Synthesis title:

Advanced Vehicle Systems – Collision Protection

Category: Vehicles

Other Relevant Topics:

- Speed (Drivers)
- Lighting (Vehicles)
- Crash Mitigation and Collision Avoidance (Vehicles)
- Telematics (Vehicles)
- Perceptions of Road Safety (Other)

Keywords:
Collision Protection, Prevention, Autonomous, Primary Safety, Active Safety

About the Road Safety Observatory

The Road Safety Observatory aims to provide free and easy access to independent road safety research and information for anyone working in road safety and for members of the public. It provides summaries and reviews of research on a wide range of road safety issues, along with links to original road safety research reports.

The Road Safety Observatory was created as consultations with relevant parties uncovered a strong demand for easier access to road safety research and information in a format that can be understood by both the public and professionals. This is important for identifying the casualty reduction benefits of different interventions, covering engineering programmes on infrastructure and vehicles, educational material, enforcement and the development of new policy measures.

The Road Safety Observatory was designed and developed by an Independent Programme Board consisting of key road safety organisations, including:

- Department for Transport
- The Royal Society for the Prevention of Accidents (RoSPA)
- Road Safety GB
- Parliamentary Advisory Council for Transport Safety (PACTS)
- RoadSafe
- RAC Foundation

By bringing together many of the key road safety governmental and non-governmental organisations, the Observatory hopes to provide one coherent view of key road safety evidence.

The Observatory originally existed as a standalone website, but is now an information hub on the RoSPA website which we hope makes it easy for anyone to access comprehensive reviews of road safety topics.

All of the research reviews produced for the original Road Safety Observatory were submitted to an Evidence Review Panel (which was independent of the programme Board), which reviewed and approved all the research material before it was published to ensure that the Key Facts, Summaries and Research Findings truly reflected the messages in underlying research, including where there may have been contradictions. The Panel also ensured that the papers were free from bias and independent of Government policies or the policies of the individual organisations on the Programme Board.

The Programme Board is not liable for the content of these reviews. The reviews are intended to be free from bias and independent of Government policies and the policies of the individual organisations on the Programme Board. Therefore, they may not always represent the views of all the individual organisations that comprise the Programme Board.

Please be aware that the Road Safety Observatory is not currently being updated; the research and information you will read throughout this paper has not been updated since 2017. If you have any enquiries about the Road Safety Observatory or road safety in general, please contact **help@rospa.com** or call **0121 248 2000**.

How do I use this paper?

This paper consists of an extensive evidence review of key research and information around a key road safety topic. The paper is split into sections to make it easy to find the level of detail you require. The sections are as follows:

Key Facts	A small number of bullet points providing the key facts about the topic, extracted from the findings of the full research review.
Summary	A short discussion of the key aspects of the topic to be aware of, research findings from the review, and how any pertinent issues can be tackled.
Methodology	A description of how the review was put together, including the dates during which the research was compiled, the search terms used to find relevant research papers, and the selection criteria used.
Key Statistics	A range of the most important figures surrounding the topic.
Research Findings	A large number of summaries of key research findings, split into relevant subtopics.
References	A list of all the research reports on which the review has been based. It includes the title, author(s), date, methodology, objectives and key findings of each report, plus a hyperlink to the report itself on its external website.

The programme board would like to extend its warm thanks and appreciation to the many people who contributed to the development of the project, including the individuals and organisations who participated in the initial consultations in 2010.

Key Facts

- Historically, active and passive vehicle[1] safety features have been treated separately. However, a more integrated approach is now common, where vehicles are equipped with a range of passive and active safety features which work together to firstly reduce the likelihood of an RTI, and secondly to reduce the severity of associated injuries if an Road Traffic Incident (RTI) does occur.
- Some technologies (such as ESC and ISA) have been extensively researched by academic and commercial bodies. Assessments of these technologies suggest that an excellent benefit-to-cost ratio in terms of road safety can be achieved with their implementation.
- The potential savings in RTI costs for a 100 per cent take up of Electronic Stability Control (ESC) amounts to some £959 million by preventing some 7,800 RTIs. (Frampton and Thomas, 2007)
- The safety effects that current Intelligent Speed Adaptation (ISA) technology can deliver are already impressive. Research has shown that an ISA system that cannot be overridden by the driver could deliver a 37 per cent reduction in fatal RTIs in the UK. (Goodwin et al., 2006)
- Brake Assist Systems (BASs) can potentially reduce fatal RTIs by 4 per cent in Europe. (Broughton et al., 2009)
- It has been calculated that the fitment of Daylight Running Lights (DRLs) to cars in EU countries could lead to an annual reduction of 2,800 deaths. (DaCoTA, 2012b)
- When comparing similar vehicles between 2010 and 2014, it was found that vehicles that were equipped with Forward Collision Warning (FCW) had a reduced involvement in rear end collisions by 27%. (Cicchino, 2017)
- A study found a 38% overall reduction in rear-end crashes for vehicles fitted with Autonomous Emergency Braking (AEB), when compared to a comparison sample of similar vehicles. (Fildes, 2015)

[1] Active safety – This is a form of safety which aids the driver in avoiding a collision or mitigating the severity of a collision.

Passive safety – This is a form of safety which tries to protect the driver and passengers from injury in the event of a collision.

Summary

In the past there has been a focus on the development of passive safety (secondary safety) features that are intended to protect vehicle occupants during road traffic incidents (RTIs). More recently there has been a shift towards the development of active safety (primary safety) features that aim to prevent RTIs. Historically, active and passive safety features have been treated separately. However, a more integrated approach is now common, where vehicles are equipped with a range of passive and active safety features. These features work together to firstly reduce the likelihood of an RTI and secondly to reduce the severity of associated injuries if an RTI does occur.

In-vehicle systems which aim to prevent RTIs by autonomous intervention include:

- Adaptive Cruise Control (ACC);
- Advanced Adaptive Front Light System (AAFLS);
- Anti-Lock Braking Systems (ABS);
- Automated lights;
- Autonomous driving;
- Autonomous Emergency Braking System (AEB)
- AEB for Pedestrians and Cyclists;
- Brake Assist System (BAS);
- Daylight Running Lights (DRL);
- VRU detection for heavy vehicles;
- Drowsiness and Distraction Recognition (DDR);
- Electronic Stability Control (ESC);
- Emergency Steering Assist;
- Forward Collision Warning (FCW);
- High Beam Assist;
- Junction Assist;
- Lane Change Assist (LCA);
- Lane Keeping Assistant (LKA);
- Intelligent Speed Adaption (ISA);
- Rear Cross Traffic alert;
- Rollover Detection;
- Two Wheeled Motor Vehicle (TWMV) braking systems;
- Vulnerable Road Users protection (VRU);
- V2X – Vehicle Communication; and,
- Youth Key (YK).

Some of the technologies (such as ESC and ISA) have been extensively researched by academic and commercial bodies. Assessments of these technologies suggest that an excellent benefit to cost ratio in terms of road safety can be achieved with their implementation. Consequently, ESC for example has become standard on all new European vehicle models and was made mandatory on all new vehicles from 2014. Despite the success of some devices, it should be noted that the majority of technologies are not common place and are typically fitted as options.

Methodology

This synthesis is focussed on in-vehicle technologies that offer an autonomous intervention, essentially taking control away from the driver and performing a function such as braking in the moments before a potential RTI. Some warning systems are included by this synthesis, but others are not as these systems are covered in the Telematics synthesis. Features such as seat belts and airbags are covered in the Crash Mitigation and other syntheses. Collision protection technologies are also known as primary safety, active safety and e-safety features. This synthesis was compiled during January – February 2013; an update was made to this synthesis in July 2017.

Note

This review includes statistics from Reported Road Casualties Great Britain 2015 (Lloyd et al, 2016).

A detailed description of the methodology used to produce this review is provided in the Methodology section of the Observatory website at http://www.roadsafetyobservatory.com/Introduction/Methods.

The steps taken to produce this synthesis are outlined below:

- **Identification of relevant research** – searches were carried out on pre-defined research (and data) repositories. As part of the initial search some additional information sources were also consulted, which included http://www.ingentaconnect.com and various project archives. Search terms used to identify relevant papers included, but were not limited to:
    - ‘Collision protection’;
    - ‘Mitigation’;
    - ‘Prevention’;
    - ‘Avoidance’;
    - ‘Automated’;
    - ‘Autonomous’,
    - ‘Braking’;
    - ‘Stability’;
    - ‘Control’;
    - ‘Adaptation’;
    - ‘Adaptive’; and,
    - ‘Legislation’.

  A total of 82 pieces of potentially relevant research were identified.

The referenced material used in this synthesis has been broken up into two sections. One section is for ‘Evidence Based References’, this will encompass published papers, conference papers, book chapters etc. The second section of references is for ‘Non-Evidence Based References’, this will contain manufacturer and supplier references of their products, these have been included as although their worth hasn’t been quantifiably measured, many of the systems are new and relevant to ADAS as a whole.

- **Initial review of research** – research items based on key criteria were sorted to ensure the most relevant and effective items went forward for inclusion in this synthesis. Key criteria included:
    - Relevance – whether the research makes a valuable contribution to this synthesis, and has adequate focus on collision protection and linkages to road safety.
    - Provenance – whether the research is relevant to drivers, road safety policies or road safety professionals in the UK. If the research did not originate in the UK, the author and expert reviewer have applied a sense check to ensure that findings are relevant and transferable to the UK.
    - Age – whether the research has been published within the last 15 years. Priority is given to the most up to date titles in the event of overlap or contradiction.
    - Effectiveness – whether the research credibly proves (or disproves) the effectiveness of a particular collision protection technology initiative or intervention.
- **Detailed review of research** – key facts, figures and findings were extracted from the identified research to highlight pertinent road safety issues and interventions.
- **Compilation of Synthesis** – the output of the detailed review was analysed for commonality and a synthesis written in the agreed format. Note that the entire process from identifying research to compiling the synthesis was conducted in a time bound manner.
- **Review** – the draft synthesis was subjected to extensive review by a subject matter expert, proof reader and an independent Evidence Review Panel.

Due to the variable quantity of available research for each technology, and to ensure balance in the final output, a decision was made to limit the references for any one technology. However, the highest scoring papers (according to the assessment against the key criteria) were included for each collision protection technology.

Key statistics

Contributory factors

Collision protection technologies aim to reduce the likelihood of an RTI. To give an indication of the potential change the collision protection technologies can facilitate, a breakdown of contributing factors which could be addressed is provided for 2015.

- 'Exceeding the speed limit' was reported as a factor in 5 per cent of RTIs, but these RTIs involved 15 per cent of fatalities. At least one of the 'exceeding the speed limit' and 'travelling too fast for the conditions' contributory factors was reported in 12 per cent of all RTIs and these RTIs accounted for 26 per cent of all fatalities.
- 'Driver/Rider failed to look properly' accounted for 44 per cent of RTIs, these RTIs accounted for 27 per cent of fatalities. 54 per cent of these RTIs occurred on motorways or A roads.
- 'Loss of control' was reported as a factor for 13 per cent of RTIs; however, it accounts for 31 per cent of fatalities. 'Loss of control' was reported as a factor for a similar proportion of RTIs across all road types.
- 'Following too close' was a reported contributory factor in 16 per cent of all motorway RTIs, whereas it only accounted for 8 per cent on A roads. Similarly, 'sudden braking' contributed to 12 per cent of all motorway RTIs, compared to 8 per cent on A roads.

(Lloyd et al, 2016)

Road traffic incident scenarios

- Of the RTIs which occurred during dry road conditions, 5.2 per cent of cars skidded.
- Of the RTIs which occurred during wet road conditions, 13.7 per cent of cars skidded.

(Lloyd et al, 2016)

Research findings

Summaries of key findings from several research reports are given below. Further details of the studies reviewed, including methodology and findings, and links to the reports are given in the References section.

Research trends

- Whilst the main focus during the last decade has been to address key problems for secondary safety (i.e. protection in the event of a RTI), the significant advances in computing and sensor technologies present an opportunity to secure important casualty reductions through the implementation of advanced primary safety systems (i.e. RTI avoidance) in the longer term.

(DfT, 2009)

- Historically, the fields of primary and secondary safety have been considered in isolation. However, in recent years the boundaries between these two areas have been blurred, largely because of the development of advanced sensor technologies that have made a much wider range of system functionality possible.

(Broughton et al, 2009)

In-vehicle systems which aim to prevent RTIs by autonomous intervention include:

- Adaptive Cruise Control (ACC);
- Advanced Adaptive Front Light System (AAFLS);
- Anti-Lock Braking Systems (ABS);
- Automated lights;
- Autonomous driving;
- Autonomous Emergency Braking System (AEB);
- AEB for Pedestrians and Cyclists
- Brake Assist System (BAS);
- Daylight Running Lights (DRL);
- VRU detection for heavy vehicles;
- Drowsiness and Distraction Recognition (DDR);
- Electronic Stability Control (ESC);
- Emergency Steering Assist;
- Forward Collision Warning (FCW);
- High Beam Assist;
- Junction Assist;
- Lane Change Assist (LCA);
- Lane Keeping Assistant (LKA);
- Intelligent Speed Adaption (ISA);
- Rear Cross Traffic alert;
- Rollover Detection;
- Two Wheeled Motor Vehicle (TWMV) braking systems;
- Vulnerable Road Users protection (VRU);
- V2X – Vehicle Communication; and,
- Youth Key (YK).

Each of the collision protection technologies will be defined and features introduced in the following sections.

Adaptive Cruise Control

- If a leading vehicle is travelling at a lower speed than the user's vehicle, or is located within the pre-set time or distance headway, the ACC system intervenes via braking pressure or throttle/engine torque control so that the headway increases.
- The system only intervenes if the current preselected speed or headway would lead to a likely RTI or the speed would reduce the set headway.
- ACC may employ radar, laser or machine vision to continuously monitor the leading vehicle. Auxiliary detectors also monitor the speed, yaw and cornering rate of the vehicle to maintain tracking of the leading vehicle in the same lane when cornering. ACC keeps a set distance to vehicle in front and can detect fixed obstacles on the road.

(Atalar et al, 2012)

Advanced Adaptive Front Light Systems

- Advanced Adaptive Front Light System (AAFLS) refer to headlights that turn relative to the vehicle to boost visibility through bends (in reaction to steering angle and sometimes yaw) although some systems can also adjust the light pattern for different road speeds and visibility (for example narrower beam on motorways). AAFLSs provide improved vision in darkness and poor visibility (weather conditions) when manoeuvring through bends.
- Other technologies closely associated with AAFLS are Cornering light assist and Auto high beam assist. Cornering Light Assist illuminates to wider than traditional angle when turning corners (especially at junctions). This can provide extra light or an extension to AAFLS. Auto High Beam is a feature that takes over the switching of high beam lights away from the driver to improve vision and to avoid dazzling oncoming drivers.

(Atalar et al, 2012)

Anti-lock Braking Systems

ABS has been mandatory for new cars in the EU since 2004.

- ABS prevents wheel lock and the associated instability under braking and permits some steering during emergency braking, thus increasing the ability of the vehicle to avoid an RTI. For vehicle/trailer combinations it also greatly reduces the chance of jacknife and trailer swing. Market penetration is relatively high, particularly for larger goods vehicles (greater than 12 tonnes) and long distance touring buses where it has been mandatory since 1991. It is now fitted to all new passenger cars, HGVs and buses, and is fitted to many new light commercial vehicles (LCVs).

(Broughton et al, 2009)

Automated lights

- Headlights and rear lights (driving lights) are activated if the driver forgets to activate them in darkness. Headlights and rear lights are switched on if the vehicle enters a tunnel or other covered area (multi story car park or road lined with dense trees) where the light level drops below a defined threshold. Most often a light sensor is mounted on the windscreen, often as part of the rear view mirror assembly. This system only works if the light switch is always in automatic position.

(Atalar et al, 2012)

No evidence related to the effectiveness of automated lights in terms of reducing RTIs was found during the compilation of this synthesis.

Autonomous driving

Autonomous driving has been defined into 6 levels of automation:

- Level 0:
    - There is no automation at this level and is where all driving activities are performed by the driver, even with help from warnings and some intervention systems
- Level 1:
    - This is where driver assistance is utilised. A driver assistance system is used to help the driver either steering or through acceleration/deceleration using information based on the environment. The expectation is that the driver will perform all remaining tasks. An example of this level of automation is ACC.
- Level 2:
    - Partial automation is in effect here. This is where one or more driving assistance systems of both steering and acceleration/deceleration use information about the driving environment. There is an expectation that the human will perform all remaining tasks.
- Level 3:
    - The driving mode specific task is an automated task, where the system does all of the driving and monitors the environment around the vehicle. The driver would be required to intervene and take control when required by the system.
- Level 4:
    - This is a high level of automation. This is where the system performs all tasks on the road and will request the driver to respond periodically. If the driver does not respond, the system will continue regardless.
- Level 5:
    - This is classified as full autonomous, where all aspects of the dynamic driving task under all roadway and environmental conditions are managed by the system. In this scenario the driver can be regarded as a passenger.

(SAE, 2016)

As a point of reference, in the current market (2017), the level of automation on the roads falls between level 2 and level 3, with systems pioneered by vehicle manufacturers such as Tesla and Volvo, with Autopilot and Pilot Assist respectively.

Autonomous Emergency Braking System

- With the aid of radar, Light Detection and Ranging (LIDAR) and/or camera systems, this technology actively assesses the driving environment for potential hazards. In particular, current systems address rear end RTIs but an oncoming vehicle will also activate the system. The systems typically first warn of a potential RTI and most then provide a level of braking support:
    - Enhancement of the driver’s braking;
    - Partial automatic braking; and,
    - Full braking.

(Atalar et al, 2012)

- Vehicle technology has increased rapidly in recent years, particularly in relation to braking systems and sensing systems. The widespread introduction of ABS has provided the building blocks for a wide variety of other braking control systems.
- In parallel to the development of braking technologies, sensors have been developed that are capable of detecting physical objects such as other vehicles or pedestrians around the vehicle.
- Theoretically, a vehicle equipped with modern braking technology and ACC is equipped with all the necessary hardware to allow a simple (braking only – no steering) RTI avoidance system that would be capable of detecting when a RTI is likely to occur and applying the emergency braking to avoid it.
- Autonomous Emergency Braking System (AEB) sensors detect a potential RTI and take action to avoid it entirely, taking control away from the driver. In the context of braking this is likely to include applying the emergency brake sufficiently early that the vehicle can be brought to a standstill before a RTI occurs. This technology is likely to have the high potential benefits but can also present a high risk if a false activation was to occur.

(Grover et al., 2008)

- AEB systems improve safety in two ways: firstly, they help to avoid accidents by identifying critical situations early and warning the driver; and secondly they reduce the severity of crashes which cannot be avoided by lowering the speed of collision and, in some cases, by preparing the vehicle and restraint systems for impact.

(Euro NCAP, 2017)

AEB for Pedestrians and Cyclists

- AEB systems which function at low vehicle speeds have the largest target population. These systems are able to sense pedestrians and cyclists as they walk/run/step out in front of a vehicle.
- Most low speed AEB systems use LIDAR and stereo camera based systems. This allows the vehicle to first identify a potential collision. When a situation has been identified, the driver is usually alerted; however, if the driver doesn't react, then the system will automatically brake and try to avoid or mitigate the collision.

(Euro NCAP, 2017)

- The stereo camera is especially efficient at detecting the distance and size of an object. This is then coupled with a vision algorithm which allows the camera to predict the direction of movement for the pedestrian.

(Bertozzi, 2005)

- The time for the system to identify a collision is especially important for impacts with pedestrians as as typically the time between the precipitating event and the collision is small. An example of this would be a child running out into the road from behind a car.

(Euro NCAP, 2017)

Brake Assist System

- It has been shown that drivers often do not use the maximum braking available to them in an emergency situation. BASs detect when a driver intends an emergency brake application and acts to increase the amount of braking applied such that maximum braking is reached earlier in the stop, thus reducing stopping distance.

(Broughton et al*.,* 2009)

- BAS has been a requirement for all vehicles in the EU since 2014.

(EU Commission, 2009)

However there are concerns regarding how this technology will affect driver behaviour.

- In general most of the devices described for improvement of braking and handling interfere with driver behaviour, and the questions of driver acceptance, risk compensation and driver reaction when the system is activated are important (especially for older drivers).

(DaCoTA, 2012a)

A further advancement to BAS is Predictive Brake Assist (PBA).

- PBA uses the vehicle's sensors from ACC and AEBs (predominantly radar) to detect impending emergency braking situations. Pilot pressure is applied to the brake system so that the required brake pressure can be generated more quickly, and the brakes are applied very gently so that the driver does not notice. In addition PBA lowers the triggering threshold for the hydraulic brake-assist system. After this initial phase the system then acts like a BAS.

(Atalar et al., 2012)

Daylight Running Lights

- DRLs are multi-purpose or specially designed lights on the front of a vehicle for use in daytime to increase its visibility and avoid multi-party RTIs. There are various DRL options all of which have positive benefit to cost ratios. The options of mandatory manual operation of dipped lights in existing cars and a compulsory advanced DRL unit fitted to new cars seem most advantageous.

(DaCoTA, 2012b)

- Since 2011, all new European cars are required to have DLRs by law. Since 2012, it has been a legal requirement for buses and lorries.

(European Commission, 2008)

Vulnerable Road User detection for heavy vehicles

- These systems use cameras and other sensing types (e.g. ultrasonic) to monitor the perimeter of the heavy vehicle and provide appropriate warnings to the driver.
- Mercedes-Benz's active brake assist four uses radar sensors to monitor the vehicle's entire front and near-side length. It will alert the driver of VRUs moving in a critical zone and autobrake for pedestrians and cyclists if required.

(Seidl et al., 2017)

Drowsiness and Distraction Recognition (DDR)

- DDR systems monitor the driver's physiology or their driving style.
- The physiology is usually monitored by camera which keeps track of the driver's eyelids and blinking speed. If the driver shows any signs of fatigue the system would alert the driver.
- The vehicle state is monitored to detect characteristics that indicate drowsiness or distraction. The vehicle will measure how the driver reacts to the driving environment, such as erratic corrections at motorway speed. The ECU will be able to detect these events and alert the driver accordingly.
- The system is also able to monitor for distractions that may have diverted the attention of the driver. An example of this would be the driver taking their eyes off the road to look at a mobile phone.

(Hynd et al., 2015)

Electronic Stability Control

- ESC is a system that utilises the electronic control of the brakes and engine to prevent the driver from losing control of the vehicle. It achieves this through a calculation of the driver's intended actions (measured through steering wheel angle, accelerator position and vehicle speed) and a comparison of the driver's intentions to the dynamic characteristics of the vehicle (taken from a lateral accelerometer and yaw rate sensor).

(Frampton and Thomas, 2007)

- ESC has been on the market since 1995.

(DaCoTA, 2012a)

- In the EU, ESC is mandatory in all new types of vehicle and was mandatory for all new vehicles from 2014.

(Atalar et al., 2012)

- A relatively new addition to addition to ESC has been added by Mercedes-Benz. The manufacturer has named it Crosswind-Assist. The technology works by measuring the strength of the wind in the lateral direction of the vehicle, caused by meteorological conditions or by a passing HGV.
- The system then recognises the instability and keeps the vehicle in the centre of its lane, either by braking individual wheels, or by dynamically adjusting the suspension system on the vehicle.

(Mercedes-Benz, 2017a)

Emergency Steering Assist

- The system utilises radar and LIDAR sensors around the vehicle to track where other vehicles are in proximity to the vehicle. When the system detects a potential collision, it will start to apply its AEB.
- If the system determines that the AEB would not be sufficient to avoid the collision, the ECU calculates the optimum steering response to avoid the obstacle.
- The ECU has software that can identify the vehicle's lane of travel, speed and the location of the vehicle's surroundings. From this information, the vehicle can plot the optimum path of the vehicle while restricting the levels of lateral acceleration.

(Nissan, 2017)

- Steering and evasion assistance systems are a new class of driver assistance systems that open up additional potentials for collision mitigation.

- Steering intervention is a sensible alternative or additional option for emergency braking systems in a collision speed range above 30 km/h. Steering intervention and evasion systems especially focus on surprising situations, where fast reactions are needed and no time is left for driver warnings.

(Eskandarian, 2012)

Forward Collision Warning

- A forward collision warning system is a system which uses radar and LIDAR to scan the road ahead. By doing this, it can detect any obstacle that the driver may encounter.

- If the system detects an obstacle, then it will alert the driver so that they can decelerate the vehicle, or take evasive action.

- FCW forms the first step in AEB. It is also used in autonomous emergency steering.

(Cicchino for IIHS, 2017)

The brake system is primed by the FCW, meaning that when the driver applies the brakes, the maximum braking potential is achieved.

High Beam Assist

- Since the increasing use of arrays of LED lights in headlamps, it is now possible to select which LEDs become fully illuminated. The system works on radar and light sensors to detect on-coming traffic.

- This detection then communicates with the headlights, and will dim or turn off the specific LEDs which cause glare for the on-coming traffic

- This system means that high beam can be utilised to a greater extent than with conventional headlamps.

(Bullough, 2014)

Junction Assist

Junction assist can be perceived in two ways, one of which is current technology, the other is functionality for the future.

- Junction assist, in the sense of today’s world, is a safety system which scans a junction as the vehicle moves across the junction. It does this through radar, cameras and LIDAR.

- When the system detects a potential collision, it works in the same way as AEB and FWC, to warn the driver and brake the vehicle to avoid the collision.

(Mercedes-Benz, 2017b)

In the future functionality of Junction assist will:

- Use the V2X infrastructure and framework to allow the vehicles to communicate with each other.
- Will allow drivers to know how long, in seconds, they have between on-coming vehicles if they are crossing a junction.
- Will be part of the larger V2X network which allows the vehicles and infrastructure to communicate with each other.

(Le at al, 2009)

Lane Change Assist (LCA)

- This is a system which checks the perimeter of the vehicle for any obstructions when changing lanes. Changing lanes is a constant source of danger when driving on the road, where drivers are taught to instinctively check their blind spot.

  LCA works by utilising two radar sensors, which are constantly monitoring the environment around the vehicle.
- If the driver indicates to change lane, radar data is used to determine whether the lane change can be executed safety, usually by lights on the wing mirror and audible information provided to the driver.

(Bosch, 2017a)

LCA, LKA, and LDW (Lane Departure Warning) all go hand in hand by providing safety when travelling in lane or when changing lane. Less advanced systems have only LDW, whereas LCA and LKA will actively use the ESC to prevent the vehicle from causing, or being involved in a RTI.

Lane Keeping Assistant

The difference between the LKA and LDW is that LDW warns of moving out of the lane but LKA prevents the vehicle from leaving its lane.

- Time to RTI in safety-critical lane changes are normally much less than one second. Driver reaction time is about one second; this means that there is not sufficient time for a driver to respond to a warning before a collision. Because there is insufficient time for reaction to a warning, lane change and merging RTIs can probably only be avoided by intervening systems known as Lane Keeping Assist (LKA). This is an automatic system which keeps the vehicle in its lane except if the turning indicator is activated and depends only on the visibility of the marking.

(DaCoTA, 2012a)

- LKA provides additional torque to the steering wheel, which increases the resistance in the steering wheel. This makes it more difficult for the vehicle to drift, therefore reducing the occurrence of minor variations in lane position. This minimises the need for the driver to make small corrections in lane position.

(Atalar et al, 2012)

In many new, premium vehicles, LKA is coupled with blind spot monitors, as well as semi-autonomous driving. An example would be the Tesla Autopilot system which will change lane for the driver when the indicator is engaged. The vehicle will check for a safe gap, and move itself without the aid of the driver.

Intelligent Speed Adaption

- Three variants of ISA are available:
  - Advisory ISA which informs the driver of the speed limit and warns the driver when the limit is being exceeded.
  - Voluntary ISA in which the information on speed limit is linked to the vehicle's engine management system and perhaps additionally to the braking system - the system comes on with the vehicle ignition, but it may be overridden by the driver at will.
  - Mandatory ISA which works like Voluntary ISA, but without the option to override.

(Lai et al, 2012)

- The in-vehicle speed limit is set automatically as a function of the speed limits indicated on the road. GPS allied to digital speed limit maps allows ISA technology to continuously update the vehicle speed limit to the road speed limit.

(DaCoTA, 2012b)

- ISA also incorporates Traffic Sign Recognition (TSR):
  - Traffic sign recognition (TSR) is an initiative that alerts the driver to the speed limits of the road that they are travelling on.
  - Many systems work by using cameras on the front of the vehicle to read the signs.
  - This sort of technology largely falls under intelligent speed adaptation, under the advisory sense. However, if Mandatory ISA was to be implemented, TSR could be a crucial part of the technology

(Hynd et al, 2015)

- Illegal and inappropriate speed is the single biggest contributory factor in fatal RTIs. It increases both the risk of an RTI happening and the severity of injuries resulting from RTIs. Managing speed is therefore the most important measure to reduce death and injury on our roads.

(Goodwin et al, 2006)

Rear Cross Traffic Alert

- The system works by identifying any traffic that may be passing across the rear of a vehicle. This is especially advantageous when reversing out of a parking space and the view of the driver is obstructed.

- The system uses two mid-range radar sensors in the rear of the vehicle. They measure and interpret the distance, speed and anticipated driving path of vehicles detected in cross traffic.

- If the function detects vehicles crossing to the left or right behind the driver's vehicle with a range of 50 metres, an audible and/or visual warning is used to alert the driver of the risk.

(Bosch, 2017b)

Rollover Detection

- Active Rollover Protection is designed to help stabilise a vehicle in order to help reduce the risk of a rollover. This system focuses on the vehicle's centre of gravity and the lateral acceleration limit or rollover threshold. The system constantly monitors driving conditions and takes corrective action, such as throttle control or braking, when sensors detect that a vehicle is in a potential rollover situation.

(Atalar et al, 2012)

Two Wheeled Motor Vehicle braking systems

- Currently, most motorcycles have separate brake controls for the front and rear brakes. This means that the driver controls the brake balance, which means that the optimum performance is not always achieved. Developing a combined brake control with an optimised brake balance system should result in an increase in the average deceleration in emergency brake manoeuvres for typical riders.
- BAS are another technology which could transfer from passenger cars to improve performance for typical riders in emergency braking manoeuvres.

(Broughton et al, 2009)

- ABS is now a functional requirement on all (with a small number of exemptions) motorcycles sold within the EU
- Autonomous Emergency Braking is now an emerging trend in ADAS for motorcycles (MAEB). It works in very much the same way as a similar system seen in a car. It combines the AEB with BAS so that if the rider does react, then a full braking force is applied. In most cases, it would be required for the motorcycle's brakes to be regulated, probably from an ESC unit, so that the rider isn't thrown from the motorcycle under braking.

(Savino et al., 2014)

- There have been questions as to the effectiveness of MAEB, especially with regard to a motorcycle braking, while cornering, and how this could affect the kinematics of the motorcycle. Savino et al., 2015, found that, when the braking was controlled with an active braking control system, that stability could be achieved while emergency braking in a corner.

(Savino et al., 2015)

Vulnerable Road Users protection

- Vulnerable Road User Protection (VRU) is an AEB system that can detect pedestrians, cyclists and animals. The system calculates the movement of pedestrians within the 'capture' zone which can be up to 30 metres away from the vehicle. The camera tracks the pedestrian movement and the information is correlated with the data received from the radar network. The system applies the brakes if the driver does not.

(Atalar et al, 2012)

- As part of Euro NCAP's 2020 road map, AEB VRU started to be tested in 2015. From 2018, a vehicle's performance in VRU tests will affect its overall Euro NCAP score.

(Euro NCAP, 2015)

V2X - Vehicle communication

- V2X refers to a vehicle communicating with something. This could be Vehicle to Vehicle (V2V), or Vehicle to Infrastructure (V2I), or Vehicle to VRU etc. It is an intelligent transport system where all vehicles and infrastructure systems are interconnected with each other. It will help to:
    - Optimise traffic flow
    - Reduce congestion
    - Reduce incident numbers
    - Minimise emissions

- It allows vehicles to automatically pass on information about things such as road conditions, traffic flow, and obstacles before they appear in the driver's visual range. Vehicles will also be able to receive signals from intelligent road signs.

- It will allow a clear path for emergency vehicles before the emergency vehicle is caught in traffic

(Seimens, 2015)

- V2X will help with Junction Assist because it can let drivers know when it is safe to cross an intersection.

- This level of technology is not currently available in series production vehicles; however, it is part of the support system expected for autonomous vehicles.

(Le et al, 2009)

- V2X will allow a car to know about a pedestrian, how fast they are travelling and where they are, before they step into the road. There is a working theory for this to be developed using smart phones to communicate with the vehicles.

(Kotte, 2017)

Youth Key

- The Youth Key (YK) system aims to limit vehicle performance or functionally with the aim of encouraging safer driving or riding - in particular for young people, although this could be extended. It has a programmable key that can limit a vehicle's top speed, limit radio volume and encourage safety-belt usage by muting the radio until front occupants buckle up. The system is marketed by Ford in the USA as MyKey as a standard or option on all vehicles.

(Atalar et al, 2012)

- A recent enhancement to Youth Key is that not only the speed, radio volume and seatbelt reminders are utilised, but it also now means that certain safety systems in the vehicle cannot be disabled when the Youth Key is in use. These safety systems could include ESC, LKA and AEB etc.

(Volvo, 2017)

Legislation

- Vehicle manufacturers have made significant progress during the last decade in making vehicles safer for all road users. This has helped to reduce the number of casualties and the severity of injuries from RTIs.
- The UK Government cannot achieve improvements in vehicle safety on its own. Vehicle regulations are set at European level and increasingly with a global perspective, given the international nature of the automotive industry. Therefore the DfT needs to work with a broad range of partners, including the European Commission, other governments, manufacturers, fleet operators and interest groups to deliver solutions for British road users.

(DfT, 2009)

- Improvements to vehicle safety result from legislation (much of which is now agreed in the European Union and within the UNECE process), consumer information, product liability considerations as well as specific initiatives of the car manufacturing industry. EU legislation aims:
    - For a minimum but high level of protection across the product line;
    - To encourage the highest possible levels of safety performance based on state of the art testing; and,
    - To provide car industry policies that increasingly promotes safety as a marketable commodity.

(DaCoTA, 2012b)

Negative impacts

- One major downside of technologies can be the so-called risk compensation effect. There is evidence to suggest that such an effect can be linked to the use of safety features in vehicles. This is particularly compelling for the case of ABS. There have been experiments asserting that drivers adapt to the safety benefit of ABS by driving more aggressively, and there is empirical evidence that RTIs occurred after the introduction of ABS because of people testing the system's thresholds.

(ETSC, 2009)

Benefit-to-cost analysis

In 2006 ECORYS conducted a benefit to cost analysis on 21 vehicle safety technologies based on existing literature, data and knowledge for the European Commission Directorate General Energy and Transport.

- Benefit to cost assessments compare the costs of installing the relevant technology in all new vehicles with the benefits for society of doing so in terms of reduced numbers of fatalities, severe injuries and slight injuries. The estimated effects on the number of fatalities, severe injuries and slight injuries are based on:
    - Existing studies;
    - RTI data;
    - Estimates of the effectiveness of the technology in terms of reducing the risk of RTI and/or the severity of injuries in case an RTI occurs; and,
    - A scenario for implementation (market penetration in the Do-something scenario and the Do-nothing scenario).

- ESC has a benefit/cost ratio (BCR) of 3.8, and is deemed to be cost effective.
- ISA has a BCR of 3.3 and is deemed to be cost effective.
- DRL has a BCR of 1.8 and is most likely cost effective.
- ACC has a BCR of 0.4 and is most likely not cost effective.
- BASs have a break even cost/benefit.

(ECORYS, 2006)

- Other studies have indicated that ISA could deliver a very healthy benefit-to-cost ratio, ranging from 3.4 to 7.4, depending on the deployment scenarios.

(Lai et al, 2012)

The benefit-to-cost ratio is dependent on the deployment scenario used. Market driven scenarios relate to the general public's demand for a technology. For example, a technology that saves money by enabling the use of less fuel, or one which prevents minor RTIs which can affect a drivers insurance premiums. Authority driven deployment is related to legislation, where a technology is deemed to be so effective in reducing casualties that it must be fitted to all vehicles.

- Of the two deployment scenarios studied, the Market driven one is substantially outperformed by the Authority driven one.
- The benefits of ISA on fuel saving and emission reduction are real but not substantial, in comparison with the benefits on RTI reduction; up to 98 per cent of benefits are attributable to RTI savings.
- In the Authority driven scenario, ISA is predicted to save 30 per cent of fatal RTIs and 25 per cent of serious RTIs over the 60-year appraisal period.

(Lai et al., 2012)

How effective?

The following sections provide key statistics for a number of the collision protection technologies of interest. These statistics give an indication of the effectiveness of each technology. It should be noted that other pieces of research are available which do not appear in this synthesis; therefore the figures presented here are not definitive.

- It is also worth noting that the UK car fleet takes around 12–15 years to turn over, and this can be noticeably longer for heavy vehicles. So it will take several years for measures being implemented now to be sufficiently widespread in the marketplace to noticeably affect casualty numbers.

(DfT, 2009)

Adaptive Cruise Control (ACC)

- A research study looked at the effectiveness of ACC and how it reduces the number of crashes on highly congested highways. The results were simulation-based and found that with current market penetration, ACC does little to prevent collisions, and in some cases will create more accidents.

- It was found that the ACC worked best when it had a more responsive operation (i.e. the data was sensed at higher frequency) and when the maximum deceleration rate was greater. It was found that a high reduction in collision risk was only achieved when ACC market penetration was increased to 30%.

(Li et al., 2017)

Advanced Adaptive Front Light System (AAFLS)

- During a Traffic Accident Causation in Europe (TRACE) study, AAFLS had an estimated effectiveness for serious injuries saved of 0.6 per cent.

(Atalar et al., 2012)

Anti-lock Braking Systems

- A meta-analysis of research studies which combined and contrasted results shows that ABS give a relatively small, but statistically significant reduction in the number of RTIs, when all levels of severity and types of RTIs are taken together. The analysis also showed that there were statistically significant increases in rollover, single-vehicle RTIs and RTIs with fixed objects when ABS is fitted. There were statistically significant decreases in RTIs with pedestrians/ cyclists/ animals and RTIs involving turning vehicles. ABS brakes do not appear to have any effect on rear-end RTIs.

(DaCoTA, 2012a)

Autonomous Emergency Braking Systems

- AEBs are expected to save a total of 9,000 severe and 53,000 slight injuries, corresponding to 10 per cent and 14 per cent of total severe and slight injuries in Germany respectively.

(Atalar et al., 2012)

- When comparing vehicles of the same make and model, one group with AEB and one group without, it has been seen that there is a 43% reduction in rear-end striking crashes and a 45% reduction in rear-end crash involvements with injuries. When the AEB was coupled with FCW, the reduction rates are seen to increase to 50% and 56% respectively.
- If all vehicles in the US market were equipped with AEB and FCW, then almost 1 million rear end crashes, and 400,000 associated injuries could have been prevented in 2014

(Cicchino for IIHS, 2017)

- A study found a 38% overall reduction in rear-end crashes for vehicles fitted with AEB, when compared to a comparison sample of similar vehicles.
- There was no statistical evidence to suggest a difference in effect between urban (<60km/h) and rural (>60km/h) speed zones.

(Fildes et al., 2015)

Brake Assist Systems

- An evaluation of German RTI data (from 2002) and driver simulator studies have led to the estimation by ECORYS (as part of an EU project) that BAS could avoid 4 per cent of fatal RTIs in Europe.
- In 2005, 5 per cent of vehicles in the EU were equipped with BAS.

(Broughton et al., 2009)

- BAS is now compulsory for all new vehicles in the EU, established by Regulation (EC) 78/2009 to enhance protection for pedestrians.
- A study into the effect of BAS on pedestrian safety has shown that although the implementation of BAS was unlikely to avoid a collision with pedestrians, in most cases the collision would result in less severe pedestrian injuries.
- In a small number of cases, the lower collision speed would actually increase head injury severity, this due to the anthropometrics of the pedestrian and head landing position of the pedestrian (e.g. A-pillar).

(Badea-Romero et al, 2013)

- It is likely that a significant number of new cars now employ a collaborative system which uses both BAS and AEB. BAS has been mandatory on all new vehicles in the EU since 2014, and with Euro NCAP testing for AEB systems since 2016, less expensive vehicles are now adopting AEB as standard (such as the 2017 Seat Ibiza).

(EU Commission, 2009)

(Euro NCAP, 2015)

Daylight Running Lights

- There is evidence to suggest that operating DRL would result in a net casualty reduction in the region of 5 per cent. This was calculated using a meta-analysis of a large body of research related to DRL. These research studies used one of three estimators of effect; the accident rate ratio (ARR), the odds ratio (OR) or the ratio of odds ratio (ROR).

(Broughton et al, 2009)

- Two meta-analyses of the effects of daytime running lights on cars show that the measure contributes substantially to reducing road RTIs. The first study, which examined daytime RTIs involving more than one party, found a reduction in the number of RTIs of around 13 per cent with the use of daytime lights, and a reduction of between 8 per cent and 15 per cent as a result of introducing mandatory laws on daytime use.
- The number of pedestrians and cyclists hit by cars was reduced by 15 per cent and 10 per cent, respectively.
- Another study found a reduction of slightly over 12 per cent in daytime RTIs involving more than one party, a 20 per cent decrease in injured victims and a 25 per cent reduction in deaths in such RTIs.
- A study of data over four years from nine American states concluded that, on average, cars fitted with automatic daytime running lights were involved in 3.2 per cent fewer multiple RTIs than vehicles without.
- A cost–benefit analysis of providing automatic light switches on cars for daytime running lamps using standard low-beam headlights found that the benefits outweighed the costs by a factor of 4.4.
- Motorized two-wheeler users have expressed concerns that daytime running lights on cars could reduce the visibility of motorcyclists. While there is no empirical evidence to indicate this is the case, researchers have suggested that if such an effect did exist, it would be offset by the benefit to motorcyclists of increased car visibility.

(Peden et al, 2004)

Electronic Stability Control

Despite widespread use of ESC, quantifying its effectiveness in terms of RTI rates has proved challenging.

- Often the basic approach used to assess the effectiveness of ESC has been to compare the RTI-involvement rates of cars with and without ESC.
- Assessing the actual effectiveness of such primary safety features in reducing the number of casualties in RTIs can be very difficult. Probably the main reason for this difficulty is that if a primary safety feature is fully effective then there would be no RTIs of the relevant type and therefore, no data for comparison. However, alternative methods use existing accident data to attempt to predict the effectiveness of technologies before they reach the market.

(Broughton et al, 2010)

In 2007 Frampton and Thomas conducted an analysis of RTI data which used a case-control methodology.

- An analysis of RTIs involving 10,475 vehicles with ESC and 41,656 vehicles without ESC in GB showed that:
    - Serious RTIs were 11 per cent lower compared to non ESC cars; and,
    - Fatalities were 25 per cent lower compared to non ESC cars.
- The potential savings in RTI costs for a 100 per cent take up of ESC amounts to some £959 million by preventing some 7,800 RTIs.
- ESC appears to offer additional benefit in adverse road conditions.
- ESC was particularly effective for skidding and overturning RTIs - typically where a driver enters a bend too quickly and attempts to steer.
- Compared to non-ESC cars, 27 per cent fewer ESC vehicles were involved in all single vehicle RTIs compared to 7 per cent for multi and single vehicle RTIs taken together. Unfortunately case numbers did not allow a reliable assessment of ESC contribution to the reduction in serious single vehicle RTIs.
- Overall, ESC has shown worthwhile reductions in both RTI frequency and cost across a wide variety of RTI situations.

(Frampton and Thomas, 2007)

- In a study conducted by Broughton et al (2010), ESC was found to reduce the overall RTI-involvement rate by about one fifth, although the effect was less for serious RTIs and not significant for fatal RTIs.
- The effects varied widely among car models, and analyses failed to yield satisfactory results for several models because of the low number of cars of these models that had ESC fitted as standard.

(Broughton et al, 2010)

During this study cars with ESC and cars without ESC were compared.

- Studies implicitly assume that cars with and without ESC are driven in similar circumstances, for similar mileages and with similar drivers, so that any differences in their RTI-involvement can be interpreted as the effects of ESC. However, analyses of STATS19 RTI data demonstrate that the driver profiles of the two groups of car may well differ in terms of age and sex.

(Broughton et al, 2010)

In a study conducted by Hoye (2011), several studies regarding the effectiveness of ESC were compared and analysed. The study found:

- ESC prevents about 40% of all crashes involving loss of control.
- All fatal crashes are reduced by around 40%; less severe crashes are unchanged when all types of crashes are regarded together.
- Fatal crashes in which rollover is the first harmful event are reduced by 70%, rollover crashes of all severities are reduced by 50%.
- Run-off-road crashes are reduced by about 40%, and single vehicle crashes are reduced by about 25%.
- Results are likely to be overestimated, especially with non-fatal crashes.

(Hoye, 2011)

Forward Collision Warning (FCW)

- When comparing similar vehicles in collisions between 2010 and 2014, it was found that the vehicles which were equipped with FCW had a reduced involvement in rear end collisions by 27%.

- FCW also related to a 20% reduction in rear end collisions involving injures in instances where a collision couldn't be avoided.

- In 2014, nearly 1 million rear end crashes, and 400,000 injuries could have been avoided if all vehicles had a combination of FCW and AEB.

(Cicchino for IIHS, 2017)

High Beam Assist

- An SAE paper researched the implications of high beam assist and what effects it could have on roads in the USA.
- It was found that the application of high beam assist on vehicles could reduce the number of night time vehicle crashes by 6.7%. This is through providing better visibility for the driver operating the vehicle, and producing less glare for on-coming vehicles.

(Bullough, 2014)

Junction Assist

- A study looked at the effect of ADAS for older drivers when crossing junctions. The main parameter that the study focussed on was the effectiveness of the junction assist.

- The junction assist in this case told the drivers how much time they had between vehicles, as well as telling them whether or not it was safe to cross the junction.

- The results showed that the system affected the driving and decisions made by the drivers. It found that they crossed the junction in a shorter time and at higher speeds, and were often crossing the junction with a critical time until collision time. This is a potential drawback of the system.

(Dotzauer et al, 2013)

Lane Keeping Assistant (LKA)

- During a TRACE study the estimated effectiveness for serious injuries saved was 5.7 per cent when LKA is used; no figures were given for the number of fatalities reduced.
- The system is most effective on rural roads and motorways where vehicles often change lanes at high speed. A LKA is far less effective on urban roads because other vehicles are in close proximity more often.

(Atalar et al, 2012)

- The technical and operational feasibility of such systems has still to be demonstrated. Most existing systems are warning only systems.

(DaCoTA, 2012a)

- A 2017 study looked at the influence on driving behaviour from a warning from a LDW system. It was found that a more effective recovery manoeuvre was seen when the warning came when there was a warning of partial lane departure, rather than full lane departure warnings.
- It was seen that drivers spent more time out of their driving lane when they received no warning from the system.
- Subjectively, LDW did not reduce mental workload on the driver, and partial lane departure warning was judged more trustworthy than full lane departure.

(Navarro et al, 2017)

- Another study found that LDW/LKA systems were estimated to reduce head-on and single vehicle collisions on Swedish roads by 53%. This reduction corresponded to a reduction of 30% for all head-on and single vehicle collisions.

(Sternlund et al, 2017)

- An Insurance Institute for Highway Safety (IIHS) report found that two-thirds of Honda drivers in the USA had LDW activated, as they found it 'annoying' when it would alert them.

(IIHS, 2016)

Mandatory Intelligent Speed Adaptation (ISA)

- Research indicates that the more the system intervenes the more significant are the benefits. The use of a mandatory ISA system, when combined with a dynamic speed limit regime, has the estimated potential to reduce overall injury RTIs by up to 36 per cent, fatal and serious RTIs by 48 per cent and fatal RTIs by 59 per cent.

(DaCoTA, 2012b)

- The safety effects that current ISA technology can deliver are already impressive. Research has shown that non-overridable intervening ISA could deliver a 37 per cent reduction in fatal RTIs in the UK.
- In other EU countries, up to 50 per cent of traffic deaths could be avoided if all cars were equipped with supportive ISA.

(Goodwin et al, 2006)

Overtaking is a complicated process where the driver must concentrate on many aspects. Drivers will need to control their interaction with the vehicle they wish to overtake and estimate the time needed to overtake safely. Simulator studies can help to identify whether overtaking behaviour changes when a mandatory ISA system is active.

- The results of a recent simulator study indicated that drivers are less inclined to initiate an overtaking manoeuvre when the mandatory ISA is active and this was particularly so when the overtaking opportunity was short.
- In addition to this, when ISA was activated drivers were more likely to have to abandon an overtaking, presumably due to running out of road.
- The quality of the overtaking manoeuvre was also affected when mandatory ISA was active, with drivers pulling out and cutting back in more sharply.
- In contrast, when driving with a voluntary ISA, overtaking behaviour remained mostly unchanged: drivers disengaged the function in approximately 70 per cent of overtaking scenarios.

- The results of this study suggest that mandatory ISA could affect the safety of overtaking manoeuvres unless coupled with an adaptation period or other driver support functions that support safe overtaking.

(Jamson et al, 2012)

Rear Cross Traffic alert

- The National Highway Traffic Safety Administration (NHTSA) released a report about Not-in-Traffic injuries and fatalities. The report details collisions on private roads, car parks and drive ways.

- In 2011, there were 189 recorded fatalities and around 12,000 recorded injuries from reversing vehicles in the USA.

(NHTSA, 2014)

Only USA data is accessible. In the UK, crash statistics are built up from the STATS 19 database, which doesn't include car parks which are classified as private land.

Two Wheeled Motor Vehicle braking systems

- Simulations were run to establish the effects that MAEB could have had on real world, motorcycle accidents. The research found that there were some positive effects from the MAEB application. It was seen that there was 10% reduction in impact speed when MAEB was applied, in certain crash situations. The results shed light on the feasibility of MAEB in different speed ranges.

(Savino et al, 2014)

Vulnerable Road Users protection

- Simulations were run to test the extent to which an AEB system is capable of identifying a cyclist or pedestrian, and the success with which it can avoid a collision.

- Scenarios with a pedestrian emerging at small time to collision from behind an obstacle prove the most difficult to mitigate with current technology, and will very likely never be avoidable for all vehicle speeds due to physical limitations.

- Scenarios with an unobstructed person walking will very likely be treatable for a wide speed range of next generation AEB systems.

(Seiniger et al, 2013)

Gaps in the research

It is well known that primary safety systems are not currently widespread. This means that there is a lack of real life data related to the effectiveness of such technologies. There also seems to be no standard way of evaluating effectiveness.

In-vehicle data recorders (“black boxes”) offer a good potential source of RTI data for understanding the performance of active technologies both in RTIs and when RTIs are successfully avoided.

In addition to RTI data it is also desirable to understand system exposure on the road in terms of, for example, number of systems in use, distance driven and type of road. This data is needed before accurate accident risks with and without the fitment of a technology can be calculated. Further work is needed to establish such exposure data and in a form that is compatible with the relevant RTI data.

Most vehicles are fitted with multiple systems, for example ESC, AEBs and airbags. A significant challenge is to isolate the effectiveness of individual systems when working alongside other systems in the same RTI in the same vehicle. The majority, if not all, of the studies presented in this synthesis do not address effectiveness in multiple systems. Similar systems can be significantly different across a range of manufacturers. For example, an ESC system in one vehicle may have a different control algorithm from an ESC system fitted to another. This represents a further challenge for the analysis of effectiveness of systems because it is not easy for the investigator to identify or understand different algorithms. It is important to be able to study performance at that level of detail in order to identify effectiveness and needs for future development.

The monitoring of driver behaviour in response to new technologies is also important and more studies which determine whether technology has a positive or negative impact on behaviour are required.

Evidence Based References

Title:	**Reported Road Casualties Great Britain: 2015 Annual Report**
Published:	D Lloyd, P Baden, D Mais, A Marshall, A Bhagat, A Wilson for Department for Transport (DfT) 2016
Link: **Free/priced:**	https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/568484/rrcgb-2015.pdf Free
Objectives:	To report statistics relating to all Road Traffic Incidents (RTIs) reported to the police in Great Britain in 2015.
Methodology:	Statistics are compiled from the STATS19 database of road traffic RTIs.
Key Findings:	• Exceeding the speed limit was reported as a factor in 5 per cent of RTIs, but these RTIs involved 15 per cent of fatalities. At least one of the exceeding the speed limit and travelling too fast for the conditions contributory factors was reported in 12 per cent of all RTIs and these RTIs accounted for 26 per cent of all fatalities. • Driver/Rider failed to look properly accounted for 44 per cent of RTIs, these RTIs accounted for 27 per cent of fatalities. 54 per cent of these RTIs occurred on motorways or A roads. • Loss of control was reported as a factor for 13 per cent of RTIs, however it accounts for 31 per cent of fatalities. This accounted for a similar proportion of RTIs across all road types. • Following too close was a reported contributory factor in 16 per cent of all motorway RTIs, whereas it only accounted for 8 per cent on A roads. Similarly, sudden braking contributed to 12 per cent of all motorway RTIs, compared to 8 per cent on A roads.
Keywords:	RTIs, Statistics
Comments:	This report gives an indication of the contributory factors that might be related to the technologies of interest.

Title:	**A Safer Way: Consultation on Making Britain's Roads the Safest in the World**
Published:	DfT, 2009
Link: **Free/priced:**	http://webarchive.nationalarchives.gov.uk/+/http:/www.dft.gov.uk/consultations /closed/roadsafetyconsultation/roadsafetyconsultation.pdf Free
Objectives:	
Methodology:	
Key Findings:	• Vehicle manufacturers have made significant progress during the last decade in making vehicles safer for all road users. This has helped to reduce the number of casualties and the severity of injuries from RTIs. • Whilst the main focus during the last decade has been to address key problems for secondary safety (i.e. protection in the event of a RTI), the significant advances in computing and sensor technologies present an opportunity to secure important casualty reductions through the implementation of advanced primary safety systems (i.e. RTI avoidance) in the longer term. • The UK car fleet takes around 12–15 years to turn over, and this can be noticeably longer for heavy vehicles. So it will take several years for measures being implemented now to be sufficiently widespread in the marketplace to noticeably affect casualty numbers. • This report looks at how the DfT can secure earlier take-up of existing technologies across the vehicle fleet, how the DfT can implement existing new technologies more quickly, and how Government can influence the development and implementation of advanced vehicles and technologies over the strategy period. • The UK Government cannot achieve improvements in vehicle safety on its own. Vehicle regulations are set at European level and increasingly with a global perspective, given the international nature of the automotive industry. Therefore the DfT needs to work with a broad range of partners, including the European Commission, other governments, manufacturers, fleet operators and interest groups to deliver solutions for British road users. • This area of primary safety vehicle technology has great potential to deliver significant road safety benefits during the lifetime of this strategy. Adopting these technologies into new vehicles quickly links closely to the climate change agenda, as they tend to add little weight.

<table>
<tr><td></td><td>DfT research in 2007 showed that passenger cars fitted with one primary safety system, ESC, are 25 per cent less likely to be involved in fatal RTIs.
Advanced primary safety systems are not yet widespread in the vehicle fleet, and consequently there are few real world data to demonstrate their effectiveness. In addition, much of our evidence comes from RTI data, but this does not capture instances where these systems prevented an RTI from occurring.
Some examples of technologies that appear to have good safety potential are: o advanced braking and lane keeping systems (already available in the fleet to some extent);
RTI avoidance systems and Intelligent Speed Adaptation (technology available in some form and expected to be available in the short/medium term);
vehicle to vehicle/vehicle to infrastructure communication (technologies that can bring about additional safety benefit through enabling other systems to operate).</td></tr>
<tr><td>Keywords:</td><td>ESC, primary safety, strategy.</td></tr>
<tr><td>Comments:</td><td>Whilst not a research article, this policy document discusses some of the important issues related to the uptake of new technologies.</td></tr>
</table>

Title:	**Road Safety Strategy Beyond 2010: A Scoping Study (Road Safety Research Report No. 105)**
Published:	J. Broughton, B. Johnson, I. Knight, B. Lawton, D. Lynam, P. Whitfield, O. Carsten and R. Allsop for DfT 2009
Link: **Free/priced:**	http://webarchive.nationalarchives.gov.uk/20100304070241/http:/www.dft.gov. uk/pgr/roadsafety/research/rsrr/theme5/rsrr105.pdf Free
Objectives:	
Methodology:	This report follows on from a presentation given to Department for Transport delegates at a meeting on 8 November 2007. It brings together and expands on inputs from those presenting papers at that meeting. The work reported on draws together research across some of the core disciplines related to road safety. It does not report on any new research.
Key Findings:	• Primary safety features are defined as those primarily intended to avoid an RTI, although such features can also reduce the severity of an RTI. Secondary safety features are those intended to avoid or reduce the severity of injuries when a RTI does occur. Tertiary safety is related to features that help reduce the consequences of injury by making it easier and/or quicker for the casualty to receive medical treatment. • In many parts of the world, particularly in Europe, the term active safety is often used as a direct alternative to primary safety, and passive safety is used as a replacement for secondary safety. • Historically, the fields of primary and secondary safety have been considered in isolation. However, in recent years the boundaries between these two areas have been blurred, largely because of the development of advanced sensor technologies that have made a much wider range of system functionality possible. • ABS prevents wheel lock and the associated instability under braking and permits some steering during emergency braking, thus increasing the ability of the vehicle to avoid an RTI. For vehicle/trailer combinations it also greatly reduces the chance of jacknife and trailer swing. Market penetration will be relatively high particularly for larger goods vehicles (greater than 12 tonnes) and long distance touring buses where it has been mandatory since 1991. It is now fitted to all new passenger cars, HGVs and buses, and is fitted to many new light commercial vehicles (LCVs). However, there is still likely to be a substantial proportion of older vehicles in the current fleet that are not so equipped. • Brake Assist System (BAS) - it has been shown that ordinary drivers often do not use the maximum braking available to them in an emergency situation. BAS detects

	when a driver intends an emergency brake application and acts to increase the amount of braking applied such that maximum braking is reached earlier in the stop, thus reducing stopping distance. It is estimated that BAS could avoid 4 per cent of fatal RTIs and that, in 2005, 5 per cent of vehicles in the EU were equipped with it already. If no further action was taken, it was estimated that market penetration would be 20 per cent in 2025. However, it is likely to be incorporated as an option within the pedestrian Directive which would be expected to greatly increase its uptake. • Electronic Stability Control (ESC) - loss of control can be shown to be a significant cause of RTIs, particularly those of higher severity. ESC detects when a vehicle is not following the path that the driver demands (as measured by the steering wheel angle) and acts to control the instability by applying the brake at individual wheels in order to create a restoring moment. • In the UK, ESC reduces the risk of becoming involved in a RTI by 7 per cent, but that the risk of a serious RTI is 11 per cent lower in ESCequipped cars and the risk of a fatal RTI is 25 per cent lower. • Adaptive front lighting - traditional headlamp systems provide a beam that is a compromise intended to fulfil as many conflicting requirements as possible. Adaptive front headlamp systems adapt to the manoeuvre or type of driving being undertaken by the vehicle at the time in order to provide the correct illumination in the right areas at all times. • Daytime running lights - there is evidence to suggest that operating daytime running lights (DRL) would result in a net casualty reduction in the region of 5 per cent. However, there is a risk, depending on the details of implementation, that this would have an adverse effect on the number of motorcyclist casualties. • Combined brake system for two wheeled motor vehicles (TWMV) - currently, most motorcycles have separate brake controls for the front and rear brakes. This means that the driver controls the brake balance, which means that the optimum performance is not always achieved. Developing a combined brake control with an optimised brake balance system should result in an increase in the average deceleration in emergency brake manoeuvres for typical riders. • TWMVABS - very few motorcycles are equipped with ABS despite the fact that it has been proven to be technically feasible for some time and the consequences of a locked wheel, particularly at the front, can be much harder for the rider to deal with. It is possible that the use of ABS on motorcycles will increase.

	• TWMV BAS - this represents another transfer of technology from passenger cars which could potentially improve the performance of typical riders in emergency braking manoeuvres. • The concept of integrated safety is a relatively new field that has been enabled mainly by the development of advanced sensors that can detect the current state of a vehicle and can also predict the likelihood of a RTI occurring. This enables actions to be taken before the RTI to reduce the likelihood of it occurring at all, reduce the severity of the RTI and/or reduce the severity of injuries resulting from the RTI. • Collision Mitigation Braking System (CMBS) - this system again uses the forward RTI sensors to determine the likelihood of a RTI. If the driver does not react to an impending RTI and the RTI becomes unavoidable, then the system automatically applies heavy braking in order to reduce the RTI speed. It has been estimated that first generation systems would reduce the number of fatalities occurring in front to rear shunt RTIs with other vehicles by between 25 per cent and 75 per cent. • Autonomous driving ultimately, the type of technology being developed has the potential to enable fully automated driving where the vehicle controls all of the necessary navigation and safety functions. However, this remains a long-term possibility and systems are unlikely to reach the market in the next 10 years.
Keywords:	Primary safety, Integrated safety.
Comments:	The analysis undertaken for this project was of limited scope and duration. The report, therefore, briefly summarises what is a very wide-ranging technical subject area and does not consider any of the aspects involved in great detail. In particular, there are a number of limitations with respect to estimates of the casualty effects.

<table>
<tr><td>Title:</td><td>Catalogue of the Current Safety Systems, Deliverable 5.2 of the EC FP7 Project DaCoTA</td></tr>
<tr><td>Published:</td><td>D. Atalar, P. Thomas, A, Kirk, P. Evgenikos, P. Papantoniou, T. Hermite, P Van Elslande. 2012</td></tr>
<tr><td>Link:

Free/priced:</td><td>http://www.dacotaproject.eu/Deliverables/DaCoTA_D5.2_v4.0_pu_13Jan12.pdf
http://www.dacotaproject.eu/Deliverables/DaCoTA_D5.2_v3.0_pu_13Jan12.xls

Free</td></tr>
<tr><td>Objectives:</td><td>To collate information about each type of safety system to inform safety system evaluation.</td></tr>
<tr><td>Methodology:</td><td>Collation of information about safety systems in an Excel spreadsheet</td></tr>
<tr><td>Key Findings:</td><td>
The assembled Excel sheets have been created to act as a central place in which analysts can quickly acquire information including:

System studied;
Aims of the system;
Functions covered by the system (intentional and unintentional);
Phases of the RTI sequence upon which the system is acting;
Level of intervention;
Technical specifications; and,
Previous evaluations.

The safety systems included are categorised as one of the following:

Visibility;
Dynamic Control longitudinal;
Driver behaviour; o Warning;
Dynamic control lateral;
Communication;
Localization;
Prevention; and,
Speed.

AAFLS - Advanced Adaptive Front Light System - Predominantly AAFLS refers to headlights that turn relative to the vehicle to boost visibility through bends (in reaction to steering angle and sometimes yaw) although some systems can also adjust the light pattern for different road speeds and visibility (for example narrower beam on motorways). AAFLSs provide improved vision in darkness and poor
</td></tr>
</table>

visibility (weather conditions) when manoeuvring through bends.

- Other technologies closely associated with AAFLS are Cornering light assist and Auto high beam assist. Cornering Light Assist illuminates to wider than traditional angle when turning corners (especially at junctions). This can provide extra light or an extension to AAFLS. Auto High Beam is a feature that takes over the switching of high beam lights away from the driver to improve vision and to avoid dazzling oncoming drivers.
- Adaptive Cruise Control (ACC) - If a leading vehicle is travelling at a lower speed than the user's vehicle, or is located within the preset time or distance headway, the ACC system intervenes via braking pressure or throttle/engine torque control so that the headway increases. The system only intervenes if the current preselected speed or control so that the headway increases. The system only intervenes if the current preselected speed or headway would lead to a likely RTI or the speed would reduce the set headway. ACC may employ radar, laser or machine vision to continuously monitor the leading vehicle. Auxiliary detectors also monitor the speed, yaw and cornering rate of the vehicle to maintain tracking of the leading vehicle in the same lane when cornering rate of the vehicle to maintain tracking of the leading vehicle in the same lane when cornering. ACC keeps a set distance to vehicle in front and can detect fixed obstacles on the road.
- Brake Assist (BA) often referred to as Emergency Brake Assist (EBA) – These systems have become mandatory for all newly launched car and light commercial vehicle types in the EU. The regulation will apply to all new vehicles from 2011 as part of a new EU regulation that aims to improve pedestrian safety. A brake assist system monitors the driver's use of the brake pedal, automatically sensing an attempt to stop the car as a result of panic. It then generates very high braking power, even when the driver is only pressing lightly on the brake pedal. When this is used together with anti-lock braking systems, it results in faster and safer braking.
- Collision avoidance (CA) also referred to as Autonomous Emergency Braking (AEB) - With the aid of radar, LIDAR and/or camera systems, this technology actively assesses the driving environment for potential hazards. In particular current systems address rear end RTIs but an oncoming vehicle will also activate the system. The systems typically first warn of a potential RTI and then most then provide a level of braking support:
    - Enhancement of the driver's braking;
    - Partial automatic braking; and,
    - Full braking.

- RTI avoidance is expected to save a total of 9,000 severe and 53,000 slight injuries, corresponding to 10 per cent and 14 per cent of total severe and slight injuries in Germany respectively.
- Electronic stability control (ESC) - ESC stabilises the vehicle and prevent skidding under all driving conditions and driving situation within the physical limits by active brake intervention on one or more wheels and by intelligent engine torque management. In the EU ESC will be mandatory in all new types of vehicle from 2011 and for all new vehicles from 2014.
- Intelligent Speed Adaptation (ISA) - ISA describes any system which either warns the driver or automatically limits the speed of the vehicle when it exceeds the legal speed limit of a given area. These systems establish the location of the vehicle and compare the current speed with what is the posted speed for that location. If the vehicle exceeds this speed, the system takes effect, either be in the form of a visual or auditory warning (informative system), or intervention (actively 30 supporting systems). Actively supporting systems may provide haptic feedback to the driver through increased pressure or vibration in the accelerator pedal, but this can be overridden by the user. Mandatory ISA automatically takes effect and lowers the speed if the vehicle exceeds the speed limit.
- Lane Keeping Assistant (LKA) – is an extension of lane departure warning systems. LKA systems actively support the driver in maintaining lane position. These systems monitor the vehicles lane position with image processing technology in the same manner as lane departure warning systems. LKA provides additional torque to the steering wheel, which increases the resistance in the steering wheel. This makes it more difficult for the vehicle to drift, therefore reducing the occurrence of minor variations in lane position. This minimises the need for driver to make small corrections in lane position.
- Predictive Brake Assist (PBA) - Uses the vehicle's sensors from ACC and CA (predominantly radar) to detect impending emergency braking situation. Pilot pressure is applied to the brake system so that the required brake pressure can be generated more quickly, and the brakes are applied very gently so that the driver doesn't notice. In addition PBA lowers the triggering threshold for the hydraulic brakeassist system. After this initial phase the system then acts like Brake Assist.
- Vulnerable Road Users Protection (VRU) – A RTI avoidance system that can detect pedestrians, cyclists and animals. The system calculates in a matter of seconds the movement of pedestrians within the "capture" zone which can be up to 30 meters away from the vehicle. The camera tracks the pedestrian movement and the information is

	correlated with the data received from the radar network. The system applies the brakes if the driver does not. • Anti-lock brakes (ABS) – ABS prevents skidding by avoiding the brakes locking the wheels, the system maintains some steering control by avoiding skidding and for most drivers, decreases stopping distances on dry and wet road surfaces. Anti-lock on cars has been mandatory in the EU since 2004. • Rollover Detection (RollD) - Active Rollover Protection is designed to help stabilize a vehicle in order to help reduce the risk of a rollover. This system focuses on the vehicle's centre of gravity and the lateral acceleration limit or rollover threshold. The system constantly monitors driving conditions and intervenes if critical lateral acceleration is detected. The system provides control of engine and retarded torque as well as automatically activates the drive axle and trailer brakes. Roll stability control systems take corrective action, such as throttle control or braking, when sensors detect that a vehicle is in a potential rollover situation. • Automated lights - headlights and rear lights (driving lights) are activated if driver forgets to activate them in darkness. Headlights and rear lights are switched on if the vehicle enters a tunnel or other covered area (multi story car park or road lined with dense trees). This system only works if the light switch is always in automatic position. • Low Friction Detection (LoFrctD) – The system aims to warn the driver of low friction levels on the road surface ahead and prepares ADAS systems for a low friction surface. • Youth Key (YK) – The system aims to limit vehicle performance or functionally with the aim of encouraging safer driving or riding - in particular for young people, although this could be extended. Programmable key that can limit a vehicle's top speed, limit radio volume and encourage safety-belt usage by muting the radio until front occupants buckle up. Marketed by Ford in USA as MyKey. Standard or option on all vehicles. No evidence of adoption for Europe by Ford.
Keywords:	Active safety, interventions
Comments:	Provides useful information about a number of safety systems.

<table>
<tr><td>Title:</td><td>Automated emergency brake systems: technical requirement, costs and benefits (PPR227)</td></tr>
<tr><td>Published:</td><td>C. Grover, I. Knight, F. Okoro, I. Simmons, G. Couper, P. Massie and B. Smith, TRL for DG Enterprise, European Commission. 2008</td></tr>
<tr><td>Link:

Free/priced:</td><td>http://ec.europa.eu/enterprise/sectors/automotive/files/projects/report_aebs_e n.pdf

Free</td></tr>
<tr><td>Objectives:</td><td>To assess the technical requirement, costs and benefits related to Automated Emergency Brake systems (AEB).</td></tr>
<tr><td>Methodology:</td><td>The project has aimed to assess systems based on:
Review of scientific literature;
Gathering information from industry;
Analysis of RTI data;
Simulation of potential implications of reduced RTI severity on congestion cost; and,
Cost benefit analysis.</td></tr>
<tr><td>Key Findings:</td><td>Vehicle technology has increased rapidly in recent years, particularly in relation to braking systems and sensing systems. The widespread introduction of anti-lock braking systems (ABS) has provided the building blocks for a wide variety of braking control systems.
In parallel to the development of braking technologies, sensors have been developed that are capable of detecting physical objects, other vehicles or pedestrians around the vehicle.
Theoretically, a vehicle equipped with modern braking technology and adaptive cruise control (ACC) is equipment with all the necessary hardware to allow a simple (braking only – no steering) RTI avoidance system that would be capable of detecting when a RTI is likely to occur and applying the emergency braking to avoid it.
Integrated safety systems based on these principles include:
RTI avoidance – sensors detect a potential RTI and take action to avoid it entirely, talking control away from the driver. In the context of braking this is likely to included applying the emergency brake sufficient early that the vehicle can be brought to a standstill before a RTI occurs. This category is likely to have the highest potential benefits but is the highest risk approach because false activation of the system has the potential to increase the risk to other road users.
Crash Mitigation Braking Systems (CMBS) – sensors detect a potential RTI but take no</td></tr>
</table>

	immediate action to avoid it. Once the sensing system has detected that the collection has become inevitable regardless of braking or steering actions then emergency braking is automatically applied (independent of driver action) to reduce RTI speed, and hence injury severity, of the RTI. This system has lower potential benefits but is lower risk because it will not take control away from the driver until a point very close to RTI where the sensing system is likely to be more reliable. • AEB are capable of autonomously mitigating two-vehicles front to rear shunt RTIs as well as some RTIs with fixed objects and motorcycles. Such systems were fitted alongside ACC and forward RTI warning systems that share the same hardware. • Systems are currently in various phases of development that will also act in pedestrian RTIs. • Clear functional requirements for AEB are in existence in Japan and appear to be appropriate to use as guidance systems in Europe subject to modification of some limit values. • There remains insufficient information available at this time to produce more rigorous standard that more closely define performance or to define methods of testing the effectiveness of the whole system. • The possibility that interference could occur when multiple sensing systems “meet” at a busy road section may require further investigation. • Substantial difficulties have been encountered in trying to define the benefits of an AEB in terms of casualty reduction. These are related to fundamental limitations in terms of the detail available in RTI databases and the reconstruction methods used to generate them. • It was found that AEB is likely to be a very effective safety measure in terms of both casualty reduction and benefit to cost ration in the relatively near future, provided that further technical development and cost reduction takes place.
Keywords:	RTI avoidance, RTI mitigation braking systems, casualty reduction.
Comments:	Provides information about AEB but may be considered dated since there have been develops in vehicle technology since 2008.

Title:	**eSafety**
Published:	DaCoTA, Project co-financed by the European Commission Directorate General for Mobility and Transport. 2012a
Link: **Free/priced:**	http://dacotapilot.swov.nl/Safety_issues/pdf/eSafety.pdf Free
Objectives:	To discusses a variety of measures which are being promoted widely as 'eSafety' measures.
Methodology:	This text discusses a variety of measures which are being promoted widely as 'eSafety' measures, the knowledge about which is gradually evolving, including information on the costs and benefits of measures. Based on current knowledge about safety impacts and feasibility, this webtext accordingly discusses measures in two broad groups: • eSafety measures - safety effects known; and, • eSafety measures – safety effects unknown. In this web text an intervention is deemed to have a 'known positive safety effect' if there are results from more than one study in the same road safety context, where the results are statistically significant and where results indicate a useful level of effectiveness.
Key Findings:	• Vehicle safety is a key strategy to address ambitious long-term and interim goals and targets as part of an integrated Safe System approach. • In the last few years primary safety or RTI avoidance technologies have started to contribute to casualty reduction and hold potentially large future promise. • eSafety is defined here as a vehicle-based intelligent safety systems which could improve road safety in terms of RTI avoidance, RTI severity mitigation and protection and post-RTI phases or indeed integrated invehicle or infrastructure based systems which contribute to more than one of these RTI-phases or all. • Vehicle safety addresses the safety of all road users and currently comprises measures for RTI avoidance and injury prevention (or primary safety); reduction of injury in the event of a RTI (RTI protection or secondary safety) and those which assist post impact care (to reduce the consequences of injury). • RTI avoidance systems - There is large future promise of casualty reduction from RTI avoidance technologies, as long as development is prioritised to provide maximum casualty reduction. Since driver behaviour can modify the performance of safety systems which aims for RTI

avoidance, assessment of the human-machine interface, while complex, is essential.

- RTI mitigation systems - These refer to active in-vehicle systems which aim to mitigate the severity of the RTI. Examples include intelligent speed adaptation and advanced braking systems.
- While many predictive studies on eSafety have been carried out, research on the effects of systems in practice on casualty reduction is just starting.
- Given the rapid development and implementation of eSafety technologies, the Euro NCAP Advanced assessment process is clearly a useful and timely next step. At the same time a scientific evaluation framework is needed urgently to identify, evaluate, deliver and monitor such technologies. Little data exists at EU level to evaluation the effectiveness of eSafety technologies in terms of their final and intermediate outcomes which needs to be addressed urgently.
- A wide variety of eSafety technologies are in use today, some of which are fitted to vehicles increasingly as standard equipment. Research on seat belt reminders, alcolocks, intelligent speed adaptation (ISA) and electronic stability control (ESC) indicates that these measures offer significant safety potential. These technologies are, accordingly, being introduced increasingly into legislation into some national safety policies as well as governmental and organisational procurement policies which encourage fast-tracking of fitment of safety equipment.
- Informative or advisory ISA gives the driver a feedback through a visual or audio signal. A Speed Alert System is an informative version of ISA; it is able to inform the driver of current speed limits and speed in excess of these limits.
- Supportive or warning ISA increases the upward pressure on the accelerator pedal. It is possible to override the supportive system by pressing the accelerator harder.
- Intervening or mandatory ISA prevents any speeding, for example, by reducing fuel injection or by requiring a "kick-down" by the driver if he or she wishes to exceed the limit.
- Electronic stability control (ESC) is an active safety system which can be fitted to cars, buses, coaches and trucks. It is an extension of antilock braking technology, which has speed sensors and independent braking for each wheel. It aims to stabilise the vehicle and prevent skidding under all driving conditions and situations, within physical limits. It does so by identifying a critical driving situation and applying specific brake pressure on one or more wheels, as required. ESC addresses the problem of skidding and RTI due to loss of control of vehicles, especially on wet or icy roads or in rollovers.

- Evaluation studies have shown that the fitment of ESC in cars has led to substantial reductions in RTIs, deaths and serious injuries at the top end of the market. UK research indicates that equipping a vehicle with ESC reduces the risk of being involved in a fatal RTI by 25 per cent. The research also shows a particularly high effectiveness for reducing serious RTIs involving other loss of control situations such as skidding (33 per cent), and rollover (59 per cent).
- ESC has been on the market since 1995 and is standard equipment in many cars of the middle and upper price classes, but not yet in smaller cars. Since 2012, ESC has to be fitted mandatorily to all new EU registered car models.
- The main purpose of ABS is to prevent skidding where loss of steering and control result from locked wheels when braking hard. Such systems are now fitted to many new cars. This is intended to provide additional steering in the emergency situation, not to decrease stopping distances.
- A meta-analysis of research studies shows that ABS give a relatively small, but statistically significant reduction in the number of RTIs, when all levels of severity and types of RTIs are taken together. There are statistically significant increases in rollover, single-vehicle RTIs and RTIs with fixed objects. There are statistically significant decreases in RTIs with pedestrians/ cyclists/ animals and RTIs involving turning vehicles. ABS brakes do not appear to have any effect on rear-end RTIs.
- Emergency Brake Assist aims to address the problem of insufficient pressure being applied to the brake by drivers in emergency situations, so increasing stopping distances. Car manufacturing trials have shown that brake assistance systems could help by providing full braking effect, where the driver does not press hard enough on the pedal.
- In general most of the devices described for improvement of braking and handling interfere with driver behaviour, and the questions of driver acceptance, risk compensation and driver reaction when the system is activated are important (especially for old drivers). There is no standard method to assess the safety performance of these devices, which makes it difficult to estimate their potential benefits; moreover, under the same name very different systems can be found, as each manufacturer has its own specification.
- Automatic Emergency Braking System (AEB) which are reported as having high casualty reduction potential. These systems detect automatically the need to brake and activate braking (without the interaction of the driver).
- Lane Keeping Warning Devices are electronic warning systems that are activated if the vehicle is about to veer off the lane or the road. Their effectiveness strongly depends on the reaction of the driver and on the visibility condition of the road markings. Times to RTI in safety-critical lane changes are normally much less than one second. Since

	mean driver reaction time is about one second, there is not sufficient time for a driver to respond to a warning before collision. Because there is insufficient time for reaction to a warning, lane change and merging RTIs can probably only be avoided by intervening systems known as Lane Keeping Assist. This is an automatic system which keeps the vehicle in its lane except if the turning indicator is activated and depends only on the visibility of the marking. The technical and operational feasibility of such systems has still to be demonstrated. Most existing systems are warning only systems.
Keywords:	eSafety, evaluation
Comments:	Although there is relevant information regarding ISA it is unclear which type of ISA has been evaluated.

Title:	**Vehicle safety**
Published:	DaCoTA, Project co-financed by the European Commission Directorate General for Mobility and Transport. 2012b
Link: **Free/priced:**	http://dacotapilot.swov.nl/Safety_issues/pdf/Vehicle%20Safety.pdf Free
Objectives:	This web text aims to give a summary overview of the main issues and developments in vehicle safety in Europe.
Methodology:	Summary overview of the main issues and developments in vehicle safety in Europe.
Key Findings:	• There is large future promise of casualty reduction from RTI avoidance and active safety technologies as long as development is prioritised to maximise casualty reduction. • The potential value of developing an integrated approach to vehicle safety, linking preventive, RTI protection and post-RTI approaches into cooperative systems for drivers, passengers and vulnerable road users as well as vehicle and road network safety systems is being increasingly understood. • Improvements to vehicle safety result from legislation (much of which is now agreed in the European Union and within the UN ECE process) consumer information, product liability considerations as well as specific initiatives of the car manufacturing industry. EU legislation aims for a minimum but high level of protection across the product line; consumer information aims to encourage the highest possible levels of safety performance based on state of the art testing; and car industry policies increasingly promote safety as a marketable commodity. • RTI avoidance or primary safety - Devices to avoid a RTI e.g. daytime running lights, electronic stability control, intelligent speed adaptation, alcolocks. EU level developments in safety are focusing much more around new vehicle based primary safety systems that may prevent RTIs occurring. Examples include Electronic Stability Control (ESC) (which are already showing substantial road safety returns), lane keeping systems and pedestrian detection and auto braking systems. There are high expectations that these new systems will provide the largest reductions in casualties into the future though the evidence in many cases remains weak. • The term active safety is often used to mean RTI avoidance but care should be taken in its use since it is also used to denote deployable systems such as RTI-protective pop-up bonnets for pedestrian protection or seat belt reminders. • In recent years there has been a move away from traditional approaches towards RTI avoidance and RTI protection

	towards holistic in-vehicle approaches. The aim here is to achieve a truly integrated technological vehicle response to the risk of RTI and better outcomes before, during and following the RTI event. Accordingly, more advanced technologies are under development and testing which support information connectivity between vehicles and with road infrastructure. These are known as cooperative systems. 37 • ISA is a system which informs, warns and discourages the driver to exceed the speed limit. The in-vehicle speed limit is set automatically as a function of the speed limits indicated on the road. GPS allied to digital speed limit maps allows ISA technology to continuously update the vehicle speed limit to the road speed limit. • Research indicates that the more the system intervenes the more significant are the benefits. Estimates show that if mandatory installation of informative or supportive ISA, injury RTIs could be reduced by 20 per cent. The use of a mandatory ISA system, when combined with a dynamic speed limit regime, has the estimated potential to reduce overall injury RTIs by up to 36 per cent, fatal and serious RTIs by 48 per cent and fatal RTI by 59 per cent. • Daytime Running Lights (DRL) are multi-purpose or specially designed lights on the front of a vehicle for use in daytime to increase its visibility and avoid multi-party RTIs. There are various DRL options all of which have positive benefit to cost ratios. The options of mandatory manual operation of dipped lights in existing cars and a compulsory advanced DRL unit fitted to new cars seem most advantageous. • Meta-analyses of the effects of DRL use in cars show that DRL contributes substantially to reducing road RTIs, car occupant and vulnerable road user injuries whatever the country's latitude. A reduction in multi-party RTIs of between 8 per cent -15 per cent was found as a result of introducing mandatory laws on daytime use. • It has been estimated that the fitment of DRL to cars in EU countries could lead to an annual reduction of 2,800 deaths. • Brake Assist in emergency situations is a technology which is fitted as standard on some new cars and will be mandatory for new cars in 2014 as part of a legislative package on pedestrian protection. • Several systems exist for detecting driver impairment caused by excess alcohol, drowsiness, illness, or drug abuse, which prevent the vehicle from starting or warn the driver or perform an emergency control function that will stop the vehicle. While many systems are at different stages of development with, in some cases, their feasibility being unknown, one particularly promising application is the alcohol interlock system.

	• A range of promising new RTI prevention technologies offer high potential for future casualty reduction, are being applied and require close monitoring to assess their effectiveness in real world RTIs. Their success is highly dependent upon proven feasibility, practicability and acceptance and use by road users. Important factors needing further research concern limitations of human adaptation to new systems and the acceptability of the driver to relinquish control over the vehicle. In general, there are no analytical strategies available to ensure that passive and active safety systems are optimised together to maximise the potential casualty reduction. In RTIs avoidance research, assessment.
Keywords:	Vehicle safety,
Comments:	Very similar to the other DaCoTA document with a wider range of technologies.

Title:	**World report on road traffic injury prevention**
Published:	M. Peden, R. Scurfield, D.Sleet, D. Mohan, A. A. Hyder, E. Jarawan and C. Mathers for World Health Organization (WHO) 2004
Link: **Free/priced:**	http://whqlibdoc.who.int/publications/2004/9241562609.pdf?bcsi_scan_E956B CBE8ADBC89F=0&bcsi_scan_filename=9241562609.pdf Free
Objectives:	• To describe the burden, intensity, pattern and impacts of road traffic injuries at global, regional and national levels; • To examine the key determinants and risk factors; • To discuss interventions and strategies that can be employed to address the problem; and, • To make recommendations for action at local, national and international levels.
Methodology:	Over 100 international professionals from the sectors of health, transport, engineering, law enforcement and education – among others – as well as the private sector and nongovernmental organizations, were involved in the development of this report.
Key Findings:	• The term, “daytime running lights” refers to the use of lights (whether multipurpose or specially designed) on the front of a vehicle while it is running during daylight hours, so as to increase its visibility. • Some countries – including Austria, Canada, Hungary, the Nordic countries and some states in the United States – now require by law varying levels of use of daytime running lights. This may involve either drivers switching on their headlamps or the fitting of switches or special lamps on vehicles. • Two meta-analyses of the effects of daytime running lights on cars show that the measure contributes substantially to reducing RTIs. The first study, which examined daytime RTIs involving more than one party, found a reduction in the number of RTIs of around 13 per cent with the use of daytime lights, and reduction of between 8 per cent and 15 per cent as a result of introducing mandatory laws on daytime use. • The number of pedestrians and cyclists hit by cars was reduced by 15 per cent and 10 per cent, respectively. • The second study found a reduction of slightly over 12 per cent in daytime RTIs involving more than one party, a 20 per cent decrease in injured victims and a 25 per cent reduction in deaths in such RTIs. • A study of data over four years from nine American states concluded that, on average, cars fitted with automatic

	daytime running lights were involved in 3.2 per cent fewer multiple RTIs than vehicles without. • A cost–benefit analysis of providing automatic light switches on cars for daytime running lamps using standard low-beam headlights found that the benefits outweighed the costs by a factor of 4.4. • Motorized two-wheeler users have expressed concerns that daytime running lights on cars could reduce the visibility of motorcyclists. While there is no empirical evidence to indicate this is the case, researchers have suggested that if such an effect did exist, it would be offset by the benefit to motorcyclists of increased car visibility.
Keywords:	Daytime running lights, casualty reduction, cost-benefit.
Comments:	Limited reference to some of the technologies of interest but provides data related to daytime running lights.

Title:	**Effectiveness of Electronic Stability Control Systems in Great Britain**
Published:	R. Frampton and P. Thomas, Loughborough University for DfT 2007
Link: **Free/priced:**	http://www.chooseesc.eu/download/studies/uk_esc_vsrc_study.pdf Free
Objectives:	Evaluate the reduction in RTI involvement of cars equipped with Electronic Stability Control (ESC) systems.
Methodology:	Analysis of RTIs involving cars with and without ESC. There were 10,475 case vehicles and 41,656 control vehicles in the dataset.
Key Findings:	• Electronic stability control (ESC) is a system that utilises the electronic control of the brakes and engine to prevent the driver from losing control of the vehicle. It achieves this through a calculation of the driver's intended actions (measured through steering wheel angle, accelerator position and vehicle speed) and a comparison of the driver's intentions to the dynamic characteristics of the vehicle (taken from a lateral accelerometer and yaw rate sensor). • The results show that ESC effectiveness is 7 per cent in RTIs of all severity. Serious RTIs are 11 per cent lower compared to non ESC cars and fatalities 25 per cent lower. The potential savings in RTI costs for a 100 per cent take up of ESC amounts to some £959 million by preventing some 7,800 RTIs. • ESC appears to offer additional benefit in adverse road conditions. Overall effectiveness was estimated as 20 per cent for icy conditions and 9 per cent for wet conditions compared to 5 per cent for dry roads. In terms of serious RTIs however, ESC effectiveness appears even more pronounced, 22 per cent for wet roads compared to 3 per cent for dry. • Skidding and overturning RTIs are typical situations on bends when the driver enters too quickly and attempts to steer. The study suggests a high ESC effectiveness 23 per cent in all skidding related RTIs and 36 per cent in all overturning RTIs. The corresponding values for serious RTIs are 33 per cent and 59 per cent respectively. • Compared to non-ESC cars, 27 per cent fewer ESC vehicles were involved in all single vehicle RTIs compared to 7 per cent for multi and single vehicle RTIs taken together. Unfortunately case numbers did not allow a reliable assessment of ESC contribution to the reduction in serious single vehicle RTIs. Overall, ESC has shown worthwhile reductions in both RTI frequency and cost across a wide variety of RTI situations.
Keywords:	ESC, cost benefit, casualty reduction.
Comments:	Informative research that provides an indication of the effectiveness of ESC.

Title:	**How much benefit does Intelligent Speed Adaptation deliver: An analysis of its potential contribution to safety and environment**
Published:	F. Lai, O. Carsten, F. Tate, Accident Analysis & Prevention, Volume 48, pp. 63–72. 2012
Link: **Free/priced:**	http://www.sciencedirect.com/science/article/pii/S0001457511000923 $41.95
Objectives:	The purpose of this paper is to explore the information gathered in the field trials in order to predict the impacts of various forms of Intelligent Speed Adaptation (ISA).
Methodology:	Two hypothetical deployment scenarios were envisaged covering a 60-year appraisal period. Three variants of ISA have been considered within the context of this paper: • Advisory ISA which informs the driver of the speed limit and warns the driver when the limit is being exceeded. • Voluntary ISA in which the information on speed limit is linked to the vehicle's engine management system and perhaps additionally to the braking system - the system comes on with the vehicle ignition, but it may be overridden by the driver at will. • Mandatory ISA which works like Voluntary ISA, but without the option to override. Following the monetisation of the potential benefits, the costs of implementing ISA was also analysed allowing the benefit-to cost ratio (BCR) to be calculated. This analysis draws on the data collected in the ISA-UK field trials and then applies that data to the prediction of changes in RTI numbers through the application of available speed RTI relationships derived from empirical observations.
Key Findings:	• ISA is a system that brings feedback about speeding behaviour into the vehicle. It may merely warn the driver about speeding or it may intervene to prevent speeding. • ISA is predicted to save up to 33 per cent of RTIs on urban roads, and to reduce CO_2 emissions by up to 5.8 per cent on 70 mph roads. • The results indicate that ISA could deliver a very healthy benefit-to-cost ratio, ranging from 3.4 to 7.4, depending on the deployment scenarios. Under both deployment scenarios, ISA has recovered its implementation costs in less than 15 years. • Of the two deployment scenarios, the Market Driven one is substantially outperformed by the Authority Driven one. • The benefits of ISA on fuel saving and emission reduction are real but not substantial, in comparison with the benefits

	on RTI reduction; up to 98 per cent of benefits are attributable to RTI savings. • In the Authority Driven scenario, ISA is predicted to save 30 per cent of fatal RTIs and 25 per cent of serious RTIs over the 60-year appraisal period. • That potential is largest on 30 mph roads, where there is considerable speeding and a large proportion of RTIs involve pedestrians. • However, on other types of road such as trunk motorways and A-roads, ISA also has considerable potential as a safety measure. • The clear finding from the predictions of the safety impact of ISA over time is that ISA can have a large effect on future RTI number and particularly on the more severe RTIs. Overall, advisory ISA is predicted to be substantially less effective than the intervening (voluntary and mandatory) forms of ISA. Although there is considerable literature on the impact of speed on RTI risk, there is not a single UK based model that is directly applicable to ISA.
Keywords:	ISA, RTIs, fuel consumption, carbon dioxide emissions, cost benefit analysis
Comments:	Informative study that highlights important gaps in ISA research.

<table>
<tr><td>Title:</td><td>Intelligent Speed Assistance - Myths and Reality, ETSC position on ISA</td></tr>
<tr><td>Published:</td><td>F. Goodwin, F. Achterberg, J. Beckmann, European Transport Safety Council (ETSC) 2006</td></tr>
<tr><td>Link:

Free/priced:</td><td>http://www.etsc.eu/documents/ISA%20Myths.pdf

Free</td></tr>
<tr><td>Objectives:</td><td>To outline the ETSC’s position on ISA</td></tr>
<tr><td>Methodology:</td><td>List of myths and realities.</td></tr>
<tr><td>Key Findings:</td><td>
Illegal and inappropriate speed is the single biggest contributory factor in fatal RTIs. It increases both the risk of a RTI happening and the severity of injuries resulting from RTIs. Managing speed is therefore the most important measure to reduce death and injury on our roads.
Modern technology offers substantial improvements to the management of speed and the compliance with speed limits. Intelligent Speed Assistance (ISA) is the term given to a range of devices that assist drivers in choosing appropriate speeds and complying with speed limits.
The safety effects that current ISA technology can deliver are already impressive. Research has shown that advisory ISA can achieve an 18 per cent reduction, and non-overridable intervening ISA a 37 per cent reduction in fatal RTIs in the UK.
In other EU countries, up to 50 per cent of traffic deaths could be avoided if all cars were equipped with supportive ISA.
There has been extensive research into ISA carried out over the last two decades, including field trials in ten countries from Northern, Southern and Eastern Europe (Austria, Belgium, Denmark, Finland, France, Hungary, Netherlands, Spain, Sweden, UK). This research has shown that:

ISA can bring substantial safety benefits.
ISA can also reduce fuel consumption and other pollutant emissions from cars – including noise.
ISA is a cost-effective road safety measure.
Test drivers show a high acceptance of the different types of ISA trialled and often wanted to keep the system after the trial.
ISA technologies are robust, reliable and ready to be implemented.

Yet it has also been clear that so far none of the relevant actors have made ISA a priority.
</td></tr>
</table>

	• Most automobile manufacturers have been sceptical towards ISA technologies. • Most European governments have had little ambitions to implement ISA. • European level action has been limited to financing research. A majority of drivers are already in favour of ISA technologies and acceptance increases as they gain experience of using the technology.
Keywords:	ISA, safety benefits
Comments:	Provides some statistics related to ISA but seems to be dated as progress has been made since 2006. The term Intelligent Speed Assistance is used instead of Intelligent Speed Adaptation.

Title:	**"PRAISE": Preventing Road Accidents and Injuries for the Safety of Employees. How can In-vehicle Safety Equipment improve road safety at work?**
Published:	European Transport Safety Council (ETSC) 2009
Link: **Free/priced:**	http://www.etsc.eu/documents/PRAISE%20Report%201.pdf Free
Objectives:	The project aims to advance work-related Road Safety Management and provide the know-how to employers who have to take on that challenge. This first thematic report aims to present how in-vehicle safety equipment can improve and manage work related road safety. This report addresses all employers managing all types of vehicle from public authorities, vehicle leasing suppliers, small two car delivery companies to large international companies and also vehicle manufacturers.
Methodology:	Summary of technologies available.
Key Findings:	• RTI most often have financial implications on a business that stretch well beyond reported costs. • In-vehicle technologies can make a lifesaving contribution to improving road safety at work. • There is a well-documented relationship between speed and RTIs resulting in death and injury with lasting effect. The adaptation of driving speed to the prevailing conditions and speed limits is a primary way of controlling the RTI risk of the driver. • A supportive Intelligent Speed Adaptation (ISA) system works in the form of increasing the upward pressure on the pedal or cancelling a driver's throttle demand if it demands more throttle than is required to drive at the speed limit. • Swedish large-scale study of the effect of informative and supportive ISA, involving nearly 4,500 vehicles, shows that if everyone had informative ISA fitted, injury RTIs could be reduced by 20 per cent in urban areas. Supportive systems have even greater potential to reduce fatal and serious RTIs. • Estimates by Carsten (2008) show that a mandatory supportive ISA scheme could lead to a reduction of 36 per cent in road traffic (injury) RTIs and 59 per cent in fatal RTIs. There would also be benefits in terms of lower fuel consumption (up to 8 per cent) and more effective road traffic enforcement. • ESC acts on the braking or power systems of a vehicle to assist the driver in maintaining control of the vehicle in a critical situation (caused, for example, by poor road conditions or excessive speed during cornering).

	• As well as saving casualties, the widespread use of ESC in vehicles could significantly reduce the traffic congestion caused by RTIs involving large vehicles.
	• Emergency Braking is already present in some vehicles. This will be extended to all large vehicles in 2013. The aim of Emergency Braking is to avoid RTIs fully automatically or to mitigate them. The system reacts if a vehicle approaches another leading vehicle or obstacle. The system reacts in three steps:
	  o Optical and acoustic warning, if the approaching obstacle could lead to an RTI.
	  o Autonomous partial braking, if the distance is reduced further.
	  o Autonomous full braking, if an RTI appears inevitable. Input is the distance and the relative speed to a leading vehicle.
	• Emergency braking has an estimated death reduction of 7 per cent on the EU 25 scale with full penetration, and one of the highest benefit-cost ratios there is for driver support systems. The eSafety Forum included it as one of the priority systems in 2008.
	• One major downside of such technologies is the so-called risk compensation effect. There is evidence to suggest that such an effect can be linked to the use of safety features in vehicles. This is particularly compelling for the case of antilock braking systems (ABS). There have been experiments asserting that drivers adapt to the safety benefit of ABS by driving more aggressively, and there is empirical evidence that RTIs occurred after the introduction of ABS because of people testing the system's thresholds.
	Employers should make every effort to apply technologies but also train staff on their use and monitor their implementation.

Keywords:	Road safety at work, ISA, ESC, Emergency Braking.
Comments:	Provides a useful summary for some of the systems of interest.

Title:	**Cost-benefit assessment and prioritisation of vehicle safety technologies**
Published:	ECORYS Nederland BV for the European Commission Directorate General Energy and Transport 2006
Link: **Free/priced:**	http://ec.europa.eu/transport/roadsafety_library/publications/vehicle_safety_te chnologies_final_report.pdf Free
Objectives:	The objective of this study is to assess the introduction of 21 vehicle safety technologies based on existing literature, data and knowledge.
Methodology:	The economic cost-benefit assessment compares the costs of installing the relevant technology in all relevant new vehicles with the benefits for society of doing so in terms of reduced numbers of fatalities, severe injuries and slight injuries. The estimated effects on the number of fatalities, severe injuries and slight injuries are based on: • Existing studies; • RTI data; • Estimates of the effectiveness of the technology in terms of reducing the risk of RTI and/or the severity of injuries in case an RTI occurs; and, • A scenario for implementation (market penetration in the Do-something scenario and the Do-nothing scenario).
Key Findings:	• Electronic Stability Control (ESC) has a benefit/cost ratio (BCR) of 3.8, and is deemed to be cost effective. • Intelligent Speed Adaptation (ISA) has a BCR of 3.3 and is deemed to be cost effective. • Daytime Running Lights has a BCR of 1.8 and is most likely cost effective. • Adaptive Cruise Control (ACC) has a BCR of 0.4, most likely not cost effective. • Brake assistant systems have a break even cost/benefit.
Keywords:	Benefit/cost ratio, cost effective, ESC, ISA, Daytime Running Lights, ACC, brake assist.
Comments:	Useful indication of the effectiveness of each technology in terms of cost and benefits. Results are based on a number of assumptions.

Title:	**Feasibility of using various data source to carry out accident studies into primary safety of cars – phase 2 (PPR511)**
Published:	J. Broughton, I. Knight and M. Keigan, TRL. 2010
Link: **Free/priced:**	https://trl.co.uk/reports/PPR511 Free
Objectives:	• To develop a user-friendly software interface for the TRL copy of the STATS19 RTI database. • To obtain details of which car models had been fitted with electronic stability control (ESC) from the UK Motor Insurance Repair Research Centre (Thatcham). • To make a practical assessment of the effectiveness of ESC based on analyses of STATS19 RTI data.
Methodology:	The basic approach used to assess the effectiveness of ESC has been to compare the RTI-involvement rates of cars with and without ESC.
Key Findings:	• The development of sophisticated electronic control stems has led to new vehicles being equipped with an increasing range of new primary safety function designed to avoid RTIs. • Assessing the actual effectiveness of such primary safety (RTI avoidance) features in reducing the number of casualties in road RTIs can be very difficult. Probably the main reason for this difficulty is that if a primary safety feature is fully effective then there would be no RTIs of the relevant type and therefore, no data for comparison. • ESC was found to reduce the overall RTI-involvement rate by about one fifth, although the effect was less for serious RTIs and not significant for fatal RTIs. • The effects varied widely among car models, and analyses failed to yield satisfactory results for several models because of the low number of cars of these models that had ESC fitted as standard. • These studies implicitly assume that cars with and without ESC are driven in similar circumstances, for similar mileages and with similar drivers, so that any differences in their RTI-involvement can be interpreted as the effects of ESC. • Analyses of STATS19 RTI data demonstrate, however, that the driver profiles of the two groups of car may well differ in terms of age and sex.
Keywords:	ESC, reduction in RTI-involvement, STATS19.
Comments:	Shows a reduction in RTI involvement rate but also highlights that comparing cars with and without ESC has flaws.

Title:	**Could Intelligent Speed Adaptation make overtaking unsafe?**
Published:	S. Jamson, K. Chorlton, O. Carsten, Accident Analysis and Prevention 48 pp. 29 – 36. 2012
Link: **Free/priced:**	http://www.sciencedirect.com/science/article/pii/S0001457510003441 Priced
Objectives:	To investigate how mandatory and voluntary ISA might affect a driver's overtaking decisions on rural roads.
Methodology:	A driving simulator was used to present drivers with a variety of overtaking scenarios designed to evaluate both the frequency and safety of the manoeuvres.
Key Findings:	• Overtaking is a complex task, with the driver needing to monitor their interaction with a lead vehicle, estimate the time to RTI of any oncoming vehicles and take into account the time required to complete the overtake based on their own speed and skill level. • This simulator study allowed an investigation of whether drivers' overtaking behaviour changed when a mandatory or voluntary ISA system was active. • The results indicate that drivers became less inclined to initiate an overtaking manoeuvre when the mandatory ISA was active and this was particularly so when the overtaking opportunity was short. • In addition to this, when ISA was activated drivers were more likely to have to abandon an overtaking, presumably due to running out of road. They also spent more time in the critical hatched area - a potentially unsafe behaviour. • The quality of the overtaking manoeuvre was also affected when mandatory ISA was active, with drivers pulling out and cutting back in more sharply. • In contrast, when driving with a voluntary ISA, overtaking behaviour remained mostly unchanged: drivers disengaged the function in approximately 70 per cent of overtaking scenarios. • The results of this study suggest that mandatory ISA could affect the safety of overtaking manoeuvres unless coupled with an adaptation period or other driver support functions that support safe overtaking. • Questionnaire measures mirrored those found in many previous studies suggesting that whilst drivers deemed mandatory ISA more useful than a voluntary one, they also found it more frustrating to drive with and believed it impaired their driving performance. This indicates that drivers can see the logic behind ISA systems, in terms of its road safety benefits. However, when actually using ISA, they find the experience not as satisfying (although in this case the ratings are not negative).
Keywords:	Simulator, speed, ISA, overtaking.
Comments:	Informative study that highlights the behavioural aspects of ISA.

Title:	**Evaluating the safety impact of adaptive cruise control in traffic oscillations on freeways**
Published:	Ye Li, Hao Wang, Wei Wang, Lu Xing, Accident Analysis and Prevention 104 pp. 137-145. 2017
Link: **Free/priced:**	http://www.sciencedirect.com/science/article/pii/S0001457517301628 Priced
Objectives:	To investigate how the addition of adaptive cruise control has affected the collision risk on congested highways in stop-and-go traffic. The primary objective of this study was to evaluate the impacts of ACC parameter settings on rear-end collisions on freeways.
Methodology:	A computer based simulation was set up to simulate congested highways. The time to collision based factors were calculated as surrogate safety measures of the collision risk. It is difficult to evaluate real world effects of ACC on highway collisions due to the varied amount of market penetration, hence simulations were used. Details from smaller scale experiments were used to determine the parameters. The simulation allowed the parameters in which the ACC operates to be changed. These parameter changes were then compared. These results were then compared to different market penetration rates of ACC equipped vehicles.
Key Findings:	• When all vehicle parameters were optimised, there was a great improvement seen, where the simulated bottle neck cleared in 5 minutes, as compared to 11 minutes in the first configuration. • The first simulation being a scenario where no vehicle was equipped with ACC. It was observed that the front vehicle, in the vehicle string, had a fairly consistent speed, whereas the speed variation amplified the further back in the string. • As higher ACC penetration was implemented into the string, the quicker the vehicle string achieved a constant vehicle speed. • For roads with few ACC-equipped vehicles, the ACC system had a negligible effect on collision risk. • When the penetration of ACC-equipped vehicles exceeded 30% a reduction in collision risk was observed. This was only observed in one group of parameters for the ACC, therefore highlighting the importance of the parameter settings.
Keywords:	ACC, traffic, congestion, reduction in collision risk
Comments:	This study sheds some light on how ACC can have an effect on the collision risk in congestion. However, it shows that ACC has little effect on safety when the market penetration is low.

Title:	**Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles (Standard)**
Published:	SAE International 2016
Link: **Free/priced:**	http://standards.sae.org/j3016_201401/ $76.00
Objectives:	To define a standard for autonomous vehicles.
Methodology:	
Key Findings:	• An international standard for levels of autonomous driving has been established. • It identifies 6 levels of driving automation from 'no automation' to 'full automation' • Describe categorical distinctions for a step-wise progression through the levels. • Educates the wider community by clarifying for each of the levels, what role (if any) that the driver has to perform while the driving automation system is engaged.
Keywords:	Vehicle standard, Autonomous driving
Comments:	This standard offers no evidence as to how autonomous driving will help in regard to safety, however it does offer a good picture of where we stand today with regard to the step required for full automation.

Title:	**Effectiveness of forward collision warning and autonomous emergency braking systems in reducing front-to-rear crash rates**
Published:	Jessica B. Cicchino for IIHS, Accident Analysis and Prevention 99 pp.142-152 2017
Link: **Free/priced:**	http://www.sciencedirect.com/science/article/pii/S0001457516304006 Priced
Objectives:	To evaluate the effectiveness of forward collision warning (FCW) alone, a low-speed autonomous emergency braking system (AEB) operational at speeds up to 19 mph that does not warn the driver prior to braking, and FCW with AEB that operates at higher speeds in reducing front-to-rear crashes and injuries.
Methodology:	Poisson regression was used to compare rates of police-reported crash involvements per insured vehicle year in 22 U.S. states during 2010-2014 between passenger vehicle models with FCW alone or with AEB and the same models where the operational systems were not purchased, controlling for other factors affecting crash risk.
Key Findings:	• FCW alone, low-speed AEB, and FCW with AEB reduced rear-end striking crash involvement rates by 27%, 43%, and 50%, respectively. • Rates of rear-end striking crash involvements with injuries were reduced by 20%, 45%, and 56%, respectively. • FCW alone, low-speed AEB, and FCW with AEB, and rates of rear-end striking crash involvements with third-party injuries were reduced by 18%, 44%, and 59%, respectively. • Almost 1 million U.S. police-reported rear-end crashes in 2014 and more than 400,000 injuries in such crashes could have been prevented if all vehicles were equipped with FCW and AEB that perform similarly as systems did for study vehicles
Keywords:	Autonomous Emergency Braking Systems, Forward Collision Warning, RTI, Front-to-Rear collision.
Comments:	This study offers a very good insight into the real world application of AEB. It also highlights that the reaction if the human driver is still important, as be seen when the FCW and AEB are combined.

Title:	**Effectiveness of low speed autonomous emergency braking in real-world rear-end crashes**
Published:	B Fildes, M Keall, N Bos, A Lie, Y Page, C Pastor, L Pennisi, M Rizzi, P Thomas, C Tingvall, Accident Analysis and Prevention 81 pp. 24-29 2015
Link: **Free/priced:**	http://www.sciencedirect.com/science/article/pii/S0001457515001116 Priced
Objectives:	To evaluate the effectiveness of low speed autonomous emergency braking systems (AEB) in current model passenger vehicles based on real-world crash experience.
Methodology:	The validating vehicle safety through meta-analysis (VVSMA) group comprising a collaboration of government, industry consumer organisations and researchers, pooled data from a number of countries using a standard analysis format and the established MUND approach. Induced exposure methods were adopted to control for any extraneous effects.
Key Findings:	• The findings showed a 38% overall reduction in real-world, rear-end crashes for vehicles fitted with AEB when compared with similar vehicles without this technology. • This research was conducted internationally and was proved to be reliable with robust findings. • The AEB system is a potentially important safety system. Widespread fitment of the technology should be encouraged in the interest of improved vehicle safety.
Keywords:	Vehicle safety, collision prevention, AEB, RTI
Comments:	This study appears to show a reliable picture of how AEB is a benefit for vehicle safety in regards to the number of collisions it is seen to prevent. The study was an international study, so results can be applied more generally.

Title:	**Assessing the benefit of the brake assist system for pedestrian injury mitigation through real-world accident investigations**
Published:	A Badea-Romero, F Javier Paez, A Furones, J Barrios, J de-Miguel, Safety Science 53 pp.193-201. 2013
Link: **Free/priced:**	http://www.sciencedirect.com/science/article/pii/S0925753512002585 Priced
Objectives:	A coordinated study performed by four Spanish Safety Research Centres aimed at assessing the potential influence of the BAS in vehicle-pedestrian collisions through the reconstruction of real-world accidents that occurred in three different cities in Spain.
Methodology:	• A total of 139 vehicle–pedestrian collisions were investigated in-depth following a common methodology, including on-the-spot data collection, analysis and reconstruction to estimate the collision speed and the pedestrian kinematics. • A specific procedure was defined to emulate, through computer simulations, the performance of the BAS acting together with the antilock braking system (ABS). • The benefit was assessed in terms of both collision speed and Injury Severity Probability (ISP) by comparing the reduction of their values from the real conditions to the virtual BAS + ABS simulations. • The pedestrian ISP was estimated, depending on the collision speed and the head impact point, using a specific application that calculated its value based on the results of headform impact laboratory tests.
Key Findings:	• The findings show that while implementing the BAS + ABS would not have prevented the collision in most of the cases, it would have reduced their consequences in terms of the estimated ISP. • It was also found that in few cases, a small reduction in the collision speed would increase the head injury severity.
Keywords:	Pedestrian safety, BAS, Vehicle-Pedestrian collisions
Comments:	This paper offers some valid points as to the effectiveness of BAS. However, the true effectiveness of BAS is likely to be difficult to plot as a lot of new ADAS systems are coupling the BAS with AEB.

Title:	**Influence of lane departure warnings onset and reliability on car drivers' behaviour**
Published:	J Navarro, J Deniel, E Yousfi, C Jallais, M Bueno, A Fort, Applied Ergonomics 59A pp.123-131. 2017
Link: **Free/priced:**	http://www.sciencedirect.com/science/article/pii/S0003687016301624 Priced
Objectives:	To assess the effects of an auditory Lane Departure Warning System (LDWS) for partial and full lane departures combined with missed warnings on drivers' performances and acceptance.
Methodology:	Lane departures were brought about by means of a distraction task whilst drivers simulated driving in a fixed-base simulator with or without an auditory LDWS.
Key Findings:	• Results revealed steering behaviours improvements with LDWS. • More effective recovery manoeuvres were found with partial lane departure warnings than with full lane departure warnings and assistance unreliability did not impair significantly drivers' behaviours. • Regarding missed lane departure episodes, drivers were found to react later and spend more time out of the driving lane when compared to properly warned lane departures, as if driving without assistance. • Subjectively, LDWS did not reduce mental workload and partial lane departure warnings were judged more trustworthy than full lane departure ones.
Keywords:	Lane Departure Warning, Lane Keeping Assistant
Comments:	This study explores a limited simulated trial of LDW, however the results look to be transferable. The materialisation of a real-world study would be difficult to implement as any recorded incidents would be where the system was ignored.

Title:	**Benefit and Feasibility of a Range of New Technologies and Unregulated Measures in the fields of Vehicle Occupant Safety and Protection of Vulnerable Road Users**
Published:	D Hynd, M McCarthy, J Carroll, M Seidl, M Edwards, C Visvikis, M Tress, N Reed, A Stevens, TRL for European Commission. 2015
Link: **Free/priced:**	https://publications.europa.eu/en/publication-detail/-/publication/47beb77e-b33e-44c8-b5ed-505acd6e76c0/language-en/format-PDF/source-31036036 Free
Objectives:	To review a range of new technologies and unregulated measures to determine the most promising candidates for regulation based on likely cost benefit and feasibilty.
Methodology:	Review of published research.
Key Findings:	• This report offers an advisory to the European Commission as to regulation regarding numerous new emerging automotive technologies. • The report suggest that for Traffic Sign Recognition, the driver can be alerted if a limit or restriction is disregarded, or • Use the information to adapt the warning and intervention strategies of other safety systems. • The TSR system was judged to be feasible as the technology has been available in the fleet since 2008. It is usually sold as an optional extra and part of a larger package of extras. • The limited research in the area of TSR suggests that its direct benefit is slim as the majority of drivers are aware of the speed limit on the roads which they travel. A bigger impact of the system could be seen if it is implemented with diferent stages if ISAs. • For DDRs, there are several different techniques to detect drowsiness; however, some are more invasive than others: o Eyelid detection o Electrocardiogram (ECG) o Electroencephalogram (EEG) o Electrodermal activity (EDA) o Vehicle control measures • Many systems can share technology, such as vehicle control measures can use existing sensors for steering, braking, acceleration, and metrics derived from these inputs (this is why vehicle control measures are preferred by vehicle manufacturers)
Keywords:	Regulations, Speed Limits, Drowsiness, Distraction
Comments:	This forms a very small part of a large report identifying emerging vehicle technologies. There is very little research, currently, into the direct effects of TSR; however, it is likely to benefit when used in conjunction with other technology. DDR is covered very well and offers pros and cons of each potential monitoring technique.

Title:	**Further development of motorcycle autonomous emergency braking (MAEB), What can in-depth studies tell us? A Multinational Study**
Published:	G Savino, M Rizzi, J Brown, S Piantini, L Meredith, B Albanese, M Pereini, M Fitzharris, Traffic Injury and Prevention 15 pp165-172. 2014
Link: **Free/priced:**	http://www.tandfonline.com/doi/full/10.1080/15389588.2014.926009#aHR0cDovL3d3dy50YW5kZm9ubGluZS5jb20vZG9pL3BkZi8xMC4xMDgwLzE1Mzg5NTg4LjIwMTQuOTI2MDA5P25lZWRBY2Nlc3M9dHJ1ZUBAQDA= Free
Objectives:	To understand the impact of MAEB on real world scenarios and to estimate the full potential through the simulating the collisions.
Methodology:	Real world data from 3 different countries was used, Australia, France and Sweden. The crashes were then analysed to see if there was potential for MAEB to be used, if so, they were selected for reconstruction.
Key Findings:	• The principal finding is that using the new triggering algorithm, MAEB is seen to apply to a broad range of multi vehicle motorcycle crashes. • Crash mitigation was achieved through reductions in impact speed of up to approximately 10 percent, depending on the crash scenario and the initial vehicle pre-impact speeds
Keywords:	Autonomous Emergency Braking, Motorcycle Braking systems, Collison Avoidance
Comments:	This study is very limited in a new emerging technology, however, it shows some of the only insight into a safety system which may soon be developed further.

Title:	**Autonomous emergency braking for cornering motorcycle**
Published:	G Savino, F Giovannini, S Piantini, N Baldanzinim, M Pierini, ESV conference, 2015, paper number 15-0220
Link: **Free/priced:**	https://www-esv.nhtsa.dot.gov/proceedings/24/files/24ESV-000220.PDF Free
Objectives:	Previous studies limited MAEB to the case of a powered two-wheeler (PTW) travelling along a straight, as the activation of AEB was considered hazardous for a leaning vehicle. This study aims to extend the applicability of MAEB to cornering scenarios.
Methodology:	A virtual PTW in a simulated environment was equipped with MAEB and Active Braking Control (ABC). MAEB consisted of a virtual obstacle detection device, triggering algorithms that identify inevitable collision states, and an automatic braking device. When an inevitable collision is detected for the host PTW and at the same time the rider is applying some braking force, MAEB deploys enhanced braking, which assists the rider reaching the maximum feasible deceleration. ABC consisted of control algorithms for the automatic braking device that stabilise the vehicle along the curved path. The complete system named MAEB+ was tested using detailed computer simulation reproducing real world crashes.
Key Findings:	In the simulation, MAEB+ was able to assist the rider in reducing the motorcycle speed prior to impact with higher deceleration compared to baseline MAEB and in maintaining the stability of the motorcycle.
Keywords:	MAEB, Motorcycle cornering, Collision mitigation
Comments:	

Title:	**Adaptive High Beam Systems: Visual Performance and Safety Effects**
Published:	J Bullough for SAE World Congress and Exhibition, 2014
Link: **Free/priced:**	http://papers.sae.org/2014-01-0431/ $27.00
Objectives:	To analyse the results of two new headlight technologies: headlights which curve around a corner, and adaptive high beam to protect on-coming vehicles.
Methodology:	This study used Visual Performance modelling to model the effects of the two headlight technologies. They set the headlights to several different parameters and measured drivers' reaction times to seeing an obstacle, as well as the amount of glare they experienced.
Key Findings:	• The overall visual performance benefit of +0.09 RVP units associated with adaptive high beam systems (relative to low beams) corresponds to a night time crash reduction of 6.7%. • This potential night time crash reduction value of 6.7% is on the same order of magnitude as night time crash reductions associated with roadway intersection lighting in Minnesota. This suggests that if the use of adaptive high beam systems were to become widespread, requirements for fixed overhead lighting systems might be reduced.
Keywords:	Headlights, Safety effects
Comments:	The visual performance measured in this study is based on only one prototype. It therefore may be better or worse than similar systems, however, it offers insight into the potential benefits if high beam assist.

Title:	**An open simulation approach to identify chances and limitations for Vulnerable Road User (VRU) Active Safety**
Published:	P Seiniger, O Bartels, C Pastor, and M Wisch, Traffic Injury Prevention 14, pp. 2-12. 2013
Link: **Free/priced:**	http://www.tandfonline.com/doi/pdf/10.1080/15389588.2013.797574?needAccess=true Free
Objectives:	To identify the chances and limitations of VRU protection as a form of active safety on vehicles.
Methodology:	Simulations were created to identify several different scenarios and speeds for vehicles encountering pedestrians and cyclists. The results from the scenarios are compared to judge the effectiveness of the safety system.
Key Findings:	• Scenarios with a pedestrian running from behind an obstruction are the most demanding scenarios and will very likely never be avoidable for all vehicle speeds due to physical limits. • Scenarios with an unobstructed person walking will very likely be treatable for a wide speed range for next generation AEB systems
Keywords:	Active safety, Pedestrian protection, Cyclist protection, crash avoidance
Comments:	This study is based on simulations and not real world data, however, it interrogates the active safety systems associated with VRUs well, and identifies good limitations and opportunities within the technology.

Title:	**Intersection assistance: A safe solution for older drivers?**
Published:	M Dotzauer, S, Caljouw, D de Waard, W, Brouwer, Accident Analysis and Prevention 59, pp. 522-528. 2013
Link: **Free/priced:**	http://www.sciencedirect.com/science/article/pii/S0001457513002923 Priced
Objectives:	To establish whether ADAS systems, and intersection assistance in particular, can help older drivers to make quicker driving decisions.
Methodology:	18 older drivers were required to repeatedly complete a drive in a simulator. Each driver would, or would not have the ADAS switched on. In order to test the intersection assistance, eight intersections were depicted for further analysis.
Key Findings:	Equipped with ADAS, drivers allocated more attention to the road centre rather than the left and right Crossed intersections in a shorter amount of time Engaged in higher speeds Crossed more often with a critical time-to-collision (TTC) value.
Keywords:	Intersection assistance, older drivers
Comments:	The study highlighted an unexpected result that with the information about time to cross a junction, older drivers appeared to take more risks, which is seen in the TTC results.

Title:	**V2X Communication and Intersection safety**
Published:	L Le, A Festag, R Baldessari, W Zhang, Advanced Microsystems for Automotive Applications 13th conference, 2015
Link: **Free/priced:**	http://www.festag-net.de/doc/2009_AMAA.pdf Free
Objectives:	To identify the applications of V2X technology, in particular, the application of intersection assistance.
Methodology:	Predominantly a literature study, looking at how the technology can faeibly work, how vehicles will communicate with one another, and possible applications which haven't yet been considered.

Key Findings:	• V2X communication has been considered a key ITS technology due to the fact that short-range wireless communication technology has become mature, inexpensive, and widely available.
	• For intersection safety, V2X communication can be used as an enabling technology to combine traffic light system, in-vehicle sensors, and infrastructure-based sensors.
	• Applications and Use Cases;
	    ○ Prevention of traffic light violation
	    ○ Prevention of turning and crossing-path collision
	    ○ Prevention of rear-end collisions
	    ○ Traffic signal adaptation for emergency warning and prioritised road users
	    ○ Traffic efficiency

Keywords:	Connected vehicles, V2X, Collisions avoidance
Comments:	This report offers a good review of the state of V2X technology. Given its 'older' publication, the technology has developed into a focus for many manufacturers and organisations with more sophisticated definitions and applications.

Title:	**In depth cost-effectiveness analysis of the identified measures and features regarding the way forward for EU vehicle safety**
Published:	M Seidl, D Hynd, M McCarthy, P Martin, R Hunt, S Mohan, V Krishnamurthy and S O'Connell of TRL Ltd for The European Commission. pp156-167, 2017
Link: **Free/priced:**	 Free
Objectives:	
Methodology:	Technical review of current systems from literature, further developed from Hynd et al., 2015. Benefit-to-cost analysis done to show the impact of the systems.
Key Findings:	• Direct vision and VRU detection systems are systems that are aimed towards HGVs and buses/coaches. They work by limiting the blind spot as much as possible by introducing direct vison requirements, or by using cameras and detection systems. • These are to try to protect VRUs from any potential collision. VRU detection systems such as radar sensors and ultra sound sensors can be used. They are used to monitor the perimeter of the vehicle. • Mercedes-Benz's active brake assist 4 uses radar sensors to monitor the vehicle's entire front and near-side length. It will alert the driver of VRUs moving in a critical zone and autobrake for pedestrians and cyclists if required.
Keywords:	Blind spot assist, driver warning, VRU protection
Comments:	

Title:	**The effects of electronic stability control (ESC) on crashes – An update**
Published:	A Hoye, Accident Analysis and Prevention 43, pp.1148-1159, 2011
Link: **Free/priced:**	http://ac.els-cdn.com/S0001457510004021/1-s2.0-S0001457510004021-main.pdf?_tid=f563251a-55c9-11e7-9714-00000aab0f6b&acdnat=1497971335_e8f661aa4c4be1348eeb76daa1a76474 Priced
Objectives:	To give an update on the effects of ESC from recent studies.
Methodology:	A meta-analysis of 12 studies into the effects of ESC on the number of different types of crashes were summarised.
Key Findings:	• ESC prevents about 40% of all crashes involving loss of control • All fatal crashes are reduced by around 40%; less severe crashes are unchanged when all types of crashes are regarded together. • Fatal crashes in which rollover is the first harmful event are reduced by 70%, rollover crashes of all severities are reduced by 50%. • Run-off-road crashes are reduced by about 40%, and single vehicle crashes are reduced by about 25%. • Results are likely to be overestimated, especially with non-fatal crashes.
Keywords:	ESC, RTIs, Prevention, Meta-Analysis
Comments:	A lot of the quoted figures of the effectiveness are likely to be overestimated. The author has made an attempt to remove any publishing bias when analysing the different studies.

Title:	**Not-in-Traffic Surveillance: Fatality and Injury Statistics in Nontraffic Crashes, 2008 to 2011**
Published:	National Highway Traffic Safety Administration (NHTSA), US Department for Transport, 2014
Link: **Free/priced:**	https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/811813 Free
Objectives:	To analyse the number of non-traffic related injuries in a 4 year period in the USA
Methodology:	Analysed statistics from NiTS data between 2008 and 2011
Key Findings:	• Reversing vehicles cause an average of 232 fatalities per year, 189 in 2011 • Reversing vehicles cause an average of 13,000 injuries per year, 12,000 in 2011
Keywords:	Crash statistics, injuries, fatalities
Comments:	This report shows some of the statistics for non-traffic related injuries. Shows how rear cross traffic alert can be a potential benefit.

Title:	**The effectiveness of lane departure warning systems – A reduction in real-world passenger car injury crashes**
Published:	S Sternlund, J Strandroth, M Rizzi, A Lie, C Tingvall, Traffic Injury Prevention 18, pp. 225-229, 2017
Link: **Free/priced:**	http://www.tandfonline.com/doi/pdf/10.1080/15389588.2016.1230672?needAccess=true Free
Objectives:	The objective of this study was to estimate the safety benefits of in vehicle lane departure warning (LDW) and lane keeping aid (LKA) systems in reducing relevant real-world passenger car injury crashes.
Methodology:	The study used an induced exposure method, where LDW/LKA-sensitive and nonsensitive crashes were compared for Volvo passenger cars equipped with and without LDW/LKA systems. These crashes were matched by car make, model, model year, and technical equipment; that is, low-speed autonomous emergency braking (AEB) called City Safety (CS). The data were extracted from the Swedish Traffic Accident Data Acquisition database (STRADA) and consisted of 1,853 driver injury crashes that involved 146 LDW-equipped cars, 11 LKA-equipped cars, and 1,696 cars without LDW/LKA systems.
Key Findings:	• The analysis showed a positive effect of the LDW/LKA systems in reducing lane departure crashes. • The LDW/LKA systems were estimated to reduce head-on and single-vehicle injury crashes on Swedish roads with speed limits between 70 and 120 km/h and with dry or wet road surfaces (i.e., not covered by ice or snow) by 53% with a lower limit of 11% (95% confidence interval [CI]). • This reduction corresponded to a reduction of 30% with a lower limit of 6% (95% CI) for all head-on and single-vehicle driver injury crashes (including all speed limits and all road surface conditions).
Keywords:	LDW, Lane keeping, Lane departure, injury
Comments:	This study shows some evidence of the effectiveness of the LDW/LKA systems, however, the parameters defined for the study are very specific, so some of the results may not be able to be generalised to improved vehicle safety as a whole.

Title:	**Regulation (EC) No 661/2009 of the European Parliament and of the Council of 13 July 2009 concerning type-approval requirements for the general safety of motor vehicles, their trailers and systems, components and separate technical units intended therefor**
Published:	European Commission, 2009
Link: **Free/priced:**	http://data.europa.eu/eli/reg/2009/661/oj Free
Objectives:	To add regulation to the new vehicle safety technology, as well as to push safety forwards by making several safety systems mandatory in a given timeframe.
Methodology:	
Key Findings:	Key safety requirements for vehicles in the EU. Regulation lays down the fundamental provisions on vehicle safety and CO_2 and noise emissions.
Keywords:	Regulation, BAS, AEB, LDW
Comments:	

Title:	**Commission Directive 2008/89/EC of 24 September 2008 amending, for the purposes of its adaptation to technical progress, Council Directive 76/756/EEC concerning the installation of lighting and light-signalling devices on motor vehicles and their trailers**
Published:	European Commission, 2008
Link: **Free/priced:**	http://data.europa.eu/eli/dir/2008/89/oj Free
Objectives:	To make daytime running lights mandatory, and add the amendment to the 76/756/EEC regulation
Methodology:	
Key Findings:	Amendment for the addition of daylight running lights, adaptive front lighting, and emergency stop signal. All M1 and N1 vehicles are in effect from 2011, and everything else from 2012.
Keywords:	Daylight running lights
Comments:	

Title:	**Concept of an enhanced V2X pedestrian collision avoidance system with a cost function-based pedestrian model.**
Published:	J Kotte, C Schmeichel, A Zlocki, H Gathmann, L Eckstein, Traffic Injury Prevention, 2017
Link: **Free/priced:**	https://www.ncbi.nlm.nih.gov/pubmed/28368684 Priced
Objectives:	To develop and implement V2X pedestrian avoidance systems that use new information sources.
Methodology:	A literature review of existing state-of-the-art pedestrian collision avoidance systems, pedestrian behavior models in advanced driver assistance systems (ADAS), and traffic simulations is conducted together with an analysis of existing studies on typical pedestrian patterns in traffic. Based on this analysis, possible parameters for predicting pedestrian behavior were investigated. The results led to new requirements from which a concept was developed and implemented.
Key Findings:	A concept for an enhanced V2X pedestrian collision avoidance system was developed and introduced. The concept uses new information sources such as smart devices to improve the prediction of the pedestrian's presence in the near future and considers challenges that come along with the usage of these information sources.
Keywords:	VRU protection, VRU Detection, V2X, V2VRU
Comments:	

Title:	**Stereo Vision-based approaches for Pedestrian Detection**
Published:	M Bertozzi, E Binelli, A Broggi, M Del Rose, 2005
Link: **Free/priced:**	https://pdfs.semanticscholar.org/7405/df6bb057eafa3705c9ab0c20a5d877c08f5d.pdf Free
Objectives:	To investigate the different approaches in pedestrian detection techniques.
Methodology:	Analysis of three different underlying approaches: warm area detection, edge-based detection, and v-disparity computation. Stereo is also used for computing the size and distance of detected objects.
Key Findings:	• Thanks to the triangulation information, the system has proven to be able to detect pedestrians even if they are partly overlapped each other. In addition, the use of three different approaches for the detection allows to detect pedestrians in complex scenarios or even when they are not warmer than the background. • Main problem is to check are about aspect ratio. Sometimes aspect ratio is not a good evaluation criterion for filtering results. • The algorithm is based on three different approaches: the detection of warm areas, the detection of vertical edges and a v-disparity computation. Distance estimation, size, aspect ratio, and a head presence are used to select pedestrians.
Keywords:	Pedestrian detection, Stereo camera
Comments:	This paper is quite old, the technology reviewed is still relevant; however, it is likely that it has progressed further since this paper was written.

Title:	**Most Honda owners turn off lane departure warning**
Published:	IIHS Status report, Volume 51, No 1, January 2016
Link: **Free/priced:**	http://www.iihs.org/iihs/sr/statusreport/article/51/1/4 Free
Objectives:	N/A
Methodology:	Research into observed vehicles at Honda dealerships.
Key Findings:	• The researchers observed vehicles brought in to Honda dealerships for service. They found that all but one of 184 models equipped with the two features had forward collision warning turned on, while only a third of vehicles had lane departure warning activated. • The findings are consistent with previous research showing that vehicle owners found lane departure warning more annoying than other crash avoidance technologies. • They also may help explain why studies so far haven't found a consistent benefit from the feature, in contrast to forward collision warning • Most lane departure warning systems use a camera to detect lane markings and depend on turn signal use to determine whether a driver intentionally changed lanes or not. Many people don't use turn signals consistently, so the result is a lot of alerts that drivers may perceive as false alarms.
Keywords:	Lane departure warning
Comments:	This offers a good insight into the social acceptance of different technologies.

Title:	**Steering and Evasion Assist**
Published:	A Eskandarian, Handbook of Intelligent Vehicles, Chapter 29, 2012
Link: **Free/priced:**	http://www.gavrila.net/Publications/29_Steering_and_Evasion_Assist.pdf Free
Objectives:	To estimate the potential benefits of steering evasion assist, as well as summarising established steering technologies.
Methodology:	Literature review
Key Findings:	• Steering and evasion assistance systems are a new class of driver assistance systems that open up additional potentials for collision mitigation. It was shown in this chapter that steering intervention is a sensible alternative or additional option for emergency braking systems in a collision speed range above 30 km/h. Steering intervention and evasion systems especially focus on surprising situations, where fast reactions are needed and no time is left for driver warnings. This requires high demands on environment perception as well as on situation analysis. Up to now environment perception algorithms concentrate on object and lane detection and measurement. A new requirement for driver assistance is the detection of free and drivable space, which has to be guaranteed to perform an evasion manoeuvre. • Three different system layouts were presented: driver-initiated evasion, corrective evasion, and automatic evasion assistance. Driver-initiated evasion only supports an intervention of the driver and therefore offers less safety potential, but due to less complexity it may soon be introduced to market. Corrective or automatic evasion assistance systems are currently investigated by industry and scientific research labs. Beside technical problems like the reliability of the environment perception, a lot of open questions have to be answered, e.g., customer controllability and acceptance. Therefore market introduction is not expected within the next 10 years.
Keywords:	Steering assist, Collision avoidance
Comments:	

Non-Evidence Based References

Title:	**Autonomous Emergency Braking**
Published:	Euro NCAP, 2017
Link: **Free/priced:**	http://www.euroncap.com/en/vehicle-safety/the-rewards-explained/autonomous-emergency-braking/ Free
Objectives:	
Methodology:	Technical review of current autonomous braking systems and summary of how AEB works.
Key Findings:	• No findings per se, however the website offers a great insight into how and why AEB is necessary. • AEB is now taken into account when the ratings are calculated for a vehicle during their testing procedure • Most AEB systems use radar, (stereo) camera and/or lidar-based technology to identify potential collision partners ahead of the car. This information is combined with what the car knows of its own travel speed and trajectory to determine whether or not a critical situation is developing. • If a potential collision is detected, AEB systems generally (though not exclusively) first try to avoid the impact by warning the driver that action is needed. If no action is taken and a collision is still expected, the system will then apply the brakes. • AEB systems improve safety in two ways: firstly, they help to avoid accidents by identifying critical situations early and warning the driver; and secondly they reduce the severity of crashes which cannot be avoided by lowering the speed of collision and, in some cases, by preparing the vehicle and restraint systems for impact.
Keywords:	AEB, Euro NCAP, Vehicle testing
Comments:	Offers very good insight into AEB, very easy to follow, with most aspects of the system explained well.

Title:	**Crosswind Assist**
Published:	Mercedes-Benz 2017a
Link: **Free/priced:**	http://techcenter.mercedes-benz.com/en/crosswind_assist/detail.html Free
Objectives:	
Methodology:	Informative website to explain the system to the reader
Key Claims:	• Crosswind technology prevents the vehicle from leaving its lane in the event of high winds • Works in accordance with the ESC and LKA • Measures the strength of the wind, and applies appropriate brake pressure to individual wheels to keep the vehicle in its lane. • If the vehicle permits (i.e. has the appropriate optional extras), the suspension system can be adapted by the ESC to perform the same task.
Keywords:	ESC, Crosswind Stabilisation, LKA
Comments:	From research conducted, it seems to be only Mercedes-Benz using this technology, although there may be more available. There is no obvious, published, evidence to directly support its use, however this is unlikely to materialise due to the very close connection to LKA.

Title:	**Euro NCAP – 2020 Roadmap**
Published:	Euro NCAP, 2015
Link: **Free/priced:**	http://www.euroncap.com/en/for-engineers/technical-papers/ Free
Objectives:	To propose new testing methods for vehicles to be tested against, in order to continue to promote safer vehicles.
Methodology:	To look at new ADAS systems and to establish the testing methods, and time frame for the implementation of new tests.

Key Findings:	• New testing and rating criteria in the following areas:
	  ◦ Occupant protection in front and side crashes
	  ◦ Autonomous braking for cars and VRU
	  ◦ Lateral assist systems
	  ◦ Speed and impaired driving

Keywords:	Euro NCAP, VRU protection, Crash testing
Comments:	This shows Euro NCAP's continued vision to promote safer vehicles on the European road network. It shows time frames for the implementation of new testing, which in turn will prompt manufacturers to develop safer vehicles.

Title:	**Future of Infrastructure – Vehicle-to-X (V2X) communication technology**
Published:	Seimens, 2015
Link: **Free/priced:**	https://www.mobility.siemens.com/mobility/global/SiteCollectionDocuments/en/road-solutions/urban/trends/siemens-vehicle-to-x-communication-technology-infographic.pdf Free
Objectives:	
Methodology:	Review of current V2X technology and how they connect, as well as explaining future applications of the technology.

Key Claims:	• V2X refers to a vehicle communicating with something. This could be Vehicle to Vehicle (V2V), or Vehicle to Infrastructure (V2I), or Vehicle to VRU etc. It is an intelligent transport system where all vehicles and infrastructure systems are interconnected with each other. It will help to:
	    o Optimise traffic flow
	    o Reduce congestions
	    o Reduce accident numbers
	    o Minimise emissions
	• It allows vehicles to automatically pass on information about things such as road conditions, traffic flow, and obstacles before they appear in the driver’s visual range. Vehicles will also be able to receive signals from intelligent road signs.
	• It will allow a clear path for emergency vehicles before the emergency vehicle is caught in traffic
	• V2X can be extended to Airplane2X, Rail2X, Ship2X etc.
	• Since intelligent traffic information on German A9 highway, there have been 35% fewer accidents, and 31% fewer people injured on the roads.

Keywords:	Intelligent Transport Systems, emerging technology, V2X
Comments:	This infographic explains the V2X technology in a very simple and easy way to follow. There is little evidence to support the impact of V2X on the roads.

Title:	**BAS PLUS with Cross-Traffic Assist**
Published:	Mercedes-Benz, 2017b
Link: **Free/priced:**	http://techcenter.mercedes-benz.com/en/bas_plus_cross_traffic_assist/detail.html Free
Objectives:	
Methodology:	Informative website to explain the system to the reader
Key Claims:	• BAS PLUS with Cross-Traffic Assist is able to detect an imminent collision with crossing traffic and warn you before it is too late. This is based on data supplied by the stereo camera and radar sensors which monitor the traffic conditions. • BAS PLUS with Cross-Traffic Assist is active at speeds of up to 72 km/h and can significantly reduce the likelihood of an accident at junctions. If a collision should ever occur, however, for the most part the accident does tend to be less severe.
Keywords:	Junction safety, collision avoidance
Comments:	There is no evidence to show the effectiveness of the system; however, it does show how it attempts to mitigate a cross junction crash scenario.

Title:	**Rear Cross Traffic Alert**
Published:	Bosch, 2017
Link: **Free/priced:**	http://www.bosch-mobility-solutions.com/en/products-and-services/passenger-cars-and-light-commercial-vehicles/driver-assistance-systems/rear-cross-traffic-alert/ Free
Objectives:	
Methodology:	Informative website to explain the system to the reader
Key Claims:	• The system works by identify any traffic that may be passing across the rear of a vehicle. This is especially advantageous when reversing out of a parking space, and the view of the driver is obstructed. • The system uses two mid-range radar sensors in the rear of the vehicle. They measure and interpret the distance, speed and anticipated driving path of vehicles detected in cross traffic. • If the function detects vehicles crossing to the left or right behind the driver's vehicle with a range of 50 meters, an audible and/or visual warning is used to alert the driver of the risk.
Keywords:	Collision warning, active safety, visibility
Comments:	There is no evidence for the effectiveness of this system. However, in principal, if offers an effect counter measure against reversing into oncoming traffic.

Title:	**Lane Change Assist**
Published:	Bosch Mobility Solutions, 2017a
Link:	http://www.bosch-mobility-solutions.com/en/products-and-services/passenger-cars-and-light-commercial-vehicles/driver-assistance-systems/lane-change-assist/
Free/priced:	Free
Objectives:	
Methodology:	Informative website to explain the system to the reader

Key Claims:	• This is a system which checks the perimeter of the vehicle for any obstructions when you are changing lanes. Changing lanes is a constant source of danger when driving on the road, where drivers are taught to instinctively check their blind spot.
	• LCA works by utilising 2 radar sensors, these are constantly monitoring the environment around the vehicle. There are two stages to LCA:
	    o If a vehicle is in the driver's blind spot, there is usually an illuminated warning first on the wing mirror of the vehicle.
	    o If this is ignored and the vehicle starts to change lane, the warning will give an audible alarm which alerts the driver.
	    o In more premium vehicles, if this is then ignored again, the vehicle will automatically use the ESC to brake the wheels on one side of the vehicle to prevent it from changing lane.

Keywords:	Driver assistance, Lane Change, Blind Spot
Comments:	Informative website article from Bosch about the product that the company supplies. No evidence of the system's effectiveness.

Title:	**Restricting the car's functions with Red Key**
Published:	Volvo Cars, 2017
Link: **Free/priced:**	http://support.volvocars.com/uk/Pages/article.aspx?article=4041178bc96bb227c0a8015106604656 Free
Objectives:	
Methodology:	Informative website to explain the system to the reader

Key Claims:	• Possible settings for Red Key:
	  ○ Speed limiter (Speed Limiter)
	  ○ Speed reminder
	  ○ Maximum volume for the speaker system
	  ○ Adaptive cruise control
	• When you lend your car to another driver using a Red Key, it is not possible for them to change the settings you made beforehand.
	• Driver support functions with Red Key
	  ○ Blind Spot Information
	  ○ Lane assistance (LDW and LKA)
	  ○ Distance Warning
	  ○ City Safety
	  ○ Driver Alert Control
	  ○ Road Sign Information (Road Sign Information)

Keywords:	Youth Key, Driving restrictions, Young Drivers
Comments:	This website offers an insight into the capabilities of a Youth Key. It doesn't offer any evidence to suggest that it makes younger drivers safer.

Title:	**Autonomous Emergency Steering System**
Published:	Nissan Motor Corporation, 2017
Link: **Free/priced:**	http://www.nissan-global.com/EN/TECHNOLOGY/OVERVIEW/autonomous_emergency_steering_system.html Free
Objectives:	
Methodology:	Informative website to explain the system to the reader
Key Claims:	• When there is an impending collision, a driver may not react fast enough to avoid it. In such a scenario, the Autonomous Emergency Steering System can apply emergency braking when it determines that an accident is unavoidable, helping the driver to avoid a potential collision. • When the system detects the risk of collision with an obstacle in front that cannot be avoided by braking only, it determines a direction without an obstacle (an escape zone). It then automatically steers the vehicle to help avoid a collision. • If the system detects the risk of a frontal collision, the Electronic Control Unit (ECU) calculates the optimum collision avoidance response. When there is time, it warns the driver audibly and visually through a warning sound and light. • After releasing the warning, if the system determines that a collision is imminent, it automatically engages the emergency brake. However, when a collision cannot be avoided through braking, steering manoeuvres are required. • The ECU features software that can identify the vehicle's lane of travel, speed and the location of the vehicle's surroundings. Using precise measuring devices, it computes various data supplied in real-time, such as imagery from the camera, and information sent by the radar sensor regarding the number of oncoming vehicles and their path of travel. • In this way, not only can the system measure the speed and distance of surrounding objects, it is able to understand quickly the likely results that would arise from certain steering inputs.
Keywords:	Autonomous Steering, Collision Avoidance
Comments:	This offers a good insight into technology which will soon be available to many vehicles on the road. A similar system has already been deployed by Tesla, however at this current stage, the technology is not widespread.

28 Calthorpe Road, Edgbaston, Birmingham, B15 1RP
Telephone: 0121 248 2000
Registered Charity No: 207823

www.rospa.com