed Adaptation (ISA), maximum speed governor, Alcolock, seat-belt lock, sleep/fatigue warning system, programmable, electronic ignition lock ("Smartcard"), adaptive cruise control (ACC) and electronic stability control (ESC). Estimates of lives saved are for the most part based on in-depth investigation of fatal accidents that may have been prevented if respective systems had been activated. The most effective is ISA with an estimation of 41 lives saved per year, the least effective system is a maximum speed governor with an estimate of 8 lives saved pr year. Estimates of lives saved for the other seven systems vary between 14.9 and 37.5 lives saved per year.

The Norwegian Public Roads Administration (NPRA) wanted estimates of driver support systems with potentials of reducing the number of fatalities at different levels of implementation. The project considered eight driver support systems. The levels of implementation were defined as follows:

- Drivers 18 – 20 years of age
- Drivers 18 – 24 years of age
- Professional drivers/drivers using cars when carrying out their occupation
- All drivers/cars (and potential passengers in some cases)

For some of the systems the NPRA wanted to estimate the effects in specific groups of drivers at high risk of being involved in fatal accidents, especially effects of ISA and maximum speed governor for drivers convicted for speed violations, and effects of alcolock for drivers convicted for drink driving, respectively.

Regarding studies of driver support systems considered in the report there are none – except for ESC – which have been evaluated on basis of accidents in real traffic. In absence of this, it has been necessary to base most of the estimations on "ex ante" or proxy methods – i.e. methods using data and assumptions based on hypothetic scenarios.

All driver support systems are treated in separate chapters where assumptions, data bases and estimation methods for each of the systems are elaborated in detail, but a short presentation of the estimation methods is also given here.

Estimating the effects of ISA is based on an ISA-system that forces the vehicle to comply with the speed limits where the driving takes place, i.e. the driver cannot override what is demanded by the ISA-system. The effect is partly expressed by the attributable risk that can be allocated to speed violations and partly by the traffic volume that each of the groups represent.

Professional driving comprises all drivers who drive vehicles as inherent in their profession, as with taxi- and bus-drivers as well as drivers who drive extensively when carrying out their occupation, as with specific groups of craftsmen. Regarding professional driving we have information of the traffic volume (total number of kilometers driven). The amount of the traffic volume executed by professional drivers is estimated to 15 % of the total volume. A second method which is also used as an alternative in some cases is data from the accident register of Statistics Norway (SSB) which states the codes of vehicles which are used by drivers in the execution of their profession.

Regarding maximum speed governor the effects are based on an assumption that the set point of maximum speed is 110 km/h and that all driving speeds of 40 kmh above the speed limit zones of 80, 90 and 100 km/h are eliminated by a maximum speed governor.

The effect of Alcolock is also based on the attributable risk attributed to drink driving and to a situation where 98 % of drink driving can be prevented – the missing 2 % then attributed to Alcolock malfunction.

By a ”seat-belt lock” is meant a system which prohibits the vehicle to start before all seat-belts are used and locked in all seat positions where people actually sit. Estimates of survival when using a seat-belt vary between seating positions and estimates from the Handbook of Road Safety Measures (2009), which are based on meta-analysis, are used and applied on fatal accident data from the regional Accident Analysis Groups in 2005-2009 regarding the number of drivers and passengers not having used seat-belts.

By a so-called “smartcard” is in this context meant a programmable ignition key, as with Ford's “MyKey”-system, which comprises options of applying specific measures for drivers and passengers using an ignition key of this kind. The specific MyKey-measures are among others seat-belt use, ISA, audio-system blocking and automatic emergency call in the case of accidents. The potential, total effect of a MyKey-system cannot be calculated, except for an estimate of MyKey's automatic emergency call system because it seems analogous to the eCall system which has been studied by a Finnish, in-depth study.

Regarding the remaining three driver support systems, i.e. warning of fatigue/sleeping-at-the-wheel, adaptive cruise-control (ACC), and electronic stability-control (ESC) the methods of estimation are quite the same for all three systems as they are all based on fatal accident data from the regional Accident Analysis Groups regarding assumptions of contributing causes in respective types of fatal accidents. In addition, the effect of ESC is based on estimates from meta-analysis done in the Handbook of Road Safety Measures (2009), which are all based on data from accidents in real traffic.

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Table S.1: Estimations of the number of lives saved according to selected driver support systems.

System / *Levels*	*Intell. Speed Adapt. (ISA)*	*Max. speed-governor*	*Alco-lock*	*Seat-belt lock*	*Warning of fatigue/sleeping at the wheel*	*Smart-card/ MyKey*	*Adaptive cruise control (ACC)*	*Electronic stability-control (ESC)*
All/All drivers	41,0	8	34,0	29,1 *	100%: 29,8 50%: 14,9	(6,3) **	37,5	30,7
Young drivers 18-20 years of age	4,9	-	-	4,3 *	-	-	-	-
Young drivers 18-24 years of age	10,5	-	-	7,6 *	-	-	-	-
Prof. driving (method 1)	6,2	-	-	3.1	100%: 4,5 50%: 2,2	-	5,6	4,6
Prof. driving (method 2)	-	-	-	2,9	100%: 1,7 50%: 0,9	-	-	-
Drink drivers			4,6					
Speed violators	0,2	-						

Estimating effects of professional drivers by method 1 means using the amount of traffic volume. Using method 2 means using Statistic Norway (SSB) vehicle codes as basis of estimation
Warning system fatigue/sleep 100%: means prevention of all accidents (50%: means 50% prevention)
"-" means "missing calculation basis". Grey color means: "Calculation not relevant"

*) Includes drivers, and passengers in front- and back-seat **) Considers only the option of automatic emergency call, i.e. only one of the options inherent in Fords MyKey.

The most effective driver support system is ISA with an estimated effect of 41 lives saved per year, the least effective system is a maximum speed governor with an estimate of 8 lives saved per year. Regarding the remaining systems the estimates vary between 14.9 and 37.5 lives saved per year when the basis for estimation is all drivers. In some cases the effects on passengers are included (marked with * in table S.1).

In addition to the eight driver support systems, the effects of eco-driving has also been considered. Eco-driving is in the present context defined as driving with lower revolutions per minute during acceleration, with increased torque as a consequence, lesser use of engine braking, and fewer gear-shifts. In sum, these behaviour changes reduce fuel consumption per kilometer driven by 6 % ($p < 0.05$). A tendency of a reduction in the number of accidents is reported, but no estimate is given.

Survey of driver support systems

A survey with the purpose of mapping the level of development of driver support systems was conducted. A total of 11 of 25 systems were reported to be under development and/or existing as prototype, while no information were stated for the remaining 14 systems.

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Sammendrag:

Førerstøttesystemer: Beregning av trafikksikkerhetseffekter ved ulike implementeringsnivåer

TØI rapport 1304/2014
Forfattere: Truls Vaa, Terje Assum og Rune Elvik
Oslo 2014 63 sider

Rapporten tar for seg trafikksikkerhetseffekter av følgende systemer: Intelligent fartstilpasning (ISA), toppfartssperre, alkolås, bilbeltelås, varsling av sovning/trøtthet, programmering av elektronisk nøkkel ("Smartcard"), adaptiv cruisekontroll/automatisert nedbremsing (ACC), og elektronisk stabilitetskontroll (ESC). For de fleste av disse benyttes anslag på sikkerhetseffekter basert på studier av dødsulykker og medvirkende årsaker som systemene antas å kunne ha virket på. Det mest effektive er ISA med et anslag på 41 sparte liv år pr år i Norge, det minst effektive er toppfartssperre med 8 sparte liv pr år. For de øvrige systemene varierer anslagene mellom 14,9 og 37,5 sparte liv pr år. Installering av alkolås i alle motorkjøretøy er beregnet til å kunne spare 34 liv pr år, mens installering i alle promilledømtes motorkjøretøy kunne ha spart 4,6 liv pr år.

Vegdirektoratet (VD) ønsket beregninger av hva førerstøttesystemer som kan tenkes å bidra til å redusere antall drepte i trafikken vil ha for effekt ved ulike implementeringsnivåer. Prosjektet tok for seg åtte førerstøttesystemer. Implementeringsnivåer ble definert som bruk av systemene innenfor følgende grupper:

- Førere 18 – 20 år
- Førere 18 – 24 år
- Yrkesførere/yrkeskjøring
- Alle bilførere/biler (og potensielle passasjerer for enkelte systemer)

For noen av systemene ønsket man å beregne virkninger i grupper av høyrisiko-førere som kan være særlig utsatt for å bli innblandet i dødsulykker. Dette gjaldt effekter av ISA og toppfartssperre for førere dømt for fartsovertredelser, og effekt av alkolås for førere dømt for promillekjøring. Når det gjelder studier av de førerstøttesystemer som vurderes i denne rapporten foreligger det – med unntak av ESC - ingen som har evaluert virkninger på ulykker i virkelig trafikk. I fravær av reelle ulykkesstudier har det derfor vært nødvendig å basere de fleste beregninger av effekter på et datagrunnlag og under forutsetninger som bare kan gi "ex ante-estimater" – dvs før virkninger av tiltakene er evaluert etter bruk i virkelig trafikk. Alle førerstøttesystemer er behandlet i egne delkapitler, og det er redegjort for forutsetninger, datagrunnlag og beregningsmetoder for hvert av de systemene som er omtalt og vurdert, men det skal her gis en kort omtale av beregningsmetodene for hvert av systemene.

Beregning av effekt av ISA tar utgangspunkt i et system som er tvingende, dvs at det ikke kan overstyres av føreren. Beregning av effekt blir dels uttrykt i form av det risikobidrag (attributable risk) som fartsovertredelsene representerer, dels på det trafikkarbeidet som utføres i hver av gruppene som betraktes.

Yrkeskjøring omfatter både bilførere som er yrkesførere og yrkesgrupper som kjører mye under utøvelse av sitt yrke, for eksempel håndverkere. For yrkeskjøring foreligger opplysninger om trafikkarbeid i kjøretøykilometer for ulike kjøretøytyper som buss, taxi og store godsbiler (lastebiler og vogntog) og små godsbiler (varebiler). Den samlede andelen av trafikkarbeidet i Norge som kan regnes som yrkeskjøring er satt til 15 %. En alternativ metode er å bruke SSBs ulykkesregister der kode for kjøretøytyper er oppgitt. Kjøretøy som antas å være brukt av yrkesførere eller i yrkeskjøring er taxi/minibuss, buss, varebil, lastebil, trekkbil og tankbil og antallet drepte førere under disse koder gir grunnlag for beregning av effekter for flere av systemene. Begge disse metoder blir brukt i beregningene.

Når det gjelder toppfartssperre i biler er det er ikke funnet undersøkelser av effekten av dette på ulykker. Utgangspunktet for beregninger blir en tenkt situasjon der en toppfartssperre blir satt ved 110 km/t for alle kjøretøy gitt at den høyeste fartsgrense i Norge er 100 km/t. Anslag blir basert på at hastigheter 40 km/t over fartsgrensene 80 km/t, 90 km/t, og 100 km/t blir eliminert ved en toppfartssperre.

For alkolås tas det utgangspunkt i anslag på risikobidraget ved promillekjøring og det antas at dersom alkolås monteres i alle motorkjøretøy, kan – med korreksjon pga feilfunksjon - 98 % av alle tilfeller av promillekjøring forhindres.

En bilbeltelås forutsettes å virke slik at bilen ikke kan startes før bilbeltet er låst på alle plasser der noen sitter. Estimater for overlevelse ved bruk av bilbelter varierer noe mellom plassering i kjøretøyet, og det brukes estimater fra Trafikksikkerhets-håndbokas meta-analyser som anvendes på data fra Statens vegvesens ulykkesanalysegrupper (UAG-gruppene) for perioden 2005-2009 når det gjelder andel personer som ikke brukte bilbelte.

Vurdering av en programmerbar tenningsnøkkel (”Smartcard”) er basert på Fords ”MyKey”. Denne inneholder muligheter for å anvende tiltak for førere og passasjerer, som bilbeltebruk, begrensninger av fartsvalg, og behov for nødhjelpassistanse ved en ulykke. Den samlede, potensielle virkning av delsystemer i MyKey kan ikke beregnes, men det foreligger en finsk undersøkelse av den potensielle virkning av eCall og denne er brukt for å beregne virkning av nødhjelpsassistansefunksjonen i MyKey fordi MyKeys system for nødhjelpsassistanse synes å være lik eCall-systemet.

Fremgangsmåten for beregninger av effekter av førerstøttesystemene varsling av sovning, adaptiv cruisekontroll (ACC) og elektronisk stabilitetskontroll (ESC) er ganske lik for alle de tre systemene. Utgangspunktet for beregningene er for alle ulykkestyper og antatte medvirkende årsaker til ulykker som fremkommer i UAG-gruppenes analyser av dødsulykker. Effekt av varsling av sovning er basert på andel trøtthet/sovning som årsak, effekt av ACC er basert på antall drepte i ulykker med samme kjøreretning og på fotgjengerulykker, effekt av ESC er basert på Trafikksikkerhetshåndbokas estimat for reduksjon av utforkjøringsulykker og på antall drepte ved utforkjøringsulykker.

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Tabell S.1: Beregning av antall sparte liv pr år ved anvendelse av utvalgte førerstøttesystemer.

System *Nivåer*	ISA	*Topp-farts-sperre*	*Alko-lås*	*Bilbelte-lås*	*Varsling sovning*	*Smart-card/ MyKey*	*Adaptiv cruise control (ACC)*	*Elektronisk stabilitets-kontroll (ESC)*
Alle/Alle førere	41,0	8	34,0	29,1 *	100%: 29,8 50%: 14,9	(6,3) **	37,5	30,7
Unge førere 18-20 år	4,9	-	-	4,3 *	-	-	-	-
Unge førere 18-24 år	10,5	-	-	7,6 *	-	-	-	-
Yrkeskjøring (metode 1)	6,2	-	-	3.1	100%: 4,5 50%: 2,2	-	5,6	4,6
Yrkeskjøring (metode 2)	-	-	-	2,9	100%: 1,7 50%: 0,9	-	-	-
Promilledømte			4,6					
Fartsdømte	0,2	-						

Ved yrkeskjøring metode 1 ligger andel av trafikkarbeidet til grunn for beregning. Ved metode 2 er det SSBs kjøretøykoder som er benyttet som grunnlag for beregning

Med varsling av sovning 100%: antas at alle ulykker kunne vært forhindret (50%: 50% kunne vært forhindret)

"-" betyr "mangler beregningsgrunnlag". Grå farge betyr: Beregning ikke relevant

*) Inkluderer førere og passasjerer i for- og baksete **) Gjelder bare tiltaket nødhjelpsassistanse, dvs bare ett av de potensielle tiltak/begrensninger som ligger i Fords MyKey.

Det mest effektive førerstøttesystemet er ISA med et anslag på 41 sparte liv pr år, det minst effektive er toppfartssperre med 8 sparte liv pr år. For de øvrige systemene varierer anslagene mellom 14,9 og 37,5 sparte liv pr år når alle førere og eventuelle passasjerer er utgangspunkt for beregningene.

I tillegg til de åtte førerstøttesystemene er også økonomisk kjøring vurdert. I de foreliggende studier er økonomisk kjøring definert som å kjøre med lavere turtall (antall omdreininger/minutt) under akselerasjon, økt dreiemoment som følge av dette, mindre bruk av motorbrems, og færre girskift. I sum gir dette en reduksjon av drivstoff pr kjørt kilometer, eller flere kjørte kilometer pr liter drivstoff. Drivstoff-forbruket er redusert med minst 6 % ($p < 0.05$). Det er rapportert en tendens til færre ulykker, men estimater er ikke oppgitt.

Spørreskjemaundersøkelser

Det er gjennomført to spørreundersøkelser for å kartlegge systemer som er under utvikling. Én undersøkelse er gjort spesielt for alkolåssystemer, mens den andre er gjort for førerstøttesystemer generelt. Det ble utarbeidet et spørreskjema for å få tak i kunnskap og utviklingsnivå på 25 ITS-systemer som er blitt navngitt i EU-prosjektet VERA. Av disse ble 11 systemer rapportert å være under utvikling og/eller at det var laget en prototyp av systemet. Spørreundersøkelsen ga ingen informasjon om de øvrige 14 systemene.

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1 Background

In September 2011, the Norwegian Public Roads Administration (NPRA) announced a call for proposals addressing estimations of driver support systems with potentials of reducing the number of fatalities at different levels of implementation. Further, the NPRA wanted descriptions of systems which could be regarded as framing dangerous driver behaviors and thus potentially limiting the number of accidents associated with a given type driver behavior. More specifically, the NPRA asked the following research questions to be addressed:

1. Which driver support systems are directed towards making aberrant behavior more compliant?
2. Which driver support systems are currently under development?
3. Which influences will different types of driver support technology have regarding road safety?

The potential impacts should be quantified for different levels of implementations and appraisals should aim at making the estimates transferable to Norwegian conditions as far as possible. Specifically, the NPRA requested estimates of lives saved as a function of systems implementations, but optional levels of implementation will depend on each system being scrutinized. Intelligent Speed Adaptation (ISA) may serve as an example for describing three levels of implementation:

- Level 1: Mandatory installation comprising all personal cars
- Level 2: Mandatory installed in car for drivers who have had their driving license revoked if they want to continue driving
- Level 3: Requiring all vehicles operated by young adults 18-20 years of age – as one of the components of a Graduated Driving License system.

Considering an alcolock-system, drunk-drivers who have had their driving license revoked, could be offered such a system as an alternative for continued driving and the effects could then be estimated for this group of drivers. For other systems, effects should be estimated for different levels of implementation on basis of the options and potentials inherent in the systems. Finally, the NPRA asked for a "free and easy narrative" to sketch how possible future scenarios might look like.

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2 Research questions and empirical data for estimations

A system supporting a driver may appear as an inherent part of the drivers strategic – i.e. conscious – decision-making process, for example planning when and where the driving shall take place, calculating travel time, speed choices, and potential consumption of – i.e. also abstaining from - drugs, alcohol and medicines, but may in addition also influence the driver's tactical and operational behavior, i.e. more automated/unconscious information processing and decision-making. Driver support systems belonging to the first group will be ISA, Alcolock and navigation systems, systems belonging to the second group will be Antilock Braking Systems (ABS) and Electronic Stability Control (ESC).

2.1 Research question 1: Systems to be considered

The statement *"… framing dangerous driver behaviors"*[1] stimulates in itself to appraisals of possible behavioral adaptations and mechanisms of risk compensation which can be initiated as a function of a given driver support system. The Institute of Transport Economics (TOI) has previously considered risk compensation mechanisms theoretically on basis of a driver behavior model where three possible outcomes can be sorted out as a function of adaptation to different types of systems (Vaa et al., 2007; Vaa 2012):

1. Systems which limit the driver's window of opportunities and consequently reduces the number of accidents as with ISA and ESC. This group of systems is considered to impede triggering of risk compensation mechanisms and will thus appear as unambiguous regarding reduction of the number of accidents.
2. Systems which enhance the driver's window of opportunities and consequently provide feelings of increased mastering of the vehicle. ABS is one example which aggregated across all accident types reduces the number of accidents by 3,5 % (Elvik et al., 2009), but which increases the number of accidents for some accident types as with collisions with overturning accidents, single vehicle accidents, accidents with fixed objects, and fatal accidents, which all are accident types that are associated with higher driving speeds (Vaa et al., 2007).
3. Systems which provide new, relevant information to the driver in contexts where a information need is salient. Examples are variable message signs warning of queues, fog and accidents which all reduce the number of accidents (Elvik et al., 2009).

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[1] In Norwegian: *"… sette rammer rundt trafikkfarlig atferd"*.

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The present project deals primarily with systems of group 1, as these are all systems which limit driver behaviors, and, as a consequence, have inherent potentials of reducing the number of accidents. Some systems of group 2 will, however, also be considered.

2.2 Research question 2: Identification of systems under development

The group of systems we are searching for is systems not yet available on the market, but still known by people associated with car industry and system development. Four sources of information were at our disposal:

- *Contacts/networks in scientific environments:* Mainly SAFER, HUMANIST, ICADTS, eSafety Forum and ECTRI.
- *Contacts with scientific journals:* Rune Elvik, co-author of the present report, was editor of Accident Analysis and Prevention (AAP). In 2012, AAP elaborated a special edition about ISA. As editor, Elvik had access to the papers of this special edition at an early stage, i.e. before the papers were finally published. This was very convenient and beneficial for the project.
- *Proceedings from ITS-conferences and magazines addressing ITS:* Beginning in Paris i 1994, then labeled "Advanced Transport Telematics", *World Conferences on Intelligent Transport Systems* were held each year and all papers presented at the conferences were published in conference proceedings. In addition, the magazines *ITS International* and *Traffic Technology,* were issued regularly several times each year.
- *EU-projects:* Several EU-projects have mapped and evaluated driver support systems. Literature has been searched for, among other the EU-projects VERA, PREVENT and AIDE.

2.3 Research question 3: "Future scenarios":

The project also aims at giving a narrative of future scenarios where driver support systems may contribute to and realize in significant ways. Important issues to appraise would be driver-vehicle interface, automated-/system-control vs manual control, system acceptance, driver age as a barrier for utilizing DSS, privacy issues, etc.

2.4 Data basis and methods for estimating effects

None of studies of the driver support systems which will be considered in the present project have, with ESC as the only exception, been evaluated on basis of data collected in real road traffic. This absence of real accident studies has necessitated estimation procedures to be based on data and assumptions which only can provide "ex ante"-estimates – i.e. estimates calculated before the system outcomes have been studied in real traffic. Each system is described and appraised in specific sections of the present report, but some comments about the methods of estimation relating specifically to each of the systems shall be provided initially.

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The evaluation of ISA takes as the point of departure a system which forces an impact on the driver, i.e. the ISA-system cannot be overruled by the driver. ISA has been studied in real traffic, but it is difficult to state anything conclusive about the outcomes, because the sizes of the studies have been too limited in providing a statistically reliable result on which an effect estimate could be based. Hence, calculation of effects will partly be based on the attributable risk represented by speed violations. An attributable risk may show how much a given number of injured drivers and driver fatalities may be reduced under 100 % compliance of speed limits. The attributable risk from speed violations in 2009-2010 is calculated to19.5 % of fatally injured drivers given a 100 % compliance of the speed limits. This contribution will be applied on the calculation of the effect of ISA for all drivers. Calculating the effect of installing ISA in all cars driven by drivers aged 18-20 and 18-24, will be based on the traffic volume created by each of these age groups in terms of the reduction of fatalities which is estimated by 100 % of implementation.

No accurate estimation of the traffic volume performed by professional drivers is available, but information about the traffic volume done by vehicle groups as buses, taxis, heavy vehicles, vans and delivery trucks can be provided. On basis of this method, the total traffic volume which can be attributed to professional drivers in Norway, is estimated to 15 %. An alternative method is to apply the accident database of the Statistical Bureau of Norway where different vehicle types have specific codes. Vehicles which are supposed to be used by professional drivers or professional driving are taxi/minibus, bus, delivery trucks, lorries, tractor-trailer, and tank lorries, and the number of killed drivers within these vehicle codes, provide a basis for calculating the effects of several of the driver support systems. These methods will both be applied in the estimation of DSS-effects.

The point of departure for the effect of DSS on drivers convicted for speed violations is the number of driver license suspensions because of speed violations. The number of license suspensions is about 6,000 per year and a presupposition is that this sub-group of drivers has the same traffic volume as the average of the total driver population in Norway, - i.e. 15,000 km per year. The total traffic volume will then be 90 million vehicle kilometers, which represent 0.2 % of the total traffic volume in Norway. We consider that this group of drivers has a higher than average risk of being involved in an accident and presuppose that they are involved in 0.5 % of the fatal accidents.

We have not found any study concerning effects of a maximum speed governor. We propose that the basis of estimation would be a future situation where the limit of a speed governor is set at 110 km/h, as the maximum speed limit in Norway is 100 km/h. Based on in-depth studies of fatal accidents, the contribution of driving speeds “substantially over the speed limit” is defined as 120 km/h in speed limit zones 80 km/h, 130 km/h in speed limit zones 90 km/h, and 140 km/h in speed limit zones 100 km/h. Given a maximum speed governor, all these driving speeds should be reduced to 110 km/h, which consequently should contribute to a reduction in the number of fatalities.

The basis for estimating an effect of Alcolock would be the attributable risk which has already been calculated for drunk driving. The assumption is that when Alcolock is installed in all cars, and correcting for malfunction, the potential will be 98 % of accidents involving drunk drivers may be prevented. Only one study has been retrieved about Alcolock’s impact on the number of accidents.

One study has been retrieved regarding convicted drink drivers. Based on this study, a reduction in the number of accidents from the before- to the after-period, adjusted for

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accidents in the control group, has been estimated. Two estimates have been calculated: One for first-time offenders, and one for drivers previously convicted for drunk driving.

A seatbelt-lock hinders a vehicle to start until the all seatbelts are locked in all positions where all vehicle occupants actually sit. The estimates of survival are collected from the Handbook of Road Safety Measures and vary somewhat for different positions in the vehicle. Survival is estimated to be 50 % for drivers, 45 % for front seat passengers, and 25 % for passengers in the back seat for car occupants wearing a seatbelt. The NPRA's Accident Analysis Groups found (AAG-groups), for the period 2005-2009, that 43 % of the drivers and passengers did not use a seatbelt and this %age is applied on all seating positions. The distribution of killed car occupants between front and back seat occupants is retrieved from SSB's accident database and applied on all drivers and for drivers aged 18-20 and 18-24 years of age. For professional drivers, two methods are used: One is based on an estimate of the proportion of the traffic volume done by professional drivers, the other is based on the vehicle-codes of SSB's database which indicate that the driver is a professional driver.

The appraisal of a programmable ignition key – or "Smartcard" - is based on Ford's "MyKey". The MyKey-system as ISA, maximum speed governor, ESC and seatbelt-lock. MyKey also contains elements of other systems as lane departure warning, dead-angel warning and eCall. The total, potential effect of this system cannot be estimated, but a Finnish in-depth accident study has estimated the potential effect of eCall and this estimate has been applied as equivalent to the emergency warning- and assistance-system of MyKey.

The estimation procedure of the effects of the driver support systems warning of fatigue/sleeping-at-the-wheel, adaptive cruise control (ACC) and electronic stability control (ESC) is quite analogous for all three systems. The point of departure for calculating their effects is, for all systems, the accident type and contributing causes which appear from the investigations of fatal accidents of the AAG-groups. The effect of fatigue warning is based on the amount of fatigue/sleeping-at-the-wheel which is stated as cause of the accident, effect of ACC is based on the number of killed in same-direction accidents and accidents involving pedestrians, effect of ESC is based on an estimate of 40 % reduction and the number of killed in running-off-the-road accidents.

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3 Effect of driver support systems at different levels of implementation

It was decided that the following driver support systems should be considered regarding potentials to reduce the number of fatalities:

- Intelligent Speed Adaptation (ISA)
- Maximum speed governor
- Alcolock
- Seatbelt lock
- Sleep/fatigue warning
- Programmable, electronic ignition lock ("Smartcard")
- Adaptive cruise control (ACC)
- Electronic stability control (ESC)
- Economic driving

Eight of these nine systems can without discussion be labeled as a "Driver Support System", whilst the ninth, however, economic driving, is not a system, but a pedagogical measure aimed at changing the behavior of drivers towards a reduction of fuel consumption and is included because the NPRA wanted it to be considered and because it also may have a potential of improving road safety.

3.1 Levels of implementation

In the present context, a "level of implementation" is defined when a given driver support system is applied on all or selected sub-groups of the Norwegian driver population and is achieved when a system is hypothetically or factually installed in all vehicles which is used by the different driver population which are considered here.

Initially, and generally, the levels of implementation were defined as follows:

- Drivers 18 – 20 years of age
- Drivers 18 – 24 years of age
- Professional drivers/drivers using cars when carrying out their occupation
- All drivers/cars (and potential passengers in some cases)

An alternative method is to apply the accident database of the Statistical Bureau of Norway[2] where different vehicle types have specific codes. Vehicles which are supposed to be used by professional drivers or professional driving are taxi/minibus, bus, delivery

[2] In Norwegian: Statistisk Sentralbyrå = SSB.

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trucks, lorries, tractor-trailer, and tank lorries, and the number of killed drivers within these vehicle codes, provide a basis for calculating the effects of several of the driver support systems. These methods will both be applied in the estimation of DSS-effects.

The group of "professional drivers" is defined as drivers of taxi/minibus, bus, delivery trucks, lorries, tractor-trailer, and tank lorries plus drivers who use their vehicle regularly when performing their profession as craftsmen, as with plumbers, electricians, carpenters, and the like.

In addition to the four general driver groups described above, some specific driver sub-groups should be addressed as being of special concern and interest regarding application of three of the DSSs:

- ISA and maximum speed governor: Drivers convicted for major speed violations
- Alcolock: Drivers convicted for drunk driving

The systems will be considered in separate chapters.

3.2 Intelligent speed adaptation

3.2.1 Problem and objective

Speeding is a major road safety problem in all highly motorised countries. It has been a problem for many years, and traditional measures against speeding have not been sufficient to eliminate the problem. In Norway, close to 50 % of traffic violates speed limits (Elvik 2010A). In the most recent years, however, there has been a tendency for speed to go down. Despite this, speeding continues to make a major contribution to road accidents and injuries. This contribution can be determined in terms of the risk attributable to speeding. Attributable risk is a concept taken from epidemiology. It shows how much the number of accidents or injured road users can be reduced by eliminating a certain risk factor, such as speeding. Table 3.2.1 shows the risk attributable to speeding in Norway at three points in time.

Table 3.2.1: Risk attributable to speeding in Norway at three points in time. % reduction in the number of killed or injured road users if speeding is eliminated.

	Time period estimates refer to		
Injury severity	1980-84	2004-06	2009-10
Killed	25.7	23.9	19.5
Seriously injured	18.4	17.3	13.4
Slightly injured	9.8	9.3	6.9

Table 3.2.1 shows the reduction in the number of traffic fatalities and injured road users that can be attained by eliminating speeding. The most recent estimates indicate that the number of killed road users can be reduced by almost 20 %, the number of seriously injured road users reduced by about 13 %, and the number of slightly injured road users reduced by about 7 % if there is 100 % compliance with speed limits. Based on the mean annual numbers for the years 2009 and 2010 (210 killed, 755 seriously injured, 8105 slightly injured), this corresponds to an annual reduction of the number of killed road users by 41, a reduction of the number of seriously injured road users by 101 and a reduction of the number of slightly injured road users by 563. When making these estimates, 100 % compliance with speed limits was, conservatively, defined as 97.7 %

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perfect compliance, with the remaining 2.3 % exceeding speed limits by a speed of up to 10 % above the limits. This definition of perfect compliance was adopted because speedometers and technology for Intelligent Speed Adaptation (ISA) will always have slight inaccuracies, and because some drivers might try to tamper with an ISA-system. It is therefore not realistic to expect that absolutely all drivers will be in perfect compliance with speed limits. Furthermore, it was assumed – again conservatively – that drivers currently driving at a speed of about 3-5 kilometres below the speed limit will not reduce their speed in response to measures designed to ensure better compliance with speed limits. It was assumed that driving speeds are normally distributed. To illustrate how estimates were made, compliance with the speed limit of 60 km/h is used as an example. Results are shown in Table 3.2.2.

Table 3.2.2: Explanation of how the effects on speed of 100 % compliance with speed limits have been estimated, using the speed limit of 60 km/h as example

Number of standard deviations from current mean speed	Share of traffic (%)	Current mean speed (km/h)	Mean speed when 100 % comply with speed limits
3-2.5 below	0.6	40.3	40.3
2.5-2 below	1.7	43.8	43.8
2-1.5 below	4.4	47.2	47.2
1.5-1 below	9.2	50.7	50.7
1-0.5 below	15.0	54.1	54.1
0.5-0 below	19.1	57.6	56.3
0-0.5 above	19.1	61.0	57.1
0.5-1 above	15.0	64.5	57.9
1-1.5 above	9.2	67.9	58.7
1.5-2 above	4.4	71.4	59.6
2-2.5 above	1.7	74.8	61.7
2.5-3 above	0.6	78.3	65.2

Mean speed was estimated as a weighted mean of the speeds in each interval of the distribution, e.g. $(0.006 \cdot 40.3) + (0.017 \cdot 43.8) + ... + (0.006 \cdot 78.3) = 59.3$ km/h. When there is 100 % compliance with the speed limit, mean speed is 55.6 km/h.

The measures currently used to ensure compliance with speed limits include police enforcement performed by uniformed or civilian patrols, speed cameras and physical measures, in particular speed humps in residential roads. None of these measures can be applied everywhere and at all times. The capacity of the police is limited. Speed cameras are costly and are therefore best suited on roads that have a high traffic volume.

It is therefore not realistic to expect conventional measures against speeding to ever be applied to such an extent that compliance with speed limits gets close to 100 %.

Intelligent Speed Adaptation (ISA) is a vehicle safety technology which can assist the driver in complying with speed limits by alerting the driver to violations or by making it difficult or impossible to exceed speed limits. The following sections present current knowledge about the effects of ISA.

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3.2.2 Description of the system

There are three main versions of Intelligent Speed Adaptation (ISA) (Almqvist 2006, Lai, Carsten and Tate 2011):

1. Informative ISA: The system informs the driver about the speed limit and violations of it. The driver can be informed about violations by means of auditory or visual signals, for example in the form of a voice message stating: "You are exceeding the speed limit – please slow down".
2. Voluntary ISA: The system creates resistance in the gas pedal when the driver attempts to exceed the speed limit. The system can be overridden by pushing harder on the gas pedal or by a "kickdown" function by which a sudden hard step on the gas pedal will de-activate ISA.
3. Mandatory ISA: The electronic system regulating fuel supply has been wired so that when the driver tries to exceed the speed limit, fuel supply is reduced, making acceleration impossible. This system cannot be overridden.

All these systems are based on Global Positioning Systems, meaning that a computer in the car will always know its geographical position and will able to determine the speed limit at any location by means of geographically coded digital maps. In early research about ISA, a fourth version of it was mentioned (Carsten and Tate 2005). This was an integrated and mandatory ISA, which not only recorded the speed limit but also measured road surface friction and sight distance. The system thereby made it possible to adapt speed not just to speed limits, but also to road surface condition and sight distance. More recent studies do not mention this system. This report therefore concentrates on the three versions of ISA mentioned above.

ISA is a system connected to speed limits. It should not be mixed up with a top speed governor, which only limits the top speed of a vehicle, independently of the speed limit at a location. Thus, a top speed governor set at a speed of, for example, 90 km/h will not prevent the driver from exceeding any speed limit below 90 km/h.

A number of field trials testing ISA have been reported in many European countries and in Australia. In these trials, cars have been equipped with ISA and been driven in normal traffic. Changes in speed and compliance with speed limits have been monitored. The trials show that ISA technology functions as intended. ISA can be retrofitted in older cars. It is currently not standard equipment on cars. EuroNCAP awards bonus points (EuroNCAP 2011) to cars that have ISA. This is intended to stimulate car manufacturers to bring more cars with ISA to the market.

3.2.3 Effect on accidents

Most field trials of ISA have evaluated effects on speed only, not effect on accidents. The only study stating changes in the number of accidents was made in the city of Lund, Sweden (Varhelyi et al. 2004). According to the study, the self-reported number of accidents per driver per year was reduced from 0.1044 (before) to 0.0510 (during) when ISA was used. In a comparison group consisting of drivers without ISA, there was a corresponding reduction of the number of accidents per driver per year from 0.0501 to 0.0480. Using the odds ratio as estimator of effect, the effect on accidents of ISA can be estimated as:

Effect on accidents (odds ratio) = (0.0510/0.1044)/(0.0480/0.0501) = 0.51.

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There was an accident reduction of 49 %. This estimate is, however, not likely to be a correct estimate of the effect of ISA. Drivers with ISA reported a higher number of accidents before the trial than drivers without ISA. One may therefore suspect that part of the accident reduction found among drivers with ISA is a result of regression-to-the-mean.

An estimate of the likely size of the regression-to-the-mean effect was obtained by assuming that 85 % of the variation in the number of accidents in a population of drivers is random. The long-term expected number of accidents per driver per year among the drivers with ISA can then be estimated as $(0.85 \cdot 0.0501) + (0.15 \cdot 0.1044) = 0.0582$. When this estimate is applied, the decline in the number of self-reported accidents becomes 9 %.

The same study reported that the number of police-reported accidents per driver per year was 0.0027 (before) and 0.0092 (after) for drivers with ISA. For drivers without ISA the corresponding numbers of accidents per driver per year were 0.0042 (before) and 0.0046 (after). These numbers suggest that using ISA is associated with an increase in the number of accidents. However, drivers with ISA had a lower number of accidents in the before-period than drivers without ISA (0.0027 versus 0.0042). Part of the increase in the number of accidents could therefore be the result of an upward regression-to-the-mean from an abnormally low number of accidents in the before-period.

It may be concluded that the effect on accidents of ISA cannot be reliably estimated on the basis of the trials reported so far. These trials have been too small to provide a satisfactory statistical basis for estimating effects on accidents. The safety effects of ISA will be estimated by relying on the effects on speed and models of the relationship between changes in speed and changes in road safety (Elvik 2011A).

Based on the ISA-trial in Lund (Varhelyi et al. 2004), the expected effects of ISA on the number of injury accidents can be estimated to a reduction of between 0 and 12 %, depending on speed limit. ISA did not have any effect when initial speed was below the speed limit, which was the case on the main urban streets in Lund.

If all motor vehicles had ISA, it is in principle possible to obtain a reduction in the number of accidents and injured road users which is close to the risk attributable to speeding, as estimated in section 3.2.1.

3.2.4 Effect on travel time

The effects on travel time of a widespread use of ISA have been estimated by means of a simulation programme for the city of Leeds (Liu and Tate 2004). If all cars had ISA, mean travel time during the rush hours was estimated to increase by 2.6 %. Outside of rush hours, mean travel time was estimated to increase by 6.4 %. For the whole day, the increase in mean travel time was estimated to be 4.1 %. Estimates were based on the assumption that all cars had mandatory ISA. The estimates controlled for the relationship between traffic volume and travel time (the volume-delay relationship).

For Norway, an estimate of the total travel time on public roads indicates that perfect compliance with speed limits would be associated with an increase of 5.6 % in total travel time. To develop the estimate, current mean speeds and the mean speeds estimated for 100 % compliance with speed limits were converted to travel time per kilometre.

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3.2.5 Effect on the environment

Fuel consumption, noise and emission are all related to speed. Model estimates for the city of Leeds (Liu and Tate 2004) indicate that if all cars had mandatory ISA, fuel consumption would be reduced by 8 %. The emissions of CO_2 would be reduced by the same %age. The estimates further indicated a 2 % reduction in CO-emissions. The emission of NO_x would not change, according to these estimates. With respect to the emission of HC (hydrocarbons) a small increase (not statistically significant) of 1 % was estimated. Similar estimates for the city of Lund (Varhelyi et al. 2004) indicated an 11 % reduction in CO-emissions, a 7 % reduction in NO_x-emissions, and an 8 % reduction in HC-emissions.

On the whole, these studies suggest that ISA may lead to a small reduction in air pollution. When speed is very low (below 30 km/h) emissions increase. However, only a small share of all traffic takes place at such low speeds and ISA is unlikely to influence low-speed traffic, since it is most commonly associated with congestion in urban traffic. No studies reporting the effect of ISA on traffic noise have been found. Noise increases as speed increases; a widespread use of ISA might therefore be associated with a reduction in traffic noise.

3.2.6 Behavioural adaptation to ISA

Few studies have been made regarding behavioural adaptation to ISA. Almqvist (2006) reported that the interaction between car drivers and other road users improved when ISA was used. Drivers who initially had a negative opinion about ISA became more positive to the system when they had tested it. Wallén Warner and Åberg (2008) studied the long-term effects of ISA in the city of Borlänge. They found that the effect diminished over time. Speeding was greatly reduced the first year, but increased again the second and third year, almost reaching the level before the ISA-trial started.

Adell (2009) studied how drivers in Lund experienced driving with ISA. Drivers reported that they had the impression their speed was lower – an impression that was confirmed by speed measurements. Moreover, drivers stated that they felt it was more demanding to drive with ISA than without the system and that the pleasure of driving had been reduced. A reduced chance of getting a ticket for speeding was reported as the most important benefit of ISA.

In a simulator study, Young et al. (2010) did not find an effect of ISA on headway or reaction time.

Jensen (2010) surveyed studies of behavioural adaptation to ISA. He concluded that there were both adaptations that would be expected to increase safety and adaptations that would be expected to reduce safety. The former included better compliance with priority rules in junctions and the duty to give way to pedestrians crossing the road in marked crossings. The latter included a poorer adaptation to difficult road surface conditions and the acceptance of smaller gaps in traffic when entering major roads. No attempt was made to quantify the effects and it is not known whether the net effect of the behavioural adaptations is favourable or adverse for safety.

Adell et al. (2011) studied 20 drivers who drove a 50 kilometre route in real traffic near the city of Turin, Italy. Reaction times were shorter when ISA was activated than when the system was turned off. Drivers did not report that driving required more effort with

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ISA than without ISA. Driver behaviour became more erratic with ISA. When ISA was active, drivers on the average crossed the centre line of the road 2.24 times, as opposed to only 1.12 times when ISA was not active. The number of lane changes was reduced when ISA was used. On the other hand, drivers braked hard to avoid red light running more often when ISA was on than when it was off.

Jamson, Chorlton and Carsten (2011) used a driving simulator to study overtaking behaviour with and without ISA. When voluntary ISA was used, drivers reduced attempts to overtake from 117 to 114. When mandatory ISA was used, the number of attempts to overtake was reduced from 120 to 78. The overtaking manoeuvres that were completed took longer with ISA than without and were associated with smaller safety margins.

Lahrmann et al. (2011) found that the effects of ISA on speed disappeared immediately when the trial was completed and ISA removed.

The results of these studies are fragmentary and not entirely consistent. There are, for example, both indications that drivers find it more demanding to drive with ISA than without (Adell 2009) and indications that driving with ISA is not more demanding than driving without it (Adell et al. 2011). Changes in reaction time appear to be minor and there is nothing to suggest that ISA makes drivers less alert, leading to longer reaction times. Harder braking for traffic signals may be an adaptation to the diminished opportunities for accelerating fast to clear a junction before the signals turn red; thus drivers are forced to stop. ISA is associated with less frequent overtaking. The studies quoted above do not suggest that drivers adapt behaviour in response to ISA to such an extent as to eliminate the favourable impacts on safety ISA has by reducing speed. It is reasonable to believe that the effects of ISA are mainly generated by its impact on speed and that it influences other risk factors less and most likely not to such an extent as to offset the favourable impacts on speed.

3.2.7 Driver attitudes to ISA

There have been many surveys of driver attitudes to ISA. The most relevant survey for Norway is the periodic survey of "Road user knowledge and attitudes regarding road safety". This survey was first made in 1998 and it has since been repeated a number of times. The most recent survey was reported in 2011. Driver attitudes to ISA are shown in Figure 3.1.1.

Drivers were asked to state their agreement with the statement: " There should be a device in the car making it unpleasant to exceed speed limits". A reasonable interpretation of this statement is that it refers to a voluntary ISA, i.e. an ISA system the driver can override if he or she wants to do so.

Figure 3.1.1 shows that a clear majority of drivers do not want such a device in the car. One may perhaps discern a weak tendency for the opposition to ISA to reduce over time and support for ISA to increase, but the pattern is irregular. It would seem that only a minor of drivers in Norway would purchase cars with ISA.

There is a remarkable difference between drivers in Norway and drivers in Sweden with respect to their opinions about ISA. In Sweden, 55 % agreed to the statement: "All cars ought to have a technical device that helps the driver comply with speed limits" (Trafikverket 2010). However, the statements referring to ISA were not identical in the two surveys; this may have influenced the results.

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In another study, drivers in Denmark, Norway and Sweden were asked about their attitudes to ISA (Bjørnskau et al. 2010; Eriksson and Bjørnskau 2012). This study found that drivers are rather positive to the use of ISA. When asked whether ISA ought to be installed in all cars, 34 % are positive in Sweden, 34 % in Norway and 40 % in Denmark. When the condition is added that ISA ought to be installed for drivers who have a high accident rate or have been convicted for speeding, support for ISA is 75 %, 84 % and 67 % in, respectively, Sweden, Norway and Denmark.

There is a two-way relationship between attitudes and behaviour. Some people who were initially negatively inclined to a technical device that would help them to comply with speed limits might change their opinion when they have tested the system. In Sweden driver understanding of ISA and opinion about it were studied when drivers has been using ISA for a period of six months to one year (Adell and Varhelyi 2008). Drivers who were initially positive to ISA (voluntary ISA) remained so after having tested the system (86 % remained positive). Among drivers who were negative to ISA, 59 % supported ISA after having tested it. Only 14 % remained negative. It therefore cannot be ruled out that testing ISA may change the attitudes drivers have towards the system.

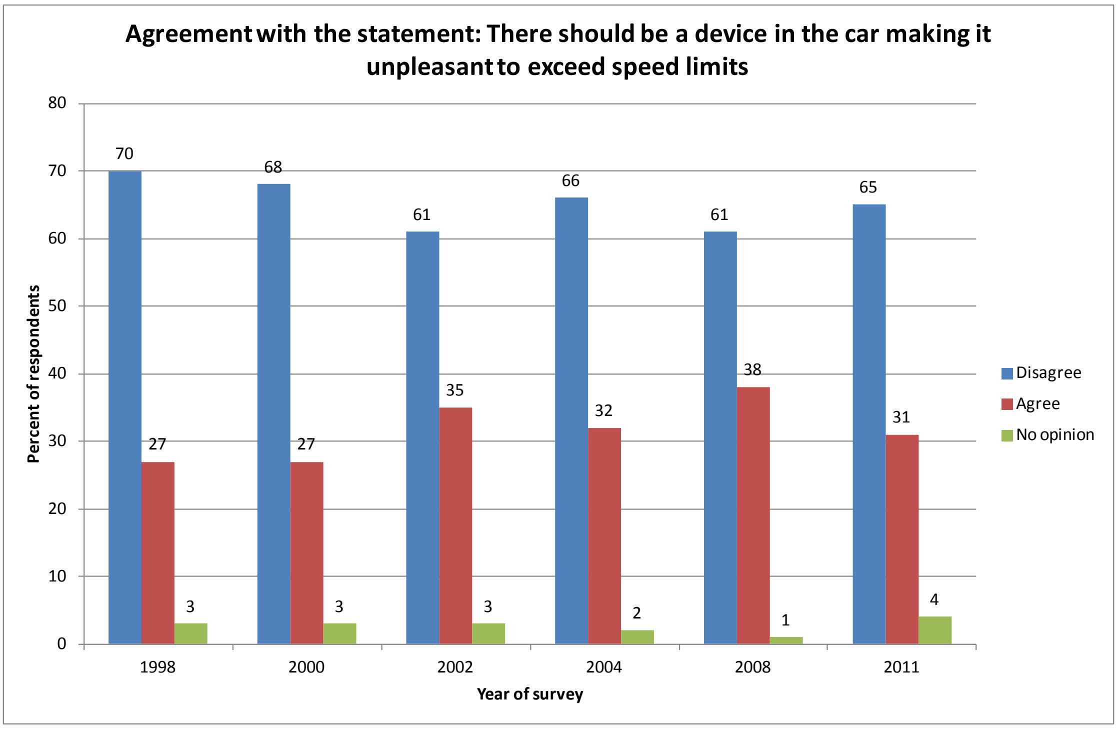

Figure 3.2.1: Driver agreement with the statement: There should be a device in the car making it unpleasant to exceed speed limits. N = about 1.500 in all surveys.

An issue that might arise if car manufacturers start offering ISA as add-on equipment on cars, is whether add-on ISA would be purchased by those who need it the most or by more cautious drivers who rarely exceed speed limits. A study in Leeds (Jamson 2006) sheds light on this question. The study was conducted both in real traffic and in a driving simulator. Drivers were driving cars with an ISA device they could switch on and off as they pleased. The study found that drivers who indicated that they enjoyed fast driving and often violated speed limits, switched off ISA more often than drivers who indicated that complying with speed limits was important. There was, in other

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words, a tendency that those who needed ISA the most were least inclined to switch it on

3.2.8 Costs of ISA

The most updated source of data regarding the costs of ISA is a British cost-benefit analysis (Lai, Carsten and Tate 2011). The current costs of installing ISA in new cars were estimated to 90 UK Pounds for voluntary ISA and 200 UK Pounds for mandatory ISA. These costs were expected to drop to 60 UK Pounds (voluntary ISA) and 135 UK Pounds (mandatory ISA) by 2020. The costs of retrofitting ISA to older cars were estimated to 247 UK Pounds in 2010 for voluntary ISA and 357 UK Pounds for mandatory ISA. The costs of retrofitting ISA were assumed to increase in future years.

The costs of updating digital maps containing speed limits were not specified, but it was stated that these costs are small compared to the costs of installing ISA.

In the short term the most realistic option is to retrofit ISA. It is unlikely that car manufacturers will offer ISA as standard equipment in the near future. For the cost-benefit analyses reported below, a cost of 357 UK Pounds for installing ISA has therefore been assumed. Applying the exchange rate for 2010, this corresponds to 3,334 Norwegian kroner (NOK). Adjusted to purchasing power parity, the cost in Norwegian currency becomes 5,072 NOK. This is rounded to 5,000 NOK. The annual cost of updating digital maps is assumed to be 100 NOK per car.

3.2.9 Cost-benefit analysis of ISA

A cost-benefit analysis of ISA has been performed. In any cost-benefit analysis, it is important to be clear about the perspective adopted, as different perspectives may produce different results. A distinction can be made between two main perspectives: the driver perspective and the societal perspective. In the societal perspective, benefits in terms of accident cost savings are fully included. In the driver perspective, on the other hand, only 60 % of accident cost savings are included. The rest of these savings are assumed to be external from the driver's point of view, i.e. about 40 % of the societal costs of accidents are covered by the public sector or third parties (Elvik 1994).

Accidents may cause travel delays. The benefits of avoiding such delays are fully included both in the driver perspective and the societal perspective. Savings in travel time obtained by violating speed limits are not included in the societal perspective. Benefits that are obtained by unlawful acts should not be included as a societal benefit in cost-benefit analyses adopting a societal perspective. These benefits are, on the other hand, included when the driver perspective is adopted, since it is reasonable to assume that drivers violate speed limits because they gain something from doing so.

There is a small increase in travel time that should be included in a cost-benefit analysis irrespective of the perspective adopted. This increase is attributable to the fact that maximum speeds are likely to be slightly below speed limits when all cars have ISA. It has been estimated that 7 % of the travel time added by a universal use of ISA refers to speeds below speed limits. Most of the added travel time is therefore attributable to the elimination of speeding.

ISA may also reduce vehicle operating costs, primarily because these costs increase when driving faster than 70 km/h. Savings in vehicle operating costs are fully included in the analyses relying both on the driver perspective and the societal perspective. ISA

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may reduce the environmental impacts of driving. Gains for the environment are fully included in the societal perspective, but not included at all in the driver perspective, because these gains are presumed to be external from the driver's point of view (Elvik 2010B). Table 3.2.3 summarises the items included in cost-benefit analysis according to the two perspectives.

Table 3.2.3: Items included in cost-benefit analysis of ISA in the societal perspective and driver perspective

Benefit or cost	Societal perspective	Driver perspective
Accident cost savings	100 % included	60 % included
Less delays due to fewer accidents	100 % included	100 % included
Added travel time by complying with speed limits	Not included	100 % included
Added travel time for speeds below speed limits	100 % included	100 % included
Lower vehicle operating costs	100 % included	100 % included
Reduced noise and pollution	100 % included	Not included
Costs of installing ISA	100 % included	100 % included
Updating of digital maps	100 % included	100 % included

The results of a cost-benefit analysis in which it was assumed that 100 % of cars in Norway have ISA are reported in Table 3.2.4. All values are in million NOK and have been discounted to present values using a discount rate of 4.5 % per year. From a societal perspective, benefits are greater than costs. From the driver perspective, benefits are negative. The main reason for this is that drivers lose the benefits they currently get from speeding. These benefits are not included in the analysis relying on the societal perspective, but it was judged as most correct to include them in the analysis adopting the driver perspective, since drivers presumable get some benefit out of speeding. It does not matter what name we give these benefits: time savings, greater enjoyment, the feeling of control, or whatever. The benefits have, however, been valued according to the value of travel time savings.

If 100 % of cars in Norway have ISA, one may, based on an average for the years 2009 and 2010, expect the annual number of fatalities to be reduced by 41, the annual number of seriously injured road users to be reduced by 98 and the annual number of slightly injured road users to be reduced by 527.

Cost-benefit analysis has been performed for the following alternative levels of implementation of ISA:

- Young drivers aged 18-20
- Young drivers aged 18-24
- Professional drivers
- Drivers convicted of serious speeding offences

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Table 3.2.4: Results of cost-benefit analysis of ISA from two perspectives

	Amount in million NOK – present values	
Benefits or costs	Societal perspective	Driver perspective
Accident cost savings	22,339	13.,03
Less delay due to fewer accidents	128	128
Added travel time by complying with speed limits	0	–56,713
Added travel time by driving slightly below speed limits	–4,170	–4,170
Reduced vehicle operating costs	2,155	2,155
Less noise and air pollution	2,854	0
Total benefits	23,305	–45,197
Costs of installing ISA	11,629	11,629
Updating of digital maps	2,955	2,955
Total costs	14,584	14,584
Net present value	8,721	–59,781
Benefit-cost ratio	1.60	Not defined

The analyses of these levels of implementation are based on the analysis of 100 % implementation, as reported in Table 3.2.4. The analyses have adopted the societal perspective. The driver perspective has been disregarded in the analyses of using ISA in selected groups of drivers.

The first option, ISA for drivers aged 18-20 years, was assessed by relying on the data provided by Bjørnskau (2009) regarding the amount of driving and the involvement in accidents of this group of drivers. Drivers aged 18-20 perform 3.3 % of all kilometres of driving in Norway. They are involved in 12.7 % of injury accidents. They represent 14.3 % of all injured car occupants and 16.4 % of all car occupant fatalities. As a rough approximation, it was assumed that ISA must be installed in 3.3 % of all cars; i.e. the share of cars that needs to have ISA is identical to the share of all kilometres driven by drivers aged 18-20. The costs of installing ISA can then be estimated as 481 million NOK.

The benefits of ISA for drivers aged 18-20 have been estimated as 12 % of the fatality reduction obtained by 100 % implementation, 11 % of the reduction of seriously injured road users obtained by 100 % implementation, and 10 % of the reduction of slightly injured road users obtained by 100 % implementation. These estimates were obtained by assuming (Bjørnskau 2009) that there are 1.6 drivers in this age group involved in injury accidents for each injured driver aged 18-20. The benefits in terms of accident cost savings were estimated (present value) to 2,569 million NOK. Other benefits were assumed to be 3.3 % of the benefits of 100 % implementation of ISA. Total benefits were estimated to 2,612 million NOK; total costs to 481 million NOK. The benefit-cost ratio is 5.43. This is considerably more favourable than for 100 % implementation, which is not surprising considering the high rate of accident involvement among young drivers.

For the second option, the same approach was adopted as for the first option. The only difference was that the age group includes drivers aged between 18 and 24, not just 18 and 20. Drivers aged 18-24 perform 9.1 % of all kilometres driven in Norway. They are involved in 22.9 % of injury accidents; constitute 25.3 % of all injured car occupants and 25.5 % of all killed car occupants. The cost-benefit analysis by making the same

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assumptions as for drivers aged 18-20 years. Drivers aged 18-24 were assumed to represent 19 % of all killed or injured road users. Benefits were estimated to 4,349 million NOK. Costs were estimated to 1,327 million NOK. Benefit-cost ratio is 3.28. Again, this is more favourable than for 100 % implementation, but less favourable than ISA for drivers aged 18-20.

The third option is to require ISA for professional drivers. The share of all driving in Norway performed by professional drivers is not known precisely. The annual report on transport in Norway (Vågane and Rideng 2011) provides information on kilometres driven by different types of vehicles. Buses, taxis and large trucks perform 6.3 % of all kilometres driven in Norway. All these vehicles are presumably driven by professional drivers. Small goods vehicles are used both for professional and private driving. These vehicles are often used by electricians, plumbers or other workers who tend to drive a lot as part of their jobs. Job-related driving does not mean that the drivers are professional, merely that their job involves a lot of driving. Vågane and Rideng state that 70 % of driving with small goods vehicles can be classified as goods transport. Small goods vehicles performed a total of 7,390 million vehicle kilometres of travel in 2010. If 70 % of this is regarded as professional driving and added to kilometres performed by buses, taxis and large goods vehicles, the share of professional driving in Norway becomes 18 %. This is judged to be on the high side and is therefore rounded down to 15 %.

Vehicles used in professional driving have a larger mass than other vehicles. Based on information about vehicles involved in accidents during 1998-2005, it is estimated that vehicles used in professional driving are involved in 30 % of fatal accidents, 20 % of accidents with serious injuries and 15 % of accidents with slight injuries. The benefits of ISA have been estimated by relying on these shares. Total benefits then become 5,588 million NOK. Total costs were estimated to 2,188 million NOK. The benefit-cost ratio is 2.55. This is better than the ratio when 100 % of cars are equipped with ISA (1.60).

The fourth option is to require drivers convicted of serious speeding offences to have ISA installed in their cars. More than 100,000 drivers get traffic tickets for speeding each year in Norway. However, most of the violations are not serious and drivers who merely get tickets are not treated as "convicted". The group classified as convicted are drivers who get their license withdrawn as a result of speeding. Drivers who lose their license will typically have exceeded speed limits by at least some 40-50 kilometres per hour.

According to police statistics, about 6,000 drivers lose their license each year as a result of speeding. The mean annual distance driven by these drivers is not known, but an average of 15,000 kilometres – which is slightly above the mean for all drivers in Norway – has been applied. Drivers losing their license as a result of speeding will then drive 90 million kilometres per year. This makes up about 0.2 % of all vehicle kilometres driven in Norway. It is reasonable to expect the high-speed drivers to have a higher rate of accident involvement than other drivers. They have been assumed to be involved in 0.5 % of fatal accidents, 0.4 % of all serious injury accidents, and 0.3 % of all slight injury accidents. It has been assumed that ISA is installed in the car as part of the punishment for speeding. 6,000 cars will annually have ISA installed.

Benefits have been estimated to 100 million NOK, costs to 29 million NOK. Benefit-cost ratio is 3.41.

Thus, all the analyses suggest that selectively introducing ISA in high-risk groups is more cost-effective than introducing it in all cars. In all options considered, benefits were clearly greater than costs.

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3.2.10 A discussion of scenarios for introducing ISA

ISA offers a definitive solution to a long-lasting road safety problem: speeding. Although a tendency has been seen in recent years for mean speeds to go down, speeding remains widespread and contributes more to road accident fatalities and injuries than any other known risk factor.

It is not always possible to find a technical solution to a social problem. When a technical solution to a problem is found, it is normally introduced quickly. Thus, vaccines have virtually eradicated a number of diseases that used to be common (smallpox, tuberculosis, measles, polio). The history of road safety, on the other hand, provides several examples of life-saving technology that took a long time to be fully utilised. Thus, seat belts were invented and widely available for many years before their use became compulsory. Although it has been largely forgotten today, many countries did not have general speed limits until the first energy crisis in 1973. Denmark and Finland, for example, did not have speed limits on all public roads before 1973.

If ISA is to become standard equipment on cars, there must be international agreement on this in the international organisations that set vehicle safety standards. It is not possible for a single country, except perhaps some of the largest countries in the world, to unilaterally require cars to have ISA. A unilateral requirement will most likely be regarded as discriminatory and a violation of free trade.

However, there is nothing to prevent a country from trying to stimulate a voluntary use of ISA. To make the use of ISA common, strong policy instruments may be needed. In a British study of willingness-to-pay for ISA (Chorlton et al. 2011) was surveyed in three groups of drivers. The first group consisted of 490 drivers who had indicated that they were willing to buy mandatory ISA. The second group consisted of 503 drivers who had indicated that they were willing to buy voluntary ISA. The third group consisted of 466 drivers who had indicated that they were not willing to buy any form of ISA. A stated-preference survey was designed for each of these groups in order to reveal how much they were willing to pay for ISA or if they were willing to buy it at all.

The first group was given a choice between mandatory and voluntary ISA. A price was charged for both systems. The price was between 0 and 9 % of the total price for the next car the drivers were intending to buy for mandatory ISA and between 0 and 4 % for the price of the car for voluntary ISA. If a voluntary ISA was bought, drivers were offered a bonus for complying with speed limits of up to 2 pence per mile driven for an annual driving distance of up to 20,000 miles. Thus, the maximum bonus that could be earned was 400 UK Pounds per year.

The second group was offered a rebate on the price of the car in order to buy mandatory ISA. The rebate amounted to between 5 and 50 % of the price of the car. These drivers still had to pay for voluntary ISA (between 0.5 and 8 % of the price of the car). They were also offered a bonus if buying a voluntary ISA on the same terms as group 1.

The third group, initially the one most sceptical to ISA, were offered a rebate of 15-40 % of the car price to buy mandatory ISA and 0-20 % to buy voluntary ISA. They were also offered a bonus for complying with speed limits.

Price, rebate and bonus were varied systematically in order to determine the probability that drivers would buy a car with a specific type of ISA. In the first group, most favourably inclined to ISA, the probability that drivers would buy a car with mandatory

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ISA was estimated as 70 %; the probability that they would buy a car with voluntary ISA was estimated as 33 %. In the second group, the probability of buying mandatory ISA was estimated as 52 %, the probability of buying voluntary ISA as 35 %. In the third group, the probability of buying mandatory ISA was estimated as 24 %; the probability of buying voluntary ISA as 26 %. A large majority of drivers in this group were, in other words, not willing to buy any form of ISA even when the price of the car was cut by 40 % and a bonus of up to 400 UK Pounds per year was offered.

A Swedish study (Adell and Varhelyi 2008) found that only 35 % of drivers who had tested ISA were willing to pay anything at all for the system. The mean willingness-to-pay of these 35 % was 841 SEK. This is considerably less that the cost of retrofitting ISA to older cars, which is about 5,000 SEK per car. Indeed, 841 SEK is smaller than even the lowest cost stated by Lai, Carsten and Tate (2011).

Based on these studies, it must be regarded as unlikely that ISA will be widely demanded as add-on equipment on cars, either new or old. Owners of car fleets, such as the military or the postal service may choose to install ISA in their fleets. If the experience in using ISA in fleets is favourable, this may generate some positive publicity that might persuade ordinary car owners that ISA is a good idea. In principle, one may also stimulate the demand for ISA by a massive deployment of speed cameras. More drivers will then appreciate the benefits of ISA as a help to avoid tickets for speeding.

3.2.11 Interaction between ISA and other road safety measures

As part of the development of the National Transport Plan (NTP) for the 2014-2023 term, the Institute of Transport economics was asked to estimate the reduction of the number of road accident fatalities and serious injuries that may be attained if certain objectives regarding road user behaviour are attained (Elvik 2011B). One of the objectives referred to compliance with speed limits. If this objective is realised, the potential for ISA to further improve safety will be reduced. The estimates were updated in 2012. It was found that if all objectives regarding road user behaviour in NTP are realised, there will be a reduction of the number of fatalities and seriously injured road users to 645 by 2024. Assuming that there will be a greater reduction of the number of road accident fatalities than of the number of seriously injured road users, the predicted number of fatalities in 2024 is 130; the predicted number of seriously injured road users is 515 and the predicted number of slightly injured road users 6,160. This means that ISA will have fewer fatalities and injuries to influence.

If the numbers above are applied, the effects of a 100 % implementation of ISA in 2024 can be estimated to a fatality reduction of 25 per year, a reduction of seriously injured road users of 69 per year and a reduction of slightly injured road users by 400 per year. Benefit-cost ratio is estimated to be 1.08. This means that benefits still exceed costs, although by a smaller margin than in the main analysis.

It may thus be concluded that even if the NTP 2014-2023 is successful in achieving the accident- and injury reductions it aims for, ISA will remain a cost-effective policy option by the year 2024. The current monetary valuation of road safety has been applied. It is, however, highly likely that this monetary valuation will be adjusted upward before 2024. It is also likely that the costs of installing ISA will be lower in 2024 than they are now.

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3.3 Top speed governor

3.3.1 Problem and objective

According to in-depth studies of fatal accidents made by the Public Roads Administration, speed well above speed limits or otherwise poorly adapted to prevailing conditions was a contributing factor to 41 % of fatal accidents in 2010 (Haldorsen 2011). A speed well above speed limits is a speed that would lead to the loss of the driving license. On roads with a speed limit of 80 km/h, this means a speed of at least 120 km/h. Speeds exceeding speed limits by this margin contributed to 14 % of fatal accidents in 2010 (Haldorsen 2011). By comparison, it has been estimated that only about 0.2 % of all kilometres driven in Norway are driven at such high speeds (Elvik 2010B). These numbers clearly suggest that high speeds increase the risk of becoming involved in a fatal accident considerably.

A measure that may prevent driving at very high speeds is a top speed governor. This is a technical device that makes it impossible to drive faster than a certain maximum speed. Mopeds and heavy vehicles have top speed governors. For mopeds, the permitted maximum speed is 45 km/h. For heavy vehicles (gross weight 3.5 metric tons or more), the maximum permitted speed is 90 km/h. Other motor vehicles do not have a top speed governor.

Most passenger cars and motorcycles can be driven at speeds of around 150-200 km/h. The highest speed limit on public roads in Norway is 100 km/h. An older Norwegian study (Fosser and Christensen 1992) found that engine tuning of mopeds increased their accident rate. The study compared the accident rate of ordinary mopeds to those that had been tuned to attain a higher top speed. The results are presented in table 3.3.1.

Table 3.3.1: Relative accident rate of tuned-up mopeds compared to mopeds not tuned-up

Accident severity	Types of accident influenced	Best estimate	95 % confidence interval
	Relative accident rate of tuned-up mopeds		
Injury accidents	All	1.48	(1.10; 2.01)
Property damage only accidents	All	1.18	(1.03; 1.37)

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Tuning up mopeds increases the risk of accident. When the relative accident rates given in Table 3.3.1 are combined with data concerning the distances driven by tuned-up mopeds and mopeds not tuned-up, the risk attributable to tuning-up can be to 0.25 (0.06; 0.59) for injury accidents and 0.11 (0.02; 0.23) for property damage only accidents. Thus, if no mopeds were tuned up, injury accidents could be reduced by 25 % and property damage only accidents by 11 %. Attributable risk was estimated as follows:

$$\text{Attributable risk} = \frac{PE \cdot (RR-1)}{(PE \cdot (RR-1\,) + 1)}$$

PE denotes the share of exposure with tuned-up mopeds. RR denotes the relative risk of tuned-up mopeds. Relative risk, see Table 3.3.1, is 1.48 for injury accidents and 1.18 for property damage only accidents. For injury accidents, attributable risk is estimated as follows:

$$\text{Attributable risk of injury accidents} = \frac{0.69 \cdot 0.48}{(0.69 \cdot 0.48)+1} = 0.248 = 25\ \%$$

The objective of a top speed governor is to prevent driving at high speeds and thus prevent accidents that are attributable to high speeds.

3.3.2 Description of the system

A top speed governor is not intended to prevent driving at legal speeds. For vehicles that currently do not have a top speed governor, the maximum speed which activates the governor can therefore not be set lower than the maximum speed limit. The maximum speed limit in Norway is 100 km/h. To permit driving at this speed, a top speed governor would probably only start to operate at a speed of about 110 km/h.

Direct fuel injection regulated electronically is the modern system for regulating the supply of fuel to the engine. A top speed governor could be linked electronically to the speedometer and cut or reduce fuel supply when the vehicle reached the preset maximum speed. Accelerating beyond this speed would then become impossible. A top speed governor set at 110 km/h would not prevent violations of lower speed limits and would tolerate small violations of a speed limit of 100 km/h.

Many modern cars have cruise control. By engaging cruise control, the car can be set to drive at a constant speed. Cruise control is, however, not a top speed governor and may be disengaged at any time by touching the gas pedal.

3.3.3 Effect on accidents

No studies have been found documenting the effect on accidents of a top speed governor, except for the study of tuning-up of mopeds quoted above. Older studies comparing the accident rate of car models with different speed performance indicate that cars with a high top speed are more often involved in accidents than cars with a low top speed (Elvik et al. 1997). Most of these studies have, however, not controlled for driver characteristics. It is not unlikely that fast cars may attract certain groups of drivers more than others.

A top speed governor preset at 110 km/h will have small effects on accidents occurring on roads with speeds limits of 70 km/h or less. It would still be possible to exceed a speed limit of 70 km/h by nearly 40 km/h. It is therefore reasonable to assume that a 110 km/h top speed governor would only influence accidents for speed limits of 80 km/h or more. For the years 2009 and 2010, there were, on the average 122 killed, 343

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seriously injured road users and 2,721 slightly injured road users in Norway for speed limits of 80, 90 or 100 km/h.

The report on in-depth studies made in 2010 (Haldorsen 2011) does not state whether high-speed accidents are more common for some speed limits than for others. Very high speed was estimated to contribute to 14 % of fatal accidents. It will be assumed that this share is the same for all speed limits. Thus, very high speeds will be defined as 120 km/h or more for the 80 km/h speed limit, 130 km/h or more for the 90 km/h speed limit and 140 km/h or more for the 100 km/h speed limit.

A 110 km/h top speed governor would reduce the speed of high-speed accidents from 120 to 110 km/h for the 80 km/h speed limit; from 130 to 110 km/h for the 90 km/h speed limit, and from 140 to 110 km/h for the 100 km/h speed limit. The effects of these changes have been estimated to reduce the annual number of fatalities by 8 (from a base of 210), the annual number of seriously injured road users by 16 (from a base of 755), and the annual number of slightly injured road users by 77 (from a base of 8,105). These effects are too small to develop meaningful estimates for certain groups of drivers, like young drivers.

A top speed governor will have considerably smaller effects on accidents than an ISA system.

3.3.4 Effect on travel time

A 110 km/h top speed governor will have negligible impacts on travel time. It can be estimated that about 1.2 % of vehicle kilometres on roads with a speed limit of 90 km/h are driven above 110 km/h. About 6.7 % of all kilometres driven on roads with a speed limit of 100 km/h are driven above 110 km/h. For all roads in Norway, in the order of 0.5 % of all kilometres driven are driven at a speed of 110 km/h or more. A top speed governor at 110 km/h would therefore have almost no effect on the mean speed of traffic.

A speed of 110 km/h is illegal, since the highest speed limit in Norway is 100 km/h. Travel time gained by driving at this speed does not represent any societal benefit and is, accordingly, not included in a cost-benefit analysis (Elvik 2006).

3.3.5 Effect on the environment

At high speeds, fuel consumption, noise and emissions increase. A top speed governor would restrain these effects, but overall effects would be marginal, given the fact that only about 0.5 % of all traffic in Norway takes place at speeds that would be curbed by a top speed governor.

3.3.6 Costs

We have not been able to find cost estimates for a top speed governor. Since the technology is simpler than ISA technology, it seems likely that costs would be lower. In the cost-benefit analysis below, a cost of 1,000 NOK per car has been assumed.

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3.3.7 Cost-benefit analysis

Based on safety effects estimated above, the benefits (present value) of a top speed governor installed in all motor vehicles in Norway have been estimated as 3,642 million NOK. Installing a top speed governor in all motor vehicles in Norway would cost about 3,000 million NOK.

It would therefore appear that benefits are larger than costs, but the results are highly uncertain.

3.3.8 Implementation of a top speed governor

In the discussion above, a 110 km/h top speed governor was used as an example. It is unlikely that Norway unilaterally could require such a top speed governor as standard equipment on motor vehicles. Such a decision would probably be viewed as discriminatory. The only possibility of having a top speed governor introduced is therefore to reach agreement on this in international bodies that set vehicle safety standards. Moreover, a top speed governor would have to be set at a speed above the highest speed limit in Europe, which is currently 130 km/h. German motorways do not have a speed limit, but a recommended maximum speed of 130 km/h. Thus, the lowest speed for a top speed governor would probably be 140 km/h.

If set at 140 km/h a top speed governor would have no effect, or at best a very small effect on road safety in Norway.

It is therefore not regarded as informative to estimate costs and benefits of a top speed governor for specific groups of drivers, like young drivers, professional drivers or drivers convicted of speeding.

3.4 Alcohol Ignition Interlock - Alcolock

Alcohol Ignition Interlock or Alcolock for short is a device connected to the ignition of a motor vehicle. This device compels the driver to blow before starting the engine. If there is alcohol above a certain limit in the driver's breath, the ignition will not start.

The alcolock is constructed to be able to distinguish between a human blowing and technical devices such as a pump, a balloon or other devices which could be used to blow air into the alcolock handset. The alcolock can be set for blowing only when starting the vehicle or for repeated blows during driving. The latter can be used if there is a risk that someone else than the driver will be blowing at the start or in case of suspicion of drinking during driving. Alcolocks can also recognize the blowing of specific persons, thus preventing other people than the designated driver from blowing.

3.4.1 Questions to be answered

The most important question for alcolocks is the same as for the other devices, i.e. the effect on road accidents. To answer this question it is necessary to discuss the ways alcolocks can be used, the necessary legislative and organizational support, the conditions to the implementation of alcolocks and the further technical development of alcolocks.

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3.4.2 Methods

The most important method is literature and document analysis. Moreover, a short questionnaire has been administered to nine alcolock experts, two in Sweden, two in Canada, one in the US, one in Germany, one in the Netherlands and one in Spain. Four of these experts have replied, and their replies have contributed importantly to the information on which this chapter is based. This small survey has been followed up by literature such and questions to other experts.

3.4.3 The effects depend on the application

The effects of alcolocks depend on the rules, in what way and by whom it is applied, and incentives to support the use of alcolocks as well as programmes to follow up the users. Most motor vehicle drivers cannot be expected to purchase alcolocks on their own initiatives and at their own costs. To be implemented alcolocks will have to be compulsory or strong incentives would have to support the use of alcolocks.

3.4.4 Alcolocks in all cars – a long term goal?

Some 0.3 % of all driving in Norway is carried out by drivers having a blood alcohol concentration (BAC) above the legal limit of 0.2 g/L, and only 0.07 % of the driving is done by drivers having a BAC above 0.5 g/L (Gjerde et al, 2011, p. 25). Installing alcolocks only in the cars used for drinking and driving, would be impossible. If all driving above the legal BAC limit should be prevented by alcolocks, also the 99.7 % of the vehicles not used for drinking and driving, would have to have alcolocks installed. Such an extensive implementation of alcolocks would be costly. The 99.7 % of the Norwegian drivers who do not drink and drive, would consider the alcolocks an unnecessary nuisance. Consequently, the mandatory installation of alcolocks in all motor vehicles at the present costs and way of handling, cannot be expected. Sweden had an ambition of making alcolocks mandatory in all new vehicles from 2012. This ambition had to be abandoned, most likely because of resistance from the European Union (Transportstyrelsen, 2010). Sweden is now working on a small-steps policy towards alcolocks in all motor vehicles (Alkolåsnytt 1 – 2010). Alcolocks in school transport is the first step according to a proposal from Transportstyrelsen (2010).

3.4.5 Other possibilities

If alcolocks are not made mandatory for all motor vehicles, the question arises whether alcolocks can be used can be applied for certain target groups, i.e. drivers being likely to drink and drive. Alcolocks made mandatory for drivers unlikely to drink and drive, would have a most limited effect on road accidents.

3.4.6 Alcolocks for drink-driving offenders

The most frequent application of alcolocks is to offer alcolock as an alternative to withdrawal of the driver's license for drink-driving offenders, willing to comply with a special programme. If fulfilling certain criteria, the offenders gain the right to drive a car equipped with alcolock, but no other cars. Such programmes may include medical check-ups of alcohol consumption at certain intervals, rehabilitation, and a course in drink-driving risks. Such programmes exist in Canada, the US and Sweden. The

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Norwegian Ministry of Justice and Public Security has appointed a committee to enquire into this matter. This committee published its report in September 2012 (Harestad et al. 2012).

To make alcolocks effective for offenders, rules concerning the application of the alcolock are needed, e.g. that the right to drive a car equipped with alcolock can be a legal alternative to license withdrawal, the conditions to this alternative, and the contents of a follow-up programme.

New Mexico, the US state to be most advanced in the application of alcolocks for offenders, has achieved a 50 % rate of offenders included in alcolock programmes. In comparison Sweden had in 2004 achieved only 11 % of offenders included in the Swedish alcolock programme (Nordbakke et al. 2007).

A survey of offenders in New Mexico 2003-2005 showed more than 60 % lower recidivism among offenders included in the alcolock program than among offenders not included. After the completion of the programme, when the alcolocks were removed, the recidivism rate was lower among those included in the program, but the difference was not significant (Marques et al., 2010). The %age of offenders included in the alcolock program was 49 in New Mexico in 2007 whereas it was less than 10 % in the US as a total (ibid. p. 20).

Wiklund (2006) estimated that mandatory alcolocks for all drink-driving offenders would reduce the number of personal injury road accidents in Sweden by 571 during a ten-year period, 281 of which would be fatal accidents or accidents with severe personal injuries.

3.4.7 Alcolock as prevention

Alcolock as prevention means that alcolocks are implemented for certain driver or vehicle categories, e.g. drivers younger than 25 years or for school busses, without any individual suspicion of drink driving among these drivers. In this case the alcolocks are considered as guarantees for sober and safe driving for the passengers.

Sweden is the most advanced country in the application of alcolocks as prevention. Sweden has made efforts to introduce alcolocks on a voluntary basis in commercial vehicles such as busses and taxis as well as in vehicles owned by public bodies. In 2008 alcolocks were installed in 46 000 vehicles in Sweden as prevention (Assum & Erke 2009).

An enquiry from the Swedish Transport Agency (Transportstyrelsen) has proposed alcolocks in school busses from 2012. This is part of an enquiry into further alcolock legislation complying with EU rules (Alkolåsnytt nr 1, 2010). In Finland mandatory alcolocks in school transport and transport of children came into effect as of August 2011 (Alkolåsnytt nr 1, 2010).

As far as can be seen from the literature, the effects on accidents of alcolocks as prevention have not been reported. The replies to questions concerning such effects is often that such effects will not have to be studied because there will be no drink driving in vehicles equipped with alcolocks. Nevertheless, empirical studies are necessary because the alcolocks can be manipulated. If alcolocks are installed in vehicle categories never used for drink driving or for driver categories usually not involved in drink driving, these alcolocks will not contribute to reduction in drink driving. If a transport company never had drink-driving accidents, alcolocks cannot reduce the number of

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such accidents. Theoretically, however, it is possible to reduce the number of possible future drink-driving accidents. In all fatal road accidents involving heavy vehicles in Norway during 2005 – 2008, a total of 247 heavy vehicles were involved. Not a single of the drivers of these vehicles was under the influence of alcohol (Assum & Erke 2009). Consequently, it is impossible to reduce further the number of alcohol-related accidents with heavy vehicles. However, possible future fatal accidents involving a heavy-vehicle driver under the influence of alcohol can in principle be prevented.

A study of the prevalence of drink driving among heavy-vehicle drivers in road traffic in Norway one driver out of the 2836 drivers checked had a BAC above the legal limit of 0.2 g/L (Assum & Erke 2009). Consequently, a substantial reduction in drink driving by heavy-vehicle drivers is hard to achieve when the prevalence is so low in the first place.

If alcolocks as prevention is to be applied, it is important to target the use of alcolocks to driver categories having a higher-than-average prevalence of drink driving or to vehicle categories used by such drivers.

The general prevalence of drink driving is low in Norway. Consequently, it is difficult to target the use of alcolocks. No matter how alcolocks will be used as prevention in Norway, the application of alcolocks will be expensive compared to the accident-reducing effects.

At least 14 % of the fatal road accidents in Norway in 2009 (26 drivers under the influence of alcohol in 186 fatal accidents) were alcohol related (Haldorsen & Rostoft, 2010). The %age of alcohol related accidents of all personal injury accidents is not known. Separating drivers under the influence from other drivers before the accidents happen to install alcolocks in the vehicles of these drivers, would be extremely difficult. Consequently, alcolocks would have to be mandatory in all vehicles if the amount of drink driving should be reduced by means of alcolocks. As mentioned above, such an effort is unrealistic in a short-term perspective. Consequently, there are three possibilities to applying alcolocks in addition to alcolock programmes for offenders. The first possibility is alcolocks applied in transport requiring extra high safety such as school busses or transport of dangerous goods. The second possibility is that public bodies or companies focusing on safety require alcolocks in their own vehicles and vehicles used in contracts for these bodies and companies. The third possibility is to stimulate the technical development of alcolocks in order to make them less costly and easier to use. Such a programme is described in the paragraph “Research and future possibilities” below.

3.4.8 Other possible applications

Alcolocks can be used voluntarily, e.g. by offender leaving the alcolocks in their cars after finishing the alcolock programme to avoid the temptation of driving after drinking. The parents of young adults driving the parents’ cars can have alcolocks installed to ensure that their children do not drive after drinking.

Alcolocks can also be used to monitor driving and rest hours for professional drivers (Swann, 2009).

3.4.9 Application of alcolocks in Norway

As part of the EU project ”Alcolock implementation in the European Union” (Silverans et al. 2006) alcolocks were installed in the busses in Lillehammer in 2004-2005. The

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purpose of this project was primarily to study the possibilities of applying alcolocks in public transport, i.e. the technical possibilities and problems, as well as the drivers', passengers' and company management's attitudes to the application of alcolocks. The drivers accepted the alcolocks after visiting the Swedish company Dalabuss which had alcolocks in their busses for several years. No case of drink driving was found in the project period. After the project was completed, the Lillehammer drivers and the company managers wanted to continue the use of alcolocks (Assum & Hagman, 2006).

Requirements about alcolocks have later on been included in the invitation to tender for public transport in the Lillehammer area. Some communities in Norway have introduced alcolocks in their school busses.

Participation in an alcolock programme has been proposed as an alternative to driver's licence withdrawal for drink-driving offenders (Ministry of Transport 2012, p. 190).

The Norwegian Abstaining Motorists Association (MA) ran a campaign concerning alcolocks in school busses in 2009. In 2011 the MA has demonstrated cars with alcolocks (Motorførernes avholdsforbund, 2011).

3.4.10 Barriers to and potentials for the application of alcolocks

Kathryn Stewart (2010) describes possible barriers against the application of alcolocks for offenders and how to overcome these barriers. Important barriers are diffuse research results, opposition from minorities, diffuse details in alcolock programmes and judges hesitating as to the application of alcolocks, as well as opposition from the offenders themselves. The most important way to overcome these barriers, is information and data concerning alcolocks as well as well-considered rules about alcolocks and alcolock programmes.

3.4.11 Effects on behaviour and accidents

The effects of alcolocks on accidents will have to be assessed in relation to the target groups, e.g. drink driving offender, school bus drivers and drivers of heavy vehicles. For alcolocks to have an accident reducing effect, a certain amount of drink driving and alcohol-related accidents will have to exist within the target group. No driver of heavy vehicles under the influence of alcohol was involved in fatal road accidents in Norway during the years 2005-2008. Consequently, no reduction in fatal accidents involving heavy vehicles can be achieved by means of alcolocks. No studies were found concerning the accident reducing effects of the preventive use of alcolocks.

Studies concerning alcolocks for offenders show that recidivism among offenders is significantly reduced when their cars are equipped with alcolocks, but there is little or no effect after the removal of the alcolock. As mentioned above Marques et al. (2010) found 60 % lower recidivism among offenders included in alcolock programmes than offenders not included in such programmes.

Bjerre and Thorsson (2008) found that recidivism among offenders with alcolocks was reduced by 60 %, whereas there was no reduction in the control groups. This difference is significant also after the effects of gender, income, work and marital status are controlled for. Bjerre and Thorsson (2008) found a greater reduction in accidents among offenders with alcolocks in their cars than in the control groups, but the differences were not significant.

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Vezina (2002) found an 80 % reduction in recidivism among first-time offender with alcolocks in their cars during the first 12 months and a 74 % reduction in recidivism among multiple offenders the first 24 months. Participation in the alcolock programme was voluntary. Consequently, the alcolock group and the control group were not similar. The results concerning collisions are not clear. There are indications of both more and fewer accidents among offenders with alcolocks than offenders without.

DeYoung et al. (2005) summarize six studies of the effects of alcolocks for offenders. Three studies show fewer accidents among offenders with alcolocks than among offenders without; two showed more accidents, and one study showed no difference. An explanation to these diverging results is that some studies are based on offenders convicted to participation in alcolock programmes. It turns out that some of these offenders do not install alcolocks in their cars after all, driving less and more carefully in order not to be detected. Offenders with alcolocks are likely to drive a lot more than offenders without alcolocks.

Elder et al. (2011) summarizing research concerning alcolocks for offenders, found that alcolocks do reduce the amount of drinking and driving during the period in which the alcolocks are installed, but not after the removal. The potential for accident reduction of the alcolock programmes is limited by the small number of participants.

There are indications for reductions in harmful alcohol consumption, absence due to illness and hospitalization as well as permanent effects on alcohol consumption habits among participants in the Swedish alcolock programme (Nordbakke et al. 2007).

Marques et al. (2010) showed a coincidence in time between the number of offenders having alcolocks in their cars and reductions in alcohol-related road accidents, fatalities and injuries. This study cannot, however, prove a causal relationship.

The effects of alcolocks on the number of fatalities and injuries are calculated for two levels of implementation:

1. All motor vehicles equipped with alcolocks
2. Alcolocks installed in the vehicles of all offenders (both first-time and multiple offenders)

For the effects of alcolocks installed in all motor vehicles, the estimated risk contribution of drink driving is used (Elvik 2010), which is estimated to 0.166 for fatalities, 0.100 (interpolated value) for severe injuries and 0.034 for slight injuries. The average number of fatalities and injuries for the years 2009-2010 were used, i.e. 210 fatalities, 755 severe injuries and 8105 slight injuries. The numbers due to drink driving are consequently estimated at 35 fatalities, 76 severe injuries and 275 slight injuries. If alcolocks are installed in all motor vehicles, 98 % of the above casualties are assumed to be prevented. 100 % of the casualties are not assumed to be prevented, because some drivers will not comply with the mandatory instalment and some alcolocks will be poorly calibrated, so that some drink drivers will be able to start the vehicle. Consequently, the effects of full implementation of alcolocks can be estimated at a reduction of 34 fatalities, 74 seriously injured, and 270 slightly injured per year.

Drivers convicted the first time for drinking and driving are assumed to have an accident involvement of 7 killed, 15 severely injured and 55 slightly injured per year. All these figures are reduced by 50 % using alcolock. The results are that 3.5 fatalities, 7.5 severely injured and 27.5 minor injuries per year are prevented. Drivers convicted earlier for drink driving are assumed to have a risk equivalent to 7 killed, 16 severely injured

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and 56 slightly injured per year. These numbers will be reduced by 15 % when using alcolock. This prevents 1.05 fatalities, 2.4 severely injured and 8.4 slight injuries per year.

Using alcolock for all convicted drunk, the number of fatalities can be reduced by 4.55 per year, the number of severely injured by 9.9 per year and the number of minor injuries by 35.9 per year.

3.4.12 Cost-benefit ratios

Nordbakke et al. (2007) have assessed cost and benefits for two applications of alcolocks, i.e. the Swedish trial as carried out and for all offenders in Sweden. The two applications have benefit/cost ratios of 2.32 and 1.8 respectively.

Reference is made to estimations of benefit/cost ratios for mandatory alcolocks in all new cars, a b/c ratio of 0.05, i.e. an extremely low benefit to cost ratio (Nordbakke et al. 2007).

Transportstyrelsen (2010) says: *"Based upon the present accident statistics there is reason to think that the direct benefits of reduced casualties are not likely to be greater than the costs of installing alcolocks."*

Lahausse & Fildes (2009) found benefit to cost ratios between 3.4 and 0.6 for alcolocks in Australia depending on efficiency, interest rates and the kind of vehicles affected.

3.4.13 Research and future possibilities

Easier to handle

"*The Driver Alcohol Detection Systems for Safety (DADSS)"* is a five-year research program started in the US in 2008 and financed by "*The National Highway Safety Administration (NHTSA)"* and the American motor industry. "*What we're doing is developing technology that won't hassle sober drivers; will require virtually no maintenance or upkeep; and will have such precision that it only stops a driver when their blood alcohol content is at or exceeds 0.08 blood alcohol content (BAC)*" (DADSS, Nov 1, 2011), i.e. to develop a device which can be installed in all motor vehicles without great inconveniences or costs. There are two lines of research – breath-based testing device for BAC detection and a touch-based approach. "*No decisions are expected regarding potential deployment in the vehicle fleet until more data is available and more development work has been completed. The DADSS program is an effort aimed at voluntary adoption of the technology"* (DADSS, Nov 1, 2011).

"Narcolock"

As indicated by the term, alcolocks prevents only driving with alcohol in the drivers' bodies, rather than all psycho-active substances. In principle developing a similar "narcolock" should be possible by combining a device for testing for psycho-active substances and an ignition interlock. Devices to screen driver for psycho-active substances on the roadside have been developed. The problem is that such devices are rather unreliable. Moreover, these devices are not able to detect all kinds of psycho-active substances.

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Fitness-to-drive testing devices

An alternative to further development of easier and better alcolocks and "narcolocks" would be to combine a test of fitness to driver and an ignition interlock. This way drivers unfit to drive for whatever reason, will not be able to start the vehicle. Such a test can be developed and entered into a small computer which is connected to an ignition interlock. Drivers unable to pass the test, will not be able to start the vehicle. Another alternative would be to use the computer already installed in most modern motor vehicles, to record irregular driving such as bilateral movements, too high speed etc, then setting the vehicle in "emergency mode" allowing only low speeds and a limited time of driving[3].

Making tests and devices sufficiently reliable for practical application, is likely to be many years into the future. Moreover, making such devices mandatory in all motor vehicles is likely to be even more years ahead. Developing such devices and making them mandatory, may, however, have a great potential for accident reduction.

3.4.14 Conclusion

The effects of alcolocks depend on the application and the legal and organizational support. Alcolocks can be implemented in several ways:

1. Mandatory in all motor vehicles,
2. As prevention for certain driver or vehicle categories,
3. As an alternative to licence withdrawal for offenders

Alcolocks have not been made mandatory for all motor vehicles in any country so far. Sweden had an ambition to make alcolocks mandatory in all new cars. This ambition had to be abandoned because of conflicting interests within the European Union.

Only a few countries have so far used alcolocks as prevention. No substantial research reports have been found concerning the accident-reducing effects of this application of alcolocks or of mandatory instalment in all vehicles.

Alcolocks reduce drink driving among offenders for the time the alcolocks are installed, but the long-term effects are uncertain. Between 10 and 50 % of the offenders in jurisdictions having alcolock programmes, participate in these programmes. The accident-reducing effects vary – in some cases the number of accidents is reduced and in other cases the number of accidents increases. These results may be explained by the fact that the participants in these programmes are too few to produce statistically significant results. Moreover, offenders driving cars equipped with alcolocks are likely to drive longer distances than drivers whose licences have been withdrawn.

To apply alcolocks in more ways than for offenders and for special driver or vehicle categories, the alcolock technology will have to be less costly and easier to use. Research and development to this effect is going on in the United States.

[3] Volvo is developing such a system called ”Limping home”.

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3.5 Effects of seatbelt-lock

New cars are often fitted with a warning which alarms the driver by a light- or sound-signal if the seatbelt is not properly locked. The alarm signal stops when the seatbelt is locked. It is known that some drivers manipulate and circumvent the alarm by putting an "empty" belt-sledge into the lock, i.e. the sledge has belt in it. Another "trick" is to let the belt go between the back of the driver and the back of the seat before locking the seatbelt.

However, the system which is considered here is a technology which blocks ignition of the engine when the seatbelt is not properly fastened and where manipulations like the ones described above will be detected by the system. We do not know if this specific system technology is available today, but it is a presupposition that such a technology is, or will be, developed and that it will be applied in all seating positions where people actually sit on a given journey. The calculation also presupposes a seatbelt-use of 100 %, even if we are aware that some drivers may have a medical certificate which exempts the driver from using a seatbelt. The amount of this kind of exemption is not known.

Using a seatbelt increases the probability of survival given that an accident has occurred. According to Trafikksikkerhetshåndboka (Elvik et al, 1997), the probability of being killed is reduced by 50 % for a driver, 45 % for a front seat passenger, and 25 % for a back seat passenger when wearing a seatbelt driving a personal car or a small goods vehicle.

There may be several reasons why the %age of survival is not higher. The NPRA's in-depth analyses list the following factors:

- Large weight difference between involved vehicles
- Critical point of impact of involved vehicles [4]
- Low crashworthiness
- No airbags

The car occupants are especially vulnerable in side impacts because the absorption of energy in the body of the vehicle is lesser, and because the seatbelts do not function very well in sideways movements. Consequently, the bodies of the car occupants would impact each other and may thus cause substantial injuries.

In-depth accident investigations have shown that in a majority of the accidents, the relative speed change, and the collision energy which is transformed, represent so high strains on the body that survival would not have possible, even if the occupant had used a seatbelt (Viano 1988; AIBN 2012). The estimates provided by Trafikksikkerhetshåndboka take these empirical evidence into account when calculating the survival probabilities stated above.

[4] A "critical point of impact" of a personal car is a point outside the deformation zones. If two vehicles collide and the point of impact is outside the deformation zones, the vehicle body will not absorb the energy of the collision, with the consequence that the level of injury will increase.

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Calculations – driver groups:

All drivers: A summary from the NPRA's Accident Investigation Teams (AIT [5]) of fatal accidents in the period 2005-2009 shows that 43 % of the car occupants did not use seatbelts (Haldorsen and Rostoft, 2010). The probabilities of survival in the driver seat, passenger in front seat and passenger in back seat are 50 %, 45 % and 25 %, respectively.

The distribution between those who used seatbelts and those who did not, is unknown and we will use the aggregated proportion of users, i.e. 43 %, on drivers as well as passengers. The accident database of Statistical Bureau of Norway provides a distribution of killed in front seats and in back seats. In the period 2001-2010 125 passengers were killed distributed with 77 in the front seat and 48 in the back seat, i.e. 62 % and 38 %, respectively.

Given this distribution, we can calculate as follows:

- Potential number of lives saved when all drivers use seatbelts: 95 killed x 0.43 x 0.50 = 20.4
- Potential number of lives saved when all front seat passengers use seatbelts: 48 x 0.62 x 0.43 x 0.45 = 6.7
- Potential number of lives saved when all back seat passengers use seatbelts: 48 x 0.38 x 0.43 x 0.25 = 2.0
- Estimated number of lives saved when all car occupants use seatbelts (100 % seatbelt usage): 20.4 + 6.7 + 2.0 = 29.1

An estimation of lives saved for professional drivers can be calculated by two approaches:

1. As a proportion of the total traffic volume: As shown when ISA was considered, this proportion was estimated to 15 % of the total traffic volume. The number of lives saved by 100 % seatbelt usage among professional drivers will then be: 95 x 0.15 x 0.43 x 0.50 = 3.1.
2. By using the vehicle codes in the accident database of Statistical Bureau of Norway, i.e. codes taxi/minibus, bus, delivery trucks, lorries, tractor-trailer, and tank lorries. In the period 2001-2010, these codes comprised 133 killed drivers, i.e. 13.3 per year. The number of lives saved by 100 % seatbelt usage among will by this approach be: 13.3 x 0.43 x 0.50 = 2.9.

These two calculation methods give estimates which are quite similar. This is interesting in itself and may also be interpreted as a reciprocal validation of the estimation methods, but both methods have weaknesses. Regarding the first method, we do not know how accurate the estimated proportion actually is. Regarding the second method, one objection would be that professional drivers of the categories listed comprise vehicles which for a substantial part have larger masses than the average mass for all vehicles, which in turn increases the probability of survival. Further, one assumption will be that the driver is the only person in the vehicle when the accident occurs.

[5] In Norwegian: "Ulykkesanalysegruppene" (UAG).

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Estimation young drivers: Regarding the groups of young drivers aged 18-20 years, and 18-24 years, the calculation basis is the number of killed drivers stated in the accident database of Statistical Bureau of Norway (www.ssb.no). The number of killed drivers 18-20 years of age were 94 in the period 2005-2010, i.e. 15.7 per year, whilst the number of killed drivers 18-24 years of age were 161 in the same period or 26.8. The estimated proportion of drivers who did not use a seatbelt is still 43 %, and the probability of survival for a driver who uses a seatbelt is still 50 %.

- **Group 18-20 years: Estimated reductions given that seat belts usage is 100% in all seating positions:** Reduction in number of killed drivers: 15.7 x 0.43 x 0.50 = 3.4, reduction in number of front seat passengers: 3.5 x 0.43 x 0.45 = 0.7, and reduction in back seat passengers: 2.3 x 0.43 x 0.25 = 0.2 Total number of lives saved – all seating positions: 4.3.

- **Group 18-24 years: Estimated reductions given that seat belts usage is 100% in all seating positions:** Reduction in number of killed drivers: 26.8 x 0.43 x 0.50 = 5.8, reduction in number of front seat passengers: 7.0 x 0.43 x 0.45 = 1.4, and reduction in number of back seat passengers: 3.5 x 0.43 x 0.25 = 0.4. Total number of lives saved – all seating positions: 7.6.

3.6 Effects of economic driving

The evaluation of economic driving is built upon two English studies: Parkes and Reed (2005) and Reed and Parkes (2009). The studies describe effects on fuel efficient driving of driver education and training in a driving simulator. The subjects were recruited from 11 companies, the average age was 44.4 years, they had had a driving license for 25.1 years (average) and had been professional drivers for 16.0 years (average). The vehicle model of the simulator was a Mercedes Actros heavy goods vehicle consisting of tractor and fully loaded trailer (44 tons).

The first study comprised 36 professional drivers who underwent three phases of education and training regarding fuel efficient driving. Driver behaviour and fuel consumption were measured before and after all three sessions of training in the driving simulator. Fuel consumption in the simulator was estimated and compared to the fuel consumption which the drivers had during real driving as professional drivers. Fuel consumption was also compared to the consumption in a control group of drivers who did not undergo simulator training.

The first study can be summarized as follows (Parkes and Reed, 2005):

- After having completed a test driving of 20 minutes (before-data) the subjects were trained in fuel-efficient driving by a qualified driving teacher. The principles of eco-driving and how these could be practiced in the simulator were explained before the subjects again drove the same route in the simulator. The test subjects received immediate feedback on how they drove this second time in the simulator.
- Fuel consumption was measured in five days before and five days after all three sessions in the simulator.
- The largest change in fuel consumption – a reduction of 9 % - was measured after the first training session. The second training session came two months after the first session. Measurements after the second training session again

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showed a reduction of fuel consumption, this time 1.68 %. The reduction after the third training session was 1.52 %.

- Several other parameters were also measured:
  - Revolutions per minute (RPM): Average reduction under acceleration. Approximately asymptotic towards 1150 RPM.
  - Average increase in torque: 53.2 %
  - Reduction in number of gear-shifts: 27.6 %
- Reduction in driving time: 7.95 % compared to baseline, which demonstrates that eco-driving will not necessarily make driving time any longer. One possible explanation may be that the principles of eco-driving improve predictions of traffic ahead by being more far-sighted.
- Number of driven kilometers increased from 3.18 km/l to 3.43 km/l[6] in the test group, whilst the control group had a quite constant consumption of 3.25.[7]
- Adjusting fuel consumption in the test group to the consumption in the control group demonstrate a reduction in fuel consumption efficiency of 15.7 % (+ 6.0; + 25.4). However, given that data is limited, and a rather large confidence interval, the authors conclude that the improvement in fuel consumption efficiency is at least 6 % ($p < 0.05$). [8]
- Converting this estimate to the more commonly used ratio of fuel consumption – i.e. consumption per distance driven – the consumption was reduced from 3.14 liters/(metric)mile to 2.92 liters/(metric)mile, or 7.0 %. Adjusting for the consumption in the control group, the reduction was 5.2 %.

There is no mention of eventual impact on accidents of eco-driving in Parkes and Reed study, but in another experiment Reed and Parkes (2009) reports a reduction in the number of accidents, lesser stress among drivers, and increased confidence regarding education and training in a driver simulator. The reporting is, however, anecdotic and no estimate of the reduction in the number of accidents is provided.

These two studies define eco-driving by lower RPMs under acceleration, increased torque, a lowered used of motor brake, and fewer gear-shifts. In sum, these changes reduce fuel consumption per kilometer driven. One outcome of eco-driving is a reduction in travel time, a reduction of 8 % is reported, which means that driving speed is increased. A (potential) reduction of accidents, together with an increase in average speed, is a paradoxical outcome and we will not conclude firmly about the effect of eco-driving and its potential effects on the number of accidents.

3.7 Effects of sleep warning systems

Fatigue and falling asleep at the wheel is a major problem regarding the safety of road traffic. It is reported as a contributory cause in 13 % of the fatal accidents in the period 2005-2009. Several EU-projects, including AWAKE and SENSATION, have had the development of warning systems against falling asleep at their objective. It is also known

[6] From 9.05 mpg to 9.75 mpg (mpg = miles/gallon, 1 mile = 1,609m, 1 gallon = 4.55 liter).
[7] 9.2 mpg.
[8]"…we can be confident that drivers will show a fuel efficiency improvement of at least 6 %".

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that there have been considerable challenges in developing reliable warning systems because assessment and selection of parameters which should indicate danger of falling asleep have been unreliable and invalid. Parameters which have been considered are movements of the steering wheel, closing of eyelids, blink durations and fixation of gaze, crossing of road markings, etc. Evangelos Bekiaris, consortium leader of the EU-project SENSATION, stated the problem issue in this way:

> ”Regarding the selection of valid parameters for warning the driver who was about to fall asleep at the wheel, the problem was only the considerable variability between drivers, but also the variability within one and the same driver”.[9]

Fatigue and danger of falling asleep at the wheel are experienced by many drivers. In a Norwegian internet-based survey 53 % of drivers aged 18-61 years state that they have fallen asleep at the wheel (Nordbakke and Sagberg, 2007). Most drivers are aware that one of the most efficient measures against falling asleep is to stop and take a nap. In spite of this knowledge drivers continue driving even if they are fatigued. Hence, it is not unreasonable to suppose that such a warning system will increase the amount of driving when fatigued because they may rely on the system’s ability to warn when a danger of falling asleep at the wheel is imminent.

It may be proposed that it would be legally complicated to sort out the responsibilities if the driver of a car with a sleep warning system actually falls asleep without having been warned by the system. In an evaluation of the Swedish research of traffic safety, a representative of Chalmers state the problem issue in this way:10

> ”When the industry starts implementation of a number of ”intelligent”safety systems, it will be evident that the knowledge of engineers must be completed by knowledge of the human operator. Swedish car manufacturers have, as a current example, developed systems which shall detect tired/fatigued drivers and some foreign car manufacturers have, as far as I understand, already started the production of such systems. Swedish manufacturers hesitate to install such systems, one matter of concern is that drivers may feel warnings are coming too early, i.e. in advance of what drivers themselves perceive as being risky. If the warning is given after the driver is very tired, it may be too late. In addition, there is a risk that drivers may misuse the system by extending the number of working hours and force themselves toward the limit of falling asleep at the wheel”. (Kolbenstvedt et al, 2007:94).

We have not found studies which have evaluated the effects of sleep warning systems on accidents. As an alternative and proxy method, the point of departure is the following three hypotheses as basis for estimating a possible effect on accidents:

1. The system will warn a driver who is about to fall asleep in a way that prevents an accident with a fatal outcome. At the same time, however, a number of drivers who believe in the system and its ability to warn and prevent an accident will choose to drive. The assumption here will be that these two possible outcomes will cancel each other out and the final and total outcome is zero.

[9] Evangelos Bekriaris’ presentation at the SENSATION workshop, Warzava, 11.03.2005.

[10] Translated from Swedish.

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2. The accident-reducing outcome of the system is larger than the accident-increasing outcome and the assumption is that the system will prevent 50 % of the fatal accidents which are caused by falling asleep at the wheel.
3. Ideally, the warning system will prevent all fatal accidents, i.e. 100 % of accidents which are caused by falling asleep.

The point of departure for calculation of effect is again the AIT-groups in-depth analysis of fatal accidents in the period 2005-2009 (Haldorsen and Rostoft, 2010). On the average, fatigue/falling asleep is stated as a contributing cause in 13 % of the fatal accidents in the period 2005-2009. Some 30 % of the drivers fall asleep at the wheel between 00-06 hours, while the %age falling asleep between 15-18 hours is 27 %, a pattern which indicates that falling asleep is associated with the biorhythms of the body. The calculations below are done for all drivers and for professional drivers, but not for young drivers as data is insufficient for the groups of young drivers.

- **All drivers**: Yearly average of fatal accidents in the period 2005-2010 was 208,5. Falling asleep was a contributing cause in 13 % - or 27.1 of these. Assuming that a warning system would have prevented 100 % of the fatal accidents, and assuming 1.10 killed per accident, an estimated 27.1 x 1.10 = 29.8 lives could have been saved. Assuming an outcome of 50 %, the estimate of lives saved is 14.9. [11]
- **Professional drivers:** The professional drivers' part of the traffic volume is set to be 15 %. Assuming 100 % effect of a warning system an estimated 29.8 x 0.15 = 4.5 lives could have been saved in the group of professional drivers. Assuming an outcome of 50 % the number of lives saved will be 14.9 x 0.15 = 2.2. '

  Using SSB's accident database, and assuming that a warning system would have prevented 100 % of the accidents caused by falling asleep, the estimate of lives saved will be 13.3 x 0.13 = 1.7 and 0.9 lives saved assuming a 50 % outcome.

We do not know how a driver will react to the warnings of a sleep warning system. Will he/she instantly understand what is happening, act rationally and try to avoid the accident, or act irrationally, get panic or be paralyzed? We do not know, different reactions and scenarios may be realized, but we will assume that that rational emergency maneuvers would be most prevalent. It may still end by an accident if the driver is warned too late, but possibly with a less severe outcome than a fatality, because of a – perhaps only partly – successful intervention. These are just reflections, we just sketch possible outcomes, but actually do not know, and hence, we cannot provide any specific estimates of these outcomes.

[11] The factor for transforming the number of fatal accidents to the number of killed is 1.10. This ratio appears by dividing the total number of fatal accidents by the total number of killed in the period 2005-2009: 1167/1061 = 1,10 (Haldorsen and Rostoft, 2010).

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3.8 Effects of Ford's MyKey-system ("Smartcard")

In 2012 Ford launched their MyKey-system, a system in which the ignition key has several programming options which may limit the performance of the vehicle and thus affecting risks which the driver and passengers may be exposed to. The MyKey-system has been described in a press release: 12

- Ford MyKey will have its European debute in 2012. By using MyKey the car owners can encourage their teen-aged children to drive safer, more fuel efficient and using seat belts.
- MyKey adds a new dimension to road safety by providing a technology which stimulates safer driving and which limits options to take risks irrespective of age and experience.
- An option which is provided to the owner of a car with the MyKey-System comprises a maximum speed governor which warns the driver of set-points between 70-100 km/h.
- MyKey prevents a disconnection of the Electronic Stability Control system (ESC).
- A warner prevents seatbelts from being disconnected, it will give continuous warnings of disconnected seat belts in all seating positions where car occupants actual sit.
- The system blocks the car's audio-system until all front seat passengers have fasten their seat belts.
- Prevents the driver from disconnecting the system which warns audibly and visually about a lane-change.
- MyKey also comprises a surveillance system which informs the driver of dead angles.

MyKey has one unit for programming and one key unit which provide the car owner with options of blocking and restrictions by programming the key which the car user needs for starting and using the car.

Ford expects to integrate MyKey with an option for assistance in emergencies. Emergency agencies will be notified swiftly in case of mishaps and accidents by sensors activated as a response of deployment of an airbag or blocking of the fuel pump. The emergency system can locate the exact site of an accident by GPS, a map database and the car user's mobile phone before the notifying and sending the information to an emergency service central using the language of country where the accident has taken place. The system is able to communicate directly with emergency services in more than 30 European countries. [13]

The emergency assistant and other selected driver support systems cannot be disconnected by a driver who does not have access to the programming unit. The system is not yet – i.e. per April 2012 - introduced in Europe, but more information and

[12] The press release is dated 1st September 2011 and was distributed by Ford Motor Norway.

[13] Fords press releases and photos are accessible at Ford Motor Companys homepages: www.media.ford.com, http://ifa2011.fordmedia.eu/, and www.ford.com.

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presentations are expected at car exhibitions in Germany in June 2012. It is still not known whether the system will provide restrictions regarding driving under influence (by an alcolock-device), driving in darkness, geographical limitations, and the number of passengers who can accompany the driver.

The MyKey-system comprises several of the driving support systems which are considered in the present context: There are elements of ISA, a maximum speed governor, electronic stability control, and ignition blocking when seat belts are disconnected. There are also elements of lane-change warning, dead-angle warning and eCALL. It is not, however, possible to estimate the isolated effect of MyKey alone because the system comprises several driver support systems. A potential calculation would have had to considered effects of interaction between systems, i.e. not the isolated effect of one single system. However, regarding the emergency assistance system, it is possible to indicate an outcome as the MyKey emergency assistant seems to be more or less identical to the eCALL-system which is currently being developed in EU-countries. The eCALL-system and McKey emergency assistance will both provide and send a message to an emergency central prompted by an accident. The message contain information about the exact time and site of the accident thereby avoiding long response time and ambiguities regarding the accident site.

The effect of eCALL is considered to be larger in rural areas, on roads with low traffic densities, and for single accidents (Høye et al, 2011). Accident types which is regarded as especially suited for automatic notification are single accidents/run-off-the-road accidents without any witnesses who could call upon immediate emergency assistance. In a Finnish in-depth study the potential number of lives saved was estimated to a 3 % reduction of fatalities, i.e. fatal accidents where lives probably would have been saved by bringing ambulance/paramedics more rapidly to the accident scene (Virttanen, 2005).

3.9 Effects of intelligent cruise-control (ICC)/automated braking

Autonomous regulation of distance may be viewed as an extension of a cruise-control system (Chira-Chavala and Yoo, 1994). A cruise-control implies that a certain speed can be set at a constant driving speed which is maintained until the driver turns it off. An autonomous control of distance implies that a certain distance to the car in front can be set, thereby regulating acceleration/deceleration via the throttle and/or the brakes.14

The Norwegian Trafikksikkerhetshåndboken (Høye et al, 2012) evaluates ICC by considering effects on accident types which potentially would have been affected if involved vehicles were equipped with ICC. Trafikksikkerhetshåndboken refers to the same accident studies as it did in the 1997-edition, i.e. there are no new evaluation studies which could add to the knowledge of 1997. The four studies are: Marburger et al. (1989), Malaterre and Fontaine (1993), Farber and Paley (1993), and Chira-Chavala and Yoo (1994).

Based on these four studies, the following average estimates of the effect on the number of accidents, can be stated:

[14] From Høye et al (2012) Trafikksikkerhetshåndboken. Chapter 4.18 Autonom avstandsregulering. In English, the system is also labeled Intelligent Cruise Control (ICC).

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- Effect on rear-end collisions: - 49.0 %
- Effect all accidents: - 5.9 %

These estimates comprise all levels of injury, in some cases also property-damage-only accidents. The agreement between studies regarding potential effects on rear-end collisions is remarkable, all estimated are close to 50 % reduction in this type of accidents. When it comes to the effect on the total number of accidents. It may be associated with the fact that the number of rear-end collisions vary from country to country, and it may depend on whether the property-damage-only accidents are included in the estimate. Regan et al (2006) have estimated that a combination of ICC and ISA could reduce the number of fatal accidents and accidents with serious injuries with 9 % and 7 %, respectively.

Several of the calculations presuppose an ideal system without considering the possibility of behavioural adaptations that may affect the outcome of the system. However, in Rudin-Brown and Parkes' study of 2004, subjects driving with an ICC-system were less attentive by delayed discovery of hazards, variation of lateral position increased significantly, and the workload was reduced. Stanton and Young (2005) also found reductions of workload, vigilance, and stress.

It is surprising that the search of literature did not have more hits regarding this system's effect on accidents. Studies which were identified and of potential relevance for the present purpose found a change of concepts – from ICC/AICC to ACC, i.e. from Autonomous/Intelligent Cruise Control to Adaptive Cruise Control. Further, there was a technological advance by developing automatic braking connected to ACC-systems. More recent studies which were identified were by and large simulator studies mostly considering issues interfaces between driver and ACC (Fancher et al, 2001), and in-depth studies of pedestrian accidents as basis of developing autonomous braking in critical situations involving pedestrians (Lenard and Danton, 2010).

In NPRA's report from the Norwegian AIT-groups' analyses of fatal accidents in the period 2005-2010, it is the accident types "Same driving direction" and "Pedestrian accidents" which are relevant as basis for calculation of the effect of an ideal ACC-system on the number of fatal accidents (Haldorsen, 2011). We assume that an ideal situation in which ACC would prevent all fatal accidents in the same driving direction – probably mostly rear-end collisions – as well as all fatal accidents with pedestrians.

- Effect of an ideal ACC on number of killed/year: The average part of fatal accidents 2005-2009 – same driving direction was 2.9 %, while the average part of fatal accidents pedestrians was 13.5 %. The yearly average of fatalities 2005-2010 was 229.2, which means that 6.6 and 30.9, in sum 37.5 lives, could have been saved by an ideal ACC-system.
- Effect among professional drivers: The basis for calculating the effect among professional drivers is the same as previously stated, but has to corrected for the part of the traffic volume which is done by professional drivers – 15 %. The estimated reduction in the number of killed given an ideal ACC applied on accidents in same driving direction is 6.6 x 1.0 lives saved, and 30.9 x 0.15 = 4.6 lives saved in pedestrian accidents, in sum 5.6 lives saved.

The assumption in this calculation is, in addition to presupposing an ideal system, is the imagined situation where all personal vehicles are equipped with the system. The calculations above are, hence, maximum estimates.

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3.10 Effects of Electronic Stability Control (ESC)

Electronic Stability Control (ESC) is an active safety system which improves the stability of the vehicle by influencing brakes and steering. The effect is dependent on the driving characteristics of the car, road conditions, and driver behaviour as movements of the steering wheel, braking, and acceleration. Systems from different producers, which are comprised by what is called ESC, may have different names: Electronic Stability Program (ESP), Dynamic Stability Control (DSC), and Vehicle Stability Control (VSC). Systems may differ regarding information from sensors, limit values, and intervention options, but system functions are by and large comparable.

In an updated meta-analysis of 2011, Høye (2011) calculates the effects of ESC to 50 % reduction of roll-over accidents, 40 % reduction of run-off-the-road accidents, and 25 % reduction of single accidents. The analyses in a report from the Norwegian Public Roads Administration's AIT-teams show that it is only the accident group "run-off-the-road accidents" which can be applied as a basis of estimating the effect on the number of fatal accidents (Haldorsen, 2011). This accident group will probably also comprise roll-over accidents and single accidents, but the distribution across accident types comprise only run-off-the-road accidents, not the two other accident types. An estimation of the effect of ESC will, as was the case with ACC, presuppose the imagined, ideal situation where all vehicles in the vehicle population have installed ESC. The maximum potential reductions of the number of killed will then be as follows:

- **Effect of an ideal ESC on number of killed/year:** In the period 2005-2010 the average number of killed was 229.2. Of these, 33.5 % were killed in run-off-the-road accidents, which amounts to 76.8 killed. Assuming an effect of 40% on run-off-the-road accidents, the maximum reduction of the number of killed would be a total of 76.8 x 0.4 = 30.7 lives saved.
- **Effect on professional drivers:** The basis for estimating the effect among professional drivers is the same as with previous calculations, but has to be corrected according to the transport volume – 15%. Estimated reduction in the number of killed when all vehicles driven by professional have ESC, again assuming an effect of 40 % for run-off-the-road accidents would be: 76.8 x 0.4 x 0.15 = 4.6 lives saved.

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3.11 Reflections on future outcomes of Driver Support Systems

The ideas of high-technology Driver Support Systems (DSS), which potentially could reduce the number of fatal accident, originated in the 1980s. The first ex-ante-analysis we know – the Marburger et al study – was published in 1989 as part of the European car-industry's PROMETHEUS-program. This program was launched as a measure to compete with Japanese and American car-industry.

The method for calculating effects of DSS which was used in the Marburger et al's study of 1989, was by considering accident types and provide estimates regarding how an imagined system could reduce the number of accidents of given accident types which were registered in German accident statistics. In 2012, 23 years after, the essential features for calculating ex-ante effects, are basically the same: The point of departure is accidents where one knows – or have good reasons to believe – the cause(s) of the accidents. What is new is the technological development of IT-systems and the fact that many systems gradually have been installed in cars, as with ABS, ESC, ACC, navigation systems, brake-assist and parking-assist systems. These are systems which have been widely disseminated.

Since 1995, one has agreed to use the concept Intelligent Transport Systems (ITS) as a generic term, which covers a wide specter of IT-applications in all sectors of transport. (Advanced) Driver Assistance Systems (ADAS) is also a term which is widely used. Several problem issues can be stated:

- What makes a system "Advanced" and not merely a "Driver Assistance System"?
- What kind of «intelligence» could be inherent in Intelligent Transport Systems?
- What kind of imaginations does these concepts create?

One impression which remains is that the concepts – and particularly "ITS" somehow «floats» uncritically within research environments, on conferences, and in the research literature.

"Advanced", "intelligent" or "support"? One example is ABS, which is one of the few systems which has been evaluated in real traffic and where the effects on accidents is known (Vaa, 2007; Høye et al, 2012). The objective of the system is to maintain the steering ability in critical situation where a driver must brake and use maximum pedal-force to avoid a cyclist, a pedestrians or an animal, which suddenly appears before the vehicle. Experienced drivers are capable of maintaining steering capacity by rapidly alternating between"brake-pumping" and steering. The most common reaction, however, is to "brake panicky", i.e. use so much force on the brake-pedal as you can, with consequence that the vehicle goes straight ahead towards the object you are trying to avoid. Vehicles with ABS reduce the number of accidents involving cyclists, pedestrians and animals significantly compared to vehicles without ABS (Vaa et al, 2007; Høye et al, 2012).

Another system where effects on the number of accidents are well documented is ESC, which use much of the same technology as ABS. The basic idea behind ESC is to hinder a car from losing grip because of under-steering in curves, slippery road surface and similar. To judge the boundaries of speed correctly when negotiating driving in curves is a problem specifically for young, unexperienced drivers. A meta-analysis of the effects of ESC estimate a reduction in the number of accidents caused by losing control to be

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40 % (Høye, 2011). In contrast to ABS where the effect is composite, ESC seems to provide an unambiguous reduction of the number of accidents which is consistent with the objective of the system.

I am not basically critical to driver support systems, but I consider it adequate to state some critical questions when appraising effects of ITS. Some objections can be stated empirically as well as theoretically. One basis for stating some viewpoints is a driver behaviour model which was elaborated in a Strategic Institute Program.15 The model, which is named the Risk Monitor Model (RMM), has been published internationally (Vaa, 2007; Vaa 2012). The original objective of the model was to describe and explain drivers' speed choices, and, if possible, explain why risk compensation is established. A central issue in explaining drivers' speed choice was to pinpoint a division between conscious and unconscious routes to information processing and decision-making, and, further, that choices of driving speeds are closely associated with emotional consequences of the choices. Another basis for appraising effects of driver support systems is by acknowledging that accidents are, individually speaking, very rare events. A numeric example can illustrate this:

- Based on Norwegian accident statistics the driver risk of personal injury is approx. 0.36 accidents per mill. km., i.e. one injured/killed per 2,800,000 km.
- Suppose that a driver begins driving at the age of 18 years and drives until he/she is 83 years, i.e. driving for 65 years.
- In Norway, the average driving distance per year is about 14,000 km. Total mileage of lifelong driving should then be 65 years x 14,000 km = 910,000 km.
- Then, a group of 2,800,000 km / 910,000 km ≈ 3 drivers is needed, on the average, to make one driver experience one personal injury during a 65-year long life of driving.
- In other words, that would be one personal injury per 200 years. Further, the probability is about 80 – 90 % that the level of personal injury would be minor.
- Conclusion: The average driver is extremely competent in dealing with the hazards in road traffic.

Transferred to DSS, «the enlarged conclusion» is that such systems shall prevent extremely rare events, and, taking the perspective of an individual driver, the events are extremely rare because the average driver is very competent in dealing with the risks and avoidance of accidents in road traffic. One hypothesis is then, that a given DSS, must prove that "the system is better than the driver". If not, the system will not be accepted by the driver.16

[15] Elaborated under the Strategic Institute Program (SIP) «Driver Behaviour Models» which was accomplished at Institute of Transport Economics (TOI) 1998-2003.

[16] The probability of a property-damage-only accident is naturally more frequent: About once per 10 years according to Norwegian accident statistics.

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The above appraisals have resulted in seven hypotheses about effects of ITS-systems (Vaa, 2011):

- Hypothesis 1: If a car with a given IT-system X provides a better feeling of control compared to a car without system X, the assumed accident risk reduction feature of system X might be compensated by a change in driver behaviour as for example by increased driving speeds.
- Hypothesis 2: An accident increase is predicted with IT-systems that enhance the 'window of opportunities', as with ABS for certain accident types.
- Hypothesis 3: An accident decrease is predicted for IT-systems that reduce the 'window of opportunities', as with ESC, ISA, Alcolock.
- Hypothesis 4: An accident increase could be expected with In-Vehicle-Information-Systems which are dissociated from primary driving tasks, by increasing the frequency of distractions, as with the use of mobile phones.
- Hypothesis 5: reducing options of implicit learning: A driver environment filled with too many warning systems may interfere with and deteriorate learning processes of the dangers in real traffic.
- Hypothesis 6: Acceptance/Reliance: System X must perform better than the driver. It will be abandoned by the driver, if it fails.
- Hypothesis 7: ITS addressing "evolutionary limitations" of risk monitoring may reduce accidents.

These hypotheses may illustrate what kind of effects which could be expected from ITS-systems. The most serious one could be the fifth hypothesis, i.e. the introduction of a new system, which is a new element implemented between the external, outer world, and the information processing, decision-making and judgement of risk. This new element implies new processes of learning, of which we do not yet know the effects, but it is possible to state hypothesis of this new element.

The most important hypothesis regarding traffic safety, however, is hypothesis number 3, which addresses the driver's 'spave of opportunities'. Several of the driver support systems which are considered here, represent restrictions of the 'space of opportunities: ISA, maximum speed governor, Alolock, seat belt lock, ESC and programmable ignition key, all belong to the group addressed by hypothesis 3.

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4 Responses to a questionnaire about driver support systems

A questionnaire was elaborated in order to collect knowledge and level of development of 25 ITS-systems which were listed in the EU-project VERA (attachment 2). The questionnaire was elaborated in English because none of the respondents were Norwegians. The questionnaire was sent to:

- Members of SAFER's Pre-crash-group
- Risto Kulmala (a representative of eSAFETY-Forum)
- ECTRIs ITS-groups
- Partners in HUMANIST VCE

In some cases we have retained the original text used by the respondents because the response itself indicate the status and the maturity of the system as well as the knowledge about them.

4.1 Responses from SAFERs Pre-crash-group

TØI participates regularly in SAFER's Precrash-group and meetings are held about every second month. The present project and its background was presented in a meeting 8th November 2011. One response – the only one - was received from Trent Victor and Claudia Wege in Volvo Technology Corporation, who submitted Deliverable 1 (D1) from the EU-project ADAPTATION. D1 was entitled:

> ***"ADAS within the ADAPTATION project - function selection, benchmark, behavioural adaptation effects and conceptual framework development" (Wege og Victor, 2010)***

D1 comprised a State-of-the-Art benchmark which provided an overview over categories of Advanced Driver Assistance Systems (ADAS).

4.2 Response from Risto Kulmala (representantive of eSafety Forum)

Risto Kulmala, who until recently worked as researcher at Finnish VTT, is a very central person among those who work with ITS in the car industry and road sector. Kulmala, who now work at Liikennevirasto (Finnish Transport Agency/Trafikvärket), referred, however, to Sören Hess (Car-2-Car Communication Consortium) and Walter Hagleitner. We sent the questionnaire to Hess and Hagleitner. Hagleitner responded that he could provide the requested information if a workshop on this topic was held in Norway. Our response was that it was impossible: The project had a tight deadline and economic resources were limited. Hess never responded.

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4.3 Request sent to ECTRI's ITS-group

ECTRI has several sub-groups, who work with specific topics under the ECTRI-umbrella.[17] One of these addresses ITS and Nour-Eddin Elfaouzi at IFSTTAR in France (former INRETS) was stated as contact person. We sent the questionnaire to him, but he did not respond. Based on information from a TØI-representative who had participated in the sub-group, we regard the group as inactive for the moment.

4.4 Responses from HUMANIST-partners

We received three responses from HUMANIST partners:

1. Andrew Morris and James Lenard from Loughborough University in England
2. Giulio Francesco Piccinini from ISEC, Portugal
3. Marcus Schmitz, Wuerzburg Institute for Traffic Sciences GmbH (WIVW)

4.4.1 Response from Loughborough University

James Lenard from Loughborough University responded as follows:

> *"Andrew [Morris] mentioned that you might be interested in the work on autonomous emergency braking that we recently carried out for Thatcham. I've attached a copy of the ESV paper (which NHTSA will post on the internet in due course) and the full report from the Thatcham website (http://www.thatcham.org/adas/index.jsp?page=1229).*

Lenard attached two reports.

1. Accident data study in support of development of Autonomous Emergency Braking (AEB) test procedures (Lenard and Danton, 2010).
2. Typical pedestrian accident scenarios for the testing of autonomous emergency braking systems (Lenard et al, 2011).

4.4.2 Response from ISEC, Portugal

Giulio Francesco Piccinini responded:

> *"I write you this mail to answer about the questionnaire on DSS.*
> *The technologies mentioned in the questionnaire are quite advanced and I am not really aware about them. So, I cannot be of great help.*
> *However, I know that there were and there are many European projects working on cooperative systems. Here it goes a list of them:*
>
> *- CVIS*
> *- Coopers*
> *- Safespot*
> *- COMeSafety*
> *- Car2car*
> *- DriveC2X.*

[17] ECTRI - European Conference of Transport Research Institutes.

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Reports from these EU-projects have been collected. Piccinini's comment is notewotthy: " *The technologies mentioned in the questionnaire are quite advanced"*. The statement indicates the level of technology as well as the width of the knowledge about the systems actually are.

4.4.3 Response from Marcus Schmitz, WIVW

The final response from HUMANIST was from Marcus Schmitz at WIVW (Wuerzburg Institute for Traffic Sciences GmbH) in Germany. Schmitz was the only one who actually filled in the questionnaire and sent it back to TØI. The questionnaire lists a total of 25 systems and Schmitz provide information about 11 of these. Schmitz response is presented in extenso in table 4.4.1:

Table 4.4.1: Systems which are being developed or exist as prototype.

Driver support system (V2V = vehicle to vehicle)	***On the market? Yes/No/ Unknown***	***Prototype exist/under development? Yes/No/ Unknown***	***If yes: Name of institution or manufacturer***	***Is any description available?***
Approaching Emergency Vehicle warning (V2V)	No	YES	www.simtd.de / BOSCH files a patent application	
Cooperative collision warning (V2V)	No	YES	www.simtd.de / research project Ko-PER partners: http://ko-fas.de/deutsch/projektpartner.html	
Crash warning (V2V)	No	YES	www.simtd.de	
Enhanced Differential GPS Corrections (V2V)	No	Yes	research project Ko-PER partners: http://ko-fas.de/deutsch/projektpartner.html	
Hybrid Intersection Collision warning (V2V)	No	Yes	research project Ko-PER partners: http://ko-fas.de/deutsch/projektpartner.html	
Intersection Collision : Vehicle-Base warning (V2V)	No	YES	www.simtd.de / research project Ko-PER partners: http://ko-fas.de/deutsch/projektpartner.html	
Lane Change Assistant (V2V)	No	Yes	research project Ko-PER partners: http://ko-fas.de/deutsch/projektpartner.html	
Left Turn assistant (V2V)	No	Yes	research project Ko-PER partners: http://ko-fas.de/deutsch/projektpartner.html	
Right Turn assistant (V2V)	No	Yes	research project Ko-PER partners: http://ko-fas.de/deutsch/projektpartner.html	
Vehicle-base Road Condition warning		YES	www.simtd.de	
Other systems ? Please specify		YES	www.simtd.de www.drivec2x.de	

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For nine of the systems listed in Table 4.4.1, Schmitz states that they are not available on the market, but are prototypes or systems being developed. For the final two systems, a prototype has been developed or is being developed, but Schmitz does not state whether the systems are available on the market. For the remaining 14 systems, Schmitz does not provide any information regarding their state of development (Table 4.4.2.)

Table 4.4.2: Systems where no information could be provided

Driver support system (V2V = vehicle to vehicle)	***On the market? Yes/No/ Unknown***	***Prototype exist/under development? Yes/No/Unknown***	***If yes: Name of institution or manufacturer***	***Is any description available?***
Blind Merge Warning (V2V)				
Cooperative Adaptive Cruise Control (V2V)				
Cooperative Glare Reduction (V2V)				
Cooperative Vehicle-Highway Automation system (Platooning)				
Curve Speed warning (V2V)				
Highway Merge assistant (V2V)				
Highway/Rail Collision warning (V2V)				
Instant (Problem) Messaging (V2V)				
Overturn warning				
Pre-crash sensing (V2V)				
Road Feature Notification (V2V)				
Smartcard (with driving restrictions) [18]				
Stop Sign Movement Assistant (V2V)				
Visibility Enhancer (V2V)				
Wrong-Way Driver warning (V2V)				

4.4.4 Appraisal of responses from the survey

The responses from the survey were not overwhelming. One factor that influence responses is naturally that time is a limited resource and that researchers often receive request about answering questionnaires. Further, some may be in a position where they do not want provide information about systems under development because of secrecy, although we have never received any statement that this could be the case.

But missing information is also a response and what is interesting could be what it represents. The landscape we tried to map through the survey was an unknown landscape which EU-project VERA had tried to map around 2008 by providing a list of systems without giving any information about level of development or labeling them precisely.

[18] The «MyKey» system developed by Ford is an electronic ignition key which can be programmed and offers the opportunity to impose driving restrictions. "MyKey" is described in Chapter 3.7.

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The ambition of the present project was to advance beyond the boundaries of the VERA-project and try to map what hitherto was unknown, but without having expectations of being able to definite answers about the status and maturity of the systems. Our method has been to utilize the networks in which we participate ourselves and where researchers may have more knowledge about these topics. Summing up the answers, we conclude by the following:

- Several respondents reply that these systems are "quite advanced" and that they themselves do not have knowledge about the systems (Guilio Francesco Piccinini and Risto Kulmala).
- Two respondents reply by providing reports which touch subsets of those systems which were listed in the questionnaire (Trent Victor and Claudia Wege from EU-prosject ADAPTATION and James Lenard about "Autonomous emergency braking").
- One respondent demands quite exclusively that a workshop has to be arranged if any information would be provided (Walter Hagleitner).
- On the other end of the scale, one respondent - Marcus Schmitz - generously provided information of a total of 11of 25 systems. In addition, Schmitz provide information about market penetration, level of development, and websites where more information may be collected.

Schmitz's way of responding illustrates that in this survey, the objective was not necessarily to achieve the highest possible response rate, but rather to find persons who have the knowledge about the systems we address. If the right person is located, one respondent is actually enough considering the purpose of the present project.

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5 Summary and results

The Norwegian Public Roads Administration (NPRA) wanted estimates of driver support systems with potentials of reducing the number of fatalities at different levels of implementation. The project considered eight driver support systems.

- Intelligent Speed Adaptation (ISA)
- Maximum speed governor
- Alcolock
- Seat belt lock
- Warning of fatigue/sleeping at the wheel
- Programming of ignition key elektronisk (”Smartcard”)’
- Adaptiev Cruise Control/automated braking (ACC)
- Electronic Stability Control (ESC)

In addition to the eight driver support systems, the effects of eco-driving has also been considered. Eco-driving was in the present context defined as driving with lower revolutions per minute during acceleration, with increased torque as a consequence, lesser use of engine braking, and fewer gear-shifts. In sum, these behaviour changes reduce fuel consumption per kilometer driven by 6 % ($p < 0.05$). A tendency of a reduction in the number of accidents is reported, but no estimate is given.

The levels of implementation were defined as follows:

- Drivers 18 – 20 years of age
- Drivers 18 – 24 years of age
- Professional drivers/drivers using cars when carrying out their occupation
- All drivers/cars (and potential passengers in some cases)

For some of the systems the NPRA wanted to estimate the effects in specific groups of drivers at high risk of being involved in fatal accidents, especially effects of ISA and maximum speed governor for drivers convicted for speed violations, and effects of alcolock for drivers convicted for drink driving, respectively.

Regarding studies of driver support systems considered in the report there are none – except for ESC – which have been evaluated on basis of accidents in real traffic. In absence of this, it has been necessary to base most of the estimations on “ex ante” or proxy methods – i.e. methods using data and assumptions based on hypothetic scenarios.

All driver support systems are treated in separate chapters where assumptions, data bases and estimation methods for each of the systems are elaborated in detail.

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Table 5.1: Estimations of the number of lives saved according to selected driver support systems.

System / Levels	Intell. Speed Adapt. (ISA)	Max. speed-governor	Alco-lock	Seat-belt lock	Warning of fatigue/sleeping at the wheel	Smart-card/ MyKey	Adaptive cruise control (ACC)	Electronic stability-control (ESC)
All/All drivers	41,0	8	34,0	29,1 *	100%: 29,8 50%: 14,9	(6,3) **	37,5	30,7
Young drivers 18-20 years of age	4,9	-	-	4,3 *	-	-	-	-
Young drivers 18-24 years of age	10,5	-	-	7,6 *	-	-	-	-
Prof. driving (method 1)	6,2	-	-	3.1	100%: 4,5 50%: 2,2	-	5,6	4,6
Prof. driving (method 2)	-	-	-	2,9	100%: 1,7 50%: 0,9	-	-	-
Drink drivers			4,6					
Speed violators	0,2	-						

Estimating effects of professional drivers by method 1 means using the amount of traffic volume. Using method 2 means using Statistic Norway (SSB) vehicle codes as basis of estimation
Warning system fatigue/sleep 100%: means prevention of all accidents (50%: means 50% prevention)
"-" means "missing calculation basis". Grey color means: "Calculation not relevant"

*) Includes drivers, and passengers in front- and back-seat **) Considers only the option of automatic emergency call, i.e. only one of the options inherent in Fords MyKey.

The most effective driver support system is ISA with an estimated effect of 41 lives saved per year, the least effective system is a maximum speed governor with an estimate of 8 lives saved per year. Regarding the remaining systems the estimates vary between 14.9 and 37.5 lives saved per year when the basis for estimation is all drivers. In some cases the effects on passengers are included.

Survey of driver support systems

A survey with the purpose of mapping the level of development of driver support systems was conducted. A total of 11 of 25 systems were reported to be under development and/or existing as prototype, while no information were stated for the remaining 14 systems (table 5.2).

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Table 5.2: Systems which are being developed or exist as prototype

Driver support system (V2V = vehicle to vehicle)	**On the market? Yes/No/ Unknown**	**Prototype exist/under development? Yes/No/ Unknown**	**If yes: Name of institution or manufacturer**	**Is any description available?**
Approaching Emergency Vehicle warning (V2V)	No	YES	www.simtd.de / BOSCH files a patent application	
Cooperative collision warning (V2V)	No	YES	www.simtd.de / research project Ko-PER partners: http://ko-fas.de/deutsch/projektpartner.html	
Crash warning (V2V)	No	YES	www.simtd.de	
Enhanced Differential GPS Corrections (V2V)	No	Yes	research project Ko-PER partners: http://ko-fas.de/deutsch/projektpartner.html	
Hybrid Intersection Collision warning (V2V)	No	Yes	research project Ko-PER partners: http://ko-fas.de/deutsch/projektpartner.html	
Intersection Collision : Vehicle-Base warning (V2V)	No	YES	www.simtd.de / research project Ko-PER partners: http://ko-fas.de/deutsch/projektpartner.html	
Lane Change Assistant (V2V)	No	Yes	research project Ko-PER partners: http://ko-fas.de/deutsch/projektpartner.html	
Left Turn assistant (V2V)	No	Yes	research project Ko-PER partners: http://ko-fas.de/deutsch/projektpartner.html	
Right Turn assistant (V2V)	No	Yes	research project Ko-PER partners: http://ko-fas.de/deutsch/projektpartner.html	
Vehicle-base Road Condition warning		YES	www.simtd.de	
Other systems ? Please specify		YES	www.simtd.de www.drivec2x.de	

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Appendix 1: Overview of some considered studies

IT-system/ Study	*Effect-variables*	*Method*	*Sample*	*Result*	*Comment*
Adaptive Cruise Control					
Stanton og Young:(2005): Driver behaviour with adaptive cruise control	Attention, workload, stress			Locus of control and trust were unaffected by ACC, whereas situation awareness, workload and stress were reduced	
BusinessWee (2006): Safety Technology: Moving Beyond Seat Belts				Potential increase of headways and reduction of rear-end accidents	
Alcolock					
ICADTS (2001) (referred in Vägverket 2003)	Drink driving convictions	10 years follow-up of drivers convicted for drink driving in the USA and Canada	Drivers convicted for drink driving	Reduction of recidivism by 40-95%	Vägverket (2003) considers the outcome to be fairly valid, but advices only to use the conservative estimate (40%)
Compulsory Speed Limiting/					
Compulsory Speed Limiting					No studies identified
Electtronic Stability Control (ESC)					
Høye (2011): Effects of Electronic Stability Control (ESC) on crashes-An update	Accidents			ESC prevents about 40% of all crashes involving loss of control. Greatest reductions for rollover crashes (-50%), run-off-road (-40%), single vehicle crashes (-25%). Results likely to be somewhat overestimated	
Informative Speed Advice					
Graham-Rove (2004): DAS – "Symmetry-seeker": Developed at National Information and Communications Technology Australia (NICTA) – Canberra	Speed, driver behaviour	3 cameras: One mounted on rear-view mirror, scans the road, one stereoscopic pair of cameras, mounted on each side of the instrument panel observing where the driver fixates. Alarm if the driver overlooks a traffic sign without reducing driving speed. System could be an alternative because alarm based on GPS is "years away".	«Full-scale field-trials soon to begin» (per november 2004).	Preliminary trials only. "Functions well at high driving speeds"	DAS: Detects road signs and warns driver only when signs are ignored (driver does not fixate on signs) Recognizes symmetrical figures: rectangles, oktagones, circles, etc (which is technologically difficult because of variable light conditions. Alarming when recognition of signs is ignored can be irritating. Alarms can be set at different "tolerance-levels" of driving speeds.
Intelligent Speed Adaptation (ISA)					
Várhely and Mäkinen (2001)	Speed, headways	Instrumented vehicle where measuring equipment was invisible	Trials on roads inside and outside densely populated areas + motorways in the Nederland-Spain-Sweden). Speed limit zones from 30 to 120 km/h .	Best effect while driving as a single vehicle, but some effect dens traffic. Suppresses high driving speeds and less speed dispersion. Reduces speeds when approaching roundabout, junctions and curves. Driving in queues more safe in 30-50 km/h	Shorter headways in 70-90 km/h. Some increase in driving time, increase of frustration and stress because of speed delimiter. A majority of subjects would accept a driver-controlled system. Half of drivers would accept ISA in their cars voluntarily.

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IT-system/ Study	*Effect-variables*	*Method*	*Sample*	*Result*	*Comment*
Martin (2002)	Speed, emissions, attitudes		Between 7000 and 8000 cars equipped with ISA in Borlänge, Umeå, Lidköping, Lund	Even a few number of cars with ISA will influence the driving speeds of other cars (in cities) Reduction of high driving speeds. reduction in average driving speeds of 3-4 km/h	If all cars had had ISA, a 20% reduction of accidents would be expected. A majority of drivers say ISA should be mandatory in city environments.
Biding and Lind (2002): Resultats of ISA in 4 municipalities (Borlänge, Lidköping, Lund, Umeå).	Speed on stretches of roads, approaching speed in junctions (reduced), driving speeds in junctions (reduced) Travel speeds (unchanged). A tendency of shorter travel times if active gas pedal Professional drivers, official cars generally negative. Some incidents of sabotage on equipment		4 Swedish municipalities Borlänge: 400 cars (info-system) Lidköping: 150 cars with info-system + 130 with active gas pedal Umeå: 4000 cars with a warning system Lund: 290 cars (see Várhely et al 2002)	Generelly: Positive expectations confirmed. Drivers experience that they become better drivers through ISA, but there are also tendencies of drivers becoming more active as well as more passive with ISA. Average driving speeds reduced by 3-4 km/h, less speed dispersion. More vigilant towards pedestrians. Potential of 20% reduction of accidents if all drivers had had ISA.	Starting point: "Give the driver ***support*** for adapting driving speeds More easy to keep speed limits with ISA. High acceptance in 30/50-streets. Small difference between systems (0.4 km/h) Warning by sound is effcient. Many technical problems with active gas pedal. ISA "unpleasant" when driving alone
Biding and Lind (2002) *Borlänge municipality*			Borlänge: 400 cars (info-system)		Description of system: Positioning with GPS, compass, map matching. Communicates with other vehicles by GSM. Display show limits of speed. Diode + sound or vibratjon in gas pedal when speed limit is violated
Biding and Lind (2002) *Lidköping municipality*			Lidköping: 150 cars with info-system + 130 with active ga spedal		Description of system: Positioning with GPS, compass, map matching. Communicates with other vehicles by GSM. Display show limits of speed. Diode + sound or vibratjon in gas pedal when speed limit is violated
Biding and Lind (2002) *Lund municipality*			Lund: 290 car (see Várhely et al 2002)		Description of system: Positioning with GPS, compass, map matching. Communicates with other vehicles by GSM. Display show limits of speed. Diode + sound or vibratjon in gas pedal when speed limit is violated
Biding and Lind (2002) *Umeå municipality*			Umeå: 4000 cars with warning system. Corresponds to 10% of car population. Cars without ISA affected		Description of system: Posistioning by transponder on lightpoles. Speed not displayed. Diode + sound if speed limit is violated
Várhely m fl (2002) ("Active gas pedal in densely populated areas»)	Speed, headways, interaction with other road users, red-light violations, travel time, environment, acceptance, attitudes, analysis of accidents	Random selection of drivers from vehicle register + especially selected professional drivers. Design: Before-after with control. Measurements of speed and headways, in-depth interviews, diaries, logging of travel times and Environment. Observation by participation as passenger (n=28). Fixed test-stretch of road (33	290 cars equipped with ISA in Lund (test area 30 – 70 km/h). Test period november 2000 to May 2001. Questionnaire among 740/840 randomly selected (response-rate 62% and 59%, respectively). Interview 61 passengers in buses with ISA and 15 taxi-passengers. Interview 100 + 160 pedestrians (before-after)	Speed zone 70 km/h, double driving lane, arterial road: 4.9 km/h reduction of average speed. Speed limit zone 50 km/h: 5.0 km/h reduction in average driving speed. Speed limit zone 50 km/h one driving lane: 3.7 km/h reduction (main street). All reductions statistically significant. 50- and 30-zone mixed traffic 1.0 and 1.7 km/h reduction, respectively (not	"Active gas-pedal": Automatic activation when entering test area. Not possible to switch off. Some technical problems (which affects acceptance of system substantially). A majority is positive to ISA, but those drivers who need ISA most are negative. No tendency of speed dispersion or compensation by higher driving speed outside test area. Voluntary use: More by women and

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IT-system/ Study	*Effect-variables*	*Method*	*Sample*	*Result*	*Comment*
		km). Control site: Helsingborg		significant). Number above 70 km/h in 70 km/h speed limit zone: Reduced from 36% to 22%. In 50-zone: Reduction from 28% to 15%. In 30-zone: Reduction from 34% to 27%. Driver error: Forget to reduce driving speed when speed limit is reduced and vice versa. Less frequent use of signaling in densely populated areas. No effect on all cars (290 cars equals 1% of all cars in Lund)	elderly drivers, less by drivers with high mileage. Estimated reduction of accidents (assumes that all will drive as test-drivers do, bais in Nilsson's Power model): Arterial roads 12-17% Main streets: 5-9 % Central streets: 11 % Fatal accidents: Twice the estimate of personal injury accidents
Static system which forces the driver to comply with speed limit (Elvik and Amundsen 2000)	Accidents	Analysis of accidents and relationship between speed level and accidents		Approx. 200 fewer killed if 95% of all vehicles have system installed	
Supportive Speed Advice	No studies identified				
Maximum speed governor					
Carlsson et al 1992	(Maximum) speed	Model simulation of relationship between speed and accidents corrected for frequency of overtaking	Heavy vehicles on two-lane roads with speed limit 90 km/h	Estimated reduction from 93 to 85 km/h: 2% (from 515 – 504 accidents)	
Elvik 1996	Maximum speed delimited linked to speed limit	Estimation of potential effect associated with all vehicles	Personal injury accidents in Norway	Potential reduction in personal injury accidents by 15 (±5) %	
Várhely 1996; 1997	Maximum speed delimited linked to speed limit	Estimation of potential effect associated with all vehicles	Personal injury accidents in Sweden	Potential reduction in personal injury accidents by 15 %	
Várhely 1996; 1997	Dynamic, automated speed delimiter system	Calculating potential effect associated with all vehicles	Personal injury accidents in Sweden	Potential reduction in personal injury accidents by 19-34 %	A dynamic, automated speed adaptation system where maximum driving speeds take light and road conditions into consideration in order to achieve increased accident risk under demanding driving conditions

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Appendix 2: Survey Driver Support Systems

From: Truls Vaa, Institute of Transport Economics (TOI) (1)
Date: 27th December 2011
Topic: Survey of Driver Support Systems under development

TOI is making a survey of driver support systems (DSS) limited to systems that already are installed in cars or which can be installed in cars (DSS as part of infrastructure are not included). The main objectives of the project are:

- **a) to map all systems in this category, and**
- **b) to elaborate estimates of potential accident-reducing effects based on empirical data (if available) or by proxy methods**

In our project, we define the total DSS-group as consisting of three subgroups:

1) **DSS already installed in cars**
2) **DSS on the market which can be installed in cars as additional systems**
3) **DSS "under development": not yet available on the market**

In this context driver support systems can be defined as technical systems installed in motor vehicles to support drivers in their choice of behavior. Examples are Intelligent Speed Adaptation (ISA), alcohol ignition interlocks, lane support, blind spot warning, etc.

The name of the project, which is commissioned by the Norwegian Public Roads Administration, is

"Driver Support Systems: Estimating effects on road safety by different levels of implementation".

A paper of the results of the project will be distributed to all contributors at the end of the project.

Below is a list of systems that have been named and identified from several sources. We have, however, not the full overview of the status of DSS, i.e. whether they are fully developed and ready for installation in cars, or if they are still under development/exist as prototype. We would therefore be very grateful if you could help us in clarifying this status. Please also add systems which are not on this list and you may also fill in if any description or reference of the system is available.

We appreciate very much if you are willing to take some minutes to answer this questionnaire and email it to tva@toi.no (Truls Vaa). Thank you in advance !

Best regards

Truls Vaa

Truls Vaa, Research Psychologist

Institute of Transport Economics

Gaustadalléen 21

NO-0349 Oslo

Norway

Phone: + 47 2257 3825

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Driver support system (V2V = vehicle to vehicle)	***On the market? Yes/No/Unknown***	***Prototype exist/under development? Yes/No/Unknown***	***If yes: Name of institution or manufacturer***	***Is any description available? (if yes, please state reference)***
Approaching Emergency Vehicle warning (V2V)				
Blind Merge Warning (V2V)				
Cooperative Adaptive Cruise Control (V2V)				
Cooperative collision warning (V2V)				
Cooperative Glare Reduction (V2V)				
Cooperative Vehicle-Highway Automation system (Platooning)				
Crash warning (V2V)				
Curve Speed warning (V2V)				
Enhanced Differential GPS Corrections (V2V)				
Highway Merge assistant (V2V)				
Highway/Rail Collision warning (V2V)				
Hybrid Intersection Collision warning (V2V)				
Instant (Problem) Messaging (V2V)				
Intersection Collision : Vehicle-Based warning (V2V)				
Lane Change Assistant (V2V)				
Left Turn assistant (V2V)				
Overturn warning				
Pre-crash sensing (V2V)				
Right Turn assistant (V2V)				
Road Feature Notification (V2V)				
Smartcard (with driving restrictions)				
Stop Sign Movement Assistant (V2V)				
Vehicle-based Road Condition warning				
Visibility Enhancer (V2V)				
Wrong-Way Driver warning (V2V)				
Other systems ? Please specify				

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Appendix 3: Basis of estimation and suggested impact on behavior

Matrix of effects: Systems x Behaviour/Exposure/Levels of implementation

Appendix 3: Notes on ex ante-effects of some driver support systems at different levels of implementation

Impact/system	**ISA**	***Maximum speed governor***	***Alcolock***	***Seat belt lock***	***Warning of sleep/fatigue***	***Smartcard (MyKey)***	***Adaptive Cruise Control (ACC)***	***Electronic stability control (ESC)***
Will the system limit driver behaviour	Yes	Yes	Yes	Yes	No	Parents may provide more access to the car, but also reduce the frequency of risk factors	Yes	Yes
Behaviour affected	Speed	Speed	Drink driving	Driving without fastening seat belt	Sleep	All driver behaviour	Attention, stress, workload	Speed in curves
Impact on total transport volume with risk factor	Unchanged ?	Reduced	Reduced	Reduced	Increased ?	Redused transport volume with risk factor, but increase in total transport volume	No	No
Impact on risk behavior	Reduced volume of driving above speed limit	Reduced volume of driving with very high driving speeds	Recidivism among convicted dring drivers reduced by 60-80 %	No driving if seat belts are not locked in positions where car occupants actually sit	Increased driving with risk of sleeping at the wheel ?	Reduced frequency of risk behaviour	Affects the distance to vehicle in front – increased frequency of braking and detecting pedestrians	Reduced frequency of risk behaviour
Level of implementation								
Young drivers 18-20	**4.9 (41 x 0.12)**	**Basis of estimation is missing**	**-**	**4.3 ***	**Basis of estimation is missing**	**Basis of estimation is missing**	**Basis of estimation is missing**	**Basis of estimation is missing**
Young drivers 18-24	**10.5 (41 x 0.255)**	**Basis of estimation is missing**	**-**	**7.6 ***	**Basis of estimation is missing**	**Basis of estimation is missing**	**Basis of estimation is missing**	**Basis of estimation is missing**
Professional drivers	**6.2 (41 x 0.15)**	**Basis of estimation is missing**	**-**	**2.9/3.1**	**100%: 4.5 50%: 2.2/0.9**	**Basis of estimation is missing**	**1.0 + 4.6 = 5.6 ***	**4.6**
All drivers/Number of lives saved	**41.0 (210 x 0.195)**	**8**	**34.0**	**29.1 ***	**100%: 29.8 50%: 14.9**	**6.3 (Ecall 3% of 210)**	**6.6 + 30.9 = 37.5 ****	**30.7**
Convicted drink drivers			**4.6**					
Convicted speed violaters	**0.2 (41 x 0.005)**	**Basis of estimation is missing**						
Grey colour means: "Not relevant"				*) Includes drivers and passengers in front- and back seat			**) Accident same driving direction and accidents with pedestrians	

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Institute of Transport Economics (TØI)

Norwegian Centre for Transport Research

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A private, non-profit foundation, TØI receives basic funding from the Research Council of Norway. However, the greater part of its revenue is generated through contract research. An important part of its activity is international research cooperation, mostly in the form of projects under the Framework Programmes of the European Commission.

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Visiting and postal address:
Institute of Transport Economics
Gaustadalléen 21
NO-0349 Oslo

+ 47 22 57 38 00
toi@toi.no
www.toi.no