Institute of Transport Economics
Norwegian Centre for Transport Research

ENGLISH Summary

Driver assistance systems and accident risk

Literature review

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Among the driver support systems that are on the market today, many are already widely used and were found in empirical studies to reduce the accident risk. Increasing uptake of driver support systems can therefore be expected to improve road safety. However, some systems may adversely affect driver behavior. For example, drivers may rely too much on the systems, and they may become more inattentive or disengage from driving altogether. The systems themselves can also be distracting. Such effects can be expected to be strongest when drivers are relieved of basic driving tasks such as keeping speed and lateral positioning. The overall effect of more and more cars having increasingly advanced driver assistance systems will therefore probably be less than one might expect based on how the individual systems work.

This report summarizes knowledge about driver support systems for passenger cars that are intended to improve traffic safety and that are already on the market today:

- How widespread are the systems in Norway?
- How do the systems affect accidents and driver behavior?
- How do road characteristics, especially road markings, affect the effect of lane keeping systems?

Table S.1 gives an overview of the driver support systems described in the report. The systems are sorted according to how they support the driver, i.e. by regulating stability, longitudinal regulation, etc. The table also states, for each system, whether it is an **emergency** system that only becomes active in specific situations to avoid a collision, whether it **alerts** the driver in critical situations or whether it is a **comfort** system that relieves the driver of general driving tasks such as keeping the car in the lane.

Table S.1: Driver support systems described in this report.

System	Type of system	Description
Stability		
ESC: Electronic Stability Control	Emergency	Reduces the risk of loss of control
Longitudinal control: Speed, deceleration		
ACC: Adaptive Cruise Control	Comfort	Maintains speed and distance to the driver in front
FCW: Forward Collision Warning	Warning	Alerts in the event of an imminent collision with a car or an object in front of the car
AEB: Automatic emergency braking	Emergency	Brakes the car in the event of an imminent collision
Warning for vulnerable road users	Warning / emergency system	Alerts the driver / brakes in the event of an imminent collision with a pedestrian or cyclist
Emergency brake assistant	Emergency	Increases braking power during emergency braking
ISA: Intelligent Speed Adaptation	Warning / Comfort	Alerts the driver / prevents driving over the speed limit
Lateral control: Lateral positioning, steering		
LDW: Lane Departure Warning	Warning	Alerts the driver when the car unintentionally leaves the lane
LKA: Lane Keeping Assistant	Comfort	Helps the driver keep the car in the lane
ELK: Emergency Lane Keeping	Emergency / comfort	As above with stronger steering input
Blind spot warning	Warning	Alerts the driver when changing lanes when something is in the car's blind spot
Door alert	Warning (possibly emergency)	Alerts (possibly prevents the door from opening) when a cyclist would otherwise drive into the car door when opening
Backwards: Reversing		
Reversing camera / parking assistant	Warning / comfort	Provides information / alerts the driver about collision risk when backing
Other		
Fatigue / distraction alert	Warning	Alerts the driver in case of fatigue or distraction
Combined systems	Warning / comfort	Helps with / takes over regulation of speed and lateral positioning

Uptake of driver assistance systems in Norway

Table S.2 gives an overview of the assumed uptake of driver assistance systems in Norway. For those systems that are mandatory on all new cars, the table also shows from which year they are mandatory. Systems that are mandatory from 2022/2024 are mandatory for type approval of new vehicles from 2022, and from 2024 all new vehicles sold in Norway must have the systems.

Table S.2: Uptake of driver assistance systems in Norway on new passenger cars and from which years the systems are mandatory on new cars.

System	Uptake in 2023[b]	Mandatory in Norway from
Stabilitet		
ESC: Electronic Stability Control	100%	**2014** (passenger cars)
Longitudinal control: Speed, deceleration		
ACC: Adaptive Cruise Control	About. 60%	Not mandatory
FCW: Forward Collision Warning	Up to 75%	Not mandatory
AEB: Automatic emergency braking	50-80%	**2022/2024** (passenger cars) **2013** (heavy vehicles)
Warning for vulnerable road users	Up to 80%	**2022/2024** (heavy vehicles)
Emergency brake assistant	100%	**2011** (all vehicles)
ISA: Intelligent Speed Adaptation	About. 50%	**2022/2024** (all vehicles; applies to warning ISA)
Lateral control: Lateral positioning, steering		
LDW: Lane Departure Warning	Up to 60%	**2015** (heavy vehicles)
LKA: Lane Keeping Assistant	Up to 40%	Not obligatory
ELK: Emergency Lane Keeping	Up to 20%	**2022/2024** (passenger cars)
Blind spot warning	Up to 40%	Not mandatory
Door alert	Unknown	Not mandatory
Backwards: Reversing		
Reversing camera / parking assistant	Up to 65%	**2022/2024** (all vehicles)
Other		
Fatigue / distraction alert	Unknown	**2022/2024** (all vehicles)
Combined systems	Unknown	Not mandatory

[b] Approximate estimates; applies to the share of new passenger cars in Norway in 2023; "Up to X %" means that the specified proportion of new cars have the system either as standard or as an option; in practice, not all of these cars will actually be sold with the system.

Effects on crash involvement and driver behavior

Table S.3 gives an overview of how the individual systems affect accident involvement and driver behavior. The results are based on literature reviews. The effects on accident involvement are stated for those accidents the systems are intended to prevent; e.g. ACC is primarily intended to prevent rear-end collision accidents.

Table S.3: The impact of driver support systems on accident involvement and driver behavior.

System	Effect on accidents[a]	Effect on driver behaviour
ESC: Electronic stability control	**Run-off-road/rollover: Reduced**	Little or no effect
ACC: Adaptive Cruise Control	**Rear end collisions: Unknown (reduced in combination with FCW)**	Negative ; more distraction / inattention and secondary tasks, longer reaction times
FCW: Forward Collision Warning **AEB:** Automatic Emergency Braking	**Rear end collisions: Reduced**	Unknown
Warning for vulnerable road users	**Pedestrian accidents: Reduced** **Bicycle accidents: No effect** (only one study)	Unknown, possibly negative (overconfidence)
Emergency brake assistant	**Collisions: Possible small reduction**	Probably no effect
ISA: Intelligent Speed Adaptation	**All accidents: Probably reduced** (from the context of speed accidents)	Both positive (fewer violations of the speed limit) and negative (more distraction; increased speed when the system is inactive)
LDW: Lane Departure Warning **LKA:** Lane Keeping Assistant	**Run-off-road/head-on: Reduced**	Both positive (better lateral positioning and use of turn signals) and negative (more distraction and inattention)
ELK: Emergency Lane Keeping	**Run-off-road/head-on: Unknown**	Unknown
Blind spot warning	**Relevant accidents: Reduced**	Unknown
Door alert	**Bicycle-door collisions: Unknown**	Unknown
Reversing camera / parking assistant	**Reversing accidents: Reduced; increased on trucks**	Used relatively little; negative effect on trucks (overconfidence)
Fatigue / distraction alert	**All accidents: Unknown**	Unknown
Combined systems	**All accidents: Unknown**	Probably negative; more distraction / inattention, often excessive confidence, possible confusion about current status

[a] Effects on accidents that the systems are intended to prevent

For most driver assistance systems, empirical studies show that they reduce the risk of specific types of accidents in many common driving situations:

- **Stability:** ESC reduces loss-of-control crashes, for example crashes that are due to excessive speed in curves.
- **Longitudinal control (speed and braking):** Several systems can support the driver in maintaining a desired speed and headways (ACC, ISA) and warn the driver or slow down the car when this is necessary (FCW, AEB, Vulnerable road user warning, emergency brake assistant).
- **Lateral control (steering):** Several systems support lane keeping (LDW, LKA, ELK). Other systems can help the driver avoid conflicts with traffic next to the car (blind spot warning, door warning).

- **Reversing:** Different types of reversing and parking assistants can help the driver avoid collisions while reversing or they can park the car on their own.
- **Other systems:** Different types of fatigue and distraction warning systems can alert the driver when the system detects signs of fatigue or distraction. Systems that provide longitudinal or lateral driver support often have mechanisms to ensure that the driver keeps attentive (or at least his hands on the wheel).

If the effects of all driver assistant systems added up, one might expect large reductions in the total number of accidents. However, one cannot expect the effects of all systems to add up. This is shown by studies that have investigated effects on driver behavior and studies of combined systems and so-called self-driving cars.

Possible reasons why the impact of driver assistance systems may be less than expected, either for individual systems or for combinations of systems, are:

- The effects on accidents may be overestimated
- There may be unintended effects on driver behavior, for example drivers may direct their attention to other tasks, and they may be generally less attentive
- Driver assistance systems may affect interactions with other road users
- Driver assistance systems may in themselves have adverse effects such as e.g. distraction; this applies specifically to comfort systems and combined systems
- Driver assistance systems may contribute to conflicts that would not have occurred without the systems, for example if the car does not detect obstacles or the driver does not react appropriately to a warning.

To summarize, it is not possible to predict how the increasing uptake of driver assistance systems, or increasing automation in general, will affect accident risk. This also applies to increasing automation of the driving task in general. Driver assistance systems and increasing automation may remove some factors that contribute to accidents, but they may create new problems that contribute to conflicts and accidents that would not have occurred without automation and the driver assistance systems.

Lane departure warning, road markings and other road characteristics

Today's lane departure warning systems (LDW) and similar systems (LKA, ELK) work only on roads with longitudinal lane markings. Circumstances where such systems work poorly or not at all are:

- **Missing, poor or invisible road markings:** Without good enough lane markings (both edge and center lines), LDW etc. will usually not work. The systems may have problems detecting lane lines when these have poor contrast or retroreflectivity, or when they are covered by snow or ice. Lane markings can also be difficult to detect under adverse light and visibility conditions, especially shadows, darkness and rain. However, technologies are under development that can make LDW independent of the quality of the road markings.
- **Narrow lanes:** LDW etc. often work poorly or not at all on roads with very narrow lanes. LDW can also warn unnecessarily often on narrow roads. The minimum road width for LDW to function properly is around 2.75 meters. LDW on trucks requires much wider lanes, at least 3.5 meters on straight sections.
- **Very wide roads:** LDW may not work well on very wide roads, but we have no basis for specifying a maximum width.

- **Sharp curves:** LDW etc. often works poorly on sharp curves, especially when the road is narrow. This is a bigger problem for trucks than for cars. However, LDW will often be inactive in narrow curves.

In Norway, most accidents that may potentially be prevented by LDW and similar systems, i.e. run-off-road and head-on collisions, happen on country roads ("Fylkesveger") with a speed limit of 80 km/h. In order to be effective, the roads must have good enough longitudinal edge and center markings. The effect will be greatest on straight stretches outside intersections and on stretches where the speed level is above 60-70 km/h.

On roads where such systems do not work, they can have adverse effects on driver behavior. Amongst other things, drivers may lose track of when the system is active and when it is not, so that situations can arise where they assume that the system will help them keep the car in the lane, while in reality the system is inactive or switched off.