Effectiveness of intelligent speed adaptation, collision warning and alcolock systems on driving behaviour and safety

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***Abstract*:** The objective of the present study is to provide an overview of the effects of selected Advanced Driver Assistance systems (ADAS), namely intelligent speed adaptation, collision warning and alcolock on driving behaviour and road safety. The methodology, developed within the SafetyCube project, was implemented in that purpose. International published studies and reports were selected and then analyzed. For each specific ADAS, the applied methodology included a rigorous and detailed literature search, qualitative analysis of studies in terms of design, methods and limitations and synthesis of findings and meta-analyses, when feasible. The findings of the present study are based on 18 high quality published studies, reports and relevant meta-analyses. Results indicate that in-vehicle technologies and related systems have the potential of playing a very important role on improving road safety. A second remark is that indirect road safety indicators are usually examined, whilst crashes and injuries are rarely considered, due to lack of relevant data. For instance, the effect of alcolock is mainly measurable through the percentage of engine size stops, the reduction in alcohol-related fines and DUI recidivism. Similarly, the effectiveness of collision warning systems is usually examined on the basis of surveys of driving performance, whilst at the same time the costs must be overcome as existing cost-benefit analyses indicate. Overall, there is lack of both quantitative reviews in the form of meta-analyses and qualitative reviews, because relevant research is relatively limited.

Keywords: Road safety; vehicle; measures; speed adaptation; collision warning; alcolock

1. INTRODUCTION

In-vehicle information systems include specialized traffic information systems, cell phones, text messaging, email, vehicle diagnostics, and, in some situations, warning systems and emergency help systems. Collision warnings have the potential to reduce the number of rear-end collisions. These systems inform the drivers when critical situations occur to use the brakes in order to reduce speed. Thus, the warning signals the drivers to react. The intention is to make drivers look immediately forward and assess the threat to make an important safety decision: either to hit the brake pedal or to continue driving at the same speed. In-vehicle collision warning systems are based on the principle to warn drivers whenever there is a high chance of a collision by either displaying a visual message or playing an audio messages. By doing so, drivers will react by breaking and thus reducing speed. Therefore, rear-end collisions could be reduced. Although it is intuitive that the presence such systems would increase road safety levels, studies indicate that the results are mixed and inconclusive.

Speed adaptation and speed limiter systems are in-vehicle devices that check if road vehicles are complying with the speed limit on roads and prevents excessive speeding. There are various variations on such systems and each one might be considerably different than the other but in general the system compared two types of data to each other. On the one hand, the data from the vehicle’s GPS receiver – which continuously identified the position of the vehicle – is compared to the data from a digital map containing all the current speed limits within the test area. Based on this comparison, feedback can be provided about the current speed to the prohibited speed. This system does not only affects the speed violators but may also assist other drivers to keep a safe speed. In-vehicle speed adaptation/speed limiter systems are based on the principle to warn drivers whenever they exceed the speed limit (or exceed the speed limit by a certain amount), by displaying visual or audio messages and warning. By doing so, drivers usually adapt and reduce speeds. Although findings from the studies demonstrate that the presence such systems leads to a reduction in travel mean speed, crash frequency, improve driving performance and increase in speed compliance, there are cases where driver workload is increased.

On the other hand, an alcohol interlock is not an in-vehicle device but needs to be installed in the vehicle at a certain point in time. Such device: "requires the driver to provide a breath sample every time an attempt is made to start" (Silverans et al., 2006). The alcohol interlock has four key elements: 1) "a breath alcohol sensor in the vehicle (and a control unit under the hood) that records the driver's blood alcohol concentration (BAC) and can be set to provide a warning if any alcohol is detected and […] that recommends the vehicle not to start if the BAC exceeds a certain threshold"; 2) "a rolling retest system, which requires at least one retest after the vehicle is underway, but in most applications a retest is required every 20 to 30 minutes while driving (the purpose of the retests is to prevent a non-driver from starting the vehicle for a person who has been drinking and also to prevent drinking once the vehicle is underway); 3) a tamper-proof system for mounting the engine part of the unit, […] along with a system to detect hotwiring or other means that bypass the interlock; and 4) a data-recording system that logs the BAC results, test compliance and engine operation, and creates a record to ensure that the offender is actually using the vehicle as expected and not simply parking it while driving with another vehicle" (Marques and Voas, 2010).

Besides the device installed in the vehicles, the offenders are also participating in accompanying rehabilitation programs. These rehabilitation programs ideally combine therapy, education, sanctions and supervision measures (Houwing, 2016). The specific implementation of such measures depend on the legal framework of the concerned countries. Such rehabilitation programs are effective in reducing recidivism in drunk drivers and can be combined with an alcohol interlock. However, when combining both measures the rehabilitation program should fit the offender's need very well in order to be effective (Boets et al., 2008).

Given the importance of these measures, the objective of the present study is the overview of the effects of selected Advanced Driver Assistance systems (ADAS), namely intelligent speed adaptation, collision warning and alcolock on driving behaviour and road safety.

2. METHODOLOGY

This study is based on the SafetyCube project (2017), which aims to identify and quantify the effects of risk factors and measures related to behaviour, infrastructure or vehicle, and integrate the results in an innovative road safety Decision Support System (DSS). Overall, the methodology consists of three distinct steps. The first step comprises thorough international literature database searches, in order to identify relevant studies, and screening and selecting relevant studies to be included in the assessment analysis on the basis of rigorous selection criteria; priority is given to studies reporting quantitative results, recent studies over older studies (before 1990), and European studies as opposed to overseas ones. The literature searches were carried out in autumn 2016. Each literature search, study coding and synopses creation for a particular risk factor was completed within the same SafetyCube partner organization. The process was documented in a standard format to make the gradual reduction of relevant studies transparent. The main databases used for behavioral risk factors were the following: Scopus, TRID, Google Scholar, Science Direct. Taylor & Francis Online, Springer Link etc. Studies considering crash data were designated the most important. However, while the actual occurrence of crashes can be seen as the ultimate outcome measure for road safety, Safety Performance Indicators (SPIs) have in recent years been taken into consideration to quantify the road safety level.

The second step includes the analysis of the studies in terms of design, analysis methods and limitations. For each study the following information was coded; Road system element (Road User, Infrastructure, Vehicle) and level of taxonomy, basic information of the study (title, author, year, source, origin, abstract), road user group examined, study design, measures of exposure to the risk factor, measures of outcome (e.g. number of injury crashes), type of effects (within SafetyCube this refers to the numerical and statistical details of a given study in a manner to quantify a particular association between exposure (either to a risk factor or a countermeasure) and a road safety outcome), effects (including corresponding measures e.g. confidence intervals), limitations, summary of the information relevant to SafetyCube (this may be different from the original study abstract).

The third step concerns the synthesis - and meta-analysis when feasible - or research results per topic, for the estimation of overall effects, general trends and the assessment of the transferability of results. The syntheses of studies for each topic were made available in the form of a ‘synopsis’ indicating the main findings for a particular risk factor derived from meta-analyses or another type of comprehensive synthesis of the results. The synopses contain contextual information for each risk factor and measure from literature that could not be coded (e.g. literature reviews or qualitative studies). However, not all the coded studies are included in the analysis of the synopsis.

In order to achieve the aims of the present study, existing studies were selected and analysed in a set taxonomy of vehicle related measures which include: a) Active safety/ ADAS-Collision Warning, b) Alcolock interlock, c) Intelligent Speed adaptation/Speed Limiter/Speed regulator. For each measure a clearly defined methodology was developed including rigorous literature search, analysis of studies in terms of design, methods and limitations and synthesis of findings and meta-analyses, when feasible.

3. RESULTS

3.1 Active safety/ ADAS-Collision Warning

After appropriate use of various search tools and databases, five (5) high quality studies were selected and coded to evaluate the effectiveness of the collision warning systems on road safety. The vast majority of existing studies applied a simulator experiment (Bueno et al., 2014; Chang et al., 2009; Jamson et al., 2008; Ruscio et al., 2015), and therefore no information on “real” road safety outcome indicators could be drawn. Most of the outcome measures are related to driver performance such as break reaction time, reaction time, minimum headway, speed etc. Similarly, the vast majority of studies examined the absolute differences in various measures such as mean travel speeds and reaction times (Bueno et al., 2014; Chang et al., 2009; Jamson et al., 2008; Ruscio et al., 2015). It is noted that another somewhat popular outcome is the minimum time headway. In order to examine the relationship between the various exposures and outcome indicators, the majority of the studies used simple before-after measurements to calculate the absolute differences. A few studies (Wege et al., 2013) utilize percentage differences. Overall, no statistical modeling takes place except from a few cases (Ruscio et al., 2015). It is also worth mentioning that usually there is no statistical evidence, because no statistical tests are applied/conducted? in many cases. Consequently, no strong conclusions can be made/drawn? And the available results must be interpreted with caution.

There are few limitations in the current literature examining the effects of collision warning on road safety. As stated above, the totality of studies is based on simulator experiments. Secondly, samples often originate from developed countries (except for 1 study conducted in Taiwan) and there is a lack of information concerning the impact of collision warning in less motorized countries, in South America or Africa, for example. These aspects limit the generalisability of the results. It is therefore advised to capture the impact of this measure in all types of environments as well from similar studies for a more collective approach. Moreover, many of the reported findings, lack statistical testing and therefore, conclusions must be drawn carefully.

Table 1: Description of coded studies regarding collision warning systems.

Author(s); Year; Country;	Sampling frame for collision warning investigation	Method for speed collision warning investigation	Outcome indicator	Main Result
Bueno et al.;2014;France	36 participants (18 men, 18 women) from 25 to 40 years old (mean 31.1) took part in this experiment. 14 additional participants were unable to complete the experiment because of simulator sickness. Participants were divided into three groups: group SL (System, Low distraction) drove with the FCWS and carried out a low difficulty secondary task; group SH (System, High distraction) also drove with the FCWS but performed a high difficulty secondary task; and group NL (No system, Low distraction) drove without the system and performed a low difficulty secondary task.	Absolute Difference	Break reaction time; Time to collision; Maximum deceleration time; Mean deceleration; Driving speed; Task load index of mental effort; Task load index of effort; Task load index of discouragement; Task load index of irritation; Task load index of stress; Task load index of annoyance	Overall, the results showed that drivers adapted their behaviour positively when the system was introduced. Nevertheless, both the effectiveness and the behavioural adaptation in the short term were dependent on the cognitive load induced by the secondary task. These findings suggest that the warning needs some attentional resources to be processed.
Chang et al.;2009;Taiwan	Young drivers with a valid driver’s license and at least 2 years of driving experience were selected as the subjects in this study. In Taiwan, the minimum age for a driver’s license is 18 years. Thirty male subjects, who ranged from 20 to 25 years of age with an average age of 23.1 years, participated in the study. Since most participants were college students, the average number of driving days per week was around two.	Absolute difference	Mean speed; Reaction time; Mean of lateral position deviation; Accident rate; Standard deviation of speed	The experimental results demonstrated that vehicles with a warning system can alert drivers to the danger of violator vehicles earlier and can, thus, reduce reaction time at an intersection. In addition, the beep sound warning system resulted in a smaller reaction time than the speech message warning did for the release of the accelerator. Although different drivers may have similar reaction time, the outcome of a traffic event in an intersection has variable results, which are either safe or involve an accident. A high driving speed may require a longer brake time in order to avoid an accident. Therefore, the driving speed was another determinant factor in the intersection accidents. The accident rate was reduced from 44% to 26% or 16% for drivers who drove a vehicle that was equipped with audio (speech or beep) warning systems. This indicates that the type of intersection warning system can affect driver behaviors and that the ICWS can reduce the likelihood of an accident.
Jamson et al.; 2008; UK	Participant drivers were drawn from a database of experienced simulator drivers; each had between 1 and 5 h of previous experience with the simulator. This provided a stable level of simulator specific driving familiarity and skill, minimised the possibility of simulator sickness, and ensured that participants were not overexposed or desensitised to the simulated environment. The 45 drivers who took part (23 males, 22 females) had a mean age of 37.4 (SD = 13.9) years. In the previous year, they had driven between 5000 and 35,000 miles (8000–56,000 km) with a mean mileage of 8260 (13,216 km).	Absolute difference	Minimum time headway	The overall result of the simulation is a benefit in road safety due to the use of FCW, both non-adaptive and adaptive: when the system was functional, brake reaction time is reduced and during the braking events, drivers remain further from a collision with a lead vehicle. Between each experimental session, several questionnaires are administered to evaluate: FCW alarm timeliness and frequency, mental effort using the FCW, user acceptance of the FCW, trust in the FCW, personal factors affected by the FCW.

Author(s); Year; Country;	Sampling frame for collision warning investigation	Method for speed collision warning investigation	Outcome indicator	Main Result
Ruscio et al.; 2015; Switzerland	Thirty subjects participated in the test, controlled for age (range: 21–72; M= 44, SD = 15) and gender (male = 15, female = 15). Body Mass Index (BMI) was also recorded (M= 24.1, SD = 3.5) to control the influence of weight and height on deceleration/acceleration rates during the braking maneuver. All subjects never used a collision warning device before, they had a driving license for a minimum of 2 years and categorized themselves as regular drivers (12,000 km/year on average).	Absolute difference	Reaction Time; Force on the brake	The authors conclude that when the warning system provided direct anticipatory information that fulfill driver's expectations, the overall BRT values were faster than the responses where the drivers didn't have previous information about the danger; When the collision warning system fails in signaling a danger, the appearance of a hazard required more time to be recognized and elaborated as a danger.
Wege et al.; 2013; various	The study analyzed glances 30 s before and 15 s after 60 naturally occurring collision warning events. The B-FCW events were extracted from the Volvo euroFOT database, which contains data from 30 Volvo trucks driving for approximately 40 000 h for four million kilometers	Absolute difference; Percentage change	Distance to lead vehicle; Minimum time headway; Minimum time to collision; Warning length; Immediately looking forward; Duration of glances; Number of glance transitions toward to the down AOI	The results show that: the break reaction is not dependent on the FCW system; during the threat-period (on second after the event) the warning causes drivers to look on road but they do not brake more than otherwise; in the post- threat-recovery-period drivers look forward for the same duration after they received a warning as they do when they do not receive a warning; in unpredictable events in the post-threat-recovery-period drivers look less on-road and more down after the warning is issued. A negative effect found in this study is that the use of a warning on the instrument cluster makes the driver look down at the instrument for a long time.

3.2 Intelligent Speed adaptation/Speed Limiter/Speed regulator

After appropriate use of various search tools and databases, six (6) high quality studies were selected and coded to evaluate the effectiveness of the speed adaptation systems on road safety. Most of studies examined the absolute differences in mean travel speeds. However, fatal and injury crashes were investigated in a few cases as well (Hjälmdahl et al., 2002; Várhelyi et al., 2004). In addition, two studies (Várhelyi and Makinen, 2001; Adell and Várhelyi, 2008) used questionnaires and examined driving performance measures change due to intelligent speed adaptation systems. When examining speed adaptation systems, another somewhat popular outcome is the time that drivers exceed the speed limit.

In order to examine the relationship between the various exposures and outcome indicators, the majority of the studies used simple before-after measurements and absolute differences. A few studies (Hjälmdahl et al., 2002) utilize percentage differences. Overall, no statistical modeling takes place. It is also worth mentioning that usually there is no statistical evidence, because no statistical tests are conducted. Consequently, no strong conclusions can be drawn and results must be interpreted with caution.

There are few limitations in the current literature examining the effects of speed adaptation on road safety. The first is that the totality of studies comes from developed countries and there is a lack of information concerning the impact of speed adaptation in less motorized countries, such as South America or Africa. The impact of this measure in these environments should be capture as well from similar studies for a more collective approach. Moreover, many of the reported findings, lack statistical tests and therefore, conclusions must be drawn carefully.

Table 2: Description of coded studies regarding intelligent speed adaptation.

Author(s); Year; Country;	Sampling frame for speed adaptation investigation	Method for speed adaptation investigation	Outcome indicator	Main Result
Adell, E., & Varhelyi, A.;2008; Sweden	Driver comprehension and acceptance of the active accelerator pedal (AAP) after long-term use were evaluated in a large-scale Swedish trial held in 2000–2002. The system was installed in the cars of 281 test drivers who then used it for between six months and a year.	Absolute Difference	Iritation score; Stress score; Safety score; Speeding tickets risk score; Speed change score; Driving effort score;	The study has shown that the concept of the AAP was rated positively while the willingness to keep and pay for the system was rather lower. The system was found to be more useful than satisfactory. High ratings such as "good" and "important" indicate a general need for a system like the AAP and high ratings such as "effective", "clear" and "informing" pointed to the fact that the system could fill those needs. The system was reported to be only slightly "pleasant" and slightly "ugly" and neither "soothing" nor "comfortable". While, using the AAP the drivers felt an increase in the "feeling of being an obstacle", "effort" and "irritation" as well as a reduction in "enjoyment". Notwithstanding, they also felt they were slightly better drivers when using the AAP. The largest effect on the driving outcome was a considerable reduction in the risk of getting speeding tickets. The drivers also felt a slight increase in their safety as well as travel time.
Adell et al.;2008; Hungary and Spain	Field experiments with ISA (intelligent speed adaptation) were carried out in Hungary and Spain in 2003 and 2004, respectively. Twenty private vehicles in each country were equipped with two kinds of systems: (1) support via an active accelerator pedal (AAP) and (2) warning via beep signals and a flashing red light when the speed limit was exceeded (BEEP). The test drivers drove for a month with both systems installed in each car.	Absolute Difference	Mean speed; Perceived safety performance	The results show a reduction of mean and 85 percentile speed while the devices were used, followed by an increase after their deactivation to almost that of the before situation in both countries. The speed variance decreased on all the analysed road types, except on motorways with a 120 km/h speed limit in Spain. The AAP system proved to be more effective in reducing speed than the BEEP system, nonetheless the drivers like it less.
Brookhuis, & de Waard; 1999; Netherlands	Twenty-four subjects, both male and female, were randomly selected from an existing subjectpool that contains over 1000 subjects and were included in a test of effects of feedback on speed behaviour, mental workload and acceptance.	Absolute Difference	Proportion of time driving above the limit; Proportion of time driving above the limit+10%	The hypothesis that ISA would interact with road segment was not supported. Although drivers in both the experimental and control group better complied to the limit in the built-up area (the display was red 4% of the time as opposed to 18% of the time in the rural area), the interaction with display-feedback was not significant. Apparently, in the present experiment ISA feedback does not add to increased rule compliance in a relevant environment.
Hjälmdahl et al.; 2002; Sweden	The effects on speeds and speed distribution were studied in a large scale field trial with an in-car system for speed adaptation in the city of Lund, Sweden. In the trial 290 vehicles were equipped with an "active accelerator pedal" and a data logger for a period of 3–11 months. Data was logged in each test vehicle during the whole trial and was analyzed for 3 one-month periods: Before activating the system, after short time use and after long time use	Absolute Difference	Mean speed; Expected decrease in the number of injury accidents; Expected decrease in the number of fatal accidents	The positive effects of the active accelerator pedal on the speed level and speed distribution could be confirmed and it could also be confirmed that the effect sustained after long time use of the system. The effects were largest on arterial roads where the vast majority of injury accidents occur. In this sense the AAP studied here demonstrated its great traffic safety potential.

Author(s); Year; Country;	Sampling frame for speed adaptation investigation	Method for speed adaptation investigation	Outcome indicator	Main Result
Várhelyi et al.; 2004; Sweden	The long-term effects of the active accelerator pedal (AAP) were evaluated in the city of Lund in 2000 and 2001. The system, installed in 284 vehicles, produced a counterforce in the accelerator pedal at the speed limit. It could, however be overridden by pressing the accelerator pedal harder.	Absolute Difference	Mean speed in test area b/a; Mean speed in non-test area b/a; Accident rate; Mean speed (test drivers/non-test drivers); Maximum approach speed at intersection; Turning speed at intersection	The mean speed decreased more where the speed level was highest with the AAP inactive. The initial decrease in speeds was greater than the decrease after long-term usage of the system. Reduction in speed variance could also be shown. In interactions of equipped vehicles with pedestrians no significant differences could be observed between equipped and non-equipped cars.
Várhelyi and Makinen; 2001; Netherlands, Spain and Sweden	Field trials in three European countries, the Netherlands, Spain and Sweden were carried out in order to investigate the effects of an in-car speed limiter. The trials were carried out on urban and rural roads including motorways. A so-called unobtrusive instrumented car was used, where all the measuring equipment was hidden.	Absolute Difference	Mean travel speed; Mean time gaps; Giving way to pedestrians; Giving way to cyclists; Giving way to cars; Mental demand score; Physical demand score; Time pressure score; Performance score; Effort score; Frustration level score; Mean turning speeds at intersection	The results suggest that, the more frequent the speed limiter interferes, the more frustrated the driver feels. The highest proportion of interference on urban roads was in the Netherlands, followed by Sweden and the lowest in Spain. On rural roads, the highest proportion of interference was in Sweden, followed by the Netherlands and the lowest in Spain. The proportion of increase in self-reported frustration level follows the same order, with the largest increase for the Dutch drivers (by 104%), followed by the Swedish drivers (by 74%) and with the smallest for the Spanish drivers (by 57%). The main conclusion is that automatic speed limiting via in-car equipment is promising within built-up areas.

3.3 Alcohol Interlock

Field experiments showed that this measure have clear effects on the level of road safety in terms of engine stops when the blood alcohol concentration is high. Two high quality experimental studies were coded. On a basis of both studies and effect numbers, it can be argued that alcolock systems have a mixed impact on road safety. There were also cases that results did not include any statistical tests, and therefore conclusions cannot be strongly supported. The results seem generally transferable but this should be done with caution.

For detailed information about background (definition of alcolock, the way in which alcolock affects road safety etc.) the reader is encouraged to refer to the alcohol-interlock by Nieuwkamp et al. (2017). Field experiments with alcolock in commercial vehicles were made in Sweden (Bjerre and Kostela, 2008; Bjerre, 2005). In these studies, alcolock was installed in all vehicles of the companies participating in the studies. The proportion of all engine start failures due to alcolock operation was 0.34% in the first experiment carried out (Bjerre, 2005). On the other hand, the respective percentage was 19% in the second study (Bjerre and Kostela, 2008) at a limit of BAC 0.02. Moreover as stated in the Handbook (Elvik and Høye, 2015), it is not known how reliable the breath tests of alcolock are. Overall, it is indicated that no studies have been found on the effects of alcolock on accidents and therefore no meaningful conclusions can be drawn.

The coded studies are mainly based on data from a specific country like Sweden. Although this is a good sample for general trends in this country, there is a lack of studies representing other countries. Moreover, the totality of studies examines commercial vehicles (buses), without differentiating between different road users (e.g. car users).

The methodology applied for capturing the impact of alcolock on road safety does not vary between studies. This is mainly in terms of the method (basically the absolute proportion) but also in terms of the outcome evaluated as dependent variables (proportion of engine start failures). It is also noted that no other statistical tests regarding this outcome measures were applied.

Table 3: Description of coded studies regarding alcohol interlcock.

Author(s); Year; Country;	Sampling frame for alcolock investigation	Method for alcolock	Outcome indicator	Main Result
Bjerre & Kostela; 2008; Sweden	Officials from 118 companies were interviewed representing 3689 alcolock-equipped vehicles used by 9614 professional drivers, an 80% compliance rate. In a contrast group of 230 transport businesses without alcolocks the interview compliance rate was 57%. Survey results probed motivation for and experience with alcolocks.	Absolute Proportion	Number of failures when first attempting to start the machine	Among 600, heavy vehicles, 0.19% of all starts were prevented by elevated BAC; most during weekends and mornings. Daytime Saturday and Sunday mornings 0.72% of the drivers had elevated BAC.
Bjerre; 2005; Sweden	Alcolock (or alcohol-interlock) devices and programs were introduced in Sweden in 1999. Two types of prevention programs were begun. A primary prevention strategy was initiated to prevent alcohol impaired driving by individuals not pre-selected for having prior DWI offences. This approach was first applied as a pilot project in three commercial transport companies (buses, trucks, taxis). Also a secondary prevention trial was begun as a voluntary 2-year program for DWI offenders involving strict medical requirements, including counseling and regular checkups by a medical doctor. The program did not require a prior period of hard suspension and focused on changing alcohol use habits.	Absolute Proportion	Number of failures when first attempting to start the machine; Number of injury crashes reported by the police. The evaluation has been made in an interlock and medical monitoring program after a DWI offence.	Three of 1000 starts in the primary prevention program were blocked by the alcolock after measuring a BAC higher than the legal limit and lock point of 0.02% (20 mg/dl).

4. CONCLUSIONS

The objective of the present study is the overview of the effects of selected Advanced Driver Assistance systems (ADAS), namely intelligent speed adaptation, collision warning and alcolock on driving behaviour and road safety. The methodology developed within the SafetyCube project was implemented in that purpose. International published studies and reports were selected and then analysed. For each specific ADAS, the applied methodology included a rigorous and detailed literature search, qualitative analysis of studies in terms of design, methods and limitations and synthesis of findings and meta-analyses, when feasible. The findings of the present study are based on 18 high quality published studies, reports and relevant meta-analyses.

The effects of speed adaptation devices in cars are mostly positive in reducing crash frequency, vehicles' mean speed and drivers exceeding the speed limit. Observational and field experiments showed that this measure affects the level of road safety, causing a reduction in travel speeds, an improvement of safety performance indicators and a reduction in fatal crashes. On a basis of both studies and effect numbers, it can be argued that speed adaptation systems create a general positive impact on road safety. Furthermore, the coded studies encompass several topics and have good levels of quality and consistency. There were cases, however, that results did not include any statistical tests, and therefore conclusions cannot be strongly supported.

In-vehicle systems related to collision warning assist drivers to react on time in order to avoid a collision. However, the effects of collision warning systems in cars have unclear effects on road safety. More specifically, simulator and fields experiments showed that this measure have mixed and unclear effects on the level of road safety, and more specifically on road safety outcome indicators like in travel speeds, reaction time, force on break etc. Five high quality studies consisting mainly of simulator experiments were coded. On a basis of both studies and effect numbers, it can be argued that collision warning systems have a mixed impact on road safety. There were also cases that results did not include any statistical tests, and therefore conclusions cannot be strongly supported.

In general, the effects of alcolock systems in vehicles have positive effects on road safety. Regarding engine size stops, the coded studies consistently showed a small proportion of engine stops when blood alcohol levels are increased. However, more research is needed as the number of relevant studies is limited. Therefore, the classification of its impact can be considered as probably effective.

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