EUROPEAN
COMMISSION

Brussels, 12.12.2016
SWD(2016) 431 final

COMMISSION STAFF WORKING DOCUMENT
Accompanying the document

Report from the Commission to the European Parliament and the Council

Saving Lives: Boosting Car Safety in the EU
Reporting on the monitoring and assessment of advanced vehicle safety features, their cost effectiveness and feasibility for the review of the regulations on general vehicle safety and on the protection of pedestrians and other vulnerable road users

{COM(2016) 787 final}

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Contents

1. Introduction ... 4
2. Key issues to be addressed in the review of the regulations ... 5
3. Candidate Measures for Consideration for Implementation in the General Safety and Pedestrian Regulations ... 6
3.1. Main items for all relevant vehicle categories ... 6
3.1.1. Automatic Emergency Braking ... 6
3.1.2. Emergency Braking Display (Stop Signal) ... 8
3.1.3. Intelligent Speed Adaptation ... 9
3.1.4. Lane Keep Assistance ... 11
3.1.5. Driver Drowiness or Distraction Monitoring ... 13
3.1.6. Safety belt reminders ... 14
3.1.7. Frontal Crashes ... 15
3.1.8. Side Crashes ... 18
3.1.9. Rear Crashes ... 19
3.1.10. Alcohol Interlock Devices ... 21
3.1.11. Crash Event Data Recorder ... 22
3.1.12. Tyre Pressure Monitoring ... 23
3.2. Trucks and Buses ... 25
3.2.1. Front-end Design and Direct Vision ... 25
3.2.2. Truck Rear Underrun Protection ... 27
3.2.3. Truck Lateral Protection ... 28
3.2.4. Fire Safety for Buses ... 29
3.3. Pedestrian and Cyclist Safety ... 30
3.3.1. Pedestrian and Cyclist Detection ... 30
3.3.2. Head Impact on A-Pillars and Front Windscreen ... 31
3.3.3. Reversing (Backing up) Detection ... 32
4. Bunching of Technologies ... 34
5. Further Studies in the Field of Vehicle Safety ... 34
5.1. Frontal crashes ... 34
5.2. Side crashes ... 35
5.3. Roll-over accidents ... 35
5.4. Rear crashes ... 35
6. Conclusions ... 35
ANNEX 1: List of proposed measures by introduction date ... 36

ANNEX 2: Full list of potential measures as established for the feasibility and cost-benefit study (published in March 2015) ... 40
A2.1. Active safety ... 40
A2.2. Car occupant and pedestrian safety ... 42
A2.3. Crashworthiness, HGV Safety and Fuel Systems ... 43
A2.4. Driver Interface, Distraction and Intelligent Transport Systems ... 44
ANNEX 3: For candidate measures, summary of feasibility and cost benefit assessment reported initially ... 46

1. INTRODUCTION

A traditional approach to analyse road safety is to identify a specific issue and to research mitigation actions. The European Parliament and Council however have given the Commission clear instructions on another way forward to review of the existing safety regulations: assessing the inclusion of further new safety features and proposal of new measures on the basis of the results of monitoring linked to the safety of pedestrians and other vulnerable road users. This is indeed the work that is being undertaken by the Commission and rather than to identify specific issues and work from there, the Commission has been reviewing a suite of unregulated measures that can be proposed in a package, with potential to provide effective incremental but significant improvements addressing a range of vehicle safety related areas.

In this context, Regulation (EC) No 661/2009 of the European Parliament and Council, amended by Commission Regulation (EU) Nos 407/2011, 523/2012, 2015/166 and 2016/1004 (the 'General Safety Regulation') governs the type-approval requirements for the general safety of motor-vehicles, their trailers and systems, components and separate technical units.

The Regulation lists the individual measures that apply on a compulsory basis and the vehicle categories to which each measure applies. To date, a number of amendments have been made to the General Safety Regulation including mandating:

- Electrical safety
- Electronic Stability Control (ESC) systems on cars, vans, trucks and buses
- Fitment of tyre pressure monitoring systems on cars
- Lane Departure Warning Systems (LDWS) and Advanced Emergency Braking Systems (AEBS) for trucks and buses
- Gear shift indicators on cars
- Rolling resistance limits, noise emission limits and wet grip performance of tyres
- Driver seat-belt reminder on cars
- ISOFIX child restraint anchorages on cars
- Cab strength crash protection of vans and trucks
- A large number of UNECE Regulations replacing repealed Directives

In addition, Regulation (EC) No 78/2009 on the type-approval of motor vehicles with regard to the protection of pedestrians and other vulnerable road users (the 'Pedestrian Safety Regulation') replaced Directive 2003/102/EC with modified and more advanced provisions, adapted to the technical progress. This includes passive safety requirements to mitigate the risk of critical injury in case of a collision between a vehicle and a person.

The General Safety Regulation Article 17 requires that the Commission reports to the European Parliament every three years with proposals for amendment to the Regulation or other relevant Community legislation regarding the inclusion of further new safety features that meet the CARS 2020[1] and the Policy Orientations on Road Safety 2011-2020 criteria. Commission monitoring reports to the European Parliament are also required, as appropriate, by the Pedestrian Safety Regulation Article 12.

As part of these requirements, a report was produced on behalf of the Commission by the Transport Research Laboratory TRL of the UK (Hynd et al, 2015)[2] concerning an overview of

1 CARS 2020: Action Plan for a competitive and sustainable automotive industry in Europe

2 Hynd, D., McCarthy, M., Carroll, J., Seidl, M., Edwards, M., Visvikis, C., Tress, M., Reed, N. and Stevens, A. (2015). *Benefit and feasibility of a range of new technologies and unregulated measures in the fields for occupant safety and protection of vulnerable road users. Final Report.* Brussels: European Commission. http://bookshop.europa.eu/en/benefit-and-feasibility-of-a-range-of-new-technologies-and-unregulated-

the feasibility and cost-benefit assessment of a wide range of possible measures for inclusion in EU legislation as regards an update of the General Safety and Pedestrian Regulations. The main outputs of the report were indicative cost-benefits provided in order to differentiate those measures that would be very likely (gren light), moderately likely (yellow light) or very unlikely (red light) to provide a benefit consistent with the cost of implementation.

The report also provided advice on the necessity and feasibility of making mandatory the 'upper legform to bonnet leading edge test' and the 'adult headform to windscreen test' that were both carried out by car producers as part of the mandatory monitoring program encompassed in the pedestrian safety legislation.

Using the results from this report and where appropriate, revised and updated information and insights in terms of the benefit and feasibilty of specific measures, further work has been performed to select candidate measures for consideration for implementation in the General Safety and Pedestrian Regulations.

This Commission Staff Working Document lists those candidate measures, their technical feasibility and legislative feasibility/readiness and potential target dates for implementation. It also summarises the further work required for their possible implementation in the General Safety and Pedestrian Regulations. Studies to perform this work are currently underway and it is planned to use the output of these studies to update the list of candidate measures upon completion of these studies.

2. KEY ISSUES TO BE ADDRESSED IN THE REVIEW OF THE REGULATIONS

The study on the 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[2] in the frame of the General Safety and Pedestrian Safety Regulations was published in March 2015. The report provides an overview of feasibility and cost-benefit assessment of a wide range of candidate measures for possible inclusion in the General Safety and Pedestrian Safety Regulations. The outputs of the report were indicative cost-benefits provided in order to differentiate those measures that are very likely, moderately likely or very unlikely to provide a benefit consistent with the cost of implementation. The information was compiled and provided with the aim to enable prioritisation of possible future measures and was debated intensively with the stakeholders and authorities of Member States and international partners.

Thus, in the initial phase of this exercise, a selection of 55 of the most promising areas of interest were established and assessed.

In the present phase, the potential regulatory measures that have shown to yield an acceptable cost benefit as well good feasibility for implementation, 19 measures are now proposed to be debated in view of the review of the General Safety and Pedestrian Safety Regulations.

In some cases, the measures are complementary to existing rules. An example is seat belt reminder that is already mandatory on the driver seat of passenger cars, but this will be expanded to all occupant seats in cars and light commercial vehicles , as well as to all front seats in trucks and buses. Tyre pressure monitoring is currently required on passenger cars only, but will be expanded to all motor-vehicles and heavy trailers.

In other cases an identified measure is split in multiple facets to facilitate a pragmatic implementation timeline. When regarding the case for Automatic emergency braking (AEB),

measures-in-the-field-of-vehicle-occupant-safety-and-protection-of-vulnerable-road-users-pbNB0714108/;pgid=Iq1Ekni0.1lSR0OOK4MycO9B0000BAJ9tQVy;sid=OT_-Ap3uO3P-V8j2wGFgpf_Lm_yCUpo9P-w=

this measure is proposed in four steps: In the first step, AEB that has sensing capability of moving vehicles ahead that are slowing down is introduced, followed by systems that can also sense stationary ones. The third implementation step actually falls under the pedestrian safety measure, but is based on exactly the same technology, namely AEB with pedestrian detection capability. The final step is foreseen for AEB systems that can also detect an imminent collision with a cyclist. Annex 1 to this Commission Staff Working Document provides a comprehensive overview of all measures and implementation steps that are divided by certain technological capabilities and applicability for specific vehicle categories.

It should further be mentioned that in some specific cases updated information concerning cost evidence could be obtained and applied towards the improved assessment of the relevant proposed measures. Namely, in the initial phase it was highlighted that further analysis would be needed to obtain a clear view on the cost-effectiveness of a few given measures that have been reviewed in isolation. Such further analysis has indeed been carried out for the purpose of providing an updated overview of the anticipated cost-effectivenss in this Commission Staff Working Document.

When certain individual safety features, yet using common hardware components, are bundled, this also reflects such commonality in the eventual cost price, with a positive cost-benefit effect. In any event, the cumulative cost of introducing technologies will be carefully assessed as part of a new in depth cost-benefit study, that will in turn form the basis for the overall impact assessment. To obtain highly credible information on technology costs, it is envisioned that a detailed cost teardown is performed where appropriate.

In this context it is important that a thorough overview can be provided on the costs that might be passed on to the end consumer, in relation to the safety features that will need to be added to future vehicles as a result of the revised General Safety and Pedestrian Safety Regulations, as well as on the economic feasibility and how this may subsequently affect the competitiveness of the automotive industry.

As part of the preparatory process, the Commission will involve stakeholders and ask citizens for their feedback on the considered new vehicle safety rules. For this purpose, the Commission will prepare an inception impact assessment[3]. The feedback that will be provided can then be taken into account for the further development of the policy proposal.

The Commission considers that, to limit the enforcement costs for the industry and in line with the better regulation principles, the requirements will need to be implemented with due lead-time and concentrated in a few implementation dates. The Commission considers that the target date for already mature and generally available technologies to become mandatory might be set to 2020 for new types of vehicles and to 2022 for new vehicles. For less developed technologies, the target date might be 2022 and 2024 respectively, with a few exceptions of longer term objectives in some specific areas.

3. CANDIDATE MEASURES FOR CONSIDERATION FOR IMPLEMENTATION IN THE GENERAL SAFETY AND PEDESTRIAN REGULATIONS

3.1. MAIN ITEMS FOR ALL RELEVANT VEHICLE CATEGORIES

3.1.1. Automatic Emergency Braking

Automatic Emergency Braking (AEB) combines sensing of the environment ahead of the vehicle with the automatic activation of the brakes (without driver input) in order to mitigate or avoid an accident. The level of automatic braking varies, but may be up to full ABS braking capability.

3 http://ec.europa.eu/smart-regulation/roadmaps/index_en.htm

From 1st November 2015, the General Safety Regulation has required the fitment of Advanced Emergency Braking Systems to new vehicles of categories M_2, M_3, N_2 and N_3. EU Regulation No. 347/2012 specifies technical requirements and test procedures for these systems. The systems shall detect the possibility of a collision with a preceding vehicle, warn the driver by a combination of optical, acoustic or haptic signals and, if the driver takes no action, automatically apply the vehicle's brakes. Two performance levels are specified with the more stringent level becoming mandatory from 1st November 2016 for new types and 1st November 2018 for all new vehicles. Note that only the more stringent level contains test pass/fail values for vehicles of categories M_2 and $N_2 \leq$ 8 tonnes, so there are no requirements for these vehicles before 1st November 2016.

First generation AEB for passenger cars (M_1) are capable of automatically mitigating the severity of two-vehicle, front to rear shunt accidents (on straight roads and curves dependent on sensor line of sight and environment 'clutter') as well as some collisions with fixed objects and motorcycles. These systems are becoming more and more common, notably through Euro NCAP encouragement for systems that can detect slow moving or even stopped vehicles ahead. This is also the case for systems that have the capability to detect pedestrians and bicyclists, although these systems are currently still less common, but increasingly available on a number of car models.

In the context of the review of the General Safety and Pedestrian Safety Regulations, an introduction timeline should be considered that allows for a phase in of the detection capabilities and mandatory introduction on passenger cars (M_1) and vans (N_1).

- Make mandatory for M_1 and N_1 vehicles (that are derived from M_1)
- 01/09/2020 moving obstacle detection for new EU approved types
- 01/09/2022 stationary obstacle detection for new EU approved types
- Plus 2-year period for all new vehicles sold in the EU
- All N_1 vehicles 2-year offset to the above dates

Technical feasibility:

AEB are in production on a number of current pssenger cars, typically at the top-end of the market but increasingly also on standard vehicles. For passenger cars (M_1), AEB are optional equipment on approximately 20-50% of 2013 vehicle models and are fitted as standard to an increasing share of vehicles.

Legislation feasibility/readiness:

Validated test procedures for AEB for M_1 vehicles have been developed and implemented by Euro NCAP and could be used as a basis for future legislation.

EU Regulation No. 347/2012 specifies the technical requirements and test procedures for advanced emergency braking systems (AEBS) for M_2/M_3 and N_2/N_3 category vehicles that detect the possibility of a collision with a preceding vehicle, warn the driver by a combination of optical, acoustic or haptic signals and, if the driver takes no action, automatically apply the vehicle's brakes. The Regulation specifies requirements on the system operation and specifies two test procedures to check the performance of the system; one with the vehicle approaching a moving target and one with the vehicle approaching a stationary target. The Regulation specifies two "Levels" of limit values on the timing of the warnings and on the vehicle speed reduction to be achieved in each of these tests, with the "Level 2" requirements being more stringent. To allow time for the development of suitable systems for lighter vehicles, vehicles with hydraulic braking systems and vehicles with mechanical rear suspension systems, the "Level 1" limits are only applied to M_3 Category vehicles, N_2 Category vehicles with a GVW greater than 8,000 kg and N_3 Category vehicles that are equipped with pneumatic or air/hydraulic braking systems and with pneumatic rear axle suspension systems.

The fitment of advanced emergency braking systems (AEBS) meeting the “Level 1” performance requirements has been mandatory for all new vehicles from 1st November 2013 and for new types of vehicle and from 1st November 2015. The fitment of advanced emergency braking systems (AEBS) meeting the “Level 2” performance requirements becomes mandatory from 1st November 2016 for new types of vehicle and 1st November 2018 for all new vehicles. The “Level 2” performance requirements include requirements N_2 vehicles with a GVW less than 8000 kg and N_3 Category vehicles that are equipped with pneumatic or air/hydraulic braking systems and with pneumatic rear axle suspension systems.

The benefit of fitting AEB to M_1 vehicles in terms of casualties saved has been estimated to be far higher than for M_2/M_3 and N_2/N_3 vehicles (Grover 2008)[4]. Even so, the break even cost per vehicle (i.e. the cost per vehicle for a benefit to cost ratio of 1) was estimated to be far higher for M_1 vehicles because there are far more vehicles of this category in the vehicle fleet. However, costs for these systems are reducing (current consumer costs for AEB are as low as £200 (Ford, VW)), so it is likely that the benefit to cost ratio of fitment of AEB to M1 vehicles will have a benefit to cost ratio greater than one. This is even more likely to be the case for ‘city’ AEB systems that help prevent the frequent low speed collisons and the associated whiplash injuries and relatively minor vehicle damage.

For consideration for implemenation in the GSR further work is required to:

- confirm benefit to cost ratio.

3.1.2. Emergency Braking Display (Stop Signal)

The emergency braking display, or emergency stop signal, consists of a rapid flashing of the brake lamp when full brakes are applied. This technology is already optionally available on motor vehicles and has proven to be very effective[5]. Drivers following the hard-braking vehicle are instantly aware that the vehicle in front is braking with a high retardation so that they can take appropriate action. This relatively simple but effective technology can thus help drivers to avoid late recognition the hard-braking situation and avoid subsequent accidents that could result.

This system is designed to address front-to-rear accidents. This system is primarily effective on highways and provides better quality information to following drivers so that rear shunt accidents can be avoided or mitigated.

The rationale behind Emergency Braking Display (EBD) is to decrease the time required to detect an emergency brake by the following driver, thereby avoiding or mitigating the effect of rear-end collisions. A road user who is temporarily not looking at the road, for instance when inspecting in-vehicle equipment, will notice through peripheral vision a flashing light more readily than the activation of ‘normal’ braking lamps. The emergency braking display, or emergency stop signal, consists of a rapid flashing of the brake lamp or hazard warning lights when full brakes (e.g. > 6m/s2 for cars) are applied. Drivers following the hard-braking vehicle are more quickly aware that the vehicle in front is braking with a high retardation so that they can take appropriate action. It is proposed:

Make emergency braking display mandatory for all M and N vehicles

- 01/09/2020 for new types
- 01/09/2022 for all new vehicles

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4 Grover C, Knight I, Okoro F, Simmons I, Couper G, Massie P and Smith B (2008). Automated Emergency Braking Systems: Technical requirements, costs and benefits.

5 http://www.unece.org/fileadmin/DAM/trans/doc/2003/wp29gre/TRANS-WP29-GRE-51-09e.pdf

Some studies have shown that flashing the amber hazard lights are a more effective emergency signal; Li at al. (2014)[6] found a 0.11s (10%) improvement in brake response time for flashing hazard lights compared with flashing red brake lights. Studies consistently find that the frequency is important and most effective at 4Hz[7], although a lower frequency (3 Hz or less) is less likely to trigger photosensitive epilepsy (PSE). However, limiting the duration of the flashing will also limit trigger of PSE, if photic simulation is limited to 2 sec or less PSE hardly occurs.

Technical feasibility:

Emergency braking display (EBD) systems are currently fitted as standard to some cars, e.g. some Mercedes vehicles are fitted with EBD which flash the stop lamps and some VW group vehicles are fitted with EBD which flash the amber hazard warning lamps. For best performance, EBD requires LED lights because this source provides a better fast response.

Legislation feasibility/readiness:

UN Regulation 48 contains specification for the lamps providing the optional emergency stop signal (EBD) to flash at 4Hz (+/- 1Hz) for LED and 4Hz (+0Hz/-1Hz) for incandescent sources when a passenger car decelerates at greater than 6 m/s2 or a truck or bus decelerates at greater than 4 m/s2.

Benefit is predicted to be significant; on the basis of data on German traffic accidents, EBD has been estimated to affect 25% of rear-end crashes in moving traffic and 15% in stationary traffic resulting in a 14% reduction in these crashes. These estimates were based on the assumption of an EBD penetration rate of 70% of the German passenger vehicle fleet (Gail et al., 2001)[8].

No information is available on costs, but they are likely to be low as it mainly concerns adaptation of the stop lamp activation software. Therefore, the benefit to cost ratio is likely to be equal or greater than 1.

For consideration for implementation in the GSR further work is required to:

- confirm benefit to cost ratio
- and decide if either system (flash stop lamps or flash hazard warning lamps) or just one (one study showed flash hazard warning lamps more effective) should be mandated.

3.1.3. Intelligent Speed Adaptation

Intelligent Speed Adaptation (ISA) describes a range of technologies which are designed to aid drivers in observing the appropriate speed for the road environment.

Speed is still the main factor linked to road accident deaths and severe injuries. Every day motorists are taking incredible chances by not adapting the driving speed to the traffic situation and road infrastructure.

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6 Li G, Wang W, Eben Li S, Cheng B and Green P (2014). Effectiveness of Flashing Brake and Hazard Systems in Avoiding Rear-End Crashes. Advances in Mechanical Engineering. Volume 2014, Article ID 792670

7 Study on the Validity of Emergency Brake light Display. Informal document No. 9. 51st GRE, 15-19 September 2003, agenda item 1.1.2.9. http://www.unece.org/fileadmin/DAM/trans/doc/2003/wp29gre/TRANS-WP29-GRE-51-09e.pdf

8 Gail J, Lorig M, Gelau C, Heuzeroth D and Sievert W (2001). Optimization of rear signal pattern for reduction of rear-end accidents during emergency braking manoeuvres. Technical Report, Federal Highway Research Institute, Bergisch Gladbach, Germany.

The link between excessive speed and increased severity/frequency of accidents has long been established (e.g. Finch et al., 1994[9]; Taylor et al., 2000[10]; Taylor et al. 2002[11]). These studies broadly conclude, across all road types, that a 1 km/h decrease in mean speed would reduce the number of road collisions by 3%. As well as the having an influence on the frequency of collisions, speed also affects injury severity since collision energy is proportional to the square of velocity, and in an accident this means that the subsequent injury risk also increases more rapidly at greater speed.

A potential solution for this problem is the introduction of mandatory intelligent speed adaptation (ISA) systems, consisting of a range of technologies which are designed to aid drivers in observing the appropriate speed for the road environment. These systems which warn the driver when the speed limit is exceeded, or prevent the driver from doing so, provide a very effective strategy for reducing accidents and injury severity. The three main forms of ISA are:

- Advisory - alert the driver to when their speed is too great;
- Voluntary - the driver chooses whether the system can restrict their vehicle speed and/or the speed it is restricted to; and
- Mandatory - the driver's speed selection is physically limited by the ISA system.

The magnitude of casualty savings depends on the type of system used and depends on the type of system used. Estimates vary between studies, however, many studies are in broad agreement with the estimates that purely advisory systems offer around 8.4% accident savings whereas mandatory systems offer up to 30% reduction[12]. However, we need to be weary of the possibility that when requiring very intrusive speed adaptation systems, this may lead to much less public support and poor user acceptance. For this reason, a pragmatic phased introduction of the measure should be reviewed.

In any case the system should always be easily overridden by the driver when necessary, e.g. when overtaking. We further suggest that it should be a system based on providing effective haptic feedback, for instance by gently pushing the pedal back to signal the vehicle is driving too fast and speed needs to be reduced. Also, consideration needs to be given to requirements for accurate recognition of speed limits.

- Current technology based on sign recognition
- Need to work on infrastructure requirements (i.e. integrated approach)
    - Initial technology based on best-effort recognition and map-data
    - Could consider to develop harmonised speed limit beacons (or other ITS solutions, t.b.d.)
- Make mandatory for all M and N vehicles
    - 01/09/2020 new types
    - 01/09/2022 for all new vehicles

Technological feasibility:

9 Finch DJP, Kompfner P, Lockwood CR and Maycock G (1994). Speed, speed limits and accidents. Crowthorne, TRL.

10 Taylor MC, Lynam DA and Baruya A (2000). The effects of drivers' speed on the frequency of road accidents. Crowthorne: Transport Research Laboratory.

11 Taylor MC, Baruya A and Kennedy JV (2002). The relationship between speed and accidents on rural single-carriageway roads. TRL Report TRL511. Crowthorne: Transport Research Laboratory

12 Wilkie SM and Tate FN (2003). ISA UK – Intelligent Speed Adaptation. Implications of travel patterns for ISA. University of Leeds and MIRA Ltd.

Many current vehicles are fitted with voluntary speed limiting systems which can be set by the driver to ensure compliance with a particular speed threshold. However, the speed limiter is set by the driver and is not linked to any digital map of speed limit information. ISA systems require an accurate knowledge of speed limits, either from a digital map with satellite navigation to locate the vehicle to the speed limit, or a series of local beacons (in traffic signs or other roadside furniture) and/or traffic sign recognition.

As the cost of technologies have decreased, GPS-based systems have emerged as the preferred solution, mostly due to their superior flexibility, the potential to integrate ISA into a package of wider "intelligent vehicle" technologies, and avoiding the need to set up a costly network of national beacons.

Legislation feasibility/readiness:

The Safety Assist protocol of Euro NCAP assesses and rewards ISA systems. This addresses functional aspects regarding the speed limitation and warning function but does not perform a performance assessment of, for example, the reliability of the speed limit detection.

The greatest benefits were predcited to be delivered for mandatory systems, save 20% of injury accidents and 37% of fatal accidents Carsten and Tate (2005)[11]. Systems which could respond to current network and weather conditions were predicted to deliver greater benefits, a reduction of 36% in injury accidents and 59% in fatal accidents. Other benefits also come from improved fuel economy. No benefit studies were found for fitment of ISA to large vehicles (N_2/N_3 and M_2/M_3), although a study on the effectiveness of Directive 2002/85/EC (the Speed Limitation Directive) found a positive impact on safety; accident reductions of 9% for fatal accidents on motorways with HCVs involved, 4% of serious injuries, and 3% of injury accidents were estimated (Transport and Mobility Leuven, 2013)[13].

A cost-benefit analysis of ISA was performed by Carsten and Tate (2005)[14] which produced ratios of 7.9 to 15.4 depending on the type of ISA system considered; mandatory ISA yield the greatest benefit to cost ratios. Other studies have also found benefit to cost ratios in excess of one and consistently show that the benefits substantially outweigh the costs of ISA implementation[15].

For consideration for implementation in the GSR further work is required to:

- confirm implementation strategy, including methods for recognition of appropriate speed limit.
- consider technology bunching, e.g. camera for sign recognition could also be used for 'Lane keeping assistance' and possibly AEB camera based systems as well, thus reducing costs.
- confirm benefit to cost ratio.

3.1.4. Lane Keep Assistance

Current Lane keep Assistance (LKA) systems help the driver to stay in their lane. They function at speeds typically from 65 km/h and work by monitoring the position of the vehicle with respect to the lane boundary, typically via a camera mounted behind the windscreen sited behind the rear view mirror. When the vehicle drifts out of the lane the LKA gently guides the

13 Transport and Mobility Leuven (2013). Ex-post evaluation of Directive 92/6/EEC on the installation and use of speed limitation devices for certain categories of motor vehicles in the Community, as amended by Directive 2002/85/EC. Transport & Mobility Leuven, Diestsesteenweg 57, 3010 Leuven – Belgium.

14 Carsten O and Tate F (2005). Intelligent speed adaptation: accident savings and cost–benefit analysis. Accident Analysis and Prevention 37 (2005) 407–416.

15 Carsten O (2005). PROSPER Results: Benefits and Costs. Presentation at the PROSPER Seminar on 23 November 2005 in Brussels

vehicle back into the lane by the application of a torque to the steering wheel or one-sided braking. LKA can take corrective action only if the lane marking is being approached very gradually: more rapid departures cannot be corrected. Future enhanced LKA systems have been developed which will be able to steer the vehicle around normal bends on highways, i.e. roads where the traffic in each direction is separated and users such as pedestrains and cyclists are not permitted. However, currently these systems are not permitted by Regulation 79, although work is ongoing in Geneva to change this.

In brief, current LKA systems can help avoid accidents in which a vehicle leaves the lane unintentionally, usually because of driver distraction or fatigue, that can result in head-on collisions with oncoming vehicles, involve impacts with roadside furniture or side-swipe of the vehicle that is travelling in the same direction in an adjacent lane.

Fitment of Lane Departure Warning Systems (LDWS) to M_2/M_3 and N_2/N_3 vehicles is mandatory from 2013 for new types and 2015 for new vehicles. LDWS warn the driver if the vehicle leaves its lane unintentionally, howver they do not guide the vehicle back into the lane.

- Make current Lane Keeping Assistance (LKA) mandatory for M_1 and N_1 vehicles (derived from M_1)
    - 01/09/2020 for new types
    - 01/09/2022 for all new vehicles
    - All N_1 vehicles 2-year offset to the above dates

Technological feasibility:

LKS are in production and offered by many of the major vehicle manufacturers, ususally offered as an optional extra typically packaged with other related systems, e.g. Lane Departure Warning (LDW), traffic sign recognition, driver alert and auto high beam.

Legislation feasibility/readiness:

ISO standard 17387 contains technical requirements that could potentially be used as a base for legislation.

Benefits of fitment of LKA for M_1/N_1 vehicles in the EU are estimated to be up to 3,500 fatalities and 17,000 serious injuries (Visvikis 2008)[16]. Benefit to cost ratios of 1.6 to 2.1 have been estimated by Cowi(2006)[17] and of 0.25 to 2.12 by Robinson et al. (2011)[18] for Lane Departure Warning Systems (LDWS) for M1/N1 vehicles. Because LKA systems are more effective than LDWS, cost benefit ratios are likely to be greater than one and closer to the higher ratios predicted by Robinson et al.

For consideration for implementation in the GSR further work is required to:

- consider technology bunching, e.g. camera could also be used for sign recognition in ISA systems and possibly AEB camera based systems as well, thus reducing costs.
- confirm benefit to cost ratio.

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16 Visvikis C, Smith TL, Pitcher M and Smith R (2008). Study on lane departure warning and lane change assistant systems: Final report. PPR374. TRL Limited, Crowthorne, UK.

17 COWI (2006). Cost-benefit assessment and prioritisation of vehicle safety technologies - Final report. Framework Contract TREN/A1/56-2004; Lot 2: Economic assistance activities. ECORYS, COWI, ECN, Ernst & Young Europe and Consultrans.

18 Robinson B, Hulshof W, Cookson R, Cuerden R, Hutchins R and Delmonte E (2011). Cost benefit evaluation of advanced primary safety systems: Final report. PPR586. TRL Limited, Crowthorne, UK.

3.1.5. *Driver Drowiness or Distraction Monitoring*

Distraction and drowsiness are both considered types of driver inattention for which the key shared feature is the absence of visual attention on the driving task, either due to fatigue or due to some activity that competes for a driver's visual attention. The current estimate for the impact of road user distraction on accidents in the EU is that it is a contributory factor in around 10-30% of road accidents[19]. Statistics relating to the proportion of road accidents attributable to driver fatigue vary between country and reporting body, but reports of it being a contributing factor in approximately 20% of accidents are common. Furthermore, there is even general agreement in the research community that any percentages based on crash data underestimate the true magnitude of the problem, since the evidence for distraction or fatigue involvement in crashes is often based on subjective criteria that exclude other factors rather than identifying definite involvement of fatigue or distraction.

Adding new technology to vehicles that can correct driver mistakes because of lack of observance will make cars a lot safer[20], but caution will be needed because a category of drivers may become dependent on these systems for reasons that are not linked to driving, for instance because of in-vehicle social media access with interactive screens.

A wide range of technologies may be used to identify distraction or drowsiness in drivers in order to minimise related accidents. Systems may employ physiological monitoring, physical monitoring or behavioural indices and patterns. The review of the General Safety Regulation should consider the introduction of technology neutral solutions that could help address this increasingly common threat to road safety .

- Technology neutral, testing protocol to be determined, but with several phases linked to the improving sophistication of the detection systems
- Make mandatory for all M and N vehicles
- Application dates recommended to be coupled with Automatic Emergency Braking and Lane Keeping Assist if possible.

Technological feasibility:

Systems to detect driver drowsiness and in some cases, driver distraction typically use camera-based systems directed at the driver for eye, face and head feature detection. The next most common type of system is based on vehicle control measures (typically the primary controls such as steering, braking and acceleration). Camera-based systems are more likely to be available as aftermarket options, whereas systems that utilise data on vehicle control inputs are more often found as original equipment on vehicles. There are also other systems that can detect driver inattention using physiological measures such as heart and brain wave feature detection. These systems are generally more invasive and thus are used more for research purposes.

Systems for monitoring driver drowsiness and distraction are available now as both aftermarket and original equipment in vehicles. There are a multitude of systems using cameras and vehicle control measures in both types of market. However, an effective system will likely need to consist of a combination of systems because of the limitations of individual systems, e.g. camera based systems that monitor percentage of eyelid closure (PERCLOS) are limited by factors such as ambient light and use of sunglasses or prescription lenses.

Legislation readiness:

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[19] EC, DGMOVE (2015). Study on good practices for reducing road safety risks caused by road user distractions. http://ec.europa.eu/transport/road_safety/pdf/behavior/distraction_study.pdf

[20] http://www.sersc.org/journals/IJAST/vol64/7.pdf

The wide range of systems available have adopted very different approaches to monitor driver drowiness and distraction. This makes standardisation of devices and protocols difficult to achieve. Further work required to determine how to define and test effectiveness of distraction/drowsiness monitoring systems and to define what action the system should take if inattention is detected.

The expected benefit of using systems to monitor for driver drowsiness and distraction is a reduction in the substantial number of collisions where these issues are a causal factor. In contrast, a possible dis-benefit is that drivers may regard the system as a 'safety net' that enables them to drive for longer when tired, and may discourage taking regular breaks or maintaining a healthy cycle of rest and wakefulness.

Costs for these systems vary substantially with a lower end of around €100 and upper end €10,000. Therefore benefit to cost ratio likely to be greater than one, because of substantial potential benefit and assuming system can be developed for reasonable cost.

For consideration for implementation in the GSR further work is required to:

- Develop a technology neutral assessment protocol with several phases to improve the effectiveness of the detection systems.
    - Possibly, Euro NCAP could help with this, by introduction of assessment of systems to detect drowiness and distraction within their rating.
- Confirm cost benefit analysis

3.1.6. Safety belt reminders

Since November 2014, safety belt reminders are mandatory on the driver seat of passenger cars through the General Safety Regulation. However, it is important to consider mandating safety belt reminders to also address the casualty problem associated with non-seat belt use on the other seats in passenger cars, as well as on the front seats of all trucks and buses.

Safety belt reminder systems detect the presence of occupants on front and rear seating positions and monitor their belt status. In order to encourage seat belt use, an audible and/ or visual warning is issued if occupants are not wearing a seat belt.

It is widely recognised that the safety belt is one of the most important and effective vehicle safety features and studies have shown that the risk of fatal injury can be reduced by 60% by using a seat belt[21]. Seat belts in the front of the vehicle are designed to, usually in conjunction with a frontal airbag, minimise injury by arresting the occupant before any hard structures are contacted. Those in the rear of the vehicle provide the same function but also prevent injurious interaction with the driver and front seat passenger.

Despite mandatory safety belt wearing legislation in the EU, the benefit provided by the safety belt has not been fully realised yet because a proportion of occupants do not wear their seat belt. For example, the seat belt wearing rate for front seat occupants in Italy and Croatia was only 64% and 65% respectively. For rear seat passengers, the seat belt wearing rate was significantly lower with just 10% and 30% respectively in these two Member States[22].

Research has further shown that even in countries with high seat belt usage rates, the potential benefit from improved wearing rates is significant because a large portion of those killed as car occupants were indeed unrestrained. Seat belt reminder systems therefore have the potential to further prevent fatalities or mitigate injuries by increasing the safety belt wearing rates across the EU.

[21] WHO (2004)

[22] WHO 2015. Global status report on road safety. http://www.who.int/violence_injury_prevention/road_safety_status/2015/en/

- Make mandatory for all front and rear seats of M_1 and N_1 vehicles
- Make mandatory for all front seats of N_2, N_3, M_2 and M_3 vehicles
    - 01/09/2020 for new types
    - 01/09/2022 for all new vehicles

It should be noted that Euro NCAP has rewarded SBRs on driver's seat since 2002 and all seat positions since 2009. This has been effective at encouraging SBRs to be fitted in advance of regulation: In 2013, the percentages of vehicles tested by Euro NCAP equipped with SBR were 100% on driver's seat, 95% on passenger's seat and 77% on rear seats. However, it must be remembered that Euro NCAP is voluntary, and changes in reward scheme may result in changes to the approach of vehicle manufacturers to future SBR fitment, hence the need for regulatory action.

Technological feasibility:

SBRs are mandatory for the driver's seat in passenger cars (M_1) and standard equipment for other seating positions in many passenger cars. No technological barriers for other vehicle types, but for passenger seats in buses and coaches (M_2, M_3) adaptations of the warning strategy would be needed.

Legislation feasibility/readiness:

Legislative text for the driver's seat of M_1 vehicles exists in UNECE Regulation No 16. The Euro NCAP test protocol sets out well established and generally accepted requirements for front and rear M_1 seating positions.

Benefit to cost ratios greater than one have been estimated for fitment of SBR to M_1 front seat passengers and all M_2/M_3 and N_2/N_3 vehicle seating positions[23]. However, for M_1 rear seated passengers benefit to cost ratio was estimated to be slightly less than one assuming a cost of €4 per rear seat.

For consideration for implementation in the GSR further work is required to:

- Confirm cost benefit analysis
- Consider legislation for M1 second and other rear row seats on the basis of safety equality.

3.1.7. Frontal Crashes

Frontal impact crash protection is currently successfully legislated through the General Safety Regulation. It is however generally agreed that one of the next major steps to improve frontal impact legislation and help worldwide harmonisation is to introduce an integrated set of test procedures containing both a full width and an offset test[24]. A full width test is required to provide a high deceleration pulse to control the occupant's deceleration and check that the car's restraint system provides sufficient protection ('softness') at high deceleration levels. An offset test is required to load one side of the car to check compartment integrity.

An important step under consideration for the medium to longer term includes an significant improvement of protection for the full range of occupants, in particular for vulnerable older

[23] McCarthy M and Seidl (2014). Benefit assessment for fitment of Seat Belt Reminder (SBR) systems to M1 passenger seat positions and to other vehicle types. CPR1818 Available from EU bookshop http://bookshop.europa.eu/en/benefit-assessment-for-fitment-of-seat-belt-reminder-sbr-systems-to-m1-passenger-seat-positions-and-to-other-vehicle-types-pbNB0214430/

[24] EEVC (2007). EEVC Approach to Develop Test Procedure(s) for the Improvement of Crash Compatibility Between Passenger Cars. 20th ESV conference, paper no. 07-0331. http://www-nrd.nhtsa.dot.gov/departments/esv/20th

occupants, small female occupants, children and rear seated occupants in general. This could be addressed by using a full width crash test in combination with the new generation THOR crash dummies. Two further steps would be to address occupant protection in case of small overlap collisions, as well as that of partner protection when two vehicles collide head-on, also known as crash compatibility[25].

The Commission is currently finalising a study on the assessment of intended and unintended consequences of vehicle adaptations to meet advanced frontal crash test provisions, in order to provide for a clear way forward in terms of a comprehensive set of regulatory measures addressing the outlined issues.

- Currently off-set impact UNECE R94 is performed for only M_1 < 2,500kg maximum mass
- Expand scope to include all M_1 and N_1
    - 01/09/2022 new types
    - 01/09/2024 all new vehicles
- Addition of full-width crash test UNECE R137 for M_1 and N_1
    - 01/09/2020 new types
    - 01/09/2022 all new vehicles
- Addition of small-overlap crash test for M_1
    - 01/09/2022 new types
    - 01/09/2024 all new vehicles

Technological feasibility:

Expand scope of Reg 94

Euro NCAP have assessed the frontal crash performance of a selection of vans (usually the passenger carrying versions) and pickups using a 64 km/h ODB test. Note that the Reg 94 test has a speed of 56 km/h. The good performance observed in these tests clearly show that both heavy M_1 as well as these N_1 vehicles have the possibility to meet the requirements of Reg 94.

The expansion of the scope is particularly important to further assess the vehicle's fuel system integrity, protection against electrical shock (in case of electric vehicles) and door latch resistance, as these are also assessed as part of the test.

Addition of Reg 137 full width test

Regulation 137 test speed is 50 km/h which is lower than the 56 km/h for US FMVSS 208. The basic set up consists of a 50th percentile Hybrid III male in the driver's seat and a 5th percentile Hybrid III female in the front passenger position. Both dummies must meet a Thorax Compression Criterion (ThCC) of 42 mm, compared with the current US chest compression of 62 mm for the 50th Hybrid III and 52 mm for the 5th Hybrid III albeit at the higher speed. By 2020, the companion 01 series of amendments would increase the ThCC stringency to 34 mm for the 5th female ATD. The fact that WP.29 have adopted Regulation 137 illustrates that it is technically feasible to meet its requirements.

Addition of small overlap test

The technical feasibility of protection against longitudinal small-overlap collisions is clearly demonstrated by the response of car manufacturers to the new IIHS small overlap test procedure.

Legislation feasibility/readiness:

[25] EEVC (2007)

Expand scope of Reg 94

IIHS in the US have used the Regulation 94 test (albeit at a higher test speed of 64 km/h) to assess vehicles with a gross vehicle mass in excess of 2,500 kg, thus demonstrating that the test is suitable for assessment of vehicles with a higher mass.

Despite the fact that they are involved in similar types of accidents, in the past EEVC recommended that the scope of Regulation 94 should not be expanded to include heavier vehicles (> 2,500 kg & < 3,500 kg) because this may increase their stiffness and hence encourage them to become more aggressive[26]. However, the introduction of a full width test should counteract this because if the vehicle is made too stiff then it will be unable to meet the requirements of Regulation 137.

For consideration for implementation in the GSR further work is required to:

- Perform cost benefit analysis

Addition of Regulation 137 full width test

The Regulation 137 full width test is suitable for regulatory application. However, an EC study that is currently being finalised indicates that the benefits that it may deliver may not be significant because most current vehicles woud meet the requirements without modification. To deliver benefit the following changes are recommended:

- Introduction of the THOR dummy (which is more biofidelic for thorax injuries) into the test, note that currently Hybrid III dummies are specified.
- Changes to enforce the introduction of adaptive restraint systems, in particular to improve protection of older persons (against thorax injuries) in lower speed impacts. With regard to restraint system adaptations (seat belt and airbags), a variety of solutions exist already for the detection of and tuning for occupants of different sizes. However, fully adaptive restraint systems remain near-to-market and further research is needed to determine how adaptable these systems can be made to accident severity and how reliable information can be obtained about the severity of the accident about to occur. One potential route is to use information from pre-crash / accident avoidance systems.

For consideration for implementation in the GSR further work is required to:

- Complete development of proposals to improve effectivenesss of Regulation 137 as noted above.
- Perform cost benefit analysis

Note that to counteract the possible disbenefit of expanding the scope of Regulation 94, the introdcution of a full width test, i.e. Regulation 137, is recommended.

Addition of small overlap test

The small overlap test used by the IIHS in the USA since 2012 would be suitable for regulatory application. No benefit estimates found for US or Europe. However, benefits could be significant because although target population is not that large, effectiveness may be high because countermeasures likely to reduce high cost head (improved airbag coverage to mitigate effect of head impact in A pillar region) and lower extremity injuries (improved

[26] EEVC (2000). EEVC report to European Commission, 'A review of the front and side Directives'. http://www.eevc.net/?site=52
Edwards et al. (2001). Review of the European frontal and side impact Directives. 17th ESV, http://www-nrd.nhtsa.dot.gov/pdf/esv/esv17/Proceed/00214.pdf

passenger compartment integrity). Therefore benefit to cost ratio could likely be greater than one.

For consideration for implementation in the GSR further work is required to:

- Perform cost benefit analysis

3.1.8. Side Crashes

Side impact still remains an issue on EU roads. Between 29 and 38% of all car crash fatalities are in side collisions where 60% are seated at the struck side and 40% at the non-stuck side [27]. In particular, the ratio of fatalities on the non-struck side is very significant and could be influenced by occupant-to-occupant interaction. It should be noted however that more research regarding these vehicle occupant deaths is needed before any introduction of targeting measures could be considered.

To reduce the number of casualties in side impacts, EEVC (WG13 and 21) performed cost benefit analysis for a number of options[28]. One option was to introduce an updated mobile deformable barrier, representing a larger and heavier car impacting into the side of the struck vehicle. Another was to introduce a pole side impact test. Also the combination of these was considered, however, it was concluded that the combination of these measures would cause a combination of costs without yielding any significant benefit over the improvement as achieved by only the mandatory introduction of the pole side impact test. Therefore, this stand-alone option should be considered for the review of the General Safety Regulation at this stage with consideration of measures to protect non-struck side occupants in the longer term.

There is currently an exemption for vehicles with high seating positions (e.g. SUVs) because little dummy injury recorded because the barrier impacts low down below the height of the seated dummy and thus the test is not worthwhile from the point of view of occupant injury. However, fuel system integrity, protection against electrical shock and door opening are also assessed as part of the test. To assess these factors it is proposed that the exemption is removed. Note that the test for currently exempted vehicles could be performed without dummies to reduce cost.

- Currently only side impact UNECE R95 is performed which consists of a mobile barrier test which represents being impacted by another vehicle
- Expand scope to include all M_1 and N_1, i.e. remove current exemption.
  - 01/09/2020 new types
  - 01/09/2022 all new vehicles
- Addition of pole impact crash test UNECE R135.
  - 01/09/2020 new types
  - 01/09/2022 all new vehicles
- Addition of far-side occupant protection
  - Test protocol needs to be established
    - 01/09/2022 new types
    - 01/09/2024 all new vehicles

Technological feasibility:

<u>Addition of Pole impact test (Regulation 135)</u>

[27] EEVC (2010): WG13: A Review and Evaluation of Options for Enhanced Side Impact Protection.

[28] EEVC (2010): WG13 & WG21: Analysis to estimate likely benefits and costs for the EU of modifying Regulation 95.

Vehicles perform well in the current Euro NCAP pole test, which is similar to the Regulation 135 one, which demonstrates clearly that current vehicles can meet the proposed test requirements.

Addition of far-side occupant protection

There now seems to be a sufficient technology base so that far-side protection can be evaluated and rated by side impact testing. A front centre side airbag has recently been introduced in three top range crossover SUVs.

Legislation feasibility/readiness:

Addition of Pole impact test

The Regulation 135 pole impact test is suitable for regulatory application. An EEVC study[29]. indicated that the benefit to cost ratio of implementing a pole test may be less than one. However, it should be noted that the costs estimated in this study were thought to be too high by some stakeholders and this study did not consider potential extra benefits related to the mitigation of ejection (partial) in rollover accidents that curtain aitrbags with adequate coverage could offer. For this reason it is proposed that an additional requirement for an assessment of the window curtain airbag coverage is added to the Regulation 135 for implementation in the EU. This requirement could be based on the Euro NCAP one, which assesses the inflated airbag position with respect to a zone defined by the seating and head positions of 5th percentile female and 95th percentile male dummies.Note that an exemption could be given for vehicles for which fitment of a curtain bag is not practical, e.g. convertibles.

For consideration for implementation in the GSR further work is required to:

- Develop airbag coverage requirement and associated exemptions needed.
- Repeat cost benefit analysis with consideration of ejection mitigation benefits.

Addition of far-side occupant protection

There are currently no requirements to fit far-side impact protection systems in vehicles, and consumer rating programmes such as Euro NCAP do not have a test that covers this scenario.

From a review of the literature its was estimated that in Europe by fitment of far-side occupant protection it could be possible that up to 670 fatalities and up to 4,600 seriously injured casualties may be prevented annually, with a monetary value of €1.2 to €1.9 billion. Component cost with installation was estimated to be about $200, so the annual cost to equip each new car each year was calcualted to be about €1.8 billion. This gives a beenfit to cost ratio in the range of 0.6 to 1.1, but likely to be greater than one because cost estiamte thought to be high.

For consideration for implementation in the GSR further work is required to:

- Develop assessment protocol. (Note that Euro NCAP plan to introduce assessment of far-side occupant protection, so will need to develop protocol to enable this).
- Perform cost benefit analysis.

3.1.9. Rear Crashes

A rear-end collision is defined as a crash in which the front of one vehicle collides with the rear of another vehicle and it has been reported that 19% of all passenger cars involved in an

[29] EEVC (2010): WG13 & WG21: Analysis to estimate likely benefits and costs for the EU of modifying Regulation 95.

accident have at least one rear impact[30]. One of the most detailed sources of fatality rates from vehicle fire data was collected by the Swedish Transport Administration between 1998 and 2008. In-depth data was recorded from fatal crashes involving passenger cars, SUVs, vans and minibuses. Viklund et al. (2013)[31] summarised the findings of the study relevant to vehicle fires. In total, 181 fire related deaths caused by 133 separate road crashes were recorded nationally, which accounted for 5% of all road fatalities that occurred during this period. Fire and smoke were ruled as the primary cause of death in 55 cases. The source of the fire was not identified for 61 of the 133 cases. However, of the remaining 72 cases, 16 fires were found to originate from the fuel tank. Two fuel tank fires were found to be caused by rear end impacts.

Rear impact testing is not mandatory in the EU, but it has been regulated in the USA and Japan for many years, notably linked to fire-related deaths. Therfore it may be expected that many vehicles on the EU roads currently already comply with one or both countries' standards. Modifying the EU legislation to include a compulsory rear impact test would aid the process of harmonising vehicle regulations. For this purpose, it is recommended that the rear impact test in UNECE R34 is made mandatory for the EU (with an exemptions to reduce cost). Also R34 should be updated to include post crash electrical safety as in Regulations 94 and 95 for the rear impact test.

A mandatory rear impact test could be deemed much less relevant if the fuel tank is not located near the rear of the vehicle, notably behind the rear axle. We should however also not forget that post-crash electric safety should also be assessed as a part of the rear impact test when high voltage parts of electrically propelled vehicles are located at their rear. These conditions should therefore be incorporated in the existing regulation that can then be introduced on a mandatory basis as part of the review of the General Safety Regulation.

- Currently no rear impact test is required to be performed to comply within the EU legislation
- Modify UNECE R34 (revision 3) to add assessment of post crash electrical safety for rear impact test as in Regulations 94 and 95.
- Make rear impact crash test in UNECE R34 mandatory, i.e. accede to R34 revision 3.
    - Make mandatory for M_1 and N_1 vehicles
    - Add exemption for vehicles which do not have fuel storage, fuel supply lines and/or high voltage components located near rear axle.
        - 01/09/2020 new types
        - 01/09/2022 all new vehicles

Technological feasibility:

There are no principal concerns regarding techncial feasiblity. Vehicles sold in the USA currently have to comply with the FMVSS 301 rear-impact test. Japan also requires a rear impact test and has recently acceded to UNECE Regulation No 34. It is not known how many manufacturers volunteer to carry out the optional UNECE Regulation No 34 assessment on their vehicles.

Legislation feasibility/readiness:

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30 Eis V, Sferco R, Fay P (2005). A Detailed Analysis of the Characteristics of European Rear Impacts. 19th ESV

31 Viklund A, Björnstig J, Larsson M and Björnstig U (2013). Car Crash Fatalities Associated With Fire in Sweden. Traffic Injury Prevention (2013), 14, 823–827.

UNECE Regulation 34 revision 3 contains a mandatory rear impact test. However, it does not include assessment of post crash electrical safety which needs to be added so that consistent with Regulations 94 and 95.

More detailed analysis is needed to quantify benefits and costs to enable cost benefit analysis to be performed. However, it hsould be noted that at present theer is only mandatory testing for fuel tanks at a component level, so it is likely that the realtively good performance in the field is due to manufacturer good practice. Ideally, this critical safety issue should be formalised in a more appropriate manner.

For consideration for implementation in the GSR further work is required to:

- Add assessment of post crash electrical safety for rear impact test in Regulation 34 as in Regulations 94 and 95.
- Develop exemption for vehicles which do not have fuel storage, fuel supply lines and/or high voltage components located near rear axle.
- Identify further cost and benefit information and perform cost benefit analysis

3.1.10. Alcohol Interlock Devices

Alcohol interlock devices require a vehicle operator to provide a breath sample or use a finger touch sensor and prevent the vehicle ignition from operating if alcohol above a pre-defined threshold is detected. Application of alcohol interlock devices is intended to reduce collision risk by restricting the opportunity for drivers to operate vehicles when under the influence of alcohol.

Despite lower alcohol limits, increased enforcement and awareness campaigns, drink-driving is still a major safety problem. Drink-driving accounts for 20-28% of all road accidents, deaths and injuries on European roads. The vast majority of the accidents in which drink-driving is involved, namely 75%, is caused by a small group of offenders thought to be around 1% of the driving population[32]. For this reason, it is difficult to justify mandatory installation of these devices from a cost-effectiveness standpoint.

However, the European Committee for Electrotechnical Standardisation CENELEC has been working on the development of a standardisation scheme as regards the connection interface for motor-vehicles. This initiative concerns a mandatory and standard format of highly detailed electrical connection information to be provided in standardised format by the vehicle manufacturers to authorised installers, as part of vehicle type-approval provisions, and it has received broad support by stakeholders. The relevant CENELEC standard is expected to become available in the short term and this will greatly help to facilitate easier fitment of alcohol interlocks to future vehicles. It has been devloped in cooperation with the Commission, device manufacturers and vehicle manufacturers, so it is tailor-made for incorporation into EU legislation. Clearly, the focus of the review of the General Safety Regulation should be on this aspect.

- Make provisions of CEN Standard 504536-7 (device interface) mandatory for all M and N vehicles
    - 01/09/2020 new types
    - 01/09/2022 all new vehicles.

Technological feasibility:

[32] http://ec.europa.eu/transport/road_safety/pdf/behavior/study_alcohol_interlock.pdf

Alcohol interlocks exist on the market and can be retrofitted to vehicles, for example those of drunk-driving offenders. Breath-based interlocks have been in use since the 1970s; transdermal (touch-based) solutions were developed recently.

Legislation feasibility/readiness:

The CENELEC standard 50436 (expected to become available in the short term) can provide the basis to ensure compatibility between interlock and vehicle ignition system to avoid vehicle designs that do not allow installation of alcohol interlocks.

Ecorys (2014)[33] estimated the casualty reduction figures for alcohol interlocks deployed across four groups based on 2010 fatality statistics and estimated benefit-cost ratios. The ratios estimated were greater than one for the offender (1.0 -2.8) and goods vehicle (1.4) groups. However they were less than one for the buses and coaches (0.3) and all passenger car groups (0.8 – 1.3).

For consideration for implementation in the GSR further work is required to:

- Perform cost benefit analysis for mandatory implementation of CENELEC standard 50436.

3.1.11. Crash Event Data Recorder

Event data recorders record a range of vehicle data over a short timeframe before, during and after a triggering, usually by the deployment of an airbag, caused by a vehicle crash. It contains critical crash related information such as vehicle speed, state of restraints and braking system as well as other relevant vehicle data at the time of the accident.

In a recent study[34], it was concluded that event data recorders appeared to largely fitted to passenger cars and vans already, so additional costs resulting from legislative action were deemed negligible. There was evidence found on the effect of device fitment on driving behaviour for commercial fleets. If similar effects would apply to private fleets, or if the effect on safety would be greater than predicted by the estimates for commercial fleets, this would have very large benefits associated with monetised casualty savings. Some other important potential benefits could not be monetised, namely improved accident data leading to enhancements in safety and benefits relating to access to justice. However, it was however that these could represent very significant benefits as well.

As cost-effectiveness appear to be supported, in addition to the benefits that significantly aid future road safety analysis in general, the review of the General Safety Regulation should strongly consider the introduction of this mandatory feature.

- Technology widely available
    - Consider harmonisation with US Part 563 prescriptions
- Cost-effective measure for accident investigation and road safety research
- Make mandatory for M_1 and N_1 vehicles
    - 01/09/2020 new types
    - 01/09/2022 all new vehicles

Technological feasibility:

EDR technology is already fitted to most passenger cars and car-derived vans in the USA and Europe, which clearly demonstrates technical feasibility. However, in Europe, access to the

33 Ecorys (2014). Study on the prevention of drink-driving by the use of alcohol interlock devices. http://ec.europa.eu/transport/road_safety/pdf/behavior/study_alcohol_interlock.pdf

34 http://ec.europa.eu/transport/road_safety/pdf/vehicles/study_edr_2014.pdf

data is deliberately blocked in many cases. For heavy vehicles, the fitment of EDRs appears feasible, but is not yet widespread because the airbag and accident detection system fitment rate is low.

Legislation feasibility/readiness:

For light vehicles, compliance with EDR standards has recently become mandatory in the USA, if EDR is indeed fitted, where CFR 49 Part 563 defines minimum performance requirements and structure of and access to the data. These minimum requirements on data could be duplicated in Europe or manufacturers could be required to make available the method of access so that any provider could make a vehicle or brand specific suitable tool (i.e. open access).

Real benefits identified, although difficult to monetise. A recent study for EC DG MOVE estimated benefit to cost ratio for fitment of EDR

- M_1 vehicles 0 to 5.7, central estimate 0.1
- N_1 vehicles 0 to 6.6, central estimate 1.0
- M_2/M_3 vehicles 0 to 4, central estimate 2
- N_2/N_3 vehicles 0 to 4.6, central estimate 2.3

However, most new M_1 and N_1 European vehicles have EDR functionality although it is currently not accessible in most, so most of the cost has already been spent. Therefore, benefit to cost ratio for the M1/N1 category of vehicles should be greater than one if approach is taken to legislate minimum performance requirements and structure of and access to the data as the US CFR 49 Part 563 or require manufacturers to make available the method of access to the EDR installed so that any provider could make a suitable tool to access it (i.e. open access).

For consideration for implementation in the GSR further work is required to:

- Perform cost benefit analysis

3.1.12. Tyre Pressure Monitoring

Severe tyre under-inflation contributes to accident causation. A pressure deviation of more than 15% generally results in noticeable change of tyre properties which affects the wear rate of the tyre and the braking and handling performance of the vehicle. The increased heat generation due to tyre under-inflation reduces the maximum lateral tyre force, creating a further safety risk. Proper tyre pressure also reduces rolling resistance and thus saves fuel and reduces CO_2 emissions. Tyre pressure monitoring has therefore been mandatory for all new passenger cars sold since 2014. A recent study on tyre safety in general[35] supported an update of the relevant provisions of the existing regulation that is currently part of the General Safety Regulation, in order to avoid regulatory loopholes and to improve its effectiveness in terms of vehicle safety.

Light and heavy commercial vehicles as well as buses are currently not subject to tyre pressure monitoring requirements even though such systems could potentially contribute to improved vehicle safety and reduce fuel consumption and CO_2 emissions as well. The review of current products and their suppliers concluded that tyre pressure monitoring for application in vans, trucks and buses is technically and economically mature at this stage[36]. Based on various studies, speed related accidents are found to account for almost 20% of heavy duty vehicle accidents. In accidents that involve deaths or severe injuries of truck occupants this

[35] http://ec.europa.eu/transport/road_safety/pdf/vehicles/study_tyres_2014.pdf
[36] http://ec.europa.eu/clima/policies/transport/vehicles/heavy/docs/tno_2013_final_report_en.pdf

share is in the range of 7.5 to 10%. A reduction in the number of speed and tyre related accidents due to proper tyre pressure conditioning should be expected and it is estimated that properly maintaining the tyre inflation pressure can reduce the number of speed and tyre related accidents by 4% to 20%, and thus the total number of accidents by 0.8% up to 4%, which is still significant. Adding mandatory tyre pressure monitoring on vans, trucks, buses and heavy trailers should therefore be considered to further improve road safety.

- Make TPM mandatory for all M and N vehicles and O_3 and O_4 trailers
  - 01/09/2020 new types
  - 01/09/2022 all new vehicles

Technological feasibility:

Tyre Pressure Monitoring Systems (TPMS) report real-time tyre-pressure information to the driver of the vehicle, either via a gauge, a pictogram display, or a simple low-pressure warning light. TPMS can be divided into two different types — direct (dTPMS) and indirect (iTPMS). TPMS are provided both at an OEM (factory) level as well as an aftermarket solution.Indirect TPMS do not use physical pressure sensors but estimate air pressures by monitoring individual wheel rotational speeds and other signals available outside of the tyre itself. First generation iTPMS systems utilize the effect that an under-inflated tyre has a slightly smaller diameter (and hence higher angular velocity) than a correctly inflated one. Second generation iTPMS can also detect simultaneous under-inflation in up to all four tyres using spectrum analysis of rotation speeds of individual wheels. The spectrum analysis is based on the principle that certain eigenforms and frequencies of the tyre/wheel assembly are highly sensitive to the inflation pressure. These oscillations can hence be monitored through advanced signal processing of the wheel speed signals. Current iTPMS consist of software modules being integrated into the ABS/ESC units. Direct TPMS employ pressure sensors on each tyre, either internal or external. The sensors physically measure the tyre pressure in each tyre and report it to the vehicle's instrument cluster or a corresponding monitor. Some units measure and alert temperatures of the tyre as well. These systems can identify under-inflation in any combination, be it one tyre or all, simultaneously. Although the systems vary in transmitting options, many dTPMS products (both OEM and aftermarket solutions) can display real time tyre pressures at each location monitored whether the vehicle is moving or parked.

A study for EC DG Clima which reviewed current products and their suppliers concluded that tyre pressure monitoring for application in vans, trucks and buses is technically and economically mature at this stage[37].

Ideally TPMS:

- Should be capable of detecting over a wide range of road and environmental conditions
- Should not be possible to deactivate
- For M_1/N_1 should detect a pressure of less than 1.5 bar or detect incorrect set/reset attempt
- Should cover any tyre of approved size, including after-market (different brand) replacement tyres
  - On this basis UNECE Regulation 64, Annex 5, clause 1.4.6 "…vehicle shall be tested with the tyres installed on the vehicle according to the vehicle manufacturer's recommendation…" should be deleted.

37 http://ec.europa.eu/clima/policies/transport/vehicles/heavy/docs/tno_2013_final_report_en.pdf

Legislation feasibility/readiness:

UNECE Regulation 64 contains the relevant prescriptions that can serve as a basis for the inclusion of other vehicle categories, provided that shortcomings in the regulatory text, noted above, are addressed.

The benefits for fitment of TPMS to for light commercial and heavy duty vehicles can be divided into two parts;

- Reduction in number of accidents
- Reduction in fuel consumption and CO_2 emissions

The study for EC DG Clima[32] investigated benefits and costs for for mandatory fitment of TPMS for light commercial and heavy duty vehicles in the EU. It was estimated that properly maintaining the tyre inflation pressure can reduce the number of speed and tyre related accidents by 4% to 20%, and thus the total number of accidents by 0.8% up to 4%, which is still significant. This equates to a societal cost reduction of 11 to 58 M€ per year.

It was also estimated that for OEM fitted TPMS (which mandatory fitment would deliver) and even with a 50% response to tyre pressure warnings TPMS would be cost effective with a payback time of generally 3.5 years or less and associated benefit of CO_2 reductions, with negative abatement costs. For these estimations an oil price of $100 a barrel was assumed. The largest benefit to cost ratios were for the long haul truck and trailer, regional trucks and service / delivery vans. For these vehicle categories TPMS was cost effective for all scenarios considered which included an assumption of 50% lower fuel savings and using current costs for TPMS. The smallest benefit to cost ratio was for municipal buses.

For consideration for implementation in the GSR further work is required to:

- Confirm cost benefit analysis

3.2. TRUCKS AND BUSES

3.2.1. Front-end Design and Direct Vision

For reasons related to efficient use of available space, mainly due to limitation of truck and trailer dimensions when driving within the EU, truck drivers are seated high on top of the engine since many decades. This high seating position is highly detrimental for the direct vision capability of the driver, especially concerning what happens in the vicinity of the truck's front end. Whilst representing only 3% of vehicles on EU roads, trucks have been involved in a disproportionate number of collisions, namely over 15%, killing more than 4000 people in 2009[38]. As regards other vulnerable road users, trucks are also disproportionately involved in fatal collisions with pedestrians and cyclists[39].

For the abovementioned reasons, and taking into account that the current 'brick' shaped cabins have the least aerodynamic shape, the Commission proposed to grant derogations to the maximum Weights and Dimensions as laid down in Directive 96/53/EC[40]. The Commission proposal, which was adopted by the European Parliament and the Council on 6 May 2015 under Directive (EU) 2015/719[41], provides the possibility, subject to certain conditions, to extend the length of cabs and thus to provide manufacturers with more space to design safer and cleaner trucks.

38 http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013SC0108&from=EN
39 https://consultations.tfl.gov.uk/roads/safer-lorries
40 OJ L 235, 17.9.1996, p. 59
41 OJ L 115, 6.5.2015, p. 1

It has been suggested that either better mirrors and detection systems or simply the addition of side windows in the lower portion of truck cab doors could be required to improve the situation, but the effectiveness of such short-term measures may not be sufficient. It has however been suggested that a comprehensive improvement of direct vision of truck drivers has the potential to greatly contribute to much improved safety for vulnerable pedestrians and bicyclists[42]. This hypothesis is supported through knowledge about the current strict passenger car forward and side vision requirements that virtually eliminate any of such issues related to the non-visibility of pedestrians and bicyclists. Hence, it would be logical to aim for similar comprehensive direct vision requirements for all motor-vehicle categories, with due lead-time for introduction.

Modified truck cabs can furthermore be made much more aerodynamic[43] than conventional cabs are today and this translates into great benefits in terms of fuel consumption and CO_2. Directive (EU) 2015/719 provides the possibility to extend cabs provided that conditions related to improved aerodynalics and visibility, reduced damage or injury to other road users in cases of collisions as well as safety and comfort for drivers are taken into account[44].

For reasons related to efficient use of available space, mainly due to limitation of truck and trailer dimensions when driving within the EU, for many decades trucks have been designed such that the drivers are seated high on top of the engine. This high seating position is highly detrimental for the direct vision capability of the driver, especially concerning what happens in the vicinity of the truck's front end. Whilst representing only 3% of vehicles on EU roads, trucks have been involved in a disproportionate number of collisions, namely over 15%, killing more than 4,000 people in 2009[45]. As regards other vulnerable road users, trucks are also disproportionately involved in fatal collisions with pedestrians and cyclists[46].

It has been suggested that either better mirrors and detection systems or simply the addition of side windows in the lower portion of truck cab doors could be required to improve the situation, but the effectiveness of such short-term measures may not be sufficient. It has however been clearly suggested that a comprehensive improvement of direct vision of truck drivers has the potential to greatly contribute to much improved safety for vulnerable pedestrians and bicyclists[47]. This hypothesis is supported though our knowledge about the current strict passenger car forward and side vision requirements that virtually eliminate any of such issues related to the non-visibility of pedestrians and bicyclists. Hence, it would be logical to aim for similar comprehensive direct vision requirements for all motor-vehicle categories, especially if this can be supported from a cost-effectiveness standpoint underpinning this aspect of the General Safety Regulation review process.

- Focus on direct vision requirements to reduce blind spots to improve safety for VRUs such as pedestrians and cyclists
    - Facilitate through Masses and Dimensions Directive (EU) 2015/719
    - Once improved safety requirements for longer cabs have been developed, consideration can be given to whether it is appropriate to apply them to vehicles which do not benefit from the length extension as mentioned in Directive (EU) 2015/719.
- In the short term deploy camera or detection systems to reduce blind spots

[42] http://etsc.eu/weights-and-dimensions-of-heavy-goods-vehicles-maximising-safety/
[43] http://www.transportenvironment.org/sites/te/files/media/2012%2002%20FKA%20Smart%20Cab%20study_web.pdf
[44] Article 9 of Directive (EU) 2015/719
[45] http://eur-lex.europa.eu/legal-content/EN/TXT/PDF/?uri=CELEX:52013SC0108&from=EN
[46] http://etsc.eu/weights-and-dimensions-of-heavy-goods-vehicles-maximising-safety/
[47] http://etsc.eu/weights-and-dimensions-of-heavy-goods-vehicles-maximising-safety/

- For this action the link to Directive (EU) 2015/719 should be further investigated
  - This action is envisaged as a complimentary measure only to improved direct vision action above in the long-term
- Make mandatory for M_2, M_3, N_2 and N_3 vehicles
  - 01/09/2020 new types – Camera and Detection (no length advantage)
  - 01/09/2022 all new vehicles – Camera and Detection (no length advantage)
  - 01/09/2028 new types – Direct Vision (length advantage, encouraging vehicle manufacturers to bring to market earlier)
  - No new vehicles date foreseen due to impact on overall truck cab designs

Technological feasibility:

The suggested improvements are technically feasible but would need to be developed and implemented by the vehicle manufacturers in the course of a cab re-design because they constitute major design changes. However, much progress has been made. Some designs with much improved direct vision are already in production such as the Mercedes-Benz Econic. This low-entry vehicle has a particularly large windscreen area and improved glazed areas to the side. Unfortunately, the design leads to certain limitations (engine size is limited because of packaging problems; no hydraulic cab support), which limits its use to regional services and doesn't allow use in long-haul traffic.

Legislation feasibility/readiness:

A mandatory direct vision standard for HGVs could potentially be developed with limited effort and could deliver high benefits. Previous research to inform the legislative process is available.

There is broad agreement among experts that improved direct vision would be effective in preventing casualties. It is predicted that improved direct vision could reduce the number of VRU fatalities by up to 553 per year in the EU[2].

For consideration for implementation in the GSR further work is required to:

- Develop direct vision standard for HGVs
- Perform cost benefit analysis

3.2.2. Truck Rear Underrun Protection

Accident data and crash tests have shown that rear under-run protection devices as currently required by legislation appear to be inadequate for collisions of modern passenger cars into the rear end of a truck or trailer, in particular at speeds exceeding 50 km/h[48]. For better performance, improvements in the strength of these devices and better vertical geometric alignment with the main structures of M_1 vehicles are needed. The relevant legislation is currently undergoing a parallel update that is supported by this review process of the General Safety Regulation.

- Work under UNECE is well advanced
- 03 Series of amendments to UNECE R58 proposed
  - 01/09/2020 new types
  - 01/09/2022 all new vehicles

Technological feasibility:

48 http://ec.europa.eu/transport/road_safety/pdf/projects/vc-compat.pdf

Technically, it is feasible to increase the strength of a rear-underrun protection device and decrease its ground clearance. However, practically this involves issues such as the effect of lowering the ground clearance on departure angles and the influence of this on the vehicle's operability (related to cost-benefit rather than feasibility).

Legislation feasibility/readiness:

A proposal to amend UNECE Regulation No 58 (Rev 3) is being considered in Geneva (changing test loads and ground clearance) currently. Introduction of an additional load condition of 100 kN applied simultaneously to three points, as suggested by Smith et al. (2008)[49], might be necessary to ensure adequate strength of device.

For fitment of a device with adequate strength, Smith et al. (2008) estimated a benefit for the EU of between 43 and 93 fatalities and 694 and 2,063 serious injuries prevented per year. This equated to a beenfit to cost ratio of 0.6 to 14.8 using best cost estimates.

For consideration for implementation in the GSR further work is required to:

- Check load conditions proposed for Regulation 58 rev 3 are adequate.
- Confirm cost benefit analysis.

3.2.3. Truck Lateral Protection

Heavy goods vehicles and their trailers are presently required to be fitted with structures to reduce the open space ahead of the rear axle(s) to provide protection to pedestrians and cyclists in collision with the side of such vehicles, reducing the likelihood of them being run over. However, the current legislative text allows for broad exemptions to fitting these structures, therefore action has now been taken on the relevant UNECE level to improve this situation, that is supported by this review process of the General Safety Regulation.

- Work under UNECE is ongoing
- 02 Series of amendments to UNECE R73
  - 01/09/2020 new types
  - 01/09/2022 all new vehicles

Technological feasibility:

The exemptions are primarily based on feasibility for certain types and uses of vehicle. Before removing the exemptions, some formal consideration should be given to the feasibility of meeting the functional requirements for vehicles with the addition of side guards. For example, some off-road activities could be completed with side guards, whilst other off-road activities may be impossible without ground clearance which prevents the fitment of side guards.

Legislation feasibility/readiness:

No barriers regarding legislative feasibility. However, it is recommended in addition to consider amendments to existing side-guard requirements in order to make their designs more effective.

Potential annual monetary benefits were estimated to range from €7.8M to €20.3M[2] by Hynd et al (2015). Also, this study estimated a beenfit to cost ratio, for fitting the currently exempt N_2 and N_3 vehicles with lateral protection, would lie in the range from 0.06 to 1.37.

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[49] Smith T, Grover C, Gibson T, Donaldson W and Knight I (2008). Development of test procedures, limit values, costs and benefits for proposals to improve the performance of rear underrun protection for trucks, ENTR 05/17. https://circabc.europa.eu/sd/a/bf5be9b8-54d5-42be-866d-a1c47e81cad4/20140903-121938_PPR317_RUP_Final_report_March_08.pdf

In summary, benefit to cost ratio likely to be less than one for vehicles that genuinely need either an exemption or adjustable side guards. However, the classification of these vehicles should be improved, so that the vehicles that do not genuinely need an exemption are identified better and for these vehicles the benefit to cost ratio is likely to be greater than one.

For consideration for implementation in the GSR further work is required to:

- Develop performance requirements for side guards
- Confirm cost benefit analysis

3.2.4. Fire Safety for Buses

Bus safety legislation is regulated on EU level through the implementation of relevant UNECE regulations. The situation for bus fire safety has been under review which is now leading to a foreseen mandatory introduction of automatic fire extinguishers in certain classes of buses through amendments to UNECE Regulation 107. In addition, in response to fire incidents with CNG powered buses, an amendment to UNECE Regulation 110 has been proposed. The proposal is to regulate the direction of discharging the pressure relief devices of the CNG containers based on existing provisions within Regulation (EU) No. 79/2009 on hydrogen vehicles. These developments are being supported by this review process of the General Safety Regulation which is underway in parallel.

- CNG: 02 Series of Amendments to UNECE R110
    - 01/09/2020 new types
    - 01/09/2022 all new vehicles
- Fire suppression: 07 Series of amendments to UNECE R107
    - 01/09/2020 new types
    - 01/09/2022 all new vehicles

Technological feasibility:

<u>CNG fire requirements</u>

Experts believe that the changes brought into force by an amended version of UN Regulation 110 would be technically feasible since they are based on provisions within Regulation (EC) No. 79/2009 on hydrogen vehicles, which use similar technologies to store and vent hydrogen.

<u>Fire suppression</u>

Automatic fire extinguishing systems for vehicles are commercially available as off-the-shelf items and are therefore technically feasible. The systems are available with several extinguishing agents which no longer damage the ozone layer.

Legislation feasibility/readiness:

<u>CNG fire requirements</u>

Proposals for amendments to the relevant UNECE Regulations are available. For consideration for implementation in the GSR further work is required to:

- Perform cost benefit analysis

<u>Fire suppression</u>

No standard type-approval test procedures for fire extinguishing systems exist yet, but the road administrations from Sweden and Norway have carried out research and proposed amendments to UNECE regulation No 107. These amendments were prepared to introduce fire suppression systems for buses and coaches upon detection of fire in the engine and/or heater compartment.

Fire suppression systems have been required by insurers in some countries and have proved effective. More analysis is required to identify benefits and calculate the benefit to cost ratio for implementation.

For consideration for implementation in the GSR further work is required to:

- Perform cost benefit analysis

3.3. PEDESTRIAN AND CYCLIST SAFETY

3.3.1. Pedestrian and Cyclist Detection

This item is closely linked to Section 3.1.1. on Automatic Emergency Braking, because pedestrian and cyclist detection are the third and fourth steps in addition to the first step in which the system detects a slow moving obstacle ahead, as well as the second step in which it detects a stationary vehicle.

Especially children act on impulse and are mostly not capable of assessing and detecting dangerous situations, frequently running in front of driving cars in urban areas. Therefore, these detection capabilities should be considered to improve the safety situation of such vulnerable road users that are hit by cars, by either reducing significantly the impact speed or by avoiding a collision altogether.

Pedestrians comprise over 21% of EU27 fatalities and in 2011 there were over 6,500 pedestrian fatalities in Europe (EC, 2013). In the same period, there were over 2,000 cyclist fatalities, comprising over 8% of all EU27 fatalities (EC, 2013). The majority of pedestrian and cyclist casualties occur in urban areas and over 80% result from collisions with motor vehicles (cars, lorries, and buses). Therefore, these detection capabilities should be integrated in the review of the Pedestrian Safety Regulation to improve the safety situation of such vulnerable road users that are hit by cars, by either reducing significantly the impact speed or by avoiding a collision altogether.

- Make mandatory for M_1 and N_1 vehicles (that are derived from M_1)
- Coupled with AEB application
    - 01/09/2024 pedestrian detection for new types
    - 01/09/2026 cyclist detection for new types
- Plus 2-year period for all new vehicles
- All N1 vehicles 2-year off-set to the above dates

Technological feasibility:

Pedestrian detection systems are currently offered as an option by approximately 5% of M_1 manufacturers. Volvo are the only manufacturer to offer a cyclist AEB system (since 2013); some other AEB systems may detect cyclists, but they are not specifically designed to do so.

Legislation feasibility/readiness:

Test procedures for pedestrian AEB have been developed by the EU FP7 AsPeCSS project[50]. Since January 2016, Euro NCAP assesses the performance of pedestrian AEB for three crossing scenarios. These are: an adult runs from the driver’s side of the vehicle; an adult walks from the passenger’s side (two tests are done for this scenario); and a child runs from between parked cars on the passenger’s side. To date, test protocols for cyclist AEB do not exist but some initial development work has been performed in the EU FP7 AsPeCSS project.

[50] http://www.aspecss-project.eu

The AsPeCSS project performed a benefit analysis for pedestrian AEB[51] and estimated that current AEB systems could reduce fatal pedestrian casualties by 2.9-6.2%, serious casualties by 4.2-4.4% and slight casualties by 2.2-4.4%. This gives a break even cost per car of about €80, indicating that current AEB systems implemented in a stand-alone manner are not likely to have a benefit to cost ratio greater than one. However, their performance is expected to improve, the AsPeCSS project estimated that this could increase the break-even cost up to around €280. Clearly, if the benefit of cyclist AEB was also added in and these systems were bunched with other systems, which also use cameras such as Lane Keep Assist, the system as a whole would likely have a benefit to cost ratio far greater than one.

For consideration for implementation in the GSR further work is required to:

- Complete development of test protocols for cyclist AEB
- Confirm cost benefit analysis

3.3.2. Head Impact on A-Pillars and Front Windscreen

Despite an introduction of automatic braking in the context of pedestrian and cyclist safety, some collisions will still be unavoidable because of certain specific factors or limitations. In this context it is noted that currently the windscreen and A-pillars are exempted from testing in terms of head impacts on these structures, whereas it is generally known that impacts frequently occur.

The idea to use airbags to protect the A-pillar and possibly the upper windscreen frame has existed for more than a decade. Whilst the centre of the windscreen may be relatively safe when hit by the head of a pedestrian, the glass towards the edge of the screen may not break at the same load. This has been confirmed from the monitoring data that has been gathered as part of the current legislation and this reporting. Also, at the base of the windscreen, it is likely that the head of a vulnerable road user would penetrate the glass sufficiently to contact the dashboard fascia underneath.

The windscreen frame itself is very stiff to persons, because it is an important load-bearing part of the vehicle's structure. Therefore impacts to the windscreen frame and around the edge of the windscreen can be considered to represent significant gaps in the protection assessed by the current legislation and this should therefore be taken into serious consideration for the review of the Pedestrian Safety Regulation.

- Extend the adult head impact zone
- Make mandatory for M_1 and N_1 vehicles (that are derived from M_1)
- Coupled with AEB application
- May consider introduction of reduced impact speeds with AEB pedestrian and cyclist detection (for windscreen and cyclist detection (for windscreen and A-pillar testing only)
    - 01/09/2024 new types
    - 01/09/2026 all new vehicles
    - All N_1 vehicles 2-year off-set to the above dates

When the legislation for pedestrian protection was implemented the head to windscreen tests were included for monitoring purposes only, based on concerns from the automotive industry that the centre of the windscreen was 'safe' and not within the control of the vehicle

[51] Edwards et al. (2014). Estimate of Potential Benefit for Europe of Fitting Autonomous Emergency Braking (AEB) Systems for Pedestrian Protection to Passenger Cars. Traffic Injury Prevention (2014) 15, S173–S182.

manufacturer. Has sufficient technological progress been made to make these tests feasible for mandating?

Technological feasibility:

In general, the vehicle manufacturer can only alter effective properties of the windscreen by changing the overall design, for example, the curvature and angle of the screen. However, for impacts to the central region of the windscreen it might be that the variation of performance of the windscreen material can be controlled more closely, and give safety improvements, via arrangements between vehicle manufacturer and glass supplier.

Pedestrian airbags (and pop-up bonnet) are now technically feasible, but are not yet adopted widely throughout the fleet.

AEB systems have the potential to avoid or reduce the speed in pedestrian impacts and hence mitigate the head impact.

Legislation feasibility/readiness:

The requirements and test procedures exist, but are currently applied for monitoring purposes only, i.e. not mandatory. Before the current headform is transferred to the windscreen for regulatory use, it is strongly suggested that the appropriateness of using the current Head Protection Criterion (HPC) with a headform, in such conditions, is demonstrated.

The GSR review estimated that the potential benefit for head-to-windscreen contacts is up to 500 fatalities and 11,000 serious injuries (~ €3 billion) in M1 vehicles[2]. The benefit to cost ratio of passive headform protection measures was estimated to lie in the range from less than 0.25 to 1. However, as mentioned above, for impacts to the central area of the windscreen, it may be possible to control the performance of the windscreen via arrangements between vehicle manufacturer and glass supplier. Therefore further research could be useful to isolate the relationship between variations in the windscreen fabrication process and HIC. Once that relationship is understood better, then the monitoring tests (to the central region of the windscreen) could become feasible and would likely have a benefit to cost ratio greater than one.

For active counter-measures, Edwards et al (2015)[52] has indicated that even with AEB for pedestrians protection of the A-pillars using airbags would still offer substantial benefits. On this basis, it is recomemnded that an integrated approach is adopted for the way forward.

For consideration for implementation in the GSR further work is required to:

- Perform further research to:
    - Understand if possible to control the performance of the windscreen central area
    - Determine appropriateness (biofidelity) of current haedform for windscreen impact
    - Investigate potential integrated solutions using AEB.
- Perform cost benefit analysis

3.3.3. Reversing (Backing up) Detection

Reversing detection systems are those that increase the view of drivers or otherwise warn them of persons or obstacles behind reversing vehicles. Particularly vulnerable in this context

[52] Edwards et al. (2015). Assessment of Integrated Pedestrian Protection Systems with Autonomous Emergency Braking (AEB) and Passive Safety Components. Traffic Injury Prevention (2015) 16, S2–S11.

are short, crouching and slow moving people, such as the elderly and children. There is an increasing concern about accidents involving young children being run over by reversing slow moving vehicles while playing in private driveways. In these circumstances, there is a possibility that these young children are too short to be seen, and so detections systems could be employed to warn the driver of such children in the path of the reversing vehicle.

The USA has recently mandated reversing cameras as a technical solution to the above mentioned problem. Whereas in the context of the revision of the General Safety Regulation we should strive for technology neutral safety solutions, we could also consider harmonising with the relevant amended FMVSS No 111 which requires one of the accepted solutions that may be developed and deployed to prevent this type of potentially fatal accidents.

- Investigate trend with more commonplace SUVs
- Reversing camera and/or acoustic warning, t.b.d.
    - Possible to consider the new US FMVSS 111 requirements designed to protect small children
- Make mandatory for all M and N, as well as O_3 and O_4 vehicles
    - 01/09/2020 new types
    - 01/09/2022 all new vehicles

Technological feasibility:

Ultrasonic, radar, and camera systems all exist on the market. Ultrasonic (parking sensors) are widely equipped to current vehicles but are not specifically designed for the detection of pedestrians. Camera and radar systems are available as optional systems on some models.

Legislation feasibility/readiness:

Although the US FMVSS 211 standard specifies a camera system, a performance requirement (which is non-technology specific) would be preferable. A minimum viewable area and quality of view could be defined. An assessment of national statistics in Europe would be required to take into account the situations causing the majority of casualties. For an assessment method to be developed the distance between the pedestrian and vehicle before reversing started may be needed as would the driving direction (i.e. turning); this is highly unlikely to be recorded with a statistical significance in any of the main accident databases.

It should be noted that NHTSA originally took the same view (Public Law 110–189, 110th Congress), but concluded that the only option currently able to fulfil all requirements was a rear view camera including specific requirements on luminance of the screen, image size, image response time, and system start up time etc.

Based on UK data, the GSR review[2] estimated that the benefit to cost ratio for mandatory fitment of pedestrian detection (camera system) to prevent pedestrian run over would likely be in the range of 0.1 to 0.5 depending on the cost of the system. However, if the benefit of prevention of damage only accidents is also included, the benefit to cost ratio rises to be in the range 1.5 to 7.5. Furthermore FMVSS 211 will be mandatory from May 2018 so system costs are likely to reduce, thus increasing the benefit to cost ratios.

For consideration for implementation in the GSR further work is required to:

- Decide approach for implementation, i.e. implementation regulation for camera based systems (following US approach) or implement perfromance based generic approach
- Perform cost benefit analysis.

4. BUNCHING OF TECHNOLOGIES

Some of the candidate measures listed above could utilise the same systems. Therefore, if these measures are considered as a package, the cost of the systems common to them would be spread amongst the individual measures and hence improve the BCR of the package as a whole compared to that of individual measures. Manufacturers already use this approach to reduce costs for measures supplied as options or standard fit, for example Autonomous Emergency Braking (AEB) is often packaged with Adaptive Cruise Control (ACC) because ACC can use the same camera / radar that is used for AEB.

System sharing between the measures listed that should be considered includes:

- Driver distraction and drowiness (DDR), Autonomous Emergency Braking (AEB) and Lane Keeping Assistance System (LKA)
  - Camera based systems with a driver view can be used to monitor a range of eye, face and head features for multiple purposes including drowsiness and distraction. Such systems can be expanded to have a forward facing camera (e.g. to monitor lane deviation and provide alerts, to record collisions, to monitor headway).
  - Systems based on vehicle control measures can monitor drowsiness by utilising existing vehicle sensors for steering, braking, acceleration and metrics derived from these inputs. This is why such systems are favoured by automotive manufacturers.
  - Systems can also utilise existing safety features of vehicles, such as lane keeping devices, to identify whether drivers appear distracted or drowsy according to the consistency with which they remain in a lane, the number of deviations and the rate of correction.
  - Systems can integrate with other vehicle telematics to transfer information about driver state and the number of alerts (e.g. to a fleet operator).
  - Some camera based products can utilise the cameras and hardware in mobile phones to provide drowsiness monitoring without the acquisition of additional hardware dedicated to this purpose.

5. FURTHER STUDIES IN THE FIELD OF VEHICLE SAFETY

In light of regulatory actions in other regions of the world, notably that of the USA and Japan, the Commission deems it appropriate to outline further steps to be taken to initiate studies on the effects of specific accident types occurring in the EU to obtain an up-to-date overview and to identify countermeasures that may need to be taken. These accidents concern frontal crashes, side crashes, roll-over accidents and rear crashes, notably with a focus on the effects due to the proliferation of SUVs with higher centres of gravity, higher masses and aggressive front-end design, linked to injuries to diverse and vulnerable occupants as well as to vehicle fires resulting from crashes.

5.1. FRONTAL CRASHES

- High speed oblique frontal impacts, causing occupants to striking vehicle interior parts due to ‘striking in a glancing blow’ or entirely ‘missing’ the frontal airbags;
- Lower speed frontal impacts and its effect on vulnerable occupants, such as the elderly, small females and children, with the aim to promote adaptive restraint systems;
- The effects of proliferation of SUVs with higher masses colliding with passenger cars;
- Car fires resulting from frontal crashes; and

- Frontal impacts in general and its effect on passengers seated in the rear, also to promote adaptive restraints for those seating positions.

5.2. SIDE CRASHES

- The effects of proliferation of SUVs with higher masses colliding with passenger cars; and
- Side crashes in general and its effect on passengers seated in the rear, including vulnerable occupants.

5.3. ROLL-OVER ACCIDENTS

- The effects of proliferation of SUVs with higher centres of gravity and tendency to roll-over, causing (partial) ejection of occupants.

5.4. REAR CRASHES

- Assessment of rear impacts, with partial or full overlap; and
- Car fires resulting from rear impacts.

6. CONCLUSIONS

The Commission has undertaken an elaborate assessment of a range of existing and mature safety technologies for passenger vehicles, trucks and buses that have great safety potential in terms of improving passive safety and mitigating crash consequences as well as active crash avoidance potential, with a particular focus on the protection of vulnerable road users.

Furthermore, to bridge the safety performance gap between different regions as well as vehicle segments and categories, the listed enhanced safety provisions are indeed proposed for light to heavy vehicles across the board to ensure that those involved in an accident benefit of the technical progress in road and vehicle safety.

It is noted that in order to ensure competitiveness of the automotive sector, it is of high importance that the issue of technology neutrality on specific solutions is respected.

Finally, technical progress in terms of advanced vehicle safety does not stop here. For this reason the European Union should be committed to continuous monitoring and to further analysis as well as to other relevant actions to improve this important work.

ANNEX 1: LIST OF PROPOSED MEASURES BY INTRODUCTION DATE

1 September 2020	
New vehicle type-approvals	New vehicle registrations

• Automatic Emergency Braking (AEB) with Moving Obstacle Detection
    ○ M_1 and N_1 (derived from M_1)
• Emergency Braking Display
• Intelligent Speed Adaptation
• Lane Keep Assistance
    ○ M_1 and N_1 (derived from M_1)
• Driver Drowiness and Distraction Monitoring
    ○ M_1, N_1 (derived from M_1), M_2, M_3, N_2 and N_3
• Safety Belt Reminders
• Frontal Crash Full Width Test
    ○ M_1 and N_1
• Side Crash elimination of exemptions
    ○ M_1 and N_1
• Side Crash Pole Side Impact
    ○ M_1 and N_1
• Rear Crash Test
    ○ M_1 and N_1
• Alcohol Interlock Devices interface
• Crash Event Data Recorder
    ○ M_1 and N_1
• Tyre Pressure Monitoring
    ○ M, N, O_3 and O_4
• Truck and Bus Front End Cameras and Detection
    ○ M_2, M_3, N_2 and N_3
• Truck Lateral Protection elimination of exemptions
    ○ N_2 and N_3
• Fire Safety for CNG Buses
    ○ M_2 and M_3
• Fire Suppression for Buses
    ○ M_2 and M_3
• Reversing Detection
    ○ M, N, O_3 and O_4	

1 September 2022

New vehicle type-approvals	New vehicle registrations
• Automatic Emergency Braking (AEB) with Moving Obstacle Detection ○ N_1 • Automatic Emergency Braking (AEB) with Stationary Obstacle Detection ○ M_1 and N_1 (derived from M_1) • Lane Keep Assistance ○ N_1 • Driver Drowiness and Distraction Monitoring ○ N_1 • Frontal Crash inclusion up to 3,500 kg ○ M_1 and N_1 • Frontal Crash Small Overlap Test ○ M_1 • Side Crash Far-Side Occupant Test ○ M_1 and N_1	• Automatic Emergency Braking (AEB) with Moving Obstacle Detection ○ M_1 and N_1 (derived from M_1) • Emergency Braking Display • Intelligent Speed Adaptation • Lane Keep Assistance ○ M_1 and N_1 (derived from M_1) • Driver Drowiness and Distraction Monitoring ○ M_1, N_1 (derived from M_1), M_2, M_3, N_2 and N_3 • Safety Belt Reminders • Frontal Crash Full Width Test ○ M_1 and N_1 • Side Crash elimination of exemptions ○ M_1 and N_1 • Side Crash Pole Side Impact M_1 and N_1 • Rear Crash Test ○ M_1 and N_1 • Alcohol Interlock Devices interface • Crash Event Data Recorder ○ M_1 and N_1 • Tyre Pressure Monitoring ○ M, N, O_3 and O_4 • Truck and Bus Front End Cameras and Detection ○ M_2, M_3, N_2 and N_3 • Truck Lateral Protection elimination of exemptions N_2 and N_3 • Fire Safety for CNG Buses ○ M_2 and M_3 • Fire Suppression for Buses ○ M_2 and M_3 • Reversing Detection ○ M, N, O_3 and O_4

1 September 2024	
New vehicle type-approvals	New vehicle registrations
• Automatic Emergency Braking (AEB) with Stationary Obstacle Detection	• Automatic Emergency Braking (AEB) with Moving Obstacle Detection

○ N_1 • Automatic Emergency Braking (AEB) with Pedestrian Detection ○ M_1 and N_1 (derived from M_1) • Pedestrian Safety A-Pillar and Windscreen Head Impact Test ○ M_1 and N_1 (derived from M_1)	○ N_1 • Automatic Emergency Braking (AEB) with Stationary Obstacle Detection ○ M_1 and N_1 (derived from M_1) • Lane Keep Assistance ○ N_1 • Driver Drowiness and Distraction Monitoring ○ N_1 • Frontal Crash inclusion up to 3,500 kg ○ M_1 and N_1 • Frontal Crash Small Overlap Test ○ M_1 • Side Crash Far-Side Occupant Test ○ M_1 and N_1

1 September 2026	
New vehicle type-approvals	New vehicle registrations
• Automatic Emergency Braking (AEB) with Pedestrian Detection ○ N_1 • Automatic Emergency Braking (AEB) with Cyclist Detection ○ M_1 and N_1 (derived from M_1)	• Automatic Emergency Braking (AEB) with Stationary Obstacle Detection ○ N_1 • Automatic Emergency Braking (AEB) with Pedestrian Detection ○ M_1 and N_1 (derived from M_1) • Driver Drowiness and Distraction Monitoring ○ N_2, N_3, M_2, M_3 • Pedestrian Safety A-Pillar and Windscreen Head Impact Test ○ M_1 and N_1 (derived from M_1)

1 September 2028	
New vehicle type-approvals	New vehicle registrations
• Automatic Emergency Braking (AEB) with Cyclist Detection ○ N_1 • Truck and Bus Front End Direct Vision ○ M_2, M_3, N_2 and N_3	• Automatic Emergency Braking (AEB) with Cyclist Detection ○ M_1 and N_1 (derived from M_1)

1 September 2030	
New vehicle type-approvals	New vehicle registrations
	• Automatic Emergency Braking (AEB) with Cyclist Detection ○ N_1

ANNEX 2: FULL LIST OF POTENTIAL MEASURES AS ESTABLISHED FOR THE FEASIBILITY AND COST-BENEFIT STUDY (PUBLISHED IN MARCH 2015)

Legend:	
Retained for further assessment	Has not been further assessed[53]

A2.1. ACTIVE SAFETY

Measure	Description
Automatic emergency braking systems (AEBS)	Combine sensing of the environment ahead of the vehicle with the automatic activation of the brakes (without driver input) in order to mitigate or avoid an accident. The level of automatic braking varies, but may be up to full ABS braking capability. First generation AEBS are in production on a number of current vehicles at the top end of the market and are capable of automatically mitigating the severity of two-vehicle, front to rear shunt accidents (on straight roads and curves dependent on sensor line of sight and environment "clutter") as well as some collisions with fixed objects and motorcycles
Lane Departure Warning system (LDWS)	A lane departure warning (LDW) system is an in-vehicle system that provides a warning to the driver of an unintended lane departure. Warning only, no corrective action
Automatic Cruise Control (ACC)	In an extension to the speed management capability of conventional cruise control systems, Automatic or Adaptive Cruise Control (ACC) maintains a desired road speed if the roadway ahead is unobstructed and a constant time gap from a moving vehicle ahead
Lane Keeping Warning system (LKS)	Monitoring the position of the vehicle with respect to the lane boundary and applying a torque to the steering wheel, or pressure to the brakes, when a lane departure is about to occur. In current systems, the level of torque varies from one system to another. In some cases, the intervention is intended to suggest the corrective action to the driver, without altering the vehicle trajectory. In other cases, the intervention is sufficient to prevent the vehicle leaving the lane
Lane Change Assist (LCA)	Lane change assistance systems warn the driver when it is unsafe to change lanes. The system will not take any direct action to prevent a possible collision; hence the driver remains responsible for the safe operation of the vehicle. They function by monitoring the area around the vehicle during a lane change manoeuvre and issuing a warning if certain criteria are met. These criteria usually relate to the proximity of other vehicles in the driver's intended lane of travel
Automatic Lighting	The fully automatic switching on/off of dipped beam headlamps depending on ambient light level, in conjunction with DRLs and always-illuminated speedometers (which may confuse drivers, who subsequently forget to put on their dipped beam). Not automatic dip and main beam nor directional lighting
Advanced Front-lighting Systems (AFS)	An Advanced Front-lighting System (AFS) is a technology which varies the pattern of light produced by headlamps to maximise clarity of the roadway at night whilst minimising the glare posed to oncoming vehicles. AFSs are designed to provide drivers with a better field of view when driving at night
Side marker lamps on passenger cars and vans to improve conspicuity	Dedicated lights on the sides of passenger cars/small vans that remain illuminated when the headlights are on to improve the lateral conspicuity of the vehicle

[53] Hynd, D., McCarthy, M., Carroll, J., Seidl, M., Edwards, M., Visvikis, C., Tress, M., Reed, N. and Stevens, A. (2015). *Benefit and feasibility of a range of new technologies and unregulated measures in the fields for occupant safety and protection of vulnerable road users. Final Report.* Brussels: European Commission. http://bookshop.europa.eu/en/benefit-and-feasibility-of-a-range-of-new-technologies-and-unregulated-measures-in-the-field-of-vehicle-occupant-safety-and-protection-of-vulnerable-road-users-pbNB0714108/;pgid=Iq1Ekni0.1lSR0OOK4MycO9B0000BAJ9tQVy;sid=OT_-Ap3uO3P-V8j2wGFgpf_Lm_yCUpo9P-w=

Measure	Description
Emergency Brake Lights (EBL)	Triggered by the strength of brake activation the rear brake lights are illuminated in different ways to indicate emergency braking manoeuvres to the following vehicles; possibly also activated by stability control system
Intelligent Speed Adaptation (ISA)	Intelligent Speed Adaptation (ISA) describes a range of technologies which are designed to aid drivers in observing the appropriate speed for the road environment. Two levels of control were considered: advisory (alert the driver when their speed is too great) and voluntary (the driver chooses whether the system can restrict their vehicle speed and/or the speed it is restricted to). Mandatory systems (where the driver's speed selection is physically limited by an ISA system that cannot be switched off) were not considered
Ambient temperature sensors	Both sensors to warn of external temperatures and V2V/I2V communications to warn following traffic of ice (or fog, or accident etc.) were considered
Blind spot detection systems	Application to turning HGVs only
Pedestrian/cyclists detection systems	Pedestrian detection may employ video, laser, radar or infrared sensors to detect the presence of pedestrians/cyclists in the path or periphery of the vehicle. Systems can either warn the driver and/or apply AEBS (both to be considered)
Improved visibility from vehicles	Better driver visibility all around the driver in terms of reduced visual obstruction caused by size and position of vehicle structure. To include vehicles not already covered by R125 (i.e. M2, M3, N), e.g. Japanese requirement for additional mirror/camera on the front of SUVs
Traffic sign recognition	The system (normally via a camera and optical recognition) detects road signs and provides in-vehicle information to the driver
Night vision systems	Night vision systems are designed to increase detection performance of critical targets such as pedestrians, cyclists, animals, and other objects. They extend the visibility of objects during poor visibility conditions by projecting improved or higher contrast images using infrared (IR) cameras on a display
Junction camera system	Camera(s) on the side of the front of a vehicle provide an unobstructed view each side of vehicles at a junction
Reversing detection and reversing camera system	Camera (or sensor) on the rear of a car to alert drivers to pedestrians behind cars, in particular to prevent accidents involving children behind reversing cars
Integrated cleaning system	Cleaning water is emitted from the wiper blades rather than nozzles on the bonnet

A2.2. CAR OCCUPANT AND PEDESTRIAN SAFETY

Measure	Description
Improved protection of seniors and small stature occupants through the adoption of advanced anthropometric test devices	In response to the potential for modifications to current safety requirements (e.g. R.94, R.95), upcoming requirements (e.g. Pole Side Impact, Full-Width frontal) and potential requirements (e.g. rear seat occupants in adult belt); safety measures, including the possibility of additional tests within each measure, to improve the safety of seniors and small stature occupants
Protection of far-side occupants in side impact collisions	In a side impact with both driver and front seat passenger (FSP) occupants, the struck-side occupant is protected by multiple airbags. However, the far-side occupant tends to slip out of the seat-belt and collide with the struck-side occupant, which may result in significant injuries to either occupant
Side impact protection for occupants of all sizes and prevention of ejection	Implementation of systems to protect the heads of occupants of all sizes and to prevent ejection of occupants as a result of a side impact crash (which would most likely mean the use of full-size side window airbags)
Rear impact protection requirements for rear seated occupants	Improvement of protection for occupants of rear-row seats in a rear impact, particularly focused on protection of occupants seated very close to the rear of the vehicle e.g. third row seats
Pre-crash seat-belt tensioners and occupant position adjustments	Improvement of occupant safety in case of an inevitable impact. Mandated measures could include pre-crash seat-belt pre-tensioning, adjustment of the seat position prior to the start of the collision (in both the occupant would be approximately stationary relative to the vehicle at the start of the collision), or dynamically moving the occupant just prior to and at the start of the collision
Seat-belt reminder systems	In front and rear passenger seating positions
Pedestrian upper leg and pelvis to bonnet leading edge protection	When the legislation for pedestrian protection was implemented there were concerns from the automotive industry that it was not feasible to meet the upper legform protection criteria proposed by EEVC Working Groups alongside that test. As a result these tests were included for monitoring purposes only. . Investigated whether or not sufficient progress has been made to make these tests feasible for mandating
Adult head to windscreen protection	When the legislation for pedestrian protection was implemented there were concerns from the automotive industry that the centre of the windscreen was 'safe' and not within the control of the vehicle manufacturer. As a result these tests were included for monitoring purposes only. Investigated whether or not sufficient progress has been made to make these tests feasible for mandating
Influence of front registration plates on pedestrian protection	The bumper test components of vehicle type-approval are conducted without the front registration plates being present. However, when a vehicle is involved in an accident these will be in place. Therefore it is possible that the real world safety levels are different from those assessed at the time of type-approval. Testing with the registration plates in place would remove this discrepancy but may offer very limited benefit and be subject to variations in plate design
Influence on safety of third-party (non-OEM) replacement parts (e.g. bonnet, front bumper, wings) on pedestrian protection	For styling or accident repair purposes, aftermarket vehicle components can be purchased. These parts can be sourced from the original manufacturer or from a third party. Third party parts may not have been assessed for safety performance in the same way as the original parts and therefore safety could be degraded through the fitting of such parts. In principle it could be required for all automotive parts to have been assessed and certified to make sure that safety levels are maintained or will still meet type-approval requirements. Alternatively, the fitting of third party parts that may affect pedestrian safety could be tracked and their effect monitored.
Strength of ISOFIX connectors installed in vehicles	To ensure appropriate protection of heavier children.
Safety of children in hot cars	Systems to raise the alarm or to cool the vehicle if the interior temperature exceeds a threshold and the presence of a child occupant is detected.

A2.3. Crashworthiness, HGV Safety and Fuel Systems

Measure	Description
Crashworthiness in case of small-overlap frontal crashes	Car occupant protection for small overlap frontal crashes, i.e. those with less than 20 to 25% overlap and no direct loading of longitudinal rails.
Compatibility with crash partners	Better compatibility in crashes with other vehicles to minimise injuries in the accident overall. Includes compatibility with other cars (M1) and rear-under-run protection on HGVs and their trailers.
Increased offset-frontal crash test speed	Increased test speed in the current regulatory frontal impact test R.94 for cars (M1). Either increasing the speed of the current test or the addition of another test.
Crashworthiness in case of full-overlap frontal crashes	Car occupant protection for full overlap frontal crashes, i.e. those with more than about 80% overlap and with direct loading of both longitudinal rails, to better assess occupant restraint systems.
Roof strength testing to protect occupants in case of roll-over accidents	Static roof strength testing similar to FMVSS216 to ensure minimum roof strength to reduce roof crush in rollover accidents. Ejection mitigation testing similar to FMVSS226 to ensure side airbags offer help to prevent ejection is also included because it is closely related.
Vehicle submersion requirements to ensure that vehicle occupants are always capable of escaping a vehicle in water	Measures to ensure things such that electric windows can be opened when/if a vehicle rolls/falls into water to allow occupants to escape. For example, that central locking does not short-circuit or fail to disengage, and power windows remain operable and do not close automatically due to water immersion, etc. Equipment such as a hammer is not included, except devices that automatically trigger and shatter the windows.
HGV side guards	To consider the removal of some or all of the current exemptions for lateral protection side guards on trailers/trucks, which are designed to protect cyclists against over-run injuries.
Safer HGV front end design	Assuming that the weights and dimension of heavy goods vehicles will be changed for fuel efficiency reasons, are there measures that should be considered that make use of the additional cab length to improve cab safety. To include self-protection, partner (car) protection and improved direct vision for vulnerable road users.
Light and heavy duty fuel systems	Comprehensive testing of fuel systems to avoid vehicle fires and possible inclusion of automatic fire extinguishers
CNG fire requirements	Specific enhanced requirement for CNG vehicles in case of fire (as proposed by the Dutch delegation in GRSG of UNECE)
Rear impact protection of the fuel tank	Crash test requirements for the integrity of the fuel tank of M1 vehicles in a rear impact (e.g. US, Canadian and Japanese requirements)
Tyre pressure monitoring system	Electronic system designed to monitor the air pressure inside the pneumatic tyres on various types of vehicles. TPMS report real-time tyre-pressure information to the driver of the vehicle, either via a gauge, a pictogram display, or a simple low-pressure warning light. TPMS can be divided into two different types, direct (dTPMS) and indirect (iTPMS). TPMS are provided both at an OEM (factory) level as well as an aftermarket solution.

A2.4. Driver Interface, Distraction and Intelligent Transport Systems

Measure	Description
Standardisation of uniform vehicle controls	Standards exist for some aspects of vehicle control interfaces. However, with new ADAS functions emerging, manufacturers differ in the way in which they implement the new functions available to the driver. This measure relates to the standardisation of new vehicle controls to ensure that drivers moving from one vehicle to another have a consistent driving experience and reduce the likelihood of control misuse. Also considering the standard location of emergency buttons (horn, hazards) parking brake, gear shift patterns, indicator stalk/wiper stalk location, etc.
Improving the intuitive operation of vehicles	The way in which vehicles are driven is evolving. New active safety and comfort systems are changing the ways in which drivers interact with their vehicles. Additional vehicle functionality can bring additional complexity to the vehicle interface. Controls that are not intuitive to use are more likely to be misused resulting in a potential increase in collision risk or disused such that the driver fails to take advantage of the potential safety/comfort benefits that such systems may deliver. This measure would improve the intuitive operation of vehicle systems to minimise these risks and maximise the benefit of the systems. Considering the definition of performance requirements for intuitive vehicle operation encouraging industry standardisation. To explore the need and opportunities, closely linked to the point above
Driver interface provisions and restrictions for on-board infotainment systems	In-vehicle display, communication and computing technologies are advancing rapidly. There is the potential for drivers to access complex functionality through native vehicle systems and/or smartphone connectivity. This measure examines provisions and restrictions for on-board infotainment systems that may deliver this functionality
Reducing driver distractions	Driver distraction is the diversion of attention from activities critical for safe driving to a competing activity. Competing activities come in an increasing variety of forms and can be within the vehicle or external. Reducing distraction to improve drivers' attention to the activities required for safe driving should reduce collision risk
Driver distraction and drowsiness recognition	Sensor technology is advancing such that it is becoming possible for technology to provide a reasonably accurate estimate of driver alertness in relation to distraction or fatigue, with some vehicle manufacturers already offering systems that deliver warnings if they detect that the driver is showing signs of fatigue. This measure relates to the effectiveness of potential interventions for measuring driver distraction or drowsiness
Cameras to replace all the rear view mirrors	Rear view mirrors do not always offer an ideal rearward view for the driver. Cameras could be situated to ensure that drivers always have optimal rearward vision. This measure is the use of cameras and in-vehicle screens to provide the driver with rear view information in place of the typical driving and wing mirrors
Alcohol interlock devices to prevent drink driving	Alcohol interlock devices require a vehicle operator to provide a breath sample and prevent the vehicle ignition from operating if the detected alcohol level is above a pre-defined threshold. This measure may reduce collision risk by restricting the opportunity for drivers to operate vehicles when under the influence of alcohol.
Interlock to prevent the use of non 'hands free' mobile telephone systems while driving	Ignition interlocks for mobile phones prevent a car from starting until the device is placed in a specific cradle. This cradle prevents the driver from manually interacting with the phone but Bluetooth connectivity enables some functions to be accessed 'hands-free'. This measure may reduce the level of driver distraction by limiting the opportunity for a driver to be distracted by manual interaction with a mobile communication device. For instance, a system that senses speech, GSM transmission activity, and use of controls, i.e. a smart system that can detect that the driver is texting, talking etc. while holding a phone
Crash event data recorders (EDR)	Crash event data recorders are devices that can record data about vehicle status and dynamic behaviour in the event of the detection of sudden, rapid acceleration (as would be expected in a collision). The presence of a data recorder supports drivers in providing objective information about the collision and may encourage better driving behaviour since drivers will be aware that unsafe driving practices may be recorded. EDR may enhance knowledge about accident causes and facilitate the development of safer vehicles
Car to Car communication (C2C)	Capability for vehicles to rapidly exchange digital messages to support a range of services/function for safety, efficiency and environmental benefits including, importantly, time critical messages to help avoid collisions or mitigate their effects.

Measure	Description
	Called "connected car" in the US. Also V2V although here it is understood that the primary focus is passenger cars and light trucks
Car to Infrastructure speed and hazard warning (C2I)	C2I is a technology that can support many functions/services involving transfer of information from vehicles to the infrastructure (roadside) and from infrastructure to vehicle. Here only cars and light vans are considered as the relevant vehicles. Also, just two functions/services are considered - warning of hazards on the road ahead and warning of speed limits (which might be variable depending on traffic and weather conditions)
Enhanced Navigation Systems	Enhanced navigation functionality to a) dynamically route around accidents and congestion hot-spots, b) ensure routes are appropriate for the class of vehicle

ANNEX 3: For candidate measures, summary of feasibility and cost benefit assessment reported initially[54]

Code	Measure	Feasible?	Benefits	Costs	BCR	Legislate?	Most applicable vehicle categories	Recommendations/Notes
AEB	**Autonomous emergency braking**: Expansion and enhancement of AEB, BAS and LDW to avoid or mitigate collisions, including inter-urban, city and those involving VRUs	✓	Prediction that AEB would bring about a reduction in casualties of approximately 11% (based on reported casualties). Retrospective insurance data show between 10-20% fewer claims in US (these include whiplash accidents under-recorded in reported road accidents).	Current consumer costs for urban AEBS are as low as £200 (Ford, VW), although some manufacturers package this with other functions (e.g. Audi) where the options pack is £2,320 (but includes AEBS, Park assist and other functions).	BCR≥1, especially for urban systems (esp including damage and whiplash). Summary: ~1	●	M1, N1	Greatest casualty benefit for AEBS is for M1 then N1 vehicles, although cost-benefit less clear than for N2/N3. System cost estimates suggest 'city safety' systems may be reaching the breakeven cost point AEBS on M2/M3 and N2/N3 mandated from 2013 (new types) and 2015(new vehicles)
EBD	**Emergency brake light display:** Standard fitment of the emergency brake light display (i.e. rapidly blinking brake lamps) in case of hard braking	✓	German data shows EBD estimated to affect 25% of rear-end crashes in moving traffic and 15% in stationary traffic, resulting in a 14% reduction in these crashes. These estimates were based on the assumption of an EBLD penetration rate of 70% of the German passenger vehicle fleet.	Not identified although considered to be low (linked to ABS or other braking systems)	No formation BCR identified, but considered ≤1 because costs low and tangible safety benefit (although TP overlap with AEB). Summary: >1	●	M1, N1 M2, M3 N2, N3	No formal BCR for EBD were identified, but costs likely to be very low and collision and injury benefits expected - therefore BCR may be >1

54 Hynd, D., McCarthy, M., Carroll, J., Seidl, M., Edwards, M., Visvikis, C., Tress, M., Reed, N. and Stevens, A. (2015). *Benefit and feasibility of a range of new technologies and unregulated measures in the fields for occupant safety and protection of vulnerable road users. Final Report.* Brussels: European Commission. http://bookshop.europa.eu/en/benefit-and-feasibility-of-a-range-of-new-technologies-and-unregulated-measures-in-the-field-of-vehicle-occupant-safety-and-protection-of-vulnerable-road-users-pbNB0714108/;pgid=Iq1Ekni0.1lSR0OOK4MycO9B0000BAJ9tQVy;sid=OT_-Ap3uO3P-V8j2wGFgpf_Lm_yCUpo9P-w=

Code	Measure	Feasible?	Benefits	Costs	BCR	Legislate?	Most applicable vehicle categories	Recommendations/Notes
ISA	**Speed support/speed assist (ISA):** Speed limiters controlled by road speed limit (speed assist, intelligent speed adaptation)	✓	Greatest benefits for mandatory systems Potential reductions of 20% injury accidents, 37% fatal accidents (based on European studies) implying savings of over €20 Billion per annum in the EU28. System that responds to network and weather conditions = 36% reduction in injury accidents; 59% fatal accidents	€350 to €450 (Carsten and Tate, 2005) plus one-off costs £8-£43 million for mapping system and £2.25-£4.5 million plus £1-£5 per vehicle.	BCR estimates 7.9-15.4 (Carsten and Tate) Estimates for 6 EU countires (Belgium, GB, France, NL, Spain, Sweden) BCRs 2.8-4.8 Depend on implementation scenario (market driven or regulation) Summary: >1	●	M1, N1 M2, M3 N2, N3	BCR>1 for 6 Member States, for voluntary activation (switched on/off by the driver) and mandatory activation, and public acceptability of the systems considered to be growing. BCR higher for mandatory activation system, but both have positive BCR Note that studies focused on M1 vehicles and commercial operations mean that N2/N3 vehicles are speed limited, but not with ISA systems.

Code	Measure	Feasible?	Benefits	Costs	BCR	Legislate?	Most applicable vehicle categories	Recommendations/Notes
LKA	**Lane keeping system**	✓	Towards upper end (or above) estimate for LDW (Same TP; greater system effectiveness) M1/N1 – Fatal 166-3,447, Serious 846-17,108, Slight 2,055-22,309 M2/M3 – Fatal 1-96, Serious 6-408, Slight 26-255 N2/N3 – Fatal 4-87, Serious 19-468, Slight 42-490	LKA are optional systems and typically packaged with other related systems. For example, Ford offer LKA packaged with LDW, Traffic sign recognition, Driver Alert and Auto High Beam for £550 (approximately €660) as a cost to the consumer. Other manufacturers offer lane departure warning functionality as part of a more advanced lane keeping system. For example, Audi offer LDW functionality as part of Lane Assist (which also include LKD) for £400 (approximately €480) cost to the consumer.	1.7-2.1 predicted by European studies (COWI and Abele et al.) M1/N1: 0.13-4.18 (Visvikis et al., 2008); 0.25-2.12 (Robinson et al., 2011) M2/M3: 0.47-23.47 (Visvikis et al., 2008) N2/N3: 0.18-6.56 (Visvikis et al., 2008) TRL consider that BCR for LKA likely to be above 1 and is toward the upper end of the BCR range predicted by Robinson et al. (2011) and possibly as high as the upper range predicted by Visvikis et al. (2008). Summary: >1	●	M1, N1 M2/M3 N2, N3	Costs higher than LDW and similar to LCA, but benefits higher because higher expected effectiveness than LDW/LCA LDWS on M2/M3 and N2/N3 mandated from 2013 (new types) and 2015(new vehicles). Consideartion could also be given to incorporation of functionality in system to aid detection of VRU in close peroimity in lower speed manoeuvres (VIS).
DDR	**Driver distraction and drowsiness recognition**	?	Likely to reduce collisions caused by driver distraction or drowsiness.	Range of costs vary substantially depending on the system (€100-€10,000).	BCR >1 for commercial and public service fleets. Summary: >1	●	M1, N1 M2, M3 N2, N3	BCR likely >1 for private cars and commercial vehicles, due to the large number of collisions involving distraction as a causative factor. However, further work required to determine how to define and test effectiveness of distraction/drowsiness monitoring systems and to define what action the system should take if inattention is detected

Code	Measure	Feasible?	Benefits	Costs	BCR	Legislate?	Most applicable vehicle categories	Recommendations/Notes
SBR	**Seat belt reminder systems:** Seat-belt reminder systems in front and rear passenger seating positions	✓	Overall benefit in Europe estimated to be between: M1/N1: €68-117/24-65 million M2&M3: €4-337 million N2¬&N3: €33-88 million	Predicted component costs: M1/N1: $4-$6 M2/M3: $6-? N2/N3: $6	Fitment costs are comparable with, or lower than the break-even estimates, with the exception of M1 rear seat passenger systems. Summary: >1	●	M1, N1 M2, M3 N2, N3	Cost-beneficial for M1 driver and outboard passenger seat, M2 and M3 passengers, all seat positions for N1, N2, N3. Could consider legislation for M1 second and other row seats on basis of safety equality and being nearly cost effective
FFW	**<u>Frontal Impact Crash Programme</u>** **Crashworthiness in full-overlap frontal crashes to better assess occupant restraint systems**	✓	Adaptive restraints: 5 – 11% of KSI car occupant casualties	No specific information could be found but: €32 to improve restraint system to meet R94 limits in full-width test (Edwards and Tanucci 2008) €182 - €280 to add 2 or 4 sensor cutain airbag system (NHTSA 2007)	Break-even costs estimated of between €84 and €175 Therefore BCR could be >1 Summary: 1	●	M1	Current proposal to amend R94 unlikely to lead to improved restraint systems, so minimal cost and minimal benefit. Further work needed in order to define requirements that would ensure improved restraint systems for a wider range of occupants in a wider range of collision severities. This will, most likely, require adoption of advanced anthropometric test devices.
FSO	**<u>Frontal Impact Crash Programme</u>** **Crashworthiness in small-overlap frontal crashes**	✓	No benefit estimates found for Europe or US However, could be significant because although target population is not that large, effectiveness may be high because countermeasures likely to reduce high cost head and lower extremity injuries	No specific cost information identified, but manufacturers have and are responding with design modifications to meet IIHS test, so costs assumed reasonable	Could possibly be > 1 – possible significant benefits and reasonable costs Summary: 1?	●	M1	Maximum benefit likely from NHTSA-style low overlap, for which there is less info available on likely EU benefits and particularly costs. Further work may be required

Code	Measure	Feasible?	Benefits	Costs	BCR	Legislate?	Most applicable vehicle categories	Recommendations/Notes
SIP	**<u>Side Impact Crash Programme</u>** **Side impact protection for occupants of all sizes and prevention of ejection (e.g. using full-size window airbags)**	✓	Monetary benefits for testing options between £9-£162 million.	Testing options vary between €70 - €505.	M1 vehicles between 1:5.2 and 1:6.2 in France N1 vehicles between 1:17.3 and 1:20.8 Summary: <1	●	M1, N1	Costs would have to be re-evaluated if a small overlap test procedure was introduced because this may encourage improved side airbags for front seat occupants and thus benefit from technology bunching. Legislation could also be considered on the basis of providing equality of protection for all occupants, including rear seat occupants. Also note that costs estimated in literature likely to be too high and also benefits low because no benefit for ejection mitigation in rollover taken into account, hence BCR likely to be > 1.
SFS	**<u>Side Impact Crash Programme</u>** **Far-side occupant protection:** Protection of far-side occupants in side impact collisions	✓	Scoping studies with far-side testing give benefit estimates. Casualty reductions of 30% for fatalities and 18 to 57% for serious injuries. Also beneficial in some rollover scenarios and predominantly in the types of side impact cases involving older occupants. Benefit estimated to be between €1.2 to €1.9 billion each year in Europe.	Cost information not available, used old information. Comparable side impact airbags cost about $200 in 2004. Anticipated that the unit cost would be lower than this. To equip the 12 million new vehicles registered each year in Europe with similar airbags (at $200 per unit) would cost about €1.8 billion.	Cost benefit ratio could be in the range of 0.6 to 1.1. Summary: >1	●	M1	Likely to be cost-beneficial (spans 1, and cost estimate considered to be high) and already in production vehicles. Work would be required to define suitable test and assessment procedures

Code	Measure	Feasible?	Benefits	Costs	BCR	Legislate?	Most applicable vehicle categories	Recommendations/Notes
RFT	**<u>Rear Impact Crash Programme</u>** **Rear impact protection of the tank (e.g. US, Canadian and Japanese requirements)**	✓	No information previously reported More detailed analysis required to quantify benefits	No information previously reported More detailed analysis required to quantify costs	Unknown at present Summary: t.b.d.	●	M1, N1	Further cost and benefit information to be identified. Scope for international harmonization. Fuel tanks are tested on component level and the fuel system installation is verified through EU legislation, however, good performance in the field likely only due to best practise of manufacturers whereas this critical safety issue may need to be formalized in a more appropriate manner. This test is however lacking for post-crash checking of electrical safety.
ALC	**Alcohol interlock devices**: Alcohol interlock devices to prevent drink driving	✓	Estimated safety benefit across Europe: Offenders: €88-€1600 million Goods vehicles: €1500 million Buses and coaches: €60 million All passenger cars: €42-€62 million	Basic alcohol interlock systems cost in the region of €1,000.	Offenders: 1.0-2.8 Goods vehicles: 1.4 Buses and coaches: 0.3 All passenger cars: 0.8-1.3 Summary: t.b.d.	●	M1, N1 M2, M3 N2, N3	Legislate to ensure that it remains possible to connect an alcohol interlock to the vehicle in the future (not for fitment of the interlock), e.g. via a standard interface

Code	Measure	Feasible?	Benefits	Costs	BCR	Legislate?	Most applicable vehicle categories	Recommendations/Notes
EDR	**Possible psychological stimulant to safe driving**: EDR acting as a possible psychological stimulant to safe driving (from DG MOVE study)	✓	Improvement of road safety by improving the data on the performance of current safety systems Access to justice using accurate and verifiable collision and pre-collision data Possible effects on driver behaviour	The purchase price of EDR download tools ranges from €2,200 to €6,500 DG MOVE study based EDR cost information primarily on that previously published by NHTSA	M1 vehicles estimated at between 0 to 5.7, central estimate 0.1; N1 vehicles was estimated at between 0 to 6.6, central estimate 1.0; M2/M3 vehicles was estimated at between 0 to 4.0, central estimate 2.0; N2/N3 vehicles was estimated at between 0 to 4.6, central estimate 2.3. Summary: >1	●	M1, N1 M2, M3 N2, N3	Real benefits identified, although difficult to monetise. However, most new European vehicles have EDR functionality (although currently not accessible in most), so most of the cost has already been spent. Recommend legislating to standardise specification for EDR and standardising technical protocols for access to the information (the latter most likely to be harmonised with US Part 563)

Code	Measure	Feasible?	Benefits	Costs	BCR	Legislate?	Most applicable vehicle categories	Recommendations/Notes
TPM	**Tyre Pressure Monotoring Systems**	✓	Costs savings associated with reduced tyre breakdown could be generated for example due to increased highway safety (the effect of tyre blowout on the surrounding traffic). It is expected that the number of yearly fatal road accidents can be reduced which effectively leads to a reduction of associated costs of 11-58 M€ in the EU	Costs for TPMS per vehicle segment (excl. VAT), truck-only (TO) and truck-trailer (TT) €5 - €146	Prospective costs / low savings potential: Payback times for OEM-fitted systems are generally 3.5 years or less and abatement costs are negative. Prospective costs / high savings potential: TPMS is cost-effective for all considered applications from a societal as well an end-user perspective irrespective of assumptions regarding the price of fuel.	●	M, N, O3, O4	When TPMS application is made mandatory through regulation, production volumes will increase significantly, what might lead to lower prices as in the “prospective cost” scenario. Analysis for the combination of the “prospective cost” scenario with scenarios for high resp. low fuel savings potential show that OEM-fitted TPMS could be cost effective for cases in the “prospective cost / high savings potential” scenario and in some of the “prospective cost / low savings potential” scenario. Therefore mandatory fitment of TPMS on new vehicles could lead in the described cost-effective scenarios to benefits for users as well as society. Given the current low market penetration of TPMS for HDVs, a regulation could accelerate mass production and reduce TPMS costs, and thereby could contribute to the materialization of appropriate cost benefits. Mandatory fitment for LCVs only could be considered as cost-effectiveness for this application is robust to all considered scenario variations. The latter is also true for long haul applications.

Code	Measure	Feasible?	Benefits	Costs	BCR	Legislate?	Most applicable vehicle categories	Recommendations/Notes
DIM	**Safer HGV front end design:** Safer HGV front end design (enabled by changes to the weights and dimensions legislation)	✓	Potential casualty benefits across EU27; based on predictive estimates: Passenger car occupants: 128-175 HGV occupants: 41-194 VRUs: 104 – 553 Monetary benefit: 0.14-1.4 billion Euros per annum (from fatality savings alone)	No reliable data identified; almost exclusively one-off costs	Break-even cost per N2/N3 vehicle: €1.448-€4,889 Summary: >1	●	N2, N3	Breakeven cost per vehicle €1,448–€4,889, so likely to be cost-beneficial. Further work needed to define suitable requirements, which will affect costs, so final BCR should be updated. Alternative active safety systems should also be investigated to ensure that the best benefit is delivered for a given cost
FCO	**Truck rear underrun programme** **Compatibility:** HGV rear under-run	✓	Car-to-HGV: Between 43 and 93 fatalities and 694 and 2063 serious injuries per year (Smith et al., 2008).	Car-to-HGV: Range €100 to €4600 depending on the complexity of the design and whether or not the development of the RUP was included in the cost (Smith et al., 2008)	Car-to-HGV: Between 0.3 and 18.7, using best estimates between 0.6 to 14.8 (Smith et al., 2008). Summary: >1	●	N2, N3	Insufficient benefit from testing for geometric alignment of M1 frontal energy absorbing structures; consideration could be given to a voluntary agreement for height of energy absorbing structures in a similar way as in the US. For HGV, improved rear under-run guard likely to have BCR>1
LAT	**Lateral protection of trailers and trucks:** Lateral protection of trailers/trucks (removal of some exemptions)	✓	Potential annual monetary benefit (from fatality reduction alone) across EU27: €7.8 –€20.3 million. However, may overlap with other measures being considered.	€480-1,800 for retrofit solutionsl cost to vehicle manufacturer considerably lower.	Break even cost per N2/N3 vehicle: €102-€657 Summary: <1 to 1	●	N2, N3	Cost benefit likely to be less than 1 for vehicles that genuinely need either an exemption or adjustable side guards; however, the classification of these vehicles should be improved, which will reduce the number of vehicles receiving an exemption

Code	Measure	Feasible?	Benefits	Costs	BCR	Legislate?	Most applicable vehicle categories	Recommendations/Notes
AFE	**Bus fire safety programme** **Comprehensive testing of fuel systems to avoid fires; possible inclusion of automatic fire extinguishers (LCV and HCV)**	✓	No information previously reported More detailed analysis required to quantify benefits	Type-approved system (excluding installation): €1,100 Type-approval test: €17,000 Type-approval equipment (one-off): €12,000 - €17,000	Unknown at present Summary:	●	M2, M3	Required by insurers for buses in some countries and has been effective; UNECE initiative well advanced.
CNG	**Bus fire safety programme** **Specific enhanced requirement for CNG vehicles:** Requirements in case of fire (as proposed by the Dutch delegation in GRSG of UNECE)	✓	No information previously reported More detailed analysis required to quantify benefits	No information previously reported	Unknown at present Summary: t.b.d.	●	M2, M3	Recommend updates to regulation 110 in line with hydrogen vehicle requirements and application of regulation 118 to class I vehicles with CNG propulsion; requirements for emergency responder access to the engine compartment may also be considered. Cost-benefit for automatic fire extinguishers not clear; these have been encouraged as after-market equipment in some markets
PCD	**Pedestrian/cyclists detection systems**	✓	Several older studies, recently ASPECSS estimated benefit of pedestrian AEB to be 2.9-6.2% of fatal pedestrian casualties, 4.2-4.4 of serious and 2.2-4.4 of slight.	Current costs (to the consumer) are high	The benefit to cost ratio (based on the available cost data) is considered to be less than 1, although the magnitude of the absolute casualty benefit is very high Summary <1	●	M1, N1	No BCR studies were identified and breakeven costs exceed current system costs if considered as a stand-alone feature. If other systems that share hardware with PCD systems are mandated and reliable system cost estimates can identified, this measure should be re-evaluated. In case of technology bunching with AEB, this measure is expected to be cost-effective

Code	Measure	Feasible?	Benefits	Costs	BCR	Legislate?	Most applicable vehicle categories	Recommendations/Notes
HED	**Adult head to windscreen protection**	✓	Benefit for head to windscreen contacts is up to 500 fatalities and 11,000 serious injuries (~ € 3 billion) in M1 vehicles In M2/M3 and N2/N3 vehicles this could be up to 150 fatalities and 1,650 serious injuries	Pedestrian airbag assumed to be roughly twice the cost of a passenger airbag Pedestrian AEBS might cost somewhere between £ 1,000 and £ 1,500 as an optional extra Costs for M1 vehicles could be somewhere between € 3.6 and 12 billion each year. Stakeholders suggest a ten times reduction in cost if manufacturing large volumes due to economies of scale.	For passive headform protection measures, anticipated to lie in the range <0.25 to 1 Dependent on the real-world effectiveness of the available countermeasures as well as the cost Summary: <1 to 1	●	M1, N1	BCR <1 to 1, depending on real-world effectiveness of measures. There are indications that performance of the central area of the windscreen can be controlled better at negligible cost and this should be investigated further. Recent work (Edwards et al. 2015) indicates that benefit of providing protection for head impact against A-pillars could be substantial.
REV	**Reverse detection:** Reversing detection and reversing camera systems to prevent accidents involving children behind reversing cars	✓	Benefit on basis of damage-only accident mitigation. No clear effectiveness information for EU casualty reduction and dependent upon technical solution (camera, ultrasonic, etc).	In the study for the FMVSS, NHTSA states that the cost will be between $132 and $142 per vehicle to fit a system to meet the requirements. However, for vehicles already equipped with a suitable display the cost is estimated to be $43 to $45 (NHTSA, 2014).	BCR>1 when including damage-only accident mitigation. Regulatory requirements are being introduced in the US, so the technology is likely to become commonplace and costs are likely to reduce. Summary: >1	●	M1	BCR>1 when including damage-only accident mitigation and regulatory requirements are being introduced in the US (mandated from May 2018), so the technology is likely to become commonplace and costs are likely to reduce further