ITS4C Congress

Smart Mobility for Climate

17 - 19 September 2019

Decarbonisation Toolbox
WORKSHOP 2

2 Lower carbon technologies and solutions

The ITS for Climate initiative (ITS4C) was established in 2015 during the ITS world Congress held in Bordeaux, under the leadership of the Nouvelle-Aquitaine Region in France to highlight the potential contribution to the reduction of CO_2 emissions of Intelligent Transportation Systems (ITS) and smart mobility innovations. In 2019, 32 Climate and Mobility experts set out to provide a "Decarbonization Toolbox» for cities, regions, national governments as well as for the ITS community and all stakeholders in the transport & mobility sector. This work was presented during the ITS4Climate Congress in Bordeaux.

www.its4climate.eu

An event organised by TOPOS, Digital Aquitaine

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Highlights

Introduction

This ITS4C Briefing Paper looks at the ways ITS can reduce emissions, with a focus on vehicles and non-motorised mobility.

Transport and climate change: a crucial issue and a major challenge

In line with the Kyoto protocol of 1997, the Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCC) was adopted by consensus on 12 December 2015 and signed in 2016.

Today, 195 UNFCCC members have signed the Paris Agreement, and 186 have become party to it. One of its objectives is to keep the increase in global average temperature to less than 2°C above pre-industrial levels, in particular by controlling carbon dioxide emissions.

In 2016, the European Commission communicated a proposal[1] to the Parliament for a European Strategy for Low-Emission Mobility. This report outlined how the transport sector plays a key role in air pollution in Europe:

• Transport represents almost a quarter of Europe's greenhouse gas emissions and is the main cause of air pollution in cities.
• Transport in the EU still depends on oil for about 94% of its energy needs, which is much higher than in any other sector and makes transport heavily dependent on imports.
• Emissions from lorries, buses and coaches currently represent around a quarter of road transport carbon dioxide emissions and are set to increase by up to 10% between 2010 and 2030.
• Urban transport is responsible for 23% of the EU's greenhouse gas emissions.
• Road transport is the largest source of nitrogen oxide (39%) and a major source of particulate matter (13%).

On a global scale, CO_2 emissions in the transport sector are about 30% in developed countries and about 23% in terms of total man-made CO_2 emissions worldwide.

There is widespread agreement to reduce CO_2 emissions from transport by a minimum of 50% by 2050 at the latest. The previously mentioned EC report also reveals that the transport industry across Europe employs more than 15 million people, accounting for 7% of total employment in the EU34.
We are therefore facing a major challenge for the planet in a sector whose economic importance creates far from ideal conditions for rapid changes in practices, even if they are accepted as absolutely necessary.

The rising role of ITS

At the same time, ITS impacts all aspects of the transport chain.
ITS means the use of Information and Communication Technologies (or ICT) in the field of transportation to create real time flows of information and data, thereby enabling more «intelligent» use of infrastructures and vehicles and enhancing Intelligent Transportation Systems management of traffic and mobility.

Our congress shows that information technologies address several aspects of transportation and mobility and, through them, can contribute to significantly reducing greenhouse gas emissions.

1 - COMMUNICATION FROM THE COMMISSION TO THE EUROPEAN PARLIAMENT, THE COUNCIL, THE EUROPEAN ECONOMIC AND SOCIAL COMMITTEE AND THE COMMITTEE OF THE REGIONS - A European Strategy for Low-Emission Mobility {SWD (2016) 244 final}

2 - 27 February 2007 - Report of the UN Foundation / Scientific Expert Group (SEG) on Climate Change and Sustainable Development prepared for the 15th Session of the CSD15.

Introduction

ITS for climate action: a new paradigm

As emphasized in the UN Climate Change and Sustainable Development report in 2007[2], to limit climate change we have to avoid the unmanageable (mitigation) and manage the unavoidable (adaptation). Mitigation reduces the height of any step-change and allows time for adaptations to become effective. But mitigation is not enough, since the world has to cope with past GHG emissions still in the atmosphere. Adaptation is also insufficient where transportation activity is cultural or expensive: transport emissions could increase at a faster rate than other emissions.
Improved transport infrastructure together with Intelligent Transportation Systems (ITS) could thus be a good combination to achieve lower emissions.

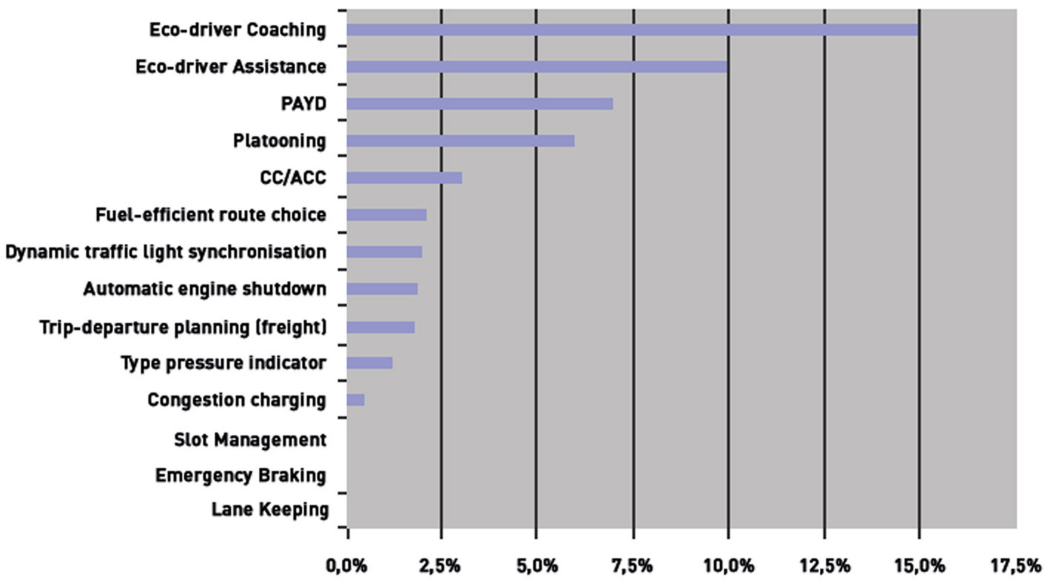

Figure 1 -ITS effect on CO_2 transport emissions
Source: EU 27, 2014

Of course, not all ITS applications have the same impact on climate change or CO_2 reduction, as shown in Figure 1. But as we will see, ITS offers multiple instruments that can help reduce greenhouse gas emissions and promote the most appropriate means of transport for clean and energy-efficient travel. Obviously, a given application may only influence a proportion of the total CO_2 emitted. But the combination and complementarity of the various ITS applications, and their enormous adaptability, can lead us to a realistic and hopeful vision of the future for climate-friendly transport.

[2] - 27 February 2007 - Report of the UN Foundation / Scientific Expert Group (SEG) on Climate Change and Sustainable Development prepared for the 15th Session of the CSD15.

Indicators and Strategies

What indicators are used to measure the effects of low carbon solutions?

What indicators make it possible to measure the impact prior and following proposed solutions and actions? Mobility basically means the movement of persons or goods from an origin to a destination. The relevant question is: for a given journey, can we minimize emissions for a given service? First of all, which greenhouse gases are we targeting, and what do we need to measure?

The climate-impact of transport can be measured by "grams of greenhouse gases (GHG) emitted": g (GHG).

Seven greenhouse gases directly influence global heating: carbon dioxide (CO_2 - the main constituent) and methane (CH4), nitrous oxides (NOx), chlorofluorocarbons (CFCs), hydrofluorocarbons (HFCs), perfluorocarbons (PFCs), sulphur hexafluoride (SF6) and nitrogen trifluoride (NF3). Emissions data are usually expressed in CO_2 equivalent: we can then summarize the overall GHG measurement with a single indicator: mass of CO_2 - equivalent measured in g (CO_2).

This overall indicator does not reveal the actual components of the reality of transportation: for our topic, for instance, it does not show the real impact of low carbon solutions on the overall emissions volume.

In order to have a more precise view of the factors influencing this indicator, we need to break it down into thematic indicators, each of them targeting a particular efficiency domain:

• Number of vehicles used for the number of persons or tons of goods transported. This indicator measures transport efficiency. It should be kept in mind that reducing emissions by reducing traffic does not necessarily mean reducing the transport supply, but perhaps simply making it more efficient by ensuring that each vehicle on the road performs its function as fully as possible by not being three-quarters empty.

• Number of persons or tons multiplied by the distance travelled to reach a destination. This indicator is a measurement of transport quantity; note that, for a given journey, the greater the number of people and the shorter the route, the better the indicator will be.

• Quantity of energy (MJ) used per unit of distance travelled to reach a destination multiplied by the number of vehicles involved. This indicator corresponds to the energy necessary for the quantity of travel involved. It can be broken down into two sub-indicators:

- Km/distance, which is a function of the route chosen.
- MJ/veh.km which is the energy needed per vehicle-kilometre actually driven, which obviously depends on the type of vehicle (using a 6-cylinder 4WD diesel or an electric bicycle in an urban environment do not leave the same carbon footprint!) and the infrastructure (urban, hilly, road design etc.). Note that it also depends to a significant degree on driving style (speed, evenness, etc.).

We also note that the shortest route is not necessarily the optimal one for energy consumption and so for carbon emissions: optimal routing means also taking into account the type of infrastructure including traffic flow conditions at the time of travel. Travelling in mountainous terrain will have a different carbon cost depending on whether you take the mountain road or the expressway with its viaduct and tunnel. In urban areas using a ring road rather than urban roads will produce different emissions depending on the time of day and type of vehicle.

• Mass of CO_2 equivalent emitted for a given amount of energy used. This indicator is clearly focusing on environmental impact. Typically, this indicator is directly related to the type(s) of energy used (human energy, electricity, hydrogen, etc.). Moreover, it is also linked with the choice of the most suitable vehicle for a given use, and the overall energy efficiency of a given vehicle, i.e. its ability to optimize the ratio between the energy released and the energy consumed for the same journey (engine downsizing, tyres, weight, aerodynamics, etc.).

Indicators and Strategies

The quant i ty of emissions is then assessed by the fundamental equalities shown in Figure 2, splitting the main indicator into meaningful sub indicators.

The indicators essent ial ly ref lect the three types of act ion that can be taken to reduce greenhouse gases: avoid travel, shift togreener modes or improve, knowing that a given indicator may apply to varying degrees to several of these types of act ion.

ITS and low carbon technologies: key parameters

The EU direct ive 2010/40/EU of July 2010 def ined ITS as systems in which informat ion and communicat ion technologies are applied to the f ield of road t ransport, including inf rast ructure, vehicles and users, and to traffic and mobility management, as well as to interfaces wi th other modes of t ransport.

Finding the role of ITS in combatting climate change comes down to:

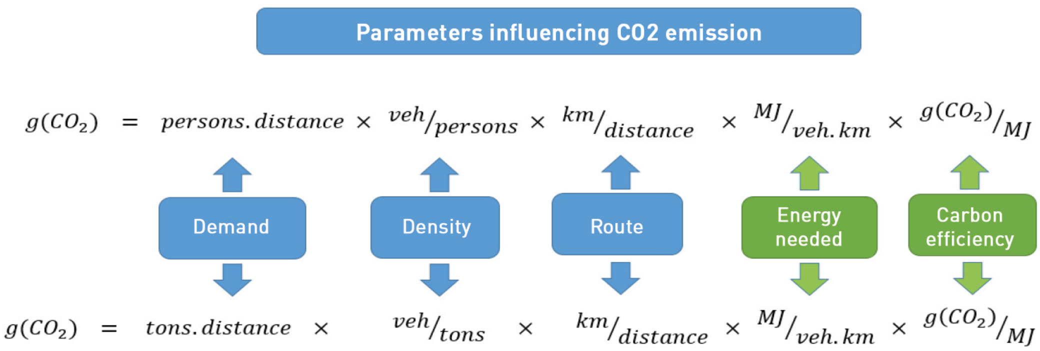

Figure 2 - Parameters influencing GHG emision

How can information and communication technology help to reduce GHG emissions? As is clear from Fig.1, ITS may affect all sub-indicators (see other topics).
Specifically, with regard to low-carbon technologies or solutions, ITS will address the energy needed for a given amount of traffic, and the carbon efficiency for a given amount of energy needed as shown in green in Figure 2.

This will impact two parameters:
• the ratio ${}^{g(CO_2)}/_{MJ}$ by creating conditions for promoting and facilitating all low-carbon or decarbonized modes,
• and also ${}^{MJ}/_{veh.km}$, which is linked to traffic management (topic 3) and also to in-vehicle parameters for instance by optimizing driving style through eco-driving.

ITS against carbon emissions: three strategies with the same goal

According to these key parameters, three strategies are available to us regarding the role of ITS, usually called A-S-I (Avoid / Shift / Improve):

• **Perhaps the most "intelligent" transport measures** are those that avoid or reduce transport, such as video or telephone-conferencing, 3D-printing or tele-working. ITS do not participate in such solutions, except in providing information on traffic conditions that might dissuade people from travelling.
Note that even these extreme measures may not be totally carbon-free, because the use of the Internet also consumes energy to power the necessary servers and networks.
Moreover, we must take into account that transportation systems perform vital services for the community, and that moving people and goods will remain necessary not only for economic reasons, but also for social reasons: ever since the dawn of humanity, people have become richer and have evolved because they have physically met with other people and traded goods.
ITS can participate in this solution, for example by providing dissuasive information on traffic conditions resulting in certain journeys being avoided, or by providing geo-fencing to prohibit some areas from certain types of vehicle.

• **A second strategy is to shift.** Two parameters are concerned:
- Carbon efficiency, for which ITS contribute to the development of non-motorized forms of transport such as walking and cycling,
- Density, for which ITS promote public transport or High Occupancy Vehicle Lanes and when doing so contribute to lower energy consumption per km and passenger-km.

• **A third strategy is to improve, for which ITS focus on vehicle and driving efficiency.** However, most if not all projections and scenarios conclude that improvements in vehicles and fuels alone will not be enough to achieve EU-long term climate change objectives. In other words, the EU will need more than technology to meet its targets.

Human energy: by far the best!

Since the radical solution of no transportation is limited to relatively few situations, and human energy is clearly the alternative with the lowest carbon expenditure, this essentially means more walking and cycling, especially in urban areas.
So how can ITS be a lever to help with the reassignment and redistribution of car use, and more generally of powered vehicle use, towards these human, natural transportation modes? For there can be no doubt that, especially in urban areas, these transfers will be crucial for the success of real transformation of our approach to transportation. The European Cyclists' Federation illustrates this necessity in Figure 3, showing that to reach the 2050 emissions target, the number of kilometres by motorized modes must be drastically reduced.
This becomes even more significant when one considers the proportion of active travel in various developed countries, as shown in Figure 4.

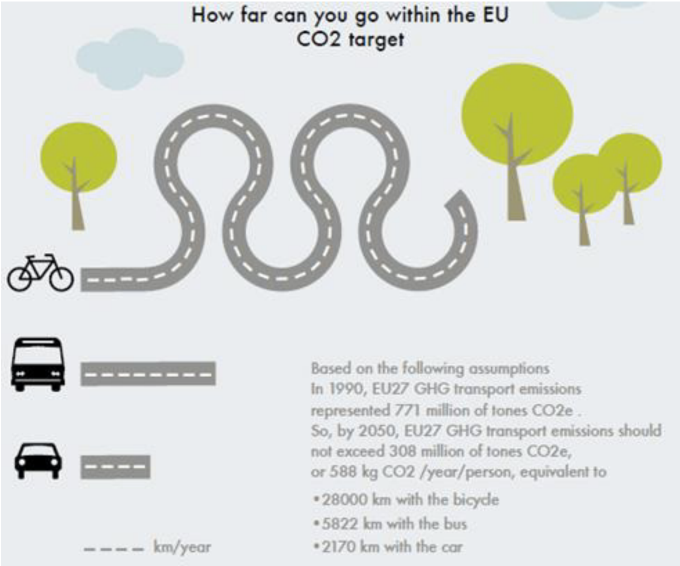

Figure 3 - Number of km per person, per year by 2050

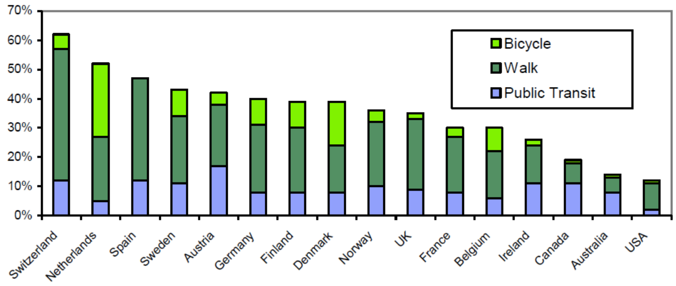

Figure 4 - Active-mode and public transport travel in wealthy countries
Source: Basset et al., 2011

Indicators and Strategies

ITS for pedestrians

Beyond the fact that walking is a travel mode in itself, it must also be considered that walking is always one of the links in the transport chain, at least at the two extremities: any traveller is always a pedestrian at some stage in their journey. In urban areas, this mode might even be predominant, as it will not only be involved at the departure and arrival points. It may also form a significant part of the travel itself due to intermodal transfers, or as the main goal of an activity such as shopping or visiting.
A widely held view in the ITS world is that the use of advanced telematics tools is reserved for intelligent roads and motor vehicle uses.
However, if we want ITS to really participate in the decarbonization of travel, we should not ignore the primary natural, carbon-free means of travel: walking.
In order to promote this lowest carbon mode – that is also highly beneficial to public health - it is essential to develop systems that enable pedestrians to benefit from ITS services of equivalent quality to those of other modes. For example, this could be guidance functions or the optimization of waiting times at traffic lights to cross a street.
To engage with these issues, locating pedestrians and modelling their flow is perhaps the first challenge for ITS in this field. This is especially important when it comes to crowd management, whether on city sidewalks or in public transit stations. It should be noted, however, that this analysis often involves video surveillance, sometimes even to the point of being able to follow a given person in a crowd on an almost continuous basis. It raises questions about privacy and the protection of individuals' freedom (GDPR).
Who has never used a smartphone to find their way in an unfamiliar city? We see here the emergence of ITS for pedestrians in the guidance function. But let us note that, for blind people for example, traditional guidance applications are still largely useless because of the precision of the guidance, which may not include obstacles. New sensors are likely to be developed, and further research is in the pipeline.
Returning to our tourist guidance example, we should also note that these applications introduce a new danger: the pedestrian, absorbed in the choice or continuation of their route, may not notice threats such as vehicles when they are crossing roads. This leads to another important field for ITS development in the pedestrian field: ITS can provide solutions to preserve their safety, especially in urban areas where they have to share space with other transport modes and where they are particularly vulnerable users. In addition, the pedestrian safety aspect underlines the need for ITS to enable the implementation of applications to extend the means of communication between pedestrians and other vehicles, which are traditionally visual and auditory. This is especially crucial with the emergence of silent (electric) engines: it will become more difficult for pedestrians to perceive the arrival of vehicles.
The V2P (Vehicle to Pedestrian) approach encompasses a broad set of road users: pedestrians, children being pushed in strollers, people with reduced mobility such as people in wheelchairs or other mobility devices, passengers embarking and disembarking buses and trains, visually impaired people or certain age categories such as the elderly or children.

ITS for cycles and pedelecs

We should first note that cycling has many advantages over low-emission alternatives or evolutions proposed for other modes:

• its level of GHG emissions is not hypothetical, or forecast by uncertain hypotheses,
• cycling is immediately available, and cheap compared to other modes; so its potential benefit is immediate and significant,
• GHG emissions linked to bicycles and their use are very marginal when compared to motorized transport. This is especially the case when compared to private motorized transport,
• cycling, as seen with walking, has important co-benefits in other areas or domains such as health, planning, time, cost, street safety, congestion, air pollution, noise pollution, energy security.

Cycling can also be a useful complement to the development of public transportation, as the last mile mode of transport.

ITS should therefore focus on this mode more than they currently do, for example by generalizing ITS Applications that help Bicycle Share Schemes (BSS).
The case of electric power-assisted bicycles, or pedelecs, deserves special attention. Studies have shown that the average pedelec commuting distance is 56% higher (9.6 km) than for commuters using a normal bicycle (6.3 km), suggesting that pedelecs allow for 56% longer daily commutes. The use of a pedelec also influences the use of other modes of transport. Pedelecs are usually a substitute for transport by bicycle (45%) or car (39%).
Like pedestrians, cyclists are VRUs (Vulnerable Road Users) and should benefit from all the future and existing ITS applications designed to improve road safety, especially in urban areas.
This can be illustrated by the following pyramid showing the factors influencing modal shift.

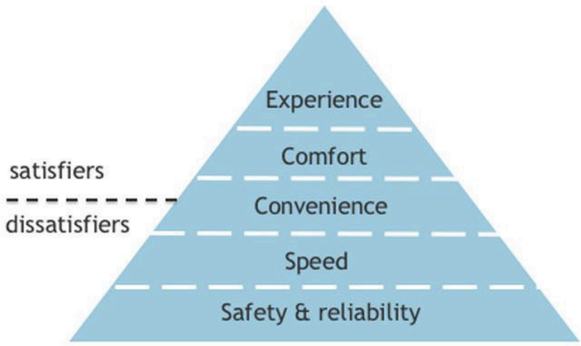

Figure 5 - Bicycle pyramid choice to shift to bicycle
Source: Koersdocument Fiets Overijssel, 2014

ITS should therefore improve the safety, reliability, speed, convenience, comfort and experience of cycling. Through apps, for example interactive/smart traffic lights, nudging apps, smart routing and parking, and tracking, cycling can become a more attractive transport mode.
All the data generated will then feed directly back to the cyclist, as shown in the virtuous loop in Figure 6.

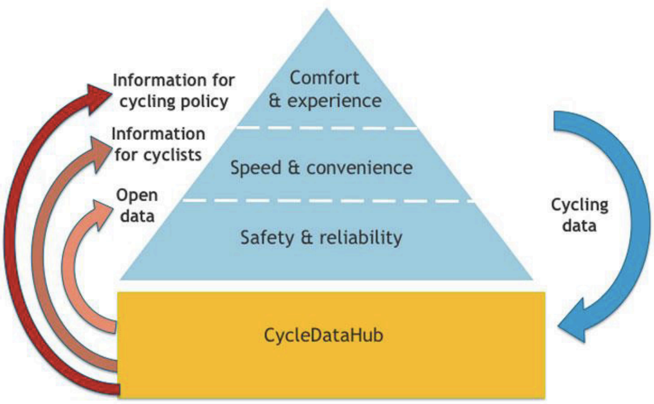

Figure 6 - How ITS can provide valuable input for cyclists

Indicators and Strategies

Eco-routing

Route Guidance Systems have greatly improved in recent years. They include on-board, off-board, and smartphone-based systems. These navigational aids now use geographic and real-time traffic information and can select optimal routes in a roadway network from specific origins to specific destinations. These systems attempt to minimize criteria such as travel time, distance, or even GHG emissions on more recent vehicles. Geo-location systems are typically coupled with route guidance systems to allow users to find specific locations, cutting down on extra driving (e.g. searching for a filling station, parking space, etc.).

Eco-driving

On-board eco-driving assistants are systems designed to:

• influence the driver's behaviour, such as gear shift indicators, stop and start system, anticipation of vehicle flows or traffic signs,

• recognise driving behaviour and provide real time on-trip advice or post-trip analysis. For example, Predictive Powertrain Control is now available on trucks and premium cars: this uses ITS coupled with vehicle and travel characteristics to anticipate a fuel-saving driving style. It uses a predictive speed profile based on a topography profile of the route to optimize control of the powertrain. Another vehicle system consists in collecting huge amounts of engine and on-board data to calculate environmental indicators and hence improve engine performance.
Eco-Cooperative Adaptive Cruise Control is another system that allows individual drivers to opt into applications that take advantage of adaptive cruise control capabilities coupled with V2V communications to minimize vehicle accelerations and decelerations with a view to reducing fuel consumption and vehicle emissions.

Platooning: eco-driving for trucks

In the same family as eco-driving, a significant improvement in heavy goods vehicle performance concerns platooning, consisting in creating a train of HGVs following each other with a reduced distance between them, thanks to on-board systems. We are not talking about completely autonomous (level 4) vehicles here! There is a driver on board each vehicle. Nevertheless, the trucks are equipped with radar and optical sensors, making them as smart as possible. The idea is not only to increase drivers' comfort (except for the one at the front), but also to improve the aerodynamics for all the HGVs following in the convoy.
This technique is far from new! In 1972-73 the European ARAMIS project implemented "trains" of as many 25 small transit vehicles travelling at about 50 mph using ultrasonic and optical range sensors. However, this was only on a French test track. More recently, there was SARTRE (Safe Road Trains for the Environment), another European Commission co-op project that ran from 2010 to 2012. Led by the engineering consultancy Ricardo UK, its sole OEM partner was Volvo on both the car and truck sides. It was the first such project to demonstrate platooning on public roads, in Spain, using vehicle-to-vehicle communication (V2V).

Indicators and Strategies

ITS and the transition to new energy sources

Elon Musk, inventor and CEO of Tesla has declared that, "in order to have clean air in cities, you have to go electric". And yes, electromobility can result in cleaner air in cities, but not necessarily elsewhere. Depending on how the electricity is produced, and the battery is made and recycled, e-vehicles may just mean that no polluting emissions are generated when and where they are driven. But what about before and after? And elsewhere?
The world map of Figure 7 - CO_2 intensity of electricity production by country - illustrates the disparity between countries regarding their carbon footprint for electricity production. France and Scandinavian countries appear clearly as exceptions in Europe, as nearly all electricity in those countries is produced from no-carbon sources (hydroelectric or nuclear).

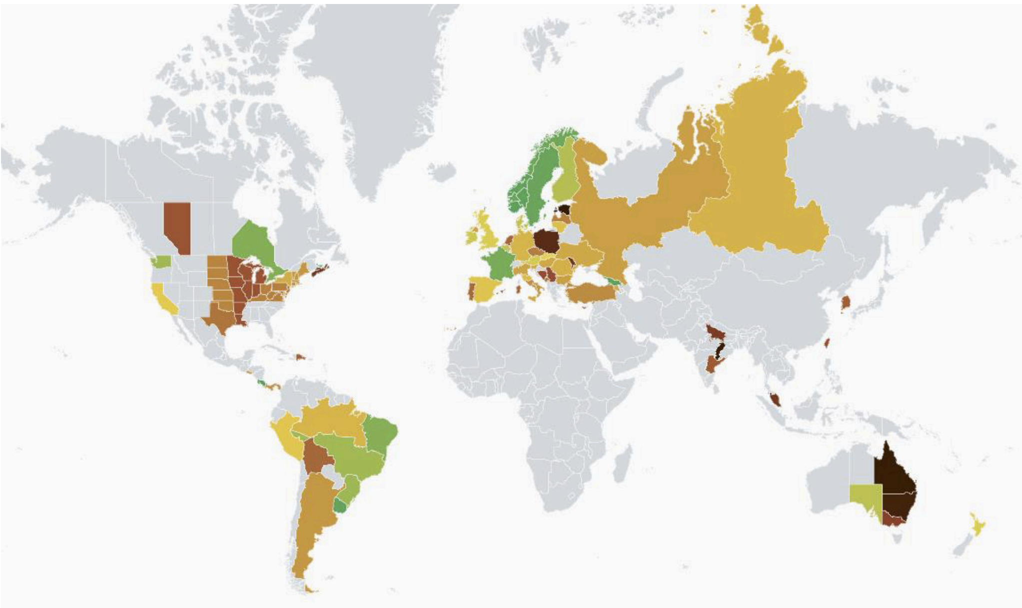

Figure 7 - CO2 intensity of electricity production by country

Figure 8, adapted from an analysis by the International Council for Clean Transportation (ICCT), shows an estimate of lifecycle emissions for a typical European conventional (internal combustion engine) car, the hybrid conventional car with the best available fuel economy (a 2019 Toyota Prius Eco), and a Nissan Leaf electric vehicle for various countries, as well as the EU average. [The Leaf was the top selling EV in Europe in 2018.] The chart includes tailpipe emissions (grey), emissions from the fuel cycle (orange) - which includes oil production, transport, refining, and electricity generation - emissions from manufacturing the non-battery components of the vehicle (dark blue) and a conservative estimate of emissions from manufacturing the battery (light blue). The dependence of electricity production on fossil fuel energy obviously has a direct impact on the CO_2 balance of the electric vehicle.

But our topic is ITS, not energy: we are not considering the relevance of alternative energy sources in transport, but rather how ITS can be used to guide consumers towards this or that solution. We will leave it to specialists to discuss the merits of alternative energy sources in terms of GHG emissions and environmental impact. Documents produced by experts and researchers show that the assessment is difficult and even controversial. However, how can ITS help to ensure that the transition is made as efficiently as possible, assuming the choice is made to convert vehicles to an alternative energy source, for instance electricity or hydrogen? In the current period of change from fossil fuels to alternative energy sources, a period when battery technology is still evolving, the most important barriers to change are, apart from the cost, the availability and density of the energy distribution network and knowledge and anticipation of a vehicle's remaining autonomy. ITS can provide both: firstly, by integrating in-vehicle maps and itineraries to recharging points, and secondly by providing efficient ICT-based solutions to show electric consumption and autonomy.

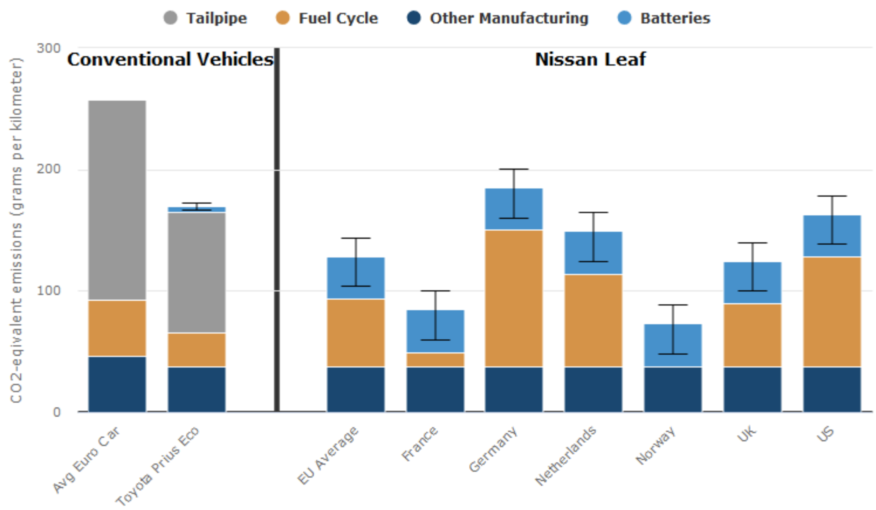

Figure 8 - Lifecycle greenhouse gas emissions: conventional vs Nissan Leaf by country
Source: CarbonBrief - Factchecks - 13 May 2019

Autonomous vehicles

There would not appear to be a direct link between autonomous vehicles and a reduction in GHG emissions. As proof, most experiments on autonomous vehicles are currently conducted with internal combustion engine vehicles. The nature of this link is quite controversial:

• On the one hand, it can be assumed that autonomous vehicles, because they are fully equipped with the ITS applications mentioned above, will be able to optimise their consumption as much as possible by combining the advantages of various technologies (eco-routing, eco-driving, anticipation, etc.).

• But experts also envisage indirect effects such as increased transport demand, empty transport when vehicles go back to a recharge point, or even competition with active modes and public transport, which would become less attractive.

ITS as vectors for low-carbon technologies

We present below some examples of ITS solutions and applications for reducing CO_2 emissions.

Crossings for groups of young pedestrians

TrafiOne is a detector for traffic management and dynamic traffic signal control developed by FLIR. TrafiOne combines a FLIR Lepton thermal imaging sensor with detection algorithms integrating thermal video to detect:

• vehicles and cyclists at the crossing in advance;

• pedestrians and cyclists on the sidewalk and/or pedestrian crossing.

The city of Metz decided to evaluate this traffic regulation strategy at a particular crossing, with a view to deploying it more widely on its territory if it proved to be an effective safety measure. The site studied was located between a college and a gymnasium. Several times a day, school groups, composed of 15 to more than 50 children, used this crossing to reach their college or gymnasium.
According to the assessment by Cerema[3] of the pedestrian crossing studied and with the parameters previously defined, the installation of TrafiOne sensors improved crossing conditions for pedestrian groups and in particular for groups of children.
This is typical example of ITS's objective of preserving active mode solutions instead of alternatives emitting GHG, such as the installation of shuttle buses over short distances.

Figure 9 - Evaluation of a thermal sensor for pedestrian detection in Metz3
Source: Cerema - Nov. 2018

[3] - Detection of groups of pedestrians and adaptation in real time of the duration of the green light - Study report - Cerema - November 2018 - https://www.cerema.fr/fr/actualites/ville-metz-cerema-participe-experimentation-nouveau-capteur

V2P application: Savari

Savari's V2P applications focus on making pedestrians and cyclists active participants in the V2X landscape, especially in Smart City scenarios. Pedestrians and cyclists are connected to vehicles and traffic lights through their smartphones. Savari offers a cloud solution: pedestrians and bicyclists are connected to the V2X environment, whether using DSRC or non-DSRC phones.
Savari currently features two pedestrian applications.
First, it alerts drivers of vehicles at an intersection of an approaching, distracted pedestrian violating the do-not-cross signs or crossing the road in unmarked areas. The alert appears on the car's infotainment display or the driver's tablet or smartphone, giving the driver life-saving reaction time.
Second, Savari, sponsored by the U.S. Department of Transportation (USDOT), has designed and developed SmartCross, an application that interfaces with traffic signal systems (see Figure 10). By communicating with the intersection traffic signal controller, the pedestrian requests a walk phase to cross the road. In addition to providing an alert when it is safe to walk, the application also provides automatic extension of the walk phase, which could be critical and life-saving for a mobility- or visually-impaired person.

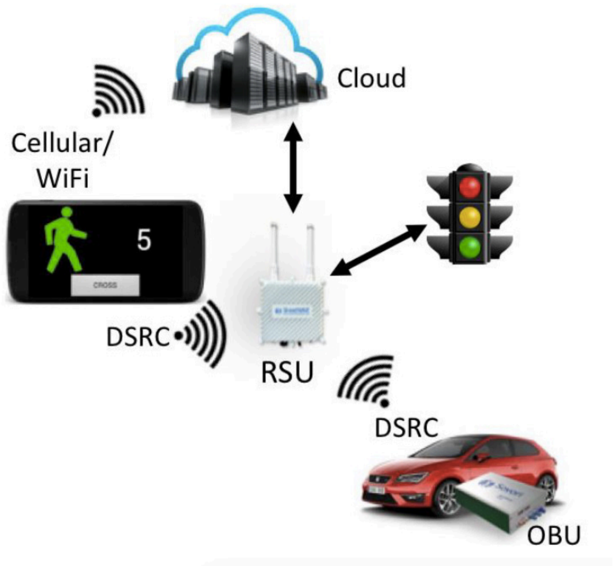

Figure 10 - SmartCross ecosystem
Source: US Department of Transportation

ITS as vectors for low-carbon technologies

Role of data and ITS in encouraging more cyclists: BITS project

As shown above, there is a lot of cycling in Denmark and the Netherlands: in Copenhagen (DK) and Zwolle (NL), cyclists account for over 30% and 48% respectively of daily travellers. It is no surprise then that they have experienced a wave of innovation with the rapid growth of e-bikes and Pedelecs (pedal electric-assisted cycles), promoting cycling as a real transport alternative.
For this reason, they are developing the B-ITS (Bicycles and ITS) project, based on the pyramids shown in the previous chapter. The key objectives of the BITS project are to

- Apply ITS to directly improve bike trips, stimulating the take-up of cycling,
- Create a Cycling Data Hub, creating added value by bringing together various cycling data on one virtual platform,
- Collect, process, manage and use this cycling data to get better insight into the specific needs of cyclists in order to drastically improve cycling policies, anchor cycling in broader mobility policies and share this data so it can used for a multimodal future,
- Reach out to other cities outside the partnership, to existing cyclists and non-cyclists.

Bringing together all the stakeholders and interested parties in the cycling ecosystem, B-ITS is building four types of ITS demonstrations: Information to cyclists, Interactive ITS, Infra-based ITS and Bicycle data collection.
A CyclingDataHub (CDH) will gather various data in a common framework. Data will be made available on an open data platform and used for evaluation.

Businesses on bicycles: "Boites à Velo"

It was in Nantes, in 2012, that the first "Boites à Velo" collective was created, at the initiative of four entrepreneurs who decided to run their businesses on two wheels.

Their objective was to create a forum to discuss the various difficulties encountered and to reflect together on the best way to overcome them, to share good ideas, and above all to appear as a strong entity in Nantes Metropole, a major driver of change in the field of urban logistics. This collective was soon emulated, first in Grenoble and then in Paris. In 2014, the Nantes "BAV" even won the national "Bicycle Talent" award. Today, there are about 500 bicycle-operated companies in France working in fields such as catering, transport, services, crafts, and personal services. Businesses on Bicycles collectives have been created in several major French cities including Strasbourg, Bordeaux, Lille and Toulouse.

Figure 11 - Compass 4D onboard device

ITS as vectors for low-carbon technologies

Eco-driving and eco-navigation

The EU carried out a major programme in connected vehicles called "eCoMove" which focused on "cooperative mobility systems and services for energy efficiency". The programme examined the latest V2I/I2V and V2V communication technologies and created an integrated solution comprising eco-driving support and eco-traffic management to tackle the main sources of wasted energy in passenger and commercial vehicles.

The eCoMove project targeted three main causes of avoidable road transport energy use in order to minimize fuel waste:

- inefficient route choice;
- inefficient driving performance;
- inefficient traffic management and control.

Another major project was **ECOSTAND,** a joint EU-Japan-U.S. task force to develop a standard methodology for determining the impacts of ITS on energy efficiency and CO_2 emissions. The overall goal was to provide support for an agreement between the three regions on a framework for a common assessment methodology for quantifying the impacts of ITS on energy efficiency and CO_2 emissions.

Compass4D was a multi-city project in Europe that focused on deploying advanced vehicle cooperative intelligent transportation systems (C-ITS) to improve road safety and energy efficiency and reduce congestion. It ran from 2013 to 2015, when it was demonstrated during the ITS world congress in Bordeaux.
Among the three services offered, the Energy Efficient Intersection (EEI) service proposed to reduce energy consumption and vehicle emissions at signalled intersections. Selected vehicles (Heavy Goods Vehicles, Emergency Vehicles, Public Transport) were given a green light when approaching the intersection, thus avoiding stops and delays. The same service also provides information to other drivers to anticipate current and upcoming traffic light phases and adapt their speed accordingly (GLOSA - Green Light Optimized Speed Advice).

C-The difference is a project that can be seen as a larger-scale demonstration of Compass4D. The aim was to deploy fleets of vehicles equipped with on-board devices more widely in the cities of Helmond (NL) and Bordeaux (FR). The project, organized by a consortium of pioneers committed to the capacity of C-ITS services, has three aims:

- To deliver comprehensive and integrated impact assessment by means of enhanced evaluation methodology and up to 18 months operation of a C-ITS services package,
- To bridge the gap between most advanced C-ITS implementations in urban environments and large-scale deployment and operations by targeting professionals responsible for urban transport planning and operations, policy makers and decision makers,
- To convince European cities to invest in mature and proven C-ITS solutions by fostering and replication through a City Twinning Programme.

Involving the public and private sectors, from industry to cities and also research institutes, C-the Difference produced an assessment of C-ITS applications with regard to GHG emissions.

Figure 12 - C-The Difference mobile application

OptiTRUCK - an EGVI (see below) - aims to improve energy efficiency by at least 20% in Euro VI HDVs (40t). To achieve this, optiTruck will develop a global optimiser which brings together the most advanced technologies from powertrain control and intelligent transportation systems, with a number of innovative and complementary elements to maximise the potential utilisation of individual innovations. Real driving trials demonstrating the optiTruck solution will take into account road topography, traffic and weather conditions, vehicle configuration, and transport mission. Another project in this sector is the Scania Driver Support system providing real-time coaching in HGVs with tips and feedback via a visual HMI.

ITS as vectors for low-carbon technologies

Platooning

We mentioned above the SARTRE project (Safe road trains for the environment) for platooning. Even though it is an old project (2010-2012), it is worth mentioning as it was so innovative.
Very significantly, this project's road train mixed trucks with cars. There was a manually driven lead truck followed by one truck and three Volvo cars. All the following vehicles were driven autonomously at speeds of up to 55 mph - in some cases with no more than a 13-foot gap between them.
The goal was to develop strategies and technologies that will ultimately make platoons viable on public highways and bring environmental and safety benefits. The long-term vision is to create a transport system where joining a road train would be easy. To facilitate that, road-train information and operation will be integrated into future Volvo vehicles when the technology is ready for production. Booking, joining and leaving a road train must be smooth and easy, says Volvo. To join a convoy in your car, you will wait at an entrance ramp while your phone "polls" passing vehicles to find one with a matching destination. Then you simply catch up with the platoon autonomously, your on-board sensors detecting the right vehicle ahead.
Another experiment took place in 2014 in Nevada[4]. There was also a demonstration held in 2016 of semi-autonomous trucking called the European Truck Platooning Challenge. Organized by the Dutch Ministry of Infrastructure and the Environment, it involved trucks from six different European manufacturers (DAF Trucks, Daimler, IVECO, MAN, Scania, and Volvo). Several trucks from each company left their home bases and travelled in platoons to the Dutch port of Rotterdam, arriving together on April 6. The trucks in each platoon were connected via Wi-Fi.

Figure 13 - Routes for European Truck Platooning Challenge

[4] - https://www.truckinginfo.com/118131/truck-platooning-system-offers-fuel-savings-potential

ITS as vectors for low-carbon technologies

ITS for alternative energy sources: EGVI

Launched in 2013, as part of the "Smart, Green and Integrated Transport" challenge of Horizon 2020, the European Green Vehicles Initiative (EGVI) succeeded the European Green Cars Initiative (2009-2013). This project brings together stakeholders from three different European Technology Platforms (ERTRAC, EPoSS and Smart Grids) to form the European Green Vehicles Initiative Association (EGVIA) with the associated European Commission services (DG RTD, DG MOVE, DG Connect). EGVI is following a system approach to tackle the challenge of the decarbonization of road transport, and contribute to the transition to greener road transport, while boosting the innovative strength and competitiveness of the European economy. Most of the project includes ITS Innovation, such as:

• **ELECTRIC** will develop, for EV users, advanced driver assistance services that help and motivate users to plan travel and charging in a way that is convenient and yet respects potential constraints on charging capacity.

• **NeMo** focuses on interoperability and seamless electro-mobility services. NeMo addresses all issues through a pan-European eRoaming Hyper-Network that allows seamless and interoperable use of electro-mobility services throughout Europe. In addition, it provides an Open Cloud Marketplace, where third parties can provide services (B2B2C) with a view to increasing EV attractiveness. The NeMo Hyper-Network is a distributed environment with open architecture based on standardised interfaces, in which all electro-mobility actors, physical (CPs, grids, EVs) or digital (CPOs, DSOs, etc.), can connect and interact seamlessly, exchange data and provide more elaborate electro-mobility ICT services in a fully integrated and interoperable way both B2B and B2C.

• **ELVITEN** will propose replicable usage schemes to boost ownership or sharing of all categories of EL-Vs (light electric vehicles) by systematic and occasional urban travellers and light delivery companies. Existing charge points in the ELVITEN Demonstration Cities, including private ones, are integrated into a Brokering and Booking service and EL-V charging possibilities will be integrated into the biggest eRoaming platform in the market, to enable EL-V users to charge independently from charge point operators.

Effectiveness of low-carbon solutions

Active modes: ITS potential positive effect

As we have seen, ITS can significantly contribute to the transition to active modes of travel. Several studies have examined the potential effect of this change on greenhouse gas emissions, which is also associated with undeniable health benefits.
The key figure to keep in mind is that that each mile of increased active travel is associated with seven miles of reduced motor vehicle travel. Given that walking or cycling could realistically be substituted for 41% of short car trips, it could lead to saving nearly 5% of CO_2 equivalent emissions from car travel.
The following studies are cited by the Victoria Transport Policy Institute[5]:

• Komanoff and Roelofs 1993 showed that each 1% shift from automobile to active travel typically reduces fuel consumption 2-4%.

• Grabow, et al. (2011) estimated changes in health benefits and monetary costs if 50% of short trips were made by bicycle during summer months in typical Midwestern U.S. communities. The combined benefits of improved air quality and physical fitness were estimated to exceed $7 billion/year.

• Rabl and de Nazelle (2012) showed that switching from driving to bicycling for a 5 km one-way commute 230 annual days provides physical activity health benefits worth €1,300 annually and air emission reductions worth €30 /year overall.

• Gotschi (2011) estimated that Portland, Oregon's 40-year bicycle facility investments in the range of $138 to 605 million will provide $388 to 594 million healthcare savings, $143 to 218 million fuel savings, and $7 to 12 billion in longevity value, resulting in positive net benefits.

VRUITS project as an illustration

The VRUITS project (Improving the Safety and Mobility of Vulnerable Road Users through ITS Applications), co-funded by the European Commission, investigated how the safety and mobility of Vulnerable Road Users (VRUs) can be improved through Intelligent Transportation Systems (ITS).
The project compared 10 systems among some of the most promising applications: VRU beacon system (VBS), Powered Two Wheelers oncoming Vehicle information (PTW2V), Bicycle to Vehicle communication (B2V), Cooperative Intersection Safety (INS), Green Wave for Cyclists (GWC), Pedestrian & Cyclist Detection with Emergency Braking (PCDS+EBR), Blind Spot Detection (BSD), Intelligent Pedestrian Traffic Signal (IPT), Crossing Adaptive Lighting (CAL) and Information on Bicycle Rack Vacancy (IVB).
The project proposes a quantitative impact assessment in terms of safety, mobility and comfort, as well as a cost-benefit analysis. It also highlights the extent of the impacts that the selected ITS systems might have on the environment, as the CBA analysis considered not only benefits in the field of safety, mobility (travel time and travel costs) and comfort, but also for the environment. For this, a simplified estimation of the potential environmental benefits of ITS was made, focusing on the impacts on emissions due to a change in the overall modal shift and passenger-km in each mode.

[5] - Victoria Transport Policy Institute, Evaluating Active Transport Benefits and Costs, Guide to Valuing Walking and Cycling Improvements and Encouragement Programs, 28 Nov.2018

Table 1 - CBA indicators for the 10 ITS applications
Source: VRUITS

	INS	PTW2V	VBS	CAL	B2V	GWC	IVB	IPT	BSD	PCDS+EBR
NPV (in M€)	2,155	1,061	677	169	114	6	-368	-553	-12,948	-36,529
Benefit/Cost ratio	7.9	20	2.6	1.8	4.8	1.5	-0.1	0.5	0.2	0.3

Two Indicators of CBA were considered:

• The Net Present Value (NPV) of costs and benefits. The best performing system in that aspect is INS (€2.2 billion). This system also delivers a very high level of benefits compared to the costs of implementing it.

• The Benefit/Cost ratio allows for the estimation of the balance of costs and benefits of a system. It indicates how many monetary units of benefits are produced in return for every monetary unit of cost invested in a project (in NPV). Here the order of the system performance is slightly different. The best performer on this indicator is PTW2V, followed by INS and B2V.

As shown in table 1, INS is the best for NPV and presents a high BC ratio. In terms of profitability, PTW2V is the best. Conversely, the benefit/cost ratio is less than 1 for IVB, IPT, BSD and PCDS+EBR systems, meaning that they produce more costs than benefits.
VRUITS shows that, for any of the ten systems, safety plays a dominant role. This is important, given that safety is clearly an obstacle in the transition from driving a car to walking or cycling.

Businesses on Bicycles

Concerning the "Boites à Velo", described in the previous section, the estimated CO_2 savings in 2013 were 35 tons per year, resulting from 8 businesses that would have used a car and 13 businesses that would have used a van. The Boites à Velo's total distance travelled by bicycle is about 105,000 km per year.
Boites à Velo members "Ze Plombier" (plumbing) and "La Bricolette" (carpentry) are 20% more profitable when using bikes rather than vans, due to reduced business travel costs. For example, most plumbers will charge between €40 and €60 as a standard call-out charge - this charge covers the costs of their vehicle, insurance, fuel, and parking. Ze Plombier charges a call-out fee of just €20, with only €5 of this going to cover costs, thereby making an additional €15 profit on the service provided.

Bicycle Share Systems

A study from the OBIS project outlined the extent to which BSSs were able to shift trips. It found that BSSs were a substitute for motorized private transport between 4% (Berlin) to 77% (Senigallia, Italy) of the time, and public transport in 8% (Barcelona) to 58% (Stockholm) of cases. In total, BSSs were a substitute for motorized transport for 52% (in Rimini) to 77% of users (in Milan)6. In several cities in France, BSS enables wider use of bikes, because owning and storing a bike in a city centre apartment is not always possible. For instance, in Lyon the launch of Velo'v increased use by 44%, and in Paris Velib' increased use by 70%.

Effectiveness of low-carbon solutions

Eco-driving and eco-navigation

Overall, the eCoMove project showed fuel savings of around 10% to 20% for eco-driving and approximately 10% savings for traffic signal operations.
Generally speaking, a gain of about 5% to 10% may be obtained in urban areas by eco-navigation.
Eco-driving is especially useful for lorries and freight transport, as vehicles are heavier:

- Cooperative adaptive cruise control (C-ACC) was tested on trucks in the euroFOT project: an average 2% fuel saving was measured.
- Predictive Powertrain Control applications on the market from OEMs like Scania (active prediction), Daimler (predictive powertrain control), or Volvo (I-See) showed an average saving of 5% of fuel /CO_2.

The Scania Driver Support system announced a 10% improvement in fuel efficiency due to real-time coaching for HGVs.
In the C-The Difference project, measurements in Helmond and Bordeaux showed that the system (which included an in-cab GLOSA service) led to an improvement in HGV CO_2 efficiency (g/km) of 5% - 10% at intersection level.

Platooning

Concerning platooning, trucks in such convoys are able to drive very close together, significantly reducing aerodynamic drag and increasing fuel-efficiency by as much as 20%, depending on which test you look at. The smaller the gap between vehicles, the better the fuel savings. The results of SARTRE (see above) clearly showed a benefit, with measured fuel savings of up to 20%.

Auburn University's GPS and Vehicle Dynamics Laboratory conducted a study, along with partners Peloton, Peterbilt, Meritor-Wabco, and the American Transportation Research Institute, and reported on the first phase of research into the possible benefits of truck platooning technologies. It showed that all trucks in a platoon gain in fuel efficiency, with the lead truck gaining as much as 5% and following trucks up to 10%.
In the Nevada experiment, Josh Switkes, Peloton CEO, said the system combines forward-looking radar, intelligent braking, and a V2V link to allow the trucks to travel close together, reducing drag and saving fuel in the process. Switkes said that in a test with C.R. England last year, they achieved a 10% improvement in fuel efficiency for the following trucks and a 4.5% increase for the front truck.

[6] - Cited by European Cyclists' Federation - Cycle more often 2 cool down the planet

Effectiveness of low-carbon solutions

Autonomous vehicles

Current research is examining how automated vehicles may affect travel demand. Preliminary results show that with a modest introduction of automated vehicles, a 5% increase in VMT (Vehicle Miles Travelled) may occur.
However, the general effects of ITS on travel demand still need to be studied in more detail. Currently, autonomous vehicles will combine the effects of changes in consumer behaviour, policy intervention, technological progress and vehicle technology. Figure 14 illustrates the range of possible vehicle automation impacts in the United States of America. This is a general issue for ITS development: ITS innovations, combined with the use of low-carbon energy and e-mobility, may discourage the use of active travel (walking, cycling) and encourage the maintenance of individual vehicles as the default mean of transport, especially in urban areas.

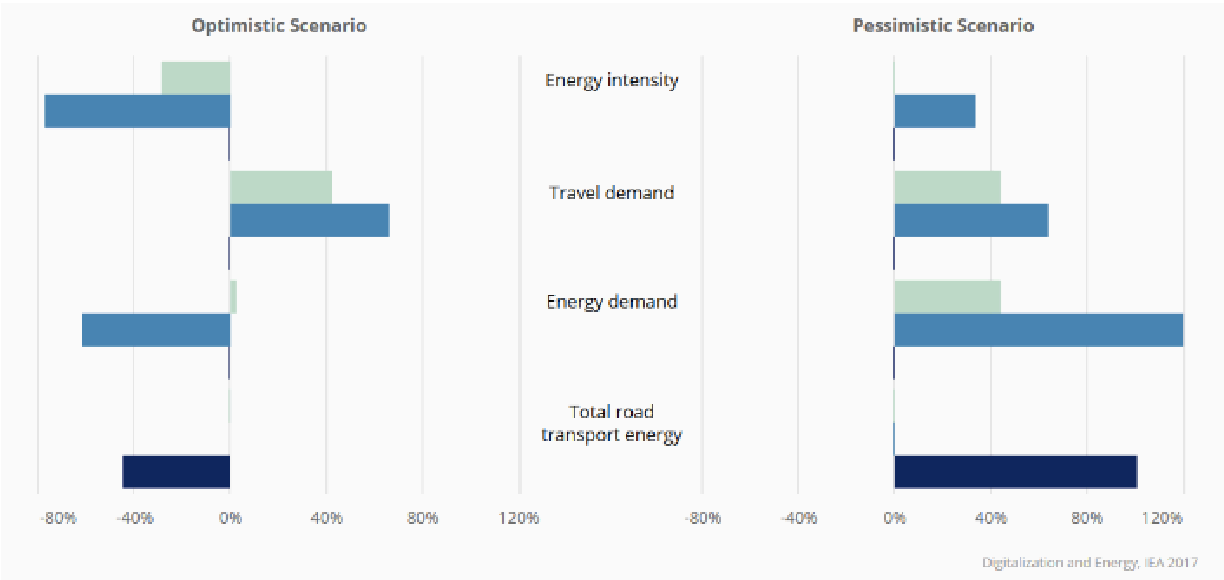

Figure 14 - "Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles"
Source: Wadud, MacKenzie and Leiby (2016),

Challenges, perspectives and opportunities

Challenges

ITS aim to improve traffic flow, creating the necessary conditions to reduce traffic jams, stops and delays for vehicles in order to reduce fuel consumption and CO_2 emissions.
However, ITS also generate their own energy demand. We must keep in mind that ITS need energy to operate, not only in terms of their own power supply but also secondary factors such as the air conditioning of buildings dedicated to computers needed for cloud computing. Moreover, ITS can generate additional travel demand by providing attractive vehicles and travel conditions on attractive roads, leading to increased demand, further amplified by people's natural attraction to cutting-edge technologies.
While one of the aims of ITS is to reduce greenhouse gas emissions from transport, they could also contribute to such emissions on the one hand by increasing traffic, and on the other by encouraging people engaged in natural walking or cycling practices to switch to more attractive, rewarding and safer means of transport.
The excitement surrounding ITS today can also lead to the operationalization of non-mature systems that could undermine their overall credibility, not to mention the multiplication of standards and the possibility of a European, national, regional, and even metropolitan patchwork of non-interoperable solutions. Because ITS manipulate high-tech instruments, there is a strong temptation to confine them to the most technical areas and to turn away from the fundamentals of the transport mode. Thus, an important, perhaps the most important, challenge for ITS, leading to a significant reduction in carbon emissions, would be to support change in the governance of mobility, which would allow both:

- a return to the most basic form of mobility: walking, and its first mechanical evolution: cycling,
- a transformation of the private car into a means of public transport: this is the central subject of the MaaS, as discussed in topic 5 dealing with Maas4C.

Perspectives and opportunities

Smart mobility in a world of connected vehicles and infrastructure, with a shared goal of lower emissions, is an overall aim of ITS for climate. Fossil-fuel vehicles will continue to become more efficient, and the market share of zero-carbon vehicles will grow rapidly, driven by European legislation, improved technologies and the supporting infrastructure.
The economics of autonomous vehicles may increase their presence on our roads, but their impact on GHG emissions and road traffic is unclear.
Cooperative systems (C-ITS) could lead to less emissions if clear evidence emerges of their effectiveness, and if a mass market develops. Data and information, both from and used by vehicles, will continue to grow exponentially, and may stimulate innovative services leading to lower emissions.
Above all, the optimisation of transport and mobility for zero or lowest emissions needs to become a much higher priority of the ITS community. It surely offers opportunities for ITS businesses to develop new markets, and for cities and public authorities to apply new tools that can at least help them meet their climate targets.

Conclusions and recommandations

Moving goods and people, even if it can sometimes be avoided thanks to new technologies (videoconferencing, 3D printing, etc.), will always be essential. Moreover, it should be viewed as desirable, considering that humanity has always been enriched by exchanges and movement.
However, transportation today is largely dependent on fossil fuels and therefore emits a large amount of greenhouse gas: in Europe transport represents almost a quarter of GHG emissions as it depends on oil for about 94% of its energy needs. Lowering carbon emissions for transportation is therefore a key issue when looking for the biggest impacts on the climate.
Meanwhile, we are at a time when technology is offering new solutions for everyone, especially in the field of transport. This applies not only to technical improvements in engines, fuels and transmission systems, but also to ICT applied to transport: ITS.
Therefore, what could be more natural than to question the possible contribution of ITS so that transportation emits less GHGs?

Lower carbon emissions: alone may be faster, but together we can go further and ITS can help

In order to limit GHG emissions, and given the urgency of the climate issue, it is tempting to devise solutions independently, that will address this or that aspect of the problem, without necessarily contextualizing it or considering a global evaluation of the proposed solution (see below). However, solutions should no longer be considered individually, but rather as part of an overall transportation system: this systemic vision will increase the effects of each solution individually.

As shown in other topics, solutions promote emission savings through a variety of measures such as: better traffic & transport management and control; innovative mobility services; alternative fuels and better engine & vehicle efficiency; higher occupancy.

In this context, ITS, being strongly linked to all these topics, could be an excellent tool to be mobilized to obtain cross action in an ASI (Avoid - Shift - Improve) perspective: improving networks, modes and systems (topic 3), focusing on freight and logistics (topic 4), considering mobility as a service for climate (topic 5)… not to mention promoting the carbon-free travel we have discussed in the present topic 2.

Not only intelligent transportation, but also broadly intelligent mobility

Subject to a sustainable trend in which information technology will play an increasingly important role, the entire transportation system should benefit from ITS contributions.
However, none of the system's components should be excluded from this evolution. In particular, the modes of transport that are by far the least carbon-intensive and which, while they may require cultural change, do not require technological change, i.e. walking and cycling.

Therefore, as underlined in ITS4Climate, ITS must be considered in a context of smart mobility. No mode can be neglected. We have seen some initiatives in the present topic of ITS targeting pedestrians or cyclists, but these are still too rare. All initiatives to apply ITS to these two "natural" modes of transport should be encouraged, and more projects funded. In addition, initiatives concerning other modes must also take into account the specificity of interactions with pedestrians and cyclists. Particularly with regard to their safety, since this aspect is one of the major obstacles to the expansion of these modes, especially in urban areas.

Conclusions and recommandations

Expand the scope of climate assessment in time and space

The issue of greenhouse gases knows no boundaries, either spatial or temporal. Pollution, and more broadly the effects on the climate or the environment, cross the administrative boundaries of our states, and persist well beyond the temporal limits of elected mandates, technological trends and even our lives.

So, we should not deal with the major problem of climate change by focusing only on where and when energy is spent, but rather consider the entire cycle, integrating the entire energy production and waste recycling cycle (Figure 15), and also the energy required to operate the datacentres and all the high-tech equipment used to make ITS implementation possible.

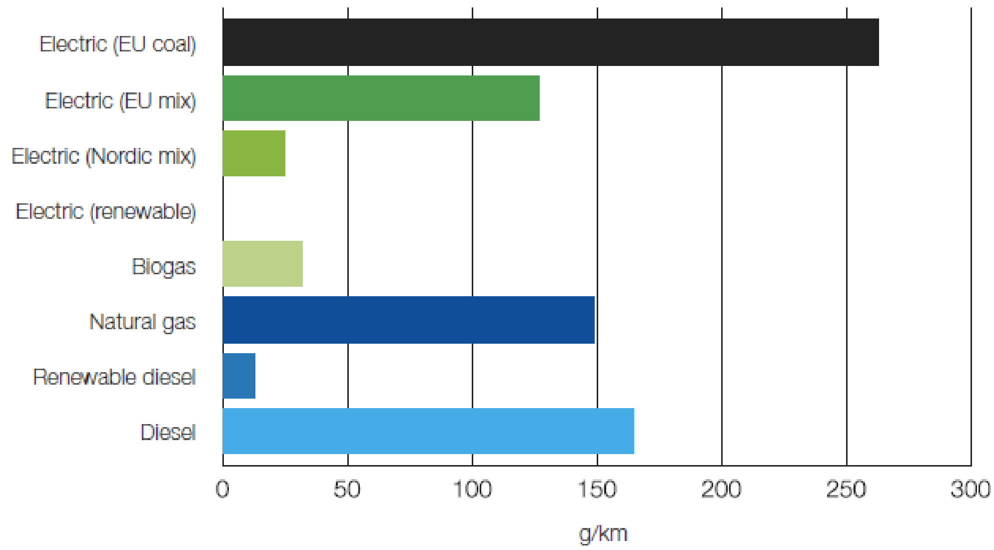

Figure 15 - Full fuel cycle (well-to-wheel) GHG emissions by passenger car energy source, from Smart Sustainable Mobility
Source: VTT - 2014

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As a projectmanager Smart & Green Mobility I have the honor of representing the City of Helmond within European, national and regional ITS projects. My main focus last year was on the lobby for ISA at the EP, as well as bringing together stakeholders and initiating projects to speed up the roll out of ISA. Since 2008, Helmond was granted a political mandate to use the City as a Living Lab for Smart Mobility. We bring a lot of usecases like FREILOT, C-the-Difference, FABULOS and now C-MobILE. Helmond aims to face challenges like pollution, and foster objectives like sustainable economic growth, in a Smart and Green way.

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