"ITS4CV" – ITS for Commercial Vehicles

Study of the scope of Intelligent Transport Systems for reducing CO_2 emissions and increasing safety of heavy goods vehicles, buses and coaches

Final approved version

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Abstract	This is the final report of an internal ERTICO study, supported by ACEA, on the potential contribution of ITS measures to reducing CO_2 emissions and increasing safety for heavy commercial vehicles. It focuses on cooperative in-vehicle applications (those which use data from the powertrain, driving behaviour and/or from the infrastructure to build estimation or prediction in order to either guide the driver or control the vehicle in some way), and also on ITS related infrastructure or back-office measures.

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Executive summary

Objective and scope

This report is the result of an internal study by ERTICO – ITS Europe, supported and funded by ACEA, the European Automobile Manufacturers' Association.

ACEA recognises the potential contribution of ITS (Intelligent Transport Systems) to reducing CO_2 emissions and increasing safety for heavy vehicles (3.5 tonnes or over) but needs evidence of the impacts of different ITS applications in order to guide further research and development. The ERTICO office has worked on projects related to eco- and energy efficient ITS for many years, and in 2015 produced a report on the CO_2 benefits of ITS in relation to passenger cars (Pandazis, Winder, 2015).

The scope of this study is to assess the contribution of existing Intelligent Transport Systems measures to reducing CO_2 emissions of heavy vehicles, to increasing their safety, or both. The focus is on heavy trucks, buses and coaches with Internal Combustion Engines (ICE) and the applications considered include in-vehicle systems and ITS-related infrastructure, back-office or cooperative systems. Because the study is focused on improving the environmental performance of heavy vehicles or the ways in which they are driven (and is aimed at guiding research in the automotive sector). The focus is on the level of improvement per kilometre driven and more precisely, where possible, by tonne-km of goods or passenger-km.

This report focuses on ITS solutions for which statistical evidence of fuel or CO_2 savings and/or potential safety improvements exist: where possible, validated data from trials, supplemented by studies involving driving simulators or modelling. On a secondary level, congestion and efficiency are considered: that is to say that projects and other initiatives are only considered for inclusion if there is evidence of fuel/CO_2 or safety benefits, but if such projects also report results relating to efficiency or congestion then this is included.

Overview of key results

The most promising (wholly or primarily) in-vehicle ITS applications identified in this study are the following:

- **Eco-driving support** can save an average of around 7% to 10% of CO_2 emissions on non-urban roads (excluding motorways). Benefits of up to 25% for HGVs and buses are possible in very localised situations, e.g. on the approach to junctions and traffic signals, provided there is no congestion, but overall benefits in urban areas are low, particularly where there is traffic congestion. Eco-driving support has been shown to reduce the incidence of illegal speeding on rural roads.
- **Eco-routing** can provide benefits of between 4% and 12% in urban areas for freight transport, but much lower in interurban situations (depending on the road network).

- **Lane Departure Warning (LDW) and Advanced Emergency Braking System (AEBS)** can reduce HGV accidents by 17% to 24%.
- **Truck platooning** can reduce CO_2 emissions by between 7% and 16% for following vehicles, depending on the inter-vehicle spacing. For the lead vehicle, between 1% and 8% CO_2 reduction is possible.
- **In-vehicle hazard warning** using vehicle-to-vehicle communications, as well as systems to enhance the driver's visibility (treating blind spots), have a high potential safety benefit.

The most promising ITS applications that are primarily infrastructure or back-office based the following:

- **Traffic signal systems** such as Energy Efficient Intersection Service (giving extended green time to selected buses or trucks) and GLOSA - Green Light Optimised Speed Advisory (giving count-down for the traffic light status change or speed information to help avoid stopping at a red light), can lead to CO_2 savings of around 5% in urban areas (typical range is zero to 10%, depending on traffic levels, spacing junctions and – for buses – locations of bus stops).
- **Delivery space booking** for goods vehicles can reduce CO_2 emissions by over 20% in the vicinity of the delivery location, as well as reduce illegal parking and its effects on traffic flow and safety. However, as a percentage of the overall journey, savings are expected to be 5%-10% for urban deliveries and lower for interurban trips. However, on the interurban level, **Intelligent Truck Parking** could achieve a small (2%) reduction in CO_2 emissions for long-distance freight transport by reducing extra distance driven to search for parking facilities, as well as contributing to a small reduction in HGV accidents by reducing collisions due to driver fatigue or illegal parking.
- Eco **ramp metering** for motorway access that gives extended green time to HGVs can result in a 14% to 17% CO_2 reduction in the immediate motorway ramp area, but 5% overall on the surrounding network.
- **Driver behaviour and CO_2 footprint monitoring** for large fleets can bring a reduction in CO_2 emissions of around 9% (range from 4% to 15%).
- **Intelligent Speed Adaptation** (ISA) can enable vehicles in urban areas to keep to the speed limit nearly all of the time, and particularly in areas with low speed zones (e.g. 30 km/h). ISA on rural roads has the potential to reduce accidents for HGVs of between 1% and 2% for an advisory ISA system and 4.5% to 5% for a voluntary system.

Table of contents

List of tables

List of acronyms and glossary

Acronym	Description
ACC	Adaptive Cruise Control *Cruise control that slows down and speeds up automatically to keep a safe space with the vehicle in front. The driver sets the maximum speed (as with standard cruise control), then a radar or LIDAR sensor watches for traffic ahead, locks on to the car in a lane, and instructs the car to stay a certain number of seconds behind this vehicle. ACC is now almost always paired with a pre-crash alert system.*
ACEA	European Automobile Manufacturers' Association
ADAS	Advanced Driver Assistance Systems systems developed to automate/adapt/enhance vehicle systems for safety and better driving. Safety features are designed to avoid collisions and accidents by offering technologies that alert the driver to potential problems, or to avoid collisions by implementing safeguards and taking over control of the vehicle.
AEBS	Advanced Emergency Braking System
ANPR	Automatic Number Plate Recognition *Roadside cameras and image treatment based on artificial vision (Optical Character Recognition – OCR) allowing the recognition of vehicle number plates in images*
ATCS	Adaptive Traffic signal Control Systems *System to optimise traffic flow by considering traffic flow at multiple sites rather than a single intersection, by enabling traffic signal controlled intersections to interact with each other. They adjust, in real time, signal timings based on the current network traffic conditions, demand, and system capacity.*
C-ACC	Cooperative Adaptive Cruise Control *ACC which includes information transmitted from a vehicle ahead in the same lane (v2v – vehicle to vehicle communications)*
CIP	Competitiveness and Innovation Programme (EU programme)
CO_2	Carbon Dioxide
CV	Commercial Vehicle (note this can be any weight or size, e.g. a light van, but for the purposes of this report we only count HDVs (buses, coaches and HGVs in classes N2 and N3, i.e. 3.5 tonnes or over)
DDWS	Drowsiness Detection and Warning System
EC	European Commission
EEI	Energy Efficient Intersection *Application in the Compass4D project*
ERTICO	ITS Europe organisation: a public-private partnership of over 110 members working together to promote Intelligent Transport Systems (see www.ertico.com)
ESC (ESP)	Electronic Stability Control (or Electronic Stability Program)

Acronym	Description
EU	European Union
FCD	Floating Car Data *Collection of vehicle position data, speed, direction of travel and time information from mobile phones in vehicles that are being driven in order to gather traffic data*
FCW	Forward Collision Warning
FOT	Field Operational Test
FP6, FP7	Sixth / Seventh EU Framework Programme for Research and Development
GHG	Greenhouse Gas
GLOSA	Green Light Optimised Speed Advisory *Traffic light phase information transmitted to drivers, together with advice on the best deceleration strategy to approach the intersection at the most energy efficient speed.*
GSI	Gear Shift Indicator
HDV	Heavy Duty Vehicle (buses coaches and HGVs (trucks) with a gross combination mass of over 3.5t
HGV	Heavy Goods Vehicle (truck with a gross combination mass of over 3.5t (i.e. UNECE categories N2 and N3)
HuD	Head-up Display *A transparent display that presents data without requiring users to look away from their usual viewpoints. Originally developed for military aviation, in this case adapted for road vehicles by displaying information in the windscreen.*
i2v	Infrastructure to Vehicle communications *Note also v2i: vehicle to infrastructure, v2v: vehicle to vehicle, v2x: vehicle to anything*
ICT	Information and Communications Technologies
ITP	Intelligent Truck Parking
ISA	Intelligent Speed Adaptation *ISA includes informative systems which warn the driver when the speed limit is reached or exceeded by visual, audible or haptic (e.g. via the acceleration pedal) means. They may also register the speed use of driver for later feedback purposes. Applications which only warn or advice the driver are called voluntary ISA and those which can directly control the speed of the vehicle and thus prevent the driver from exceeding the speed limit are called mandatory ISA. In most cases, the driver has the possibility to switch off the system.*
ITS	Intelligent Transport Systems
LDW	Lane Departure Warning
LTL	Less than truckload shipping (loads up to 9 tonnes)

Acronym	Description
M1-3	UNECE categories for passenger carrying vehicles: M1: passenger cars (up to 8 seats + driver's seat); M2: small bus (over 8 seats + driver's seat and weight up to 5t); M3: large bus (over 5t).
N1-3	UNECE categories for goods vehicles: N1: light goods vehicles up to 3.5t; N2: HGV over 3.5t and not exceeding 12t; N3: HGV over 12t
OEM	Original Equipment Manufacturer
PCC	Predictive Cruise Control *Cruise Control system that looks for its route a short distance in advance and adjusts engine output to the road ahead (gradients, etc)*
RHW	Road Hazard Warning *Application in the Compass4D project*
RLVW	Red Light Violation Warning *Application in the Compass4D project*
rpm	Revolutions per minute (engine speed)
t	Metric tonne (1000kg)
TRL	Technology Readiness Level *A method of measuring product or programme concepts, technology requirements, and demonstrated technology capabilities. Based on a scale from 1 to 9, with 9 being the most mature technology.*
UNECE	United Nations Economic Commission for Europe
UTC	Urban Traffic Control *Method of coordinating traffic signals (traffic lights) in a network by the use of timing plans loaded on a central computer. Timing plans that vary by time of day are loaded by the computer and the timings on street change accordingly*
V2V	Vehicle to Vehicle communications *See also I2V*
VMS	Variable Message Sign *Roadside or gantry-mounted electronic sign using Light-Emitting Diode (LED) technology to display text, pictograms or both, to convey information, advice or instructions to drivers.*
VSL	Variable Speed Limits Speed limits that change based on road, traffic, and weather conditions, with display using electronic signs.

1. Introduction

1.1 Background

The present study has been undertaken in the context of the challenges faced by the European car, bus and truck industry (OEMs) and its representative association **ACEA** (the European Automobile Manufacturers' Association) in reducing the CO_2 footprint of vehicles while also improving the safety of road transport. Transport accounts for about a quarter of Greenhouse gases (GHGs) in Europe and the road sector accounts for around 70% of total transport-related GHGs.

The vehicle manufacturing industry faces ambitious EU targets for CO_2 reduction. The EU targets a 20% reduction in greenhouse gas emissions by 2020 with respect to 1990 levels and 60 % by 2050. The desired improvements cannot be realistically achieved from the vehicle's engine alone; neither can environmental goals be met by vehicle manufacturers in isolation. An integrated approach is needed both in terms of working with different stakeholders and using applications within and external to the vehicle to make road transport greener, safer and more efficient. One of the key opportunities for achieving these goals is more widespread and coordinated deployment of **Intelligent Transport Systems (ITS)** in the road and automotive sector.

In 2014, ACEA launched an integrated approach to reducing CO_2 emissions from Heavy Goods Vehicles (HGVs) in Europe, which commenced with a study by Transport & Mobility Leuven, producing a first version of a report entitled **GHG reduction measures for the Road Freight Transport sector up to 2020**. ACEA then initiated a consultation process on this report between November 2014 and June 2015, bringing together 17 relevant stakeholders representing the different aspects of this integrated approach: Vehicle & trailer; Fuels & alternative fuels; and Operations (infrastructure and logistics). This resulted in an update to this report and its release in July 2015[1].

A parallel activity dealing with the CO_2 challenge with respect to passenger cars was launched by ACEA in early 2015: the **Joining Forces** initiative, which brought together stakeholders in a series of workshops covering four main themes: ITS and the connected car; Eco-driving; Infrastructure; and Fuel options. This led to a report by the appointed consultants and workshop moderators, entitled **Joining forces to tackle the road transport CO_2 challenge**, which was publicly launched by ACEA in May 2016[2].

One of the stakeholders in the Joining Forces initiative was **ERTICO**, which contributed to the ITS/connected car and eco-driving themes. **ERTICO – ITS Europe** is a public-private partnership which serves as a cooperation platform for the development and deployment of Intelligent Transport Systems in Europe, across all land transport modes but with a major focus on the road sector. ERTICO's vision is to bring intelligence to mobility to ensure safer, smarter and cleaner transport systems. ERTICO comprises over 110 partners, who cooperate in different research and deployment

[1] Breemersch, T., Akkermans, L. (2016f)
[2] ACEA/Aspect Consulting (2016)

projects, platforms (cooperation activities), knowledge sharing (including ITS Congresses organised by ERTICO), as well as other advocacy and dissemination activities. ACEA and several of its members in the automotive industry are ERTICO partners, alongside other partners from several sectors including national and local public authorities, industrial partners, the research and university sector, user associations, telecom and network operators and service providers.

As with ACEA and its member organisations, ERTICO has a strong interest in making road vehicles "greener", including actions to reduce CO_2 and other emissions caused by road transport. It has participated in several EU-funded projects working specifically towards this goal, including ECOSTAND, eCoMove, Amitran and ecoDriver[3], as well as numerous other projects and activities focusing on connected vehicles, Field Operational Tests (FOTs), Cooperative ITS (C-ITS) for cities and for logistics.

In November 2014, ERTICO released a **thematic paper on ITS for Energy Efficiency**[4], which presented the current situation as well as the potential contribution of ITS measures to reducing CO_2 emissions or fuel consumption. The aim of this paper was to show that several ITS measures already exist that can contribute to this important goal. This was followed up in 2015 with an **ERTICO Partnership study** supported by ACEA on the scope of **ITS for reducing CO_2 emissions for passenger cars**[5], which studied existing evidence from in-vehicle systems and infrastructure-based ITS applications impacting vehicles. This study ran parallel to the Joining Forces initiative and collaborated closely with it.

As a continuation of ACEA's integrated approach for heavy duty commercial vehicles, and as a follow on to the ERTICO study for passenger cars, ACEA requested that ERTICO investigate the scope of ITS applications to reduce CO_2 emissions and also to improve safety, efficiency and congestion in the **HDV commercial vehicle sector**. This study – "ITS for Commercial Vehicles", or **ITS4CV** for short – was consequently agreed to by the ERTICO Supervisory Board.

1.2 Scope of the study

Intelligent Transport Systems (ITS) can be defined as systems or services using Information and Communications Technology (ICT) for inland transport. It includes the collection, use and process of data from different sources necessary to optimise these systems or services.

ITS applications can provide assistance, information, guidance or control to transport or infrastructure operators, administrations and/or end users (including drivers, passengers, pedestrians, logistics clients, etc.). They can bring benefits such as more efficient operations (e.g. through better traffic flow and reduced congestion), improved safety and security, better services, accessibility or "comfort" for users, and environmental benefits including reducing emissions from transport.

The **present study** focuses in particular on ITS measures related to the following sectors:

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[3] See Chapter 6.1 for details and links to these projects
[4] Pandazis, J-Ch. (2014)
[5] Pandazis, J-Ch., Winder, A. (2015)

- ITS measures **within Heavy Duty Vehicles (HDVs)** which can reduce CO_2 emissions and/or increase safety. These cover in-vehicle applications which use data, also from outside the vehicle, to build estimation or prediction in order to either guide the driver or control the vehicle in some way.
- ITS related **infrastructure, back-office or cooperative systems** which can reduce CO_2 emissions and/or increase safety for HDVs.
- Studies identified fulfilling the above criteria are also checked for any reported effects on efficiency of transport (freight or passenger) operations and congestion effects.

The range of ITS applications considered in this study covers those that have an **impact on the vehicle performance** in reducing fuel consumption and therefore CO_2 emissions, or in augmenting safety / reducing accidents (their probability or severity).

1.3 Report structure

Chapter 2 presents the approach and methodology for this study, including the applications considered and the different types of indicators and data.

Chapters 3 and 4 present the findings relating respectively to in-vehicle systems and infrastructure (or back-office) systems that impact upon vehicles. These provide descriptions of the studies or deployments which contribute (purpose, scope and key CO_2 or fuel saving and/or safety, efficiency and congestion related results) and the headline results generated.

Chapter 5 summarises the key applications contributing to the goals of the study and their effects, classed by type of operation (vehicle and road type).

2. Methodology

2.1 Overall approach

The overall approach has been to collate, analyse and (as far as possible) compare results from other projects, studies and implementations. This study does not produce new results or data.

Several previous activities have studied the CO_2 reduction and safety potential of ITS applications, while many others have considered fuel savings, which can be taken as a proxy for CO_2 reduction. Most have focused either on all traffic or on cars only, but some have covered commercial vehicles, particularly goods vehicles.

Some studies have used modelling to predict likely effects and others have involved trials or deployments on various scales. Therefore, the types of data and their reliability (or transferability) can vary widely. This report cites all data sources in order to maintain transparency. Data from different sources or which was collected or calculated differently are not aggregated, averaged or weighted in any way.

The approach has been to identify and review relevant studies and deployments in the heavy commercial vehicle sector (trucks, buses and coaches), focusing on those producing quantitative data. Although the scope is Europe, data from elsewhere is included where it is relevant and where solutions are potentially transferable.

As an ERTICO Partnership study, ERTICO partners were invited to contribute data to this study, as well as ACEA partners and other stakeholders. Relevant stakeholders were contacted by email outlining the scope of the study and type of data requested. Those contributing are acknowledged on the inside front page (ii).

2.2 Definition and categorisation of relevant ITS applications

Several different ways of defining categorising Intelligent Transport Systems are possible. Given the motivation behind the study was to tackle CO_2 emissions, we started from the classification used in the ECOSTAND[6] project, subsequently adapted by the Amitran[7] project (both of which focused on CO_2 emissions). The categorisation in Amitran[8] comprises the following six high level categories:

1. Navigation and Travel Information;
2. Traffic Management and Control;
3. Demand and Access Management;
4. Driver Behaviour and Eco-driving;
5. Logistics and Fleet Management;
6. Safety and Emergency Systems.

Applications from all of these categories are included within the scope of this report, with the exception of Demand and Access Management, as we focus here on benefits per kilometre, per passenger-km or freight tonne-km, or per trip.

It was decided in consultation with ACEA to include in this study the ITS applications listed in Table 1 below. These were chosen as the most promising with respect to CO_2 emissions, safety or both. Many of the measures were already studied in the 2015 ERTICO study with respect to cars, so some of the data sources were already known, along with evidence of effectiveness in the passenger car sector. To these, several applications relating to safety, logistics, Cooperative ITS and automation were added which are the subject of current research and deployment projects. Some of these, such as platooning and automated driving, are not yet deployed in real world situations so data is limited.

The table below divides the ITS applications into ones which are principally on-board and infrastructure (or back-office) based. Many applications are cooperative, linking the vehicle to the infrastructure and/or the fleet operator's back office, however for the purposes of this report they have been classified according to where most of the data comes from and where the system is mainly operated. This distinction has been made because the in first category (on-board applications), the main deployment actors are the vehicle manufacturers (also component and after-market suppliers), whereas in the second category, the lead actors are the road operators, public authorities or fleet operators (logistics and public transport companies), even though some of these applications have an on-board driver interface as well.

[6] ECOSTAND (2010-2013)
[7] Amitran (2011-2014)
[8] http://amitran.teamnet.ro/index.php/ITS_applications lists the applications within each category which are relevant in terms of potential CO_2 reduction.

Table 1: ITS applications covered in this study

ITS category	On-board ITS applications in commercial vehicles	Infrastructure and back-office-based ITS applications impacting commercial vehicles
Navigation and Travel Information	• Eco-routing	
Traffic Management and Control		• Traffic signal control including green wave • Ramp metering for HDVs • Traffic control & vehicle monitoring (particularly for hazardous loads)
Driver Behaviour and Eco-driving (including automation)	• Eco-driving support • Predictive powertrain control • Automation, including Cooperative ACC (Adaptive Cruise Control) and platooning	• ISA (Intelligent Speed Adaptation) • Driver behaviour & CO_2 footprint monitoring
Logistics and Fleet Management		• Intelligent Truck Parking • Delivery space booking • Fleet management & routing • Cargo transport optimisation, fleet management & tracking • e-Freight.
Safety and Emergency Systems	• In-vehicle road hazard warning • Lane Departure Warning (LDW) • Advanced Emergency Braking Systems (AEBS) • Electronic Stability Control (ESC)	

2.3 Categorisation of result types

This study has identified different types of activity producing output. Activities include EU projects (research and development, demonstrations); national or local projects including public authorities, industry, research institutes, etc.

The types of output are:

- Data on fuel savings, reduced distances, speed changes, safety or efficiency gains coming from trials or deployments on public roads;
- Modelled or calculated data, including extrapolated or scaled-up data (results of impact assessment studies).

For safety benefits, data on actual changes to numbers of accidents and casualties can of course only come from before-and-after studies of real implementations taking place over a significant period of time. Since research projects and trial deployments cannot generate this data, changes to driving dynamics (using indicators like average speed or percentage of trip over which the legal speed limit is exceeded) are used as a proxy. Modelled data (for example based on analysis of different accident types and causation factors) can also contribute.

Different data present different levels of data confidence or robustness, as well as scalability and transferability. This report concentrates as far as possible on quantitative and validated data which can be referenced, and where the conditions that applied generating and validating the data are known. However in some situations data from modelling or simulation studies has been used, particularly for applications for which little or no validated real world data is available. Where this is the case, it is clearly explained, as the level of confidence or transferability of these outcomes may well be lower, depending on the data and techniques used.

The reliability of data depends on the scope of the trial or implementation, for example the extent to which data from a local trial site can be applicable globally depends on local or national specificities of the trial site. Factors to be considered include:

- Range of different geographical area(s), i.e. a single trial site or several in different countries;
- Type(s) of road network(s) involved (urban, rural, motorway, etc.) and speed limits;
- Traffic situation (fluidity) and vehicle mix;
- Environmental conditions;
- Year of study (recent or old);
- Trial or evaluation period;
- Number of vehicles or drivers involved;
- Vehicle types: driveline characteristics (manual, automatic, hybrid), fuel type, weight;
- Load factor;
- Distances driven;
- Scale of deployment (geographical or network coverage, or penetration rate among vehicles or users);
- Logic of the operation of the ITS application (e.g. similar systems may be operated according to different procedures, parameters or algorithms);
- Approach to evaluation where two or more ITS applications are implemented together;
- Means of comparing to a baseline situation without the ITS application.

2.4 Data collection and measurement units

Data has been collected from a number of stakeholders including ERTICO partners, participants in relevant projects, iMobility Working Group members, conference papers, Internet search, etc. The key data from trials is summarised in tables the introductory sections of Chapters 3 and 4.

2.4.1 CO_2 reduction

Measurement units used are most commonly a percentage reduction in fuel use from a "before" situation without the ITS measure to an "after" situation with the measure being used. In some cases, fuel efficiency (before and after) in litres per 100km (or miles per gallon, which have been converted to litres/100km) or CO_2 efficiency in grams per kilometre are given by studies. In others a reduction in absolute CO_2 emissions in tonnes is given.

Fuel use savings are assumed to be equivalent to CO_2 savings for the purposes of this report (an assumption that is used by almost all studies looking at CO_2 effects). While this would be true in percentage terms, the absolute reduction in CO_2 emissions from a given fuel saving would vary according to the fuel being used, the particular vehicle and the way in which it is driven. CO_2 emissions from a litre of diesel are between 2.6 and 2.7kg (various sources give slightly different figures, e.g. 2.62kg in a study for the European Commission[9] and 2.66kg by the UK Government[10]).

2.4.2 Safety

HGVs (over 3.5t) are involved in about 17% of the fatalities and 7% of serious accidents in the EU and the percentages for buses and coaches (over 3.5t) are 3% and 2% respectively. Around 90% of all accidents involve human error, 30% are influenced by the environment (visibility, road surface, etc.) and 10% due to a vehicle-related issue (e.g. tyre blowouts) – note the totals come to more than 100% as two or three of these factors combine to cause accidents in many cases[11]. The most common human factors contributing to HGV accidents are not looking/noticing hazards and misjudgement of other vehicles or pedestrians (path or speed). Where collisions are caused by (or contributed to) by heavy vehicles the lack of visibility due to blind spots is the most common factor.

The potential effects of ITS applications on safety are difficult to ascertain, as changes in the actual number of accidents, injuries or fatalities following the deployment of a system can only be measured with any degree of confidence in cases of a major deployment (in terms of network coverage) over a significant period of time. Otherwise, there is a need for extrapolation, modelling or proxy data. The effects of a system (whether it makes driving smoother, reduces speed or red light violations, increases visibility, reduces traffic conflicts, etc.) cans sometimes be measured and compared with data on the causes of accidents or casualties. However, in some cases assumptions would need to be made on the extent to which drivers would have avoided a risky situation on their own without the aid of the ITS application. For example, according to Volvo Trucks (2013):

- 15% to 20% of those killed or seriously injured in HGV accidents are truck occupants. 50% of these accidents are single accidents and 30% are collisions with another heavy truck.

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[9] IEEP (2009), "Environmentally Harmful Subsidies: Identification and Assessment", Annex 5. Study for the European Commission, DG Environment: http://ec.europa.eu/environment/enveco/taxation/pdf/Harmful%20Subsidies%20Report.pdf

[10] UK Defra and Department of Energy and Climate Change (2012), "2012 Guidelines to Defra / DECC's GHG Conversion Factors for Company Reporting: www.gov.uk/government/uploads/system/uploads/attachment_data/file/69554/pb13773-ghg-conversion-factors-2012.pdf

[11] Volvo Trucks (2013)

- 55% to 65% of those killed or seriously injured in heavy truck accidents are car occupants.
- 15% to 25% of the victims in HGV accidents are vulnerable road users (pedestrians, cyclists and motorcyclists), with many of these accidents occurring at low speed and with limited visibility being one of the main causes. In more than 75% of fatal accidents involving pedestrians and cyclists, the unprotected road user is run over by one or more of the truck wheels.
- 10% of all HGV accidents involve the truck running off the road accidents and 12% are due to the truck colliding with the rear of another vehicle.
- About 20% of all heavy truck accidents occur during night hours.

Hence, a range of different indicators can be used to measure *potential* changes to the level of safety. These include:

- Changes to average speed. This is not a particularly reliable indicator as small average speed reductions may not have any safety benefit on certain types of road (for example motorways) or on roads where speeds are not generally an accident causation factor. Furthermore, with respect to heavy vehicles, average speeds are usually lower than for cars and speeding is hence a less common accident causation factor for HDVs. Despite the unreliability of this indicator, it is the most common type of data collected from trials with relevance to safety.
- Percentage time spent driving at an unsafe speed: usually this means time (or distance) driven at over the legal speed limit. This data is less common as it requires constant knowledge of the vehicle's speed and the speed limits for each section of road used. It is also rather crude as it does not distinguish between driving at only slightly over the speed limit and committing a serious speeding violation. However it is a more reliable indicator of safety than changes to average speeds. For HDV drivers, whose ability to drive at excess speed on motorways is restricted by speed limiters, the main safety benefit would occur on rural roads where the speed limit is lower than that imposed by the speed limiter.
- Effects on braking and other "smooth driving" aspects.
- Reducing potential conflicts between traffic flows or between vehicles and pedestrians, for example using traffic signal control.
- For warning systems (red light, speed, detection of persons or objects, etc.) the number of alarms activated for a given number of kilometres driven can provide an indicator of the potential safety benefit, particularly where statistics exist on the likelihood of a given situation-type leading to an accident and its likely severity.

3. On-board ITS applications in commercial vehicles

3.1 Navigation and travel information

3.1.1 Overview

Navigation systems for vehicles are based on maps to guide the driver through the network. Dynamic navigation integrates up-to-date traffic information (e.g. RDS-TMC information) and is either integrated into the vehicle, or attached as an aftermarket or nomadic application (Smartphone or specific HMI display). Some systems are enhanced by specific information such as estimated fuel consumption, including real-time information. This is **eco-routing** or eco-navigation. Sometimes these applications are combined with eco-driving support.

3.1.2 Contributing studies and evidence

This application has effects on pre-trip route choice, departure time choice and on-trip route choice. The reliability of assessment is however low, as its effectiveness depends on the nature of the journey and road network (e.g. availability of different route options), the degree of flexibility (generally lower for commercial heavy vehicles than for private cars) and the driver's local knowledge. Trials of such systems therefore need to be naturalistic and cannot follow identical runs without (baseline) and with the system. Hence, individual results are not reliable but larger scale trials, e.g. using fleets over a period of time, have produced promising savings, albeit with often wide variations in benefit depending on the local situation and driver knowledge or behaviour.

On a societal level, dynamic navigation and eco-routing may in some cases lead to an increase in traffic, accident risk and pollution along secondary (diversionary) roads, which avoid already congested roads, if suitable traffic management measures are not put in place (e.g. local HGV restrictions). Some studies have shown that while there are benefits in terms of reduced travel time (and often reduced distance, fuel consumption and emissions) for users of the system, there are sometimes negative externalities for non-users. An integrated approach to traffic management and individual vehicle routing is therefore important to maximise benefits and avoid unwanted effects.

Use in freight transport can increase the efficiency of vehicle use, allowing trucks to be rerouted to achieve maximum capacity utilisation and to reduce vehicle-kilometres. The advantage is greatest when a small number of people has access to such technology and is reduced with higher levels of penetration. Travel time reductions for all users are greatest if the road network is used to a level near its maximum capacity and in the event that one-off (isolated) disruptive incidents take place on the network.

A trial by Navteq[12] using both cars and commercial vehicles (generally vans, so not within the scope of this study) found an average fuel saving of 12% using eco-navigation systems.

[12] Navteq (2010)

These relatively high figures can be applicable to urban distribution, but for longer distance freight transport the savings generated by routing advice are much lower in terms of percentage of the whole journey. Effects also vary greatly according to the experience and knowledge of the driver: for regular trips between the same locations where the route is known (particularly for very short distance local distribution and for vehicles running on fixed routes, e.g. scheduled bus services), benefits are likely to be very low or non-existent.

Most other studies (like the above, also those reported in the ITS4rCO2 study by ERTICO in 2015) either covered cars only or did not distinguish between cars and other vehicles. Evidence from TomTom (see eco-driving support systems under Chapter 3.2) showed that their fleet management tool which combines eco-navigation and eco-driving can reduce distance driven by 16% for fleets and increase fuel efficiency by 11%.

Lastly, a US study focused on acceptance of navigation systems by truck drivers, with a survey in 2012 among 677 professional truck drivers finding that trust in navigation systems is generally high with 67% of drivers “somewhat trusting” and 6% “very trusting” of the accuracy of the information given[13].

Table 2 summarises the studies contributing to this application.

Table 2: Data summary for in-vehicle systems: Navigation and travel information (eco-routing)

Project or activity name	ITS measure	Description	Type of work (trial, study, etc.) and year	Achieved benefits
Navteq (DE)	Eco-routing	On-road trial with 90 vans, average 222km driven per vehicle[14]	Naturalistic driving (N1 and N2 trucks, mixed urban/ suburban, 2008)	12% (applies to routing in urban and suburban areas for mostly short trips)

3.1.3 Overall assessment

CO_2 and fuel reduction

- Up to 12% but varies significantly in function on driver (knowledge of road network), trip length and road types (network density and traffic density, availability of alternative routes). For urban logistics, a 10% saving is feasible (assuming that the required loading and unloading points are not identical for each trip) but for longer distance freight, 5% is at the higher end of

[13] Park, L. & Fender, K. (2013)

[14] Note that this trial was with vans (light vehicles) so is not within the scope of this report, but is included for indicative purposes as it deals with commercial vehicles and was significant trial.

the benefit range (based partly on figures for cars), assuming a range of alternative routes is available.

There is no measured or expected impact on safety.

3.2 Driver behaviour and eco-driving (vehicle-based, including automation)

3.2.1 Overview

Eco-driving is driving in an efficient way so as to minimise fuel use and emissions. Taking certain pre-trip measures (for example appropriate vehicle maintenance) and driver training can make driving "greener", but ITS applications to support drivers and fleet managers also have a major potential. In-vehicle eco-driving support systems can help drivers to adopt and maintain a more eco-friendly driving style, in particular by using data on the road ahead (topography, curvature, junctions, traffic, etc.) from maps and/or sensors to calculate advice to the driver (speed and gear selection) in real time, for example advice to reduce speed on the approach to a junction or bend. Such in-car systems (using a visual and/or haptic HMI) can have a greater potential than training as they can help maintain a driver's "eco-performance".

Eco-driving applications can store trip records and give the driver overall feedback, advising on the elements where improvement most needs to be made. This type of feedback is particularly relevant in the commercial vehicle sector, where the fleet manager can analyse fuel consumption, the performance of different drivers and target coaching according to their needs. Eco-driving support systems which promote smoother driving usually also have safety benefits. Systems however need to be able to provide advice to the driver in a non-distracting way in order to ensure safety.

Simple gear-change advice indicators which rely solely on the engine speed are not included as ITS here (as they are entirely internal to the vehicle), however map- and sensor-based systems fall under the scope of this report, as they adjust advice according to upcoming road features and/or the presence of other vehicles. More advanced applications may include real-time traffic light status information (these are GLOSA applications – Green Light Optimised Speed Advisory, and are covered in Chapter 4).

Fleet management systems may include eco-driving support with other services such as eco-routing (navigation). They may also take into account aspects such as weather conditions and load factor, which can affect driving styles and fuel consumption.

Predictive Powertrain Control uses vehicle, infrastructure and topographic data to anticipate a fuel saving driving style. Systems currently focus on the topography, using slope data ahead of the vehicle to generate a predictive speed profile to optimise the control of the powertrain.

Changes in the road environment such as a change in gradient ahead of the vehicle are predicted and the speed is adapted for optimal fuel economy. It is often associated with Predictive Gear Shifting. The objective for both is to maximise the use of the highest possible gear in order to minimise rpm.

Cooperative Adaptive Cruise Control (C-ACC) is an enhancement to Adaptive Cruise Control (ACC) systems that can optimise a vehicle's speed profile by adding communication with other vehicles and/or infrastructure. Like classic ACC, C-ACC influences speed, headway and driving dynamics, however due to the communication with other vehicles or infrastructure it takes more parameters into account for a better optimised operational profile, leading to a further reduction in fuel consumption.

Automatic guidance or **platooning** of vehicles offers is potentially a key enabler for improving safety and efficiency of road transport, with the greatest opportunity (and most research and testing so far) being the platooning of heavy trucks. Here, platooning refers to a situation in which the trucks are coupled electronically and exchange information, but they still require the presence of drivers in order to steer the trucks and manage entering/leaving the platoon. The leading truck is driven conventionally and the following ones are temporary autonomous mode, regarding brake and acceleration, Platooning and V2X (C-ACC) have a strong relation since V2X is a basic requirements for Platooning at short distances.

Automation beyond truck platooning, i.e. Level 4 (high automation) and Level 5 (full automation) has had a high profile in the media recently, with respect to advances in driverless cars. However there have so far only been a few isolated prototypes in the heavy vehicle sector, e.g. Daimler trucks in Stuttgart. There are no public quantifiable figures yet but the main benefit is expected to be safety. Environmental benefits from automated trucks (excluding platooning) are not yet quantifiable, but some positive benefit is expected due to smoother accelerating and braking, as well as potentially lower maximum speeds.

3.2.2 Contributing studies and evidence

Like eco-routing, the benefits provided by **eco-driving** applications can vary significantly, depending on the driver's performance without the system, the vehicle and road type, levels of traffic congestion, etc.

The EU project ecoDriver developed and tested different systems across cars and heavy vehicles, and found reductions in fuel consumption and CO_2 averaging 4.2%, with the highest saving (5.8%) on rural roads. The embedded (integrated into the vehicle) ecoDriver system developed and tested by Daimler Trucks on a Mercedes-Benz Actros with trailer (without cargo) gave fuel savings of around 10% (ranging from zero, typically in congested traffic, to a maximum of 25% on some sections of road).

The TomTom OptiDrive 360 (also developed in ecoDriver project: combined eco-routing and eco-driving support system) was analysed in the UK with a mixed fleet (mostly vans) belonging to SGN (Scottish Gas Network). It resulted in a 16% reduction in distances driven and an 11% improvement in fuel efficiency. Furthermore, inefficient driving events were reduced by 24%, idling was reduced by

68%, time spent speeding was reduced by 15% and vehicle maintenance costs were reduced by 5%. Note that this system is more comprehensive than just eco-driving advice.

In the EU project eCoMove, CO_2 and fuel savings for trucks between 2.4% and 13.3% was reported using simulators, and from 12% and 15.3% in the field.

Acceleration limiters and speed limiters were tested on trucks in the EU project Freilot. The aim was to improve safety rather than to reduce fuel consumption: speeding above the legal limit was reduced by up to 20%, whereas the effect on fuel use was broadly neutral (-2 to +2 % change). However with eco-driving support, maximum fuel reductions between 6.6% in the 0-100 km/h range and 15.3% in the 0-50 km/h range were measured (across four test sites).

The European project COSMO tested an enhanced bus intersection logistic with eco driver support. A small-scale trial in Sweden (3 intersections and 6 buses equipped) informed the bus drivers of the status of traffic lights so that they could adjust their speed and potentially reduce emissions. However the trial findings did not show any significant saving. Low driver compliance with the system was found to be an issue, as was the position of the Human-Machine Interface. Such systems for buses could therefore still have some potential for CO_2 reduction with greater compliance and a better HMI.

The Scania Driver Support system[15], which provides real-time coaching in HGVs with tips and feedback via a visual HMI, achieved a 10% improvement in fuel efficiency (from around 37 to 33 litres/100km) in trials in northern Sweden and Norway[16].

A trial in Sweden conducted by Chalmers University concerned an eco-driving assistance system on an urban bus route and found a saving of 6.8% in fuel and CO_2 emissions[17]. The system gave feedback to bus drivers on average fuel consumption, harsh deceleration, speeding, idling and rollout.

A similar study by VTT in Finland involved 23 drivers of urban buses in Helsinki using an eco-driving support application over 16 months and a reference group of 120 drivers who did not use the system. It found an average 3.8% reduction in fuel consumption and CO_2 in the long term[18].

A GNSS data-based approach to eco-driving support for trucks is being tested at six European pilot sites in the CO-GISTICS project: results are expected in spring 2017.

Predictive Powertrain Control applications already exist on the market from OEMs like Scania (Active Prediction), Daimler (Predictive Powertrain Control) and Volvo (I-See), and an average reduction of 5% fuel consumption (and therefore CO_2 emission) has been measured by these OEMs.

[15] www.scania.co.uk/products/trucks/safety-driver-support/driver-support-systems/scania-driver-support
[16] Lundström, A. (2011)
[17] Strömberg, H. H. & Karlsson, M. (2014)
[18] Innamaa, S. & Penttinen, M. (2014)

A Swedish study which included a field experiment with a predictive control system for heavy trucks designed to incorporate the geometry of the road ahead into the cruise control mechanism found fuel and CO_2 savings of 3.5% over a 120 km long trip (without an increase in travel time).

Cooperative ACC can help maintain a safe distance, and it can prevent some rear-end accidents from happening. It can help make driving smoother (better “anticipation” for disturbances in the traffic flow ahead).

The system can influence the infrastructure capacity by minimising the headway and aligning the speed. Tests on trucks in the euroFOT project found an average 2% fuel saving with C-ACC. The ICT-Emissions project covered cars only, but identified fuel savings of 1.5 to 7.5%, depending on road type.

Regarding **platooning**, trials have shown that it is feasible and the main barriers are legal (liability in case of accident) as well as public acceptance and non-user safety (interaction with other vehicles using the same infrastructure). Business models for platooning also remain to be established (e.g. some kind of payment by the following vehicles to the owner of the leading vehicle in exchange for the increased efficiency offered).

An ongoing US project, “Driver Assistive Truck Platooning” (DATP) has initial results that indicate a 4 to 7% reduction in CO_2 emissions for trucks with platooning. The EU project SARTRE recently found savings of 1 to 8% for the leading truck and 8 to 16% for the following trucks with platooning and traffic simulations done in Japan found very similar figures (zero to 9% for the leading truck and 12 to 22% savings for the following trucks).

Platooning clearly also has potential to increase road capacity and reduce congestion, due to closer spacing of vehicles, but the extent of these benefits would be very much dependent on the type of infrastructure (e.g. number of traffic lanes) and the mix of platooned vehicles versus conventional ones. It might even be that capacity is reduced if a separate lane for platoons is required in certain situations or if dynamic entering or leaving of platoons requires extra capacity.

Table 3 summarises data relating to driver behaviour systems including eco-driving support, Predictive Powertrain Control and automation (including C-ACC and platooning).

Table 3: Data summary for in-vehicle systems: Driver behaviour and eco-driving (in-vehicle systems, including automation)

Project or activity name	ITS measure	Description	Type of work (trial, study, etc.) and year	Achieved benefits
eCoMove (EU)	Eco-driving support	Trial on 14km urban route in Helmond (NL)	Urban on-road trial (1 N3 truck, 2013)	12% to 15.3% CO_2 reduction
eCoMove (EU)	Eco-driving support with visual HMI	Eco-driving simulator test on simulated urban network in Munich (DE)	Truck driving simulator, urban (2013)	2.4% to 13.3% CO_2 reduction
ecoDriver (EU)	Eco-driving support with visual HMI	Trial on 109km mixed route between Stuttgart and Ulm (DE) with 1 HGV	Interurban on-road trial (N3 truck, 2015)	0 to 25% CO_2 reduction. Average was 10% in non-urban areas. Zero or close to zero benefits on urban or congested networks, highest benefits on rural roads.
Freilot (EU)	Eco-driving support	Urban ITS measures to increase energy efficiency of freight services: Driver – Enhanced "green driving" support in trucks (ES, FR)	Urban demonstration (N2 and N3 trucks, 2011)	Up to 15.3% fuel and CO_2 reduction in urban areas (speed 50km/h or below); up to 6.6% reduction overall (for all road types)
Scania (SE)	Scania Driver Support (eco-driving)	Deployment of real-time coaching in HGVs with tips and feedback	Interurban on-road trials (N3 trucks, 2011)	10% improvement in fuel efficiency and CO_2
Chalmers University (SE)	Eco-driving support	Trial using 54 urban buses	Urban on-road trials (M3 buses, 2011)	6.8% fuel and CO_2 reduction in urban areas for buses
VTT (FI)	Eco-driving support	Trial using 23 bus drivers	Urban on-road trials (M3 buses, 2013)	3.8% fuel and CO_2 reduction in urban areas for buses
SARTRE (EU)	Truck platooning	Trials of HGV platoons in Spain and Sweden	Interurban on-road trials (N3 trucks, 2013)	1 to 8% for the leading truck and 8 to 16% for the following trucks

3.2.3 Overall assessment

CO_2 and fuel reduction

- **Eco-driving support:** 2% to 15% reduction, with most results for commercial vehicles in the 4 to 10% range. This varies according to several factors, the most important one being the driver's initial performance and reaction to the system. A "good" driver who already drives in a fuel-efficient way will gain little improvement from such a system, as would a driver who is unwilling to put into practice the advice and tips given by the system. Hence the 4 to 10% potential applies to "average" drivers who have not received eco-driving coaching but who are willing to adapt their behaviour on the system's advice.
- **Predictive Powertrain Control:** 3% to 5% savings for interurban HGVs assuming moderate hilliness and relatively straight roads (e.g. motorways). Savings would be lower (or indeed negligible) at slow speeds (e.g. in urban areas) or on flat terrain.
- **C-ACC:** Average 2% reduction (euroFOT project).
- **Platooning:** Zero to 9% reduction for leading truck, 7% to 22% for following trucks (from simulation modelling).

Congestion

- **Eco-driving support:** No effect measured specifically for heavy vehicles, but effect could be negative in congested networks as eco-driving behaviour can reduce road capacity.
- **Platooning:** With 100% penetration, road capacity can be increased by 30%. Significant increase in flow at 60% penetration[19].

Efficiency (other than distance or fuel savings)

- Reduced vehicle maintenance costs are likely (up to 5% as reported in one example by TomTom Telematics).

3.3 Safety and emergency systems

3.3.1 Overview

In-vehicle road hazard warning systems monitor the road in front of the vehicle and warn the driver when a collision risk is detected. Subsystems may include detection systems for other vehicles, pedestrians or animals.

Lane Departure Warning (LDW) and **Advanced Emergency Braking Systems (AEBS**) systems also come under this category, however these are both mandatory for heavy vehicles in the EU, whereas this study focuses on systems which are less widely deployed in order to assess their potential for contributing towards the objectives. LDW warns the driver when the vehicle begins to move out of its lane (unless a turn indicator is on in that direction). It relies on sensors and its performance depends on the visibility of lane markings. AEBS employs sensors to monitor the proximity of vehicles in front, detecting situations where the speed and distance indicate an imminent collision. Emergency braking

[19] DATP study, Auburn University for US Federal Highway Administration, 2015

can then be automatically applied following a warning phase (3 seconds before the expected collision).

Electronic Stability Control (or **Program) (ESC** or **ESP)**, also known as Vehicle Stability Control, improves the directional stability during cornering or rapid manoeuvres, giving enhanced protection against vehicle roll-over. It detects and reduces skidding by, for example, automatically applying the brakes to individual wheels to help steer the vehicle in the direction intended by the driver. As with LDW and AEBS, ESC is now mandatory on new heavy vehicles.

3.3.2 Contributing studies and evidence

A demonstration project in France and Germany called **Inter-Vehicle Hazard Warning** fitted an HMI to both cars and trucks which warned the driver of upcoming hazards in real-time, based on v2v communications. The notification is triggered by the driver but it can, for example, be done by the driver of a passing vehicle not involved in an accident. Therefore the effectiveness of the system depends not only on the penetration rate but also the number of other vehicles on the road which can potentially trigger an incident notification. An analysis of in-depth accident analysis from French and German accident databases estimated potential savings of 100 to 300 lives in both of these countries, depending on penetration rates (this figure was for all vehicle types combined, including heavy vehicles). The system was particularly useful in helping avoid secondary accidents (thus reducing the number of incidents involving the collision of three or more vehicles) and was most effective during the daytime and on motorways, as the greater levels of traffic increase the likelihood of an equipped user being able to trigger the notification[20].

In London, a **Cycle Safety Shield** system was developed for heavy vehicles and trialled in the Borough of Ealing. This included 360° Bird's Eye View around the vehicle, Headway Monitoring and Forward Collision Monitoring to avoid accidents with other motor vehicles, High Beam Control to automatically lower the lights blinding for incoming traffic and Speed Monitoring. This safety system warned drivers of potential collisions only with vulnerable road users (cyclists, pedestrians or motorcyclists) with detection up to 30 metres away and filtering out objects such as bus stops and lamp posts, to eliminate false alarms. A six-month trial using a medium duty (N2) DAF truck belonging to Ealing Council Highways Department was found to have avoided 15 potential collisions with a vulnerable road user as well as increasing fuel efficiency by 8% due to less aggressive acceleration and braking[21].
The Mack Intelligent Vehicle Initiative in the USA (2000-2006)[22] involved fitting **LDW** system to 22 heavy trucks and testing them over an 8-month period. The system was manufactured by SafeTRAC and included a digital camera and an image processing/user display unit. It system detects visual lane markings and can estimate some lane boundaries when visual lane markings are missing or of poor quality. Driver feedback and warnings included a user HMI display to indicate vehicle position in the lane, an "alertness measure" in the display that indicates consistency in maintaining a vehicle's position within the lane, an audible lane departure warning and the ability to control vibrating

[20] Haumann, M., Gelau, C. et al (2003)
[21] Slobodova, O. (2016)
[22] US Department of Transportation (2006)

(tactile/haptic) seats as an auxiliary warning device. Results showed the LDW system can reduce driving conflicts by 31% on straight roads and 34% on curves. From this, deployment of the LDW system on heavy trucks was estimated by this project to lead to approximately 21 to 23% reduction in single vehicle roadway departure crashes and 17 to 24% reduction in rollover crashes by HGVs. Note that these are based on US accident statistics. The results also indicated that the system can improve safety-related driving behaviour, even with experienced drivers.

In the United States, the Insurance Institute for Highway Safety updated a study in 2006 showing that **ESC** reduces the risk of single vehicle collisions by 40% (all vehicles)[23], with higher benefits for larger vehicles. The US National Highway Traffic Safety Administration (NHTSA) estimates that mandatory fitment on HGVs will save up to 49 lives and prevent up to 1759 accidents each year in the US, as well as providing net economic benefits of more than $300 million annually[24].

Table 4: Data summary for in-vehicle systems: Safety and emergency systems

Project or activity name	ITS measure	Description	Type of work (trial, study, etc.) and year	Achieved benefits
Mack (USA)	In-vehicle road hazard warning	Lane Departure Warning System on 22 trucks on various roads in different parts of USA	Interurban on-road trial (N3 trucks, 2008)	No effects on CO_2/fuel. Can reduce driving conflicts by 31% on straight roads and 34% on curves. Deployment of LDW system for HGVs estimated to lead to 21 to 23% reduction in single vehicle roadway departure crashes and 17 to 24% reduction in rollover crashes.
Cycle Safety Shield (UK)	In-vehicle detection of vulnerable road users	Driver assistance and warning to overcome blind spot problems and detect pedestrians and cyclists	Urban on-street trials (N2 truck, 2014)	Only one vehicle used (in an urban environment) but in six month period 15 potentially serious accidents were avoided. 8% increase in fuel economy.

23 IIHS News (2006), www.iihs.org/iihs/news/desktopnews/electronic-stability-control-could-prevent-nearly-one-third-of-all-fatal-crashes-and-reduce-rollover-risk-by-as-much-as-80-effect-is-found-on-single-and-multiple-vehicle-crashes

24 Fleet Owner (2015), http://fleetowner.com/regulations/nhtsa-announces-electronic-stability-control-mandate-class-7-8-tractors

3.3.3 Overall assessment

Despite the high potential safety benefit, the effect on CO_2 emissions is generally low, with benefits mostly accruing from reduced incident-related congestion that should result from fewer collisions, but sometimes also from smoother driving behaviour. Potential additional congestion and emissions emanating from road traffic accidents (and hence the potential of collision-reducing applications to also reduce CO_2 emissions) was researched but such data is not available. Very few studies have covered the effects of accidents on congestion at a macro-level, and those that have done so were based on modelling (e.g. introducing a stopped vehicle or blocked road in a traffic model) and found large variations depending on the form and density of the road network and the traffic density.

However applying some limited trial data to overall accident statistics can give some indication, for example, the Cycle Safety Shield developed in London could reduce collisions between HGVs and vulnerable road users in urban areas by up to 50% (the approximate percentage of such accidents due to the driver not seeing the pedestrian or cyclist). Vulnerable road users represent 15% to 25% of casualties (killed or seriously injured) in accidents involving HGVs but is higher than this average in urban areas due to a higher prevalence of pedestrians and cyclists and more vehicle turning movements at junctions.

4. Infrastructure and back-office-based ITS applications impacting commercial vehicles

4.1 Traffic management and control

4.1.1 Overview

Traffic signal (traffic light) control using online actuation, based on traffic information collected by local detectors and/or provided by a central computer, has the potential to increase infrastructure capacity, reduce congestion and influence driving dynamics. Buses can benefit in applications which incorporate public transport priority. Similar priority can be given to other vehicles, for example trucks in certain circumstances (e.g. to reduce congestion in port areas or other locations with a very high proportion of freight movements).

Coordinated systems ("green waves") apply such control on a network basis to maximise throughput on a major axis running through several traffic signals.

A variation of traffic signal control is **ramp metering** to ensure smoother traffic flow on motorways. This is widely deployed but not measured purely in terms of benefits for HDVs. However the eCoMove project included a trial whereby trucks were given priority for motorway access, hence this is within the scope of the present study.

Vehicle monitoring, incident/risk identification and management of goods (particularly hazardous loads) can offer traffic management and safety benefits. It uses remote vehicle and infrastructure monitoring technology and advanced communications between the road operator, emergency services and the transporters of dangerous goods. Strategies may include routing that minimises risk, on-line rerouting, coordinated section closures or cancelling of routes in dangerous conditions.

4.1.2 Contributing studies and evidence

Regarding **traffic signal control**: from the Freilot CIP project: cities that update their traffic management system to support selective priority for eligible goods vehicle will benefit from the possibility to “steer” goods traffic towards preferred roads or preferred times of the day (e.g. early hours in the morning), through an incentive scheme. The measured impact in this project from test sites in Helmond and Lyon found that fuel consumption / CO_2 emissions were reduced by 8 to 13% in the equipped areas. For longer distance haulage, however, the percentage change is negligible as the equipped urban section represents only a small part of the whole journey.

A study on the implementation of traffic signal priority for buses in Copenhagen[25] found a reduction in CO_2 emissions of 1.17% for buses, and also a very small reduction (less than 1%) for cars, but a consequent increase in truck emissions of between 2% and 3%. However, for all vehicles together, the

[25] Goinga, Y. (2015)

outcome was slightly positive (but less than 0.5% improvement). The main benefit however was reduced delays for buses and better reliability.

The European project Compass4D deployed a cooperative Energy-Efficient Intersection (EEI) service in seven European cities. Not all of these covered heavy vehicles, but measurements in Helmond and Bordeaux showed that this system (which included an in-cab GLOSA service) led to an improvement in HGV CO_2 efficiency (g/km) of between 5% and 10% at intersection level. Within the same project, these applications were tested for buses in Copenhagen, Helmond and Vigo, which were able to benefit from an extended green phase at traffic signals. Results were mixed, with no measurable change in Vigo and a slight deterioration in Helmond. In Copenhagen, an overall CO_2 improvement of 1.8% across the entire route for eight bus lines masked wide differences by route: from a 4.6% deterioration to a 7.1% improvement. It was found that the main reason for this variation was the location of bus stops, whereby a bus approaching a traffic light triggered a green phase extension request but then had to stop for passengers before the traffic light itself, thereby missing the green phase. Some of the poorer results were due to the presence of roadworks during the pilot operations. Therefore although overall results were not particularly positive, the more positive figures indicate what is achievable providing that the system is carefully tailored to the road network, including bus stop locations.

In the eCoMove project, the ecoGreenWave application for traffic signals (tested in Helmond) gave a 5% reduction in CO_2 for heavy vehicles on a section of road with traffic signals during off-peak hours and a 10.6% reduction in peak periods.

The CO-GISTICS project is currently testing a Priority and Speed Advice service for commercial vehicles with respect to traffic signals in in five urban pilot sites: results will be available in spring 2017.

The main benefits of **ramp metering** are reduced congestion but in the EU project eCoMove, an ecoRamp metering application was implemented with the objective of maintaining the benefits of ramp metering for the mainline while reducing the negative side-effects at the on-ramp. It does so by minimising start-stop waves through a virtual stop line and distinguishing between high emitting and low emitting vehicles. This showed an overall CO_2 emission reduction in the surrounding network of 5%. There was also a 14%-17% overall CO_2 reduction on ramps when truck priority was implemented.

Studies on **hazardous goods** monitoring have indicated benefit/cost ratios of 1 to 97 depending on the type of material to be transported. The highest ratios have been obtained for transport of explosives. ITS applications for hazardous materials incident response have been estimated to have a benefit-to-cost ratio ranging from 0.3:1 to 2.5:1. Examples of projects include MENTORE (EU project, 2009, on GNSS tracking and tracing technologies), and SCUTUM (EU project, 2011, on securing the EU GNSS adoption in the transport of dangerous materials). There is no known quantitative evaluation of these systems in terms of emission or accident reduction, although traffic control and monitoring are considered by road operators to be essential tools for efficient network management and for providing other ITS services.

The following table gives an overview of traffic management and control systems impacting commercial vehicles, focusing on traffic signals and ramp metering. For traffic signals, there is some overlap with the preceding chapter on in-vehicle systems, as some emerging or currently research systems using v2i communications are effectively in-vehicle systems but using real-time data from the infrastructure.

Table 5: Data summary for infrastructure and back-office systems: Traffic management and control

Project or activity name	ITS measure	Description	Type of work (trial, study, etc.) and year	Achieved benefits
Freilot (EU)	Traffic management and Energy Efficient Intersection	Urban ITS measures to increase energy efficiency of freight services (FR & NL)	Urban demonstration (N2 & N3 trucks, 2011)	10% fuel and CO_2 reduction in Lyon pilot site (using a refuse truck). 13% reduction in the equipped corridor at the Helmond pilot site
eCoMove (EU)	Traffic signal control	Dynamic green waves, cooperative traffic light control, balanced priority for (groups of) vehicles, Helmond (NL) and Munich (DE)	Simulation modelling (N3 trucks, urban, 2013)	CO_2 reduction between 5% (off-peak periods) and 10.5% (peak periods)
Compass4D (EU) (results for buses)	Energy-efficient intersection (EEI)	Deployment in 7 cities, of which 3 (Copenhagen, DK; Helmond, NL and Vigo, ES) apply to buses. EEI enables traffic signal green phases to be extended for approaching buses.	Urban demonstration (M3 buses, 2015)	Copenhagen: Small improvement (1.8%) in CO_2 efficiency (gCO_2/km) but varied across 8 bus routes from 7.1% positive effect to 4.6% worsening. During daytime peak (08:00 to 17:00) results were better, with an average 0.7% improvement. Helmond and Vigo: no significant reduction in emissions or gCO_2/km
Compass4D (EU) (results for HGVs)	Energy-efficient intersection (EEI)	Deployment in 7 cities, of which 2 (Bordeaux, FR and Helmond, NL) are relevant to heavy trucks.	Urban demonstration (N2 trucks, 2015)	Bordeaux: 10% improvement in CO_2 efficiency Helmond: 6.4% improvement in CO_2 efficiency. About 11% fewer stops at equipped intersections in both cases

Project or activity name	ITS measure	Description	Type of work (trial, study, etc.) and year	Achieved benefits
eCoMove (EU)	Eco-ramp metering	Cooperative control and advice measures at metered motorway on-ramps on A9 between Haarlem and Amsterdam (NL).	Simulation modelling (N3 trucks, interurban) (2013)	CO_2 reduction between 14% (off-peak periods) and 17% (peak periods) for HGVs, but only for the part of the journey on the ramp itself

4.1.3 Overall assessment

CO_2 and fuel reduction

- **Traffic signal control:** Overall, any benefit for trucks in uncertain. While studies have shown that improved traffic signal control reduces emissions from cars, the results for trucks are positive in some cases and negative in others. Unless traffic signal phases are specifically geared to prioritise a certain class of vehicle (for example bus priority), then it appears that this is not an application that benefits emissions for heavy vehicles. With priority for certain vehicles (e.g. buses), a reduction in CO_2 of between 4% and 7% is most likely, but this depends highly on the traffic mix and the density of traffic lights on the network. Where benefits have been achieved, these are at the local level only, e.g. in an equipped corridor in an urban area.
- **Ramp metering:** 5% reduction overall (from simulation modelling). Greater reductions only on a very localised basis (short distance movements on motorway ramps).
- **Vehicle monitoring:** CO_2 reduction benefits are not expected except potential small reductions due to more efficient emergency response and reduced resultant congestion.

Safety:

- The main benefits are expected to be from **vehicle monitoring** (particularly hazardous loads), both in terms of routing sensitive loads via appropriate roads where possible and in terms of enabling more rapid emergency response in case of an incident. These are of course highly dependent on location and traffic mix.

4.2 Driver behaviour and eco-driving (infrastructure and back-office based)

4.2.1 Overview

Intelligent Speed Adaptation (ISA) assists the driver in keeping the speed limit. There are advisory systems that warn the driver that he is driving faster than allowed on the given road and systems which directly intervene to make speeding harder or impossible. As opposed to cruise control, the system does not impact the speed if it is lower than the speed limit and only reacts to speed limits. The system helps the driver to reduce the speed of the vehicle and hence reduce the risk and severity of accidents.

There four main categories of speed control application: informative systems which inform drivers when they exceed the speed limit, systems providing haptic feedback to the driver, systems registering the speed use of driver for later feedback purposes, and applications which can directly control the speed of the vehicle and thus prevent the driver from exceeding the speed limit (mandatory ISA).

Driver behaviour and CO_2 footprint monitoring is a "background" ITS application which does not provide benefits on its own, but which is a tool to collect data in order to allow effective measures to be taken to reduce emissions. These systems recognise driving behaviour, collecting and analysing data collecting data on speed, headway and driving dynamics. They store or transmit data to a back office (either to an analysing tool for manual checking). They can be used by fleet operators to monitor performance of their drivers and improve training by focusing on areas where drivers can improve.

As with eco-driving support, the overall fuel savings depend on the driver's behaviour (including baseline level of performance) and on the situation (e.g. urban, motorway or mixed, road geometry, traffic congestion, etc.), but also on the measures taken by the fleet operator. Unlike eco-driving support, this application does not interface directly with the driver.

4.2.2 Contributing studies and evidence

The magnitude of the impact of **ISA** depends on the type of the system implemented and the user group. However for heavy vehicles which are already fitted with speed limiters, the additional benefit is small (and mostly confined to rural roads, as the system would have no effect on motorways). Results of existing studies indicate that a mandatory ISA system would reduce the number of fatalities by 20% in urban areas but this is for all traffic, mostly made up of cars, while average speeds of trucks and buses in cities is already low.

The only trial in Europe of ISA using HGVs was a UK study led by the University of Leeds[26], which only featured one vehicle. The University of Leeds then conducted a simulation to estimate the effects of ISA on HGVs on different road types[27]. It calculated a potential accident reduction on urban roads for HGVs of 1% for an advisory ISA system and 5% for a voluntary system. For rural roads, the corresponding estimations were 2% for an advisory ISA system and 4.5% for a voluntary system.

CO_2 reduction is likely to be smaller: estimates by TM Leuven at EU level in 2013 are a reduction of 1% for trucks and 2% for buses with ISA.

Transport for London recently conducted an ISA trial on two bus routes in the city. Although the full report is not yet available, first results show that the system enabled buses to stay within the speed

[26] Lai, F. et al (2007)
[27] Carsten, O. et al (2008)

limit 97% to 99% of the time and that it was particularly effective in 20 miles-per-hour (32 km/h) zones[28].

A small field test using ISA with heavy trucks and seven drivers in Australia found that an advisory ISA system reduced the time travelled over the speed limit. The likelihood of travelling over the legal speed limit was 21% lower when ISA was active[29].

A **CO_2 footprint estimation service** is being deployed in the CO-GISTICS project to measure the CO_2 output of the vehicles operating in the pilots. This will make it possible to estimate CO_2 emissions of a certain cargo operation. Full results are awaited in the CO-GISTICS project (due in 2017), but trial results of an equivalent application in China (led by German logistics operator DB Schenker, covering 800,000km of driving) has shown a fuel saving (and CO_2 emission reduction) of 4 to 15% (approx. 180 litres/month for a 12-tonne truck).

The following table summarises driver behaviour data.

Table 6: Data summary for infrastructure and back-office systems: Driver behaviour and eco-driving

Project or activity name	ITS measure	Description	Type of work (trial, study, etc.) and year	Achieved benefits
ISA (UK)	Intelligent speed adaptation	ISA on-road trial with one truck and driver on commercial service on a repeated route	Urban and interurban naturalistic driving (N3 truck, 2008)	No CO_2 or fuel benefit. Reduction of percentage of drive above legal speed limit of between 23% and 50% (depending on speed limit) contributing to safety. Biggest speed reduction benefit on 40mph (64km/h) suburban or semi-rural roads. 1% to 5% reduction in accidents calculated, depending on the ISA mode used (advisory or voluntary).
TfL (UK)	Intelligent speed adaptation	ISA on-road trial on two bus routes in London	Urban naturalistic driving on fixed routes (M3 buses, 2015)	97-99% compliance with speed limits in urban areas.

[28] TfL website, 2016, http://tfl.gov.uk/info-for/media/press-releases/2016/march/successful-trials-prove-effectiveness-of-speed-limiting-technology-on-buses and ETSC website, 2016, http://etsc.eu/london-to-require-isa-on-all-new-buses-from-next-year

[29] Fitzharris, M., Truong, J, et al (2011)

Project or activity name	ITS measure	Description	Type of work (trial, study, etc.) and year	Achieved benefits
The Victorian intelligent speed assist and heavy vehicles trial (AU)	Intelligent speed adaptation (Voluntary ISA)	ISA trial with 7 truck drivers from 3 companies in Victoria, Australia	On-road naturalistic driving (Mostly interurban, N3 trucks, 2014)	Reduction of speeding by HGVs by 21% (reduction in time spent driving above the posted limit)
DB Schenker (CN)	CO_2 footprint monitoring and estimation	Large scale trial in China, including driver coaching	Implementation (Mostly interurban, N3 trucks, 2014)	4%-15% CO_2 reduction when combined with eco-driving education

4.2.3 Overall assessment

CO_2 and fuel reduction

- **ISA:** 1 to 2% reduction (TM Leuven, 2013), but more when combined with eco-driving support.

Safety

- **ISA:** No measured benefit on motorways as trucks and buses are fitted with speed limiters. Potential accident reduction for HGVs of between 1% and 2% for an advisory ISA system and 4.5% to 5% for a voluntary system. Higher levels were reported for an intervening system but based on modelling only. Significant reduction in illegal speeding on rural roads (21% to 50%). For urban buses, the key safety benefits applied to low speed zones (below the standard urban speed limit of 50 km/h or equivalent).

4.3 Logistics and fleet management

4.3.1 Overview

The objective of **Intelligent Truck Parking (ITP)** is to provide HGV drivers and hauliers with dynamic and reliable information about available capacities and facilities as well as to support management of parking areas via different means, including cross-border seamless and consistent information and forecasts on available parking places, regardless of the organisation responsible for the network or parking operations.

ITP can take the form of a truck parking online information system, intelligent compact parking (information on, or control of, prospective departure times for lanes in parking areas so trucks with the same planned departure time can park in one lane and do not block each other) and/or secure truck parking sites for high value cargo. Making relevant data available in standardised formats to service providers can increase the efficiency of truck operations.

For interurban goods transport, this service helps optimise the drivers' stops along their route. It supports the drivers before and during their journey in helping them to comply with traffic and driving regulations, as well as guiding them in order to help reduce wasted mileage, risk of fatigue or dangerous behaviour. Intelligent parking can also be implemented in cities or at terminals (including intermodal hubs), also reducing potential delays, ensuring smoother and more efficient operations.

ITP is recognised by the European Commission as an important step to easing infrastructural problems, achieving the optimum use of existing capacity, providing seamless cross-border services on trans-European routes, improving information to truck drivers to help them to respect traffic and driving regulations, and improving safety and security. Hence EU projects have been funded in this area such as SETPOS – Secured European Truck Parking Operational Services, which produced a best practice handbook for operators[30], and its follow-on project LABEL, which created a Label for secured truck parking areas[31].

Delivery space booking and **real-time urban delivery space management** are variations of intelligent truck parking, comprising online information and booking. This measure has to be jointly implemented with an enforcement measure to ensure that the booked delivery space is not occupied by another vehicle.

Fleet management and routing is effectively a pre-trip ITS application, with the routing part also known as a tour planning system. It delivers information on suitable routes and relevant key figures like distance, time, costs or emissions of alternative transport modes to a strategic or tactical transport planner. The dynamic (on-trip) part of routing is covered under the section on Navigation and travel information (eco-routing systems). Several fleet management packages encompass both of these aspects.

Cargo optimisation services encompass all operations from vehicle acquisition to disposal to satellite positioning and data communication to back office applications.

Electronic freight services (e-Freight) involve paperless, electronic flow of information for a simple and harmonised procedure to support the flow of goods. It includes functions for tracking cargo from door-to-door irrespective of the combination of modes and for tracing its movements if needed. Electronic systems for freight transport can also incorporate information on permissive load and unload times in different areas of a city.

4.3.2 Contributing studies and evidence

Results identified for **ITP** relate to "soft" benefits such as better comfort and traffic management. Although ITP has been deployed in several parts of Europe, notably under the auspices of the

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30 Secured European Truck Parking: Best Practice Handbook, 2010, http://ec.europa.eu/transport/modes/road/parking/doc/2010_04_28_setpos_project_handbook.pdf

31 http://truckparkinglabel.eu

EasyWay programme, followed on by the European ITS Platform[32], which includes the URSA MAJOR project dedicated to freight traffic on the Trans-European Road Network between the North Sea Ports, Germany, the Alps and Italy[33], there has not yet been quantitative evaluation on their effects on emissions or safety (although some evaluation results are expected in 2017).

A scientific study carried out in Sweden[34] concluded that ITP brings significant quantifiable benefits to drivers in terms of parking facility search time and reduction of accidents due to fatigue, as well as lesser benefits concerning reduction of parking-related theft and insecurity and reduction of accidents as a result of roadside parking. The main benefits to road haulage companies are a reduction in insecurity and hence a reduction in insurance premiums.

Another Swedish study, "Benefits related to Intelligent Truck Parking"[35] looked at fatigue as a cause of accidents and stated that 38% of drivers and road haulage companies in Sweden have problems complying with driving and rest time regulations, and that random police controls of HGVs on Swedish roads found that 292 out of 2020 drivers had violated driving and rest time regulations. Fatigue-related accidents for HGVs are estimated at 57% globally and 25% of all Swedish road accidents. Also, collisions with (or obstructions due to) parked HGVs have increased and up to 10% of accidents related to parking (for all vehicle types) could have been avoided if drivers had parked in an appropriately designed parking area. The European Truck Accident Causation study[36] found that 3% of HGV accidents where human factors were involved occurred due to entry or exit from a parking area and that 2% of all truck accidents are related to wrongly parked HGVs. The "Benefits related to Intelligent Truck Parking" study estimated that €378,000 in driving time costs could be saved annually in Sweden as a result of ITP, €326,000 in distance-based vehicle costs could be saved, as well as €136,000 in efficient use of non-driving time, €105,000 in fuel savings related to searching for parking places and €89,000 in reduction of fatigue-related accidents[37]. Although based on scientific data analysis rather than ex-post evaluation, this shows the potential significant benefits in Sweden. In many other parts of Europe where there are greater volumes of HGV traffic, including transit traffic, as well as greater levels of congestion and accidents than Sweden, the benefits are likely to be greater.

In the EU project eCoMove, there was an "ecoTruck" application, for truck parking on motorways. This generally did not affect fuel use or emissions, but had some small safety benefits in guiding the driver to a parking location as well as the safety benefits of reducing illegal truck parking on a road or motorway. Reducing the possibility of truck drivers exceeding their legal hours while looking for parking was also a benefit.

A **delivery space booking service** was successfully piloted in Bilbao by ten organisations within the Freilot project (2009-2012). Results showed a reduction of 27% of travel distance to find a parking

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[32] www.its-platform.eu
[33] http://ursamajor.its-platform.eu
[34] Sochor, J. et al (2009)
[35] Mbiydzenyuy, G. et al (2010)
[36] ETAC (2004-2006)
[37] 2010 prices, reported in Swedish krona and converted to euro at the average 2010 rate of 9.48SEK = 1 EUR

place with this service and a resultant reduction of 29% of fuel consumption at the location where the truck is delivering. Four delivery spaces were available and 124 trucks of three different types participated to the pilot: 15% small trucks (3.8t), 10% medium trucks (6.95t) and 75% heavy trucks (28t), This service gave the driver the ability to book a delivery space before reaching the delivery point, permitting an increase in the number of stops made in designated delivery spaces and decreasing the amount of double-parking and its negative consequences. It also reduces driver stress, optimises delivery time operations and improves drivers work conditions. It should be noted that in some cases a small negative effect in terms of distance and emissions was noted when using the delimited parking areas because during base-line (without the system) some drivers were double-parking in front of the delivery point.

Fleet management and routing applications have a potentially high impact on CO_2 emissions, given the effects on trip generation, strategic route and mode planning, pre-trip route and mode planning, vehicle choice, occupancy (load factor) and departure time choice . However benefits are more on a strategic level (when planning a freight movement for example) rather than at the operational level.

Fleet management systems like TomTom's Webfleet (incorporating OptiDrive 360, see under eco-driving support above) has led to a reduction in distances driven of 16% for one client and vehicle maintenance costs were reduced by 5%.

The EU project eCoMove performed simulation modelling for 2 trucks (12t) using a furniture delivery schedule in Munich, with and without an "ecoTourPlanningSystem" which aims to allow logistics companies to define eco-efficient tours considering drivers' eco-performance, vehicle payload and road infrastructure status. Three simulated trips of just over 200km were performed for each of the two vehicles without and with the system. With the ecoTourPlanningSystem, trip duration was reduced by 10% and distance driven was reduced by 8%, while performing the same number of trip stops.

Cargo optimisation is able to assist in the selection and acquisition of vehicles and keep track of vehicle movements and which vehicles will be in maintenance at which moment. It can affect route choice, since some heavy vehicles might be restricted on the roads that they can use. Efficiency and emission benefits accrue in cases where vehicles are in congestion, as the systems can make it easier to change the route on-trip.

A study conducted by Motorola in 2008 by survey of a large number of enterprises found that use of GPS fleet tracking solutions led to significant time savings (54 minutes a day on average) and fuel savings by reducing the distance travelled by the fleet. This was achieved through optimised route organisation.

ITP, Delivery Areas Management and Cargo Transport Optimisation are also the subject of current trials in the CO-GISTICS project in urban, highway and airport locations, with results due in spring 2017.

E-Freight can lead to a reduction in waiting times and could accordingly reduce transport times to load and unload freight. It also enhances the data quality through standardisation of data and data formats, hence reducing delays due to incomplete or lacking documentation. This could make a small impact on CO_2 emissions but the reliability of any assessment would be low and no quantitative publicly available data has been identified concerning measured or modelled changes to fuel use and emissions.

Project data from logistics and fleet management applications are shown in the following table:

Table 7: Data summary for infrastructure and back-office systems: Logistics and fleet management

Project or activity name	ITS measure	Description	Type of work (trial, study, etc.) and year	Achieved benefits
Freilot (EU)	Delivery space booking	Pilot project in Bilbao, ES	Urban demonstration (N2 and N3 trucks, 2011)	29% CO_2 reduction in the locality where the vehicle is delivering (localised result only)
eCoMove (EU)	Eco-Tour Planning System	Modelling simulation on the network of Munich, DE	Simulation modelling (N3 trucks, urban, 2013)	Estimated 8% CO_2 reduction due to reduction in distance travelled (221km to 204km)

4.3.3 Overall assessment

CO_2 and fuel reduction

- **ITP:** Although this has not been quantified, the Swedish study "Benefits related to Intelligent Truck Parking" assumed 20% of fuel used by HGVs is searching for parking spaces. This might be realistic at an urban level but for long distance travel the figure is likely to be much lower. If the figure is 5% and ITP can reduce time and distance searching for parking on long distance trip, then this would equate to a 2% reduction in CO_2 emissions. However this is only an estimate and the benefit will depend strongly on the geographical situation, parking availability and the volume and nature of freight traffic.
- **Delivery space booking and real-time urban delivery space management:** 29% reduction for the part in the immediate delivery area. Real overall benefits highly dependent on location and space availability as well as average delivery journey length. For example in Paris 62% of commercial deliveries involve illegal parking whereas in London the figure is only 21% (note this applies to all goods vehicles, most of which in a city will be light ones). For an overall trip (particularly a long distance one) the fuel and emission benefits are negligible in percentage terms, but benefits at local level can be high. Note that some benefits may not accrue to the delivery vehicle itself but to other traffic, due to reduced double-parking and congestion.

- **Fleet management and routing:** Depending on the system, there could be an overlap of benefits with eco-routing or eco-driving (some systems, both from HDV manufacturers and after-market providers, combine all of these). Taking away the eco-driving and routing part of the equation (which are the main factors bringing down CO_2 emissions), fleet management systems can save approximately 5% on (non-fuel) vehicle costs and trip planning software can deliver potential savings of 8% in urban areas, but this figure was from a modelling simulation only and is likely to vary considerably according to the local road network characteristics and the type of truck operation (this was for urban delivery rounds for 12 tonne trucks).

Safety

- **ITP:** If, as suggested in the Swedish study above, wrongly parked HGVs account for 2% of truck-related accidents and if ITP can reduce this by about half, there could be an overall benefit of around 1% reduction in accidents.
- **Delivery space booking and real-time urban delivery space management:** Qualitative feedback only: fleet operators in the Freilot demonstration considered that when their companies unload the goods using delivery space booking, the delivery load is safer. Safety benefits from reduction of illegal or obstructive double-parking on streets (not quantified), which also brings **reduced congestion**.

Efficiency

- **ITP:** Greater level of efficiency for truck drivers and haulage companies as estimated in the Swedish study described above (elements including driving time costs, vehicle costs use of non-driving time and fuel savings), as well as avoiding fines (due to reduced illegal parking or exceeding drivers' hours regulations) and greater goods security leading to potential lower insurance premiums.
- **Delivery space booking and real-time urban delivery space management:** Qualitative feedback only: drivers in the Freilot demonstration believed the delivery space booking service increased the efficiency of their work, facilitating their delivery operations and increasing the efficiency of the delivery operation.
- Efficiency gains from fleet management, cargo transport optimisation and e-freight, but statistics from operators are not in the public domain.

5. Global analysis and conclusions

Many advances have been made in the heavy commercial vehicle sector over recent years to reduce their carbon footprint and to increase safety. Cleaner engines and auxiliary systems have achieved significant reductions in CO_2 whereas nitrogen oxide (NO_X) and particulate matter emissions are a fraction of what they were in the 1990s. The number of fatal accidents involving heavy commercial vehicles has fallen by around 40% in ten years and a range of on-board safety systems have been adopted by manufacturers, several of them now having been made mandatory in Europe.

Despite these successful developments, resulting from extensive research and investment, continued progress towards the objectives of cleaner and safer transport is necessary, and Intelligent Transport Systems can (and already do) make an important contribution to this. However the more progress is made, the more difficult (technically, financially, commercially or politically) it is likely to be to make each further incremental improvement. The key concept to be borne in mind is “room for improvement”: for a driver, vehicle or network that is already highly performant, there is less scope for improvement than in the case where one or more of these elements under-performs.

Considering “room for improvement”, one clearly cannot add up the benefits of different systems. As a level of improvement is reached by one system, there is less potential for a subsequent system to achieve further improvements in the same area. The effects of different ITS applications working together cannot be evaluated in this study except where an evaluation study actually covered an integrated deployment (for example in the Compass4D project: and in that case only the results of the integrated deployment are known and not the individual effects of each system on its own).

Furthermore, the potential of different systems to bring improvements is highly dependent on factors such as the driver (skill, behaviour, attitude, familiarity with the road network), the road type (speed, curvature, gradient, urban/rural/motorway), weather and road conditions, traffic density, trip type (short or long distance, regular or one-off, regular stops or not), vehicle type, etc. Even if an “average” level of performance (mean, median, etc.) can sometimes be estimated from available data, it is likely to be misleading: in particular, if a system delivers a much lower benefit than the “average”, it should not be implied that it has been unsuccessful, but rather that the optimal conditions for success were not met. Similarly, for instances where benefits above the average, these are not necessarily outliers which are unrepresentative of what can be achieved, but indicative of the potential of the system given the right framework conditions.

Hence it is generally more appropriate to indicate a most likely range of benefits to indicate what is most realistic in a “typical” case, while also indicating the maximum potential and the minimum potential (the latter may be zero or in some cases even a worse performance than without the ITS application: this occasionally results from studies and trials, often due to an unexpected localised factor, effect or user reaction).

It is important to consider the different scales of benefits involved. Infrastructure-based systems especially often only produce benefits at the locations where they are deployed, so while an impressive reduction of CO_2 emissions (such as >20%) can sometimes be obtained, this is often only over 100 to 200 metres, so the overall effect for the vehicle over the whole trip would be almost zero. However other benefits can accrue, such as improved air quality at local level (e.g. less particulate matter due to less sharp braking) as well as reduced congestion and more reliable journey times.

The following sub-sections highlight the ITS applications that have been found to offer the greatest potential benefit in terms of (firstly) CO_2 reduction and (in Chapter 5.2) safety. Within each section, the most promising applications are given for different scenarios such as road or trip type.

5.1 Key ITS applications for CO_2 reduction

5.1.1 Urban networks (buses and short-haul logistics)

In-vehicle systems:

- Eco-driving support generally provides only limited benefits for HGVs in urban areas, as driving dynamics are generally constrained by the traffic volume and road layout, however such support for urban buses has been shown to have a potential of around 3% to 6% CO_2 reduction. However eco-driving can save up to 25% of CO_2 for HGVs and buses in very localised situations, e.g. on the approach to junctions and traffic signals, provided there is no congestion. But the overall benefit over an urban logistics trip or a bus journey would be negligible.
- Eco-routing can provide benefits of up to 12% in urban areas for freight transport, when combined with a fleet management system, but around 8% to 10% is a more realistic average for urban distribution using medium or large vehicles (N2 or N3 class).

Infrastructure or back-office systems:

- Traffic signal systems such as Energy Efficient Intersection Service (giving extended green time to selected buses or trucks) and GLOSA (Green Light Optimised Speed Advisory) can lead to CO_2 savings of around 5% in urban areas (typical range is 1% to 7%, depending on the network, density of junctions and – for buses – locations of bus stops).
- Delivery space booking for goods vehicles can reduce CO_2 emissions by over 20% in the vicinity of the delivery location (however as a percentage of the entire trip it is negligible), as well as reduce illegal parking.
- An ecoTour Planning System for urban deliveries (combining eco-routing above with delivery planning, drivers' eco-performance, vehicle payload and road infrastructure status, can potentially save 8% of distance driven and emissions (note that this is from a simulation in one city, so actual results would be highly dependent on local conditions).

5.1.2 Interurban networks (coaches and regional/long haul logistics)

In-vehicle systems:

- Eco-driving support can save an average of 7% to 10% of CO_2 emissions for HDVs on non-urban roads (excluding motorways, where benefits are negligible). Depending on the road topography and driver, it could be higher. In any case, there is a positive benefit-cost ratio in all cases, with few barriers to deployment.
- Eco-routing has less potential for savings on interurban networks than on urban ones, with an estimate of 5% for regional logistics, but less for long haul trips.
- Predictive Powertrain Control can reduce CO_2 emissions by 3.5% to 5% for heavy vehicles on interurban trips.
- Truck platooning can increase this saving to between 7% and 16% for following vehicles, depending on the inter-vehicle spacing. For the lead vehicle, between 1% and 8% CO_2 reduction is possible.

Infrastructure or back-office systems:

- Eco-ramp metering for motorway access that gives extended green time to HGVs can result in a 14% to 17% CO_2 reduction in the immediate motorway ramp area, but 5% overall on the surrounding network. For an entire trip the benefit is negligible.
- Driver behaviour and CO_2 footprint monitoring for large fleets can bring a reduction in CO_2 emissions of around 9% (range from 4% to 15%).
- Intelligent Truck Parking could achieve a small (2%) reduction in CO_2 emissions for long-distance freight transport by reducing extra distance driven to search for parking facilities.

5.2 Key ITS applications for safety improvement

5.2.1 Urban networks (buses and short-haul logistics)

In-vehicle systems:

- A “safety shield” comprising combining speed and headway monitoring and collision warning, could reduce collisions between HGVs and vulnerable road users in urban areas by up to 50% by improving visibility and driver warning, as well as reducing collisions with cars.

Infrastructure or back-office systems:

- ISA can enable vehicles in urban areas to keep to the speed limit nearly all of the time, and particularly in areas with low speed zones (e.g. 30 km/h).
- Delivery space booking can reduce accidents due to illegal double parking for short-term loading or unloading in urban areas.

5.2.2 Interurban networks (coaches and regional/long haul logistics)

In-vehicle systems:

- Lane Departure Warning and AEBS can reduce HGV accidents by 17% to 24%.
- Inter-vehicle hazard warning using vehicle to vehicle communications has a high potential benefit especially in terms of avoiding secondary accidents.
- Eco-driving support has been shown to reduce the incidence of illegal speeding on rural roads.

Infrastructure or back-office systems:

- ISA on rural roads has the potential to reduce accidents for HGVs of between 1% and 2% for an advisory ISA system and 4.5% to 5% for a voluntary system. It can reduce illegal speeding on rural roads by between 21% and 50%.
- Intelligent Truck Parking could achieve a small (1%) reduction in HGV accidents by reducing collisions due to driver fatigue or illegal parking.

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