ITS4C Congress
Smart Mobility for Climate
17 - 19 September 2019

Decarbonisation Toolbox
WORKSHOP 1

1 Climate goals Mesuring and Evaluating GHG emissions

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.

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Introduction

This topic cover the domain of climate change and assessment of Greenhouse Gas (GHG) emissions. Other expert groups are highlighting the effectiveness of advanced technologies for low-carbon vehicles traffic networks and public transport, goods transport and logistics, and Mobility as a Service (MaaS), challenges and barriers.

Context

Climate change is among the most pressing challenges facing the world today. Given the current concentrations of GHG, the world is already on track for significant heating. This is a serious threat to human civilization and lives, given the wide range of expected climate impacts on natural systems as well as on human societies, as assessed in the most recent report of the Intergovernmental Panel on Climate Change.

The severity of these impacts will depend in part on the outcomes of global efforts to mitigate climate change. Sustainable development remains at the core of the global agenda as emphasized in several reports of the World Bank and as highlighted by the United Nations' Sustainable Development Goals (SDGs).

Importance of cities in GHG mitigation

Urbanisation is a defining phenomenon of this century. The EU is part of this transformation, where more than 75% of Europeans live in cities. This transformation represents a challenge, but also a huge opportunity to harness the growth and development benefits of urbanization while proactively managing its negative effects.
The importance of cities for mitigating climate change is indisputable: EU urban areas account for 60 to 80% of global energy consumption and almost the same share of carbon dioxide (CO_2) emissions (Fig. 1).

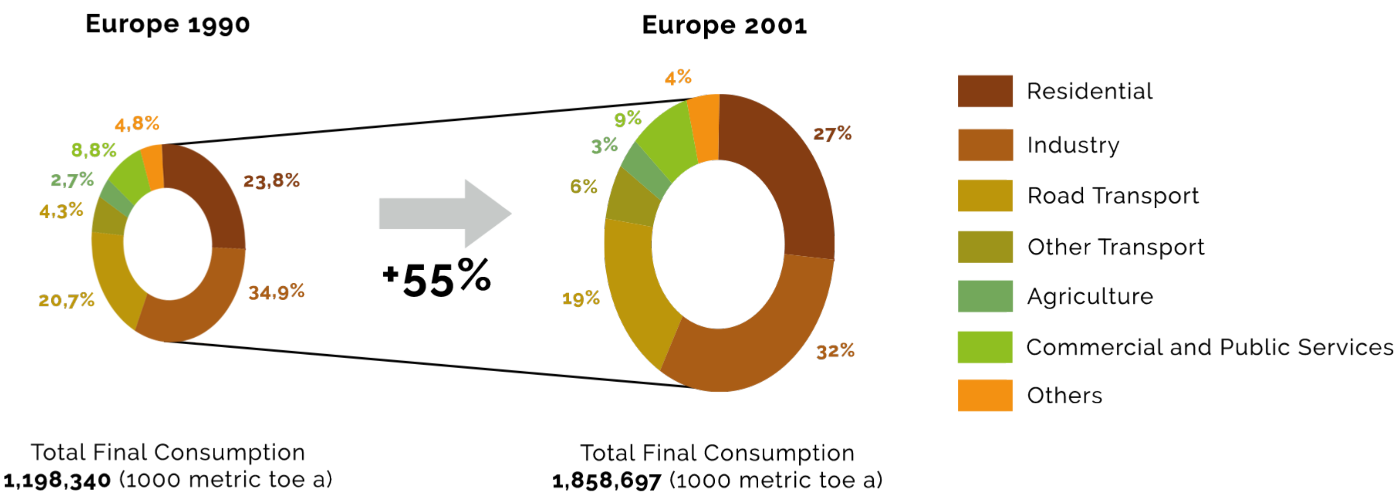


Figure 1 - Energy Consumption by sectors in Europe
Source: World Resources Institute — www.earthtrends.wri.org

Introduction

Accordingly, cities will have a major role to play in monitoring and reducing greenhouse gas (GHG) emissions and mitigating climate change.

For Europe to reduce its GHG emissions by 40% by 2030 compared with 1990, its members and more particularly its cities will have to align their policies on that goal enabling the EU to move towards a low-carbon economy and implement its commitments under the Paris Agreement. Many cities are indeed willing to do so. The EU has launched the Covenant of Mayors in 2008 to endorse and support the efforts of local authorities in the implementation of ambitious sustainable climate and energy. Today over 9,000 municipalities have signed up and are creating sustainability plans.

Transport sector CO_2 and Total GHG emissions

According to the annual EU GHG inventory[35], transport is the second highest source of GHG emissions in Europe (EU-28), contributing to 27% of those emissions in 2016. This value decreases to 20% if international emissions from aviation and maritime are excluded.

Between 1990 and 2016 (see Fig. 2), GHG emissions decreased by 24% reaching their lowest level during this period in 2014. **This decrease occurred in the majority of sectors except for transport where GHG emissions increased by 18%** (excluding international aviation and maritime). If international emissions are included, this value reaches more than 26%.

In 2016, GHG emissions from international aviation more than doubled compared to 1990 levels (114%), followed by increases in international shipping (33%) and road transportation (22%) emissions.

This trend in the transport sector can be explicated by increased fossil fuel use resulting in a significant rise in passenger-kilometre and tonne-kilometre demand. Almost a quarter of total energy consumption comes from transport (Fig. 1 and 2). At the same time the transport sector is still highly dependent on petroleum products with only 4% of its energy consumption met by renewables in 2016 (IRENA).

[35] - EEA (2018a). Annual European Union greenhouse gas inventory 1990–2016 and inventory report 2018—EEA Report No 5/2018. https://www.eea.europa.eu/publications/european-union-greenhouse-gas-inventory-2018

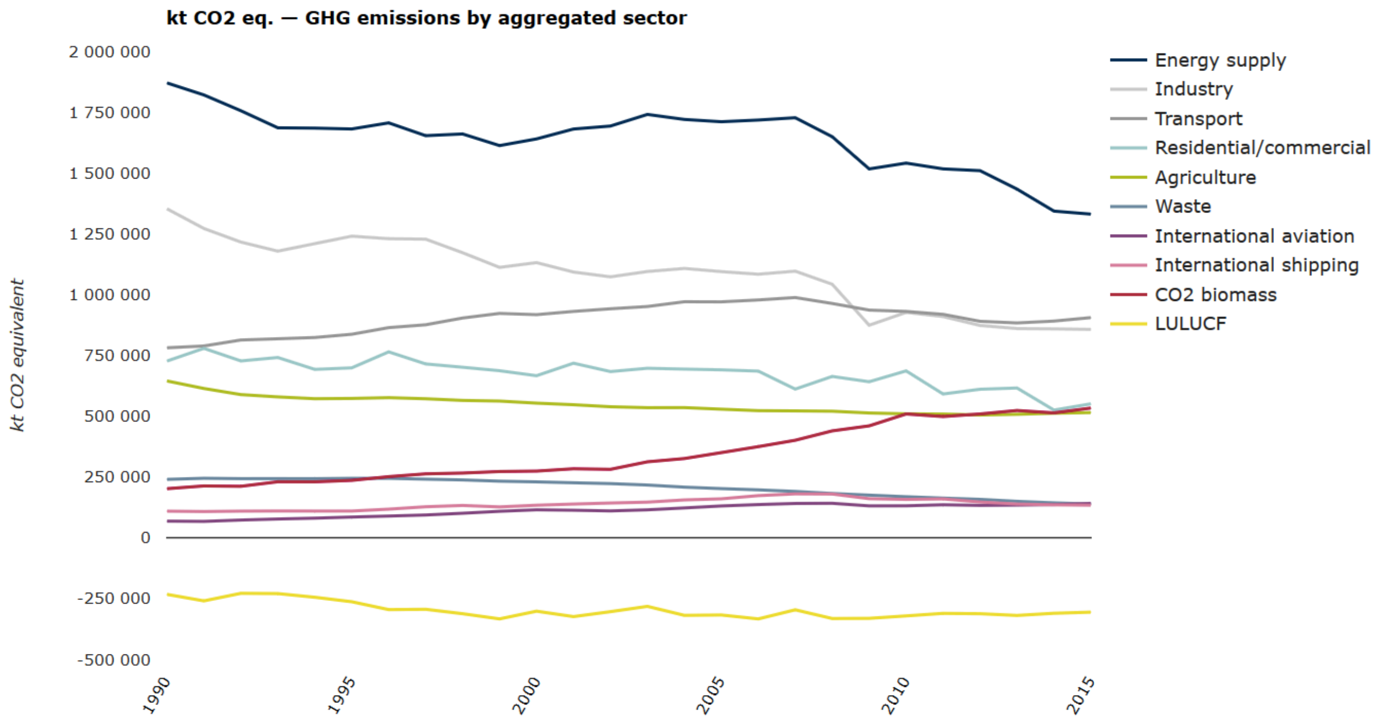


Figure 2 - GHG emissions trends between 1990 and 2015 in Europe GHG emissions by aggregated sector37.
Source : www.eea.europa.eu/data-and-maps/daviz/ghg-emissions-by-aggregated-sector-2#tab-chart_1

In Europe the most important GHG is CO2, accounting for 81 % of total GHG emissions in 2016. Road transportation accounts for 25% of total CO2 emissions in the same year. It is the greatest source of those emissions[35]. Transport-related emissions will need to fall by two thirds by 2050 to meet the 60% GHG emission reduction targets of the 2011 Transport White Paper[36].

[37] - EEA (2019). GHG emissions by aggregated sector—Data visualization.
https://www.eea.europa.eu/data-and-maps/daviz/ghg-emissions-by-aggregated-sector-2#tab-chart_1
[36] - EEA (2018b). Greenhouse gas emissions from transport—Indicator Assessment.
https://www.eea.europa.eu/data-and-maps/indicators/transport-emissions-of-greenhouse-gases/transport-emissions-of-greenhouse-gases-11

Introduction

Setting transport sector emission targets

By international agreement, e.g. the Paris Agreement of COP 21 in 2015, countries and the EU have committed to actions to limit emissions consistent with keeping global heating to no more than 1.5o. However, for regions, cities, businesses and individuals this has little or no meaning or influence on their emission-causing activities. What is needed is a robust way to break down and allocate emission targets and commitments to smaller units, including to cities, to businesses and other activity centres, and ultimately to individual travellers and goods consignments.

Such a breakdown of targets is needed for any scheme of emission reduction with accompanying charges, penalties or incentives. It's also necessary for actors at all levels to know how effective they are at meeting their individual targets.

It is accepted that urgent strategies and measures to reduce CO2 and total GHG emissions are required to avoid further climate change. This major challenge should be surmountable in a period when information is omnipresent, making it possible to optimize uses in terms of resources or network use, for example in traffic. This information in the broad sense, coming from different horizons, on very different aspects, offers means of supervision and action through the fusion and intersection of the different fields.

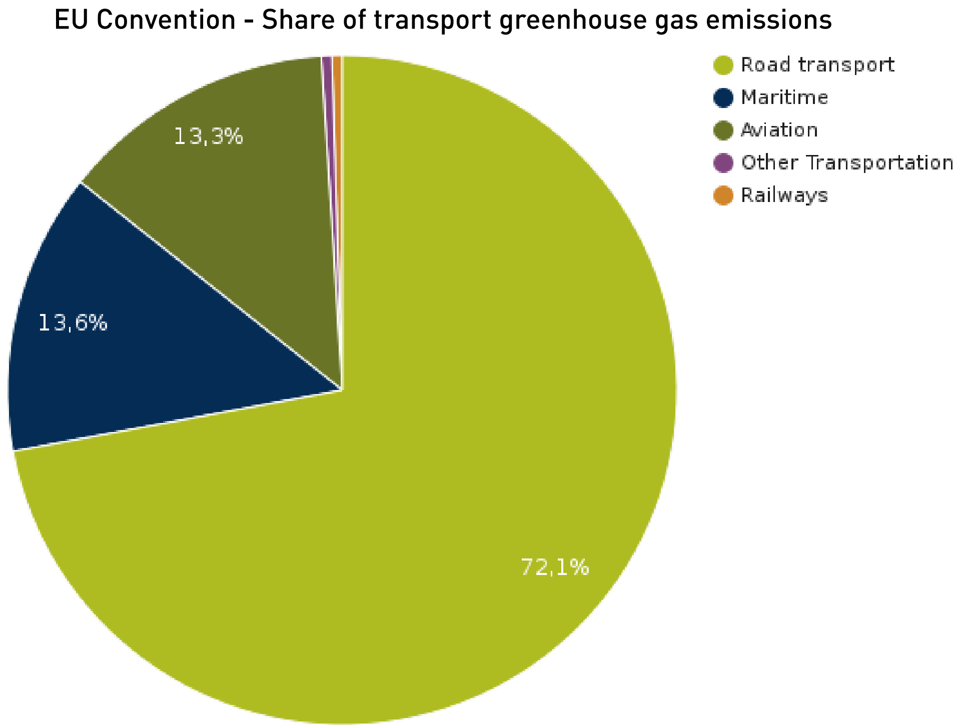


Figure 2 - 2016 Share of Transport GHG Emissions in Europe (EU-28).
Source: www.eea.europa.eu/publications/european-union-greenhouse-gas-inventory-2018

GHG/CO2 Emissions from Transport Activities

For climate change mitigation, it is fundamental to quantify the GHG emissions attributable to each sector. **Emissions must be measurable to be manageable.** Countries, regions and cities will otherwise not be able to set meaningful targets for emissions reductions, track progress towards achieving such targets, or obtain financing readily.

GHG emitted by transport mainly consist of carbon dioxide (CO_2), in addition to small amounts of methane (CH4) and nitrous oxide (N2O). In order to compare the warming effects of different GHG, the global warming potential (GWP) is used. The GWP relates the amount of heat trapped in the atmosphere by a particular GHG to the amount of heat trapped by a similar mass of CO_2. In this way, the sum of all GHG emissions can then be indicated as CO_2 equivalents.
The global warming potential (for a time horizon of 100 years) of carbon dioxide, methane and nitrous oxide are as follows (cf. IPCC[1]):

CO_2: 1 CH_4: 24 N_2O: 298

It can be challenging to account for road transport activity sector emissions in urban areas given the nature of the road transport, which contains numerous mobile sources moving within but also across the boundaries of the urban territory, according to various patterns. Depending on the aim of the inventory, the energy consumption and associated emissions could be accounted for in different ways. **There are four main types of boundaries that could be used to quantify GHG emissions from transport in a given area** (Figure 5).

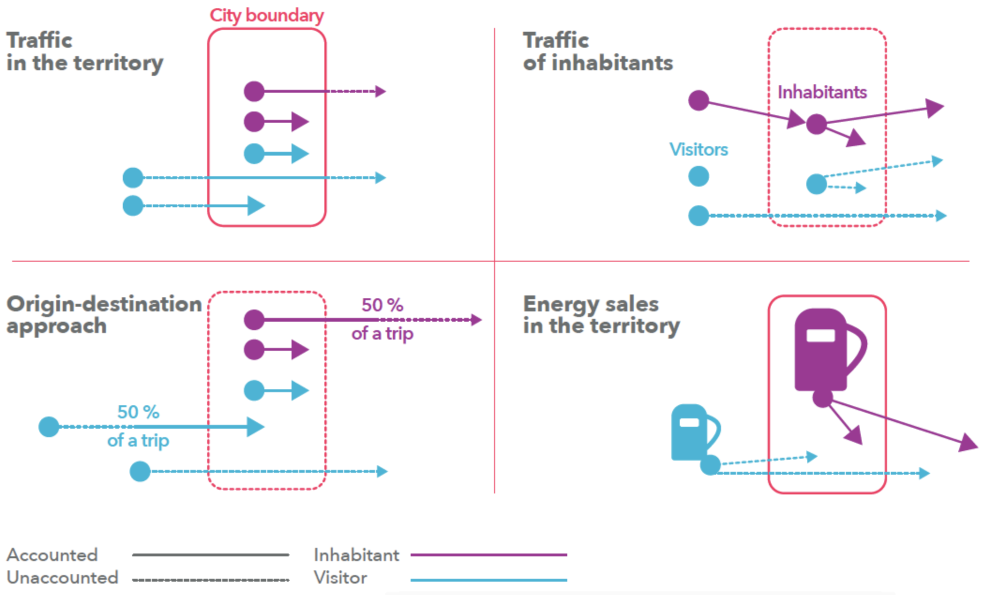


Figure 5 - Possible boundaries to quantify GHG emissionsfrom the transport sector
Source : MYC, 2017, MobiliseYourCity - Monitoring & reporting approach for GHG emissions, http://mobiliseyourcity.net/wp-content/uploads/sites/2/2017/09/MobiliseYourCity_MRV_Approach.pdf

[1] - The Intergovernmental Panel on Climate Change.

GHG/CO2 Emissions from Transport Activities

Measuring and quantifying GHG emissions

Once those boundaries defined, the transport related GHG emissions can be quantified according to complementary methods. One is based on in situ measurements. The other is based on estimations. Those methods hereafter presented quantify the emissions that physically occur from road transport, i.e. emissions produced by the combustion of fuels. Moreover, this section focuses on methods applied at local and territory scales. We discuss below the growing need for detailed real-time data on actual emissions from individual vehicles, travellers and even goods consignments.

1. **Measuring transport GHG emissions.** The World Resources Institute identifies two main measurement methods — the predictive emissions monitoring system (PEMS) and the continuing emissions monitoring system (CEMS) (World Resources Institute, 2002).

2. **Estimating transport GHG emissions.** There are two basic ways that can be used to estimate air emissions: the energy-based approach and the activity-based approach. Both are founded in the following formula as presented in the basic schema in Fig 6.

Energy-based approach is primarily relevant for the national level since, despite to obtain geographically complete information, it and only offers very basic information on the local level.

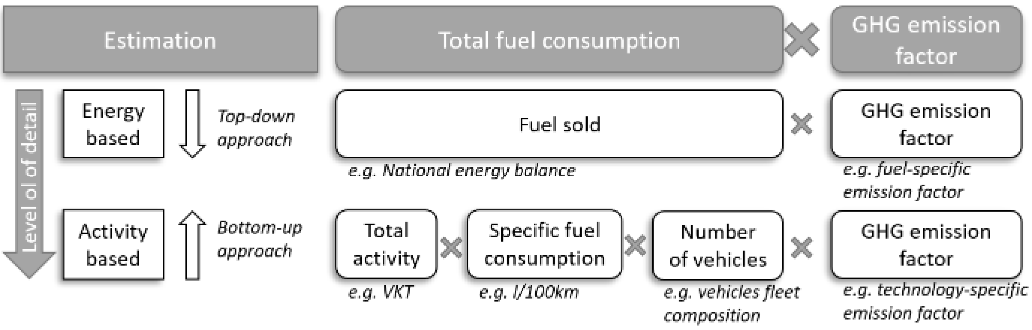


Figure 6 - Framework for calculation of Transport GHG Emissions

To identify levels for policy interventions, especially in cities and regions scales, the **activity-based approach** is recommended. The amount of air emissions is estimated in this case starting from local information to develop an understanding of travel patterns.

The **activity-based approach** is founded on data collected and processed at the local level. This requires more data collection and analysis than the energy-based approach method, but also provides far more useful information to guide local policy and planning. In this case, the total emission for each type of GHG is calculated as the product of the following data and parameters.

The **vehicle fleet distribution** indicates the share of each vehicle type. At a minimum, the fleet distribution should distinguish between passenger cars, heavy and light-duty vehicles, buses and other vehicles used for public transport services and two-wheelers. It can also distinguish between vehicles of different vintages. The fleet distribution can be estimated based on one of the following sources: traffic counts (this does not reveal relative driving levels), vehicles registered in the municipality, national statistics and Eurostat statistics at national or regional level.

The **travel activity** by vehicle type as a measure of traffic flow on the transport infrastructure of the area considered. A good example of this input data is the "Vehicle kilometres travelled" (VKT). This data at city or territory scale can be derived from information on traffic flows and length of the street network. These can be accessed from local sources, such as the municipal transport department or the local road management authorities. In the case of public transportation, the kilometres driven can be estimated using the information in the odometers of the vehicles. Many cities now have traffic models, calibrated with real-time traffic flow meters, but those models are rarely used to quantify GHG emissions.

The **specific fuel consumption** in tonnes of fuel per kilometre and the **GHG emissions factor** in kilograms of the GHG emitted per tonne of fuel, both for the vehicle type.

In Europe, COPERT[29] and HBEFA[30] are the leading tools used to estimate specific fuel consumption and air emissions factor for the transport sector. In an urban context, HBEFA offers more granularity those parameters depend on the road type and congestion levels. HBEFA nevertheless requires a lot of data for reliable analysis.

The basic input data for GHG emissions factor estimation are resumed as follows :

- Vehicles fleet composition;
- Temperature and Relative Humidity;
- Composition of the fuels used;
- Road grades;
- Average speeds;
- Loading rates for heavy-duty vehicles.

Using disaggregated data and parameters for various vehicle types, road types and traffic situations (speed and acceleration) allows local agencies to account for the impact of travel behaviour and road network performance on fuel consumption and emissions. This approach needs however disaggregated transport activity data at the city level as well as reliable emission factors.
It is possible to calibrate activity-based data with available energy statistics. In this case, the calculated and the statistical total energy consumption per fuel are compared by performing an energy balance. Any discrepancies which are identified are resolved, most often by adjusting the vehicle kilometres travelled. To ease the need for detailed data that can be expensive and time-consuming to collect, MYC is developing the **TRIGGER tool**[31] to help developing countries and cities to quantify GHG emissions from transport in their perimeter.

As detailed in the next section, there are further needs to harmonize the modelling approaches to be able to compare GHG emissions monitoring and mitigation efforts. ITS technologies can definitely help quantify GHG emissions by making traffic activity measurement more affordable and accurate.

Measuring real, individual emissions in transport

With the advent of connected vehicles, of smart and wearable devices and of cloud data services, we are entering a new phase for mitigating GHG emissions from transport. It is now routine to collect real-time vehicle-sourced data such as position, speed and engine data – today they are used as a basis for real-time traffic information. Indeed, on-road data collection is used in vehicle testing for compliance with EU and UN CO2 and pollutant emission standards.

To support schemes for individual traveller carbon budgets or incentives, it will be necessary to allocate a part of public transport or shared vehicles emissions to an individual. For this, clearly not only must the vehicle's emissions be measured but also the number of passengers. Internet of Things (IoT), Wi-Fi, and Bluetooth technologies could be applied for that purpose.
Useful information can also be gathered from smartphones and smart wearable devices, using data from motion sensors.

[29] - EMISIA, 2019, COPERT, https://www.emisia.com/utilities/copert/
[30] - INFRAS, 2019, HBEFA, https://www.hbefa.net/e/index.html
[31] - GIZ, 2019, TRIGGER, https://www.changing-transport.org/tool/trigger/

Methodology for Evaluating GHG/CO2 Emission

It is possible to deduce a traveller's means of travel from the individual "signature" of each mode. This would allow to close the loop between actual travel behaviour, emissions and consequences, such as incentives, rewards, penalties etc. It would also represent a huge increase in the volume and type of mobility data that could be used at enterprise, city and national levels to monitor actual emissions.

As stated above, any action to reduce GHG/CO2 emissions at any level, requires that the authority in change has a good overview on the emission sources and their respective reduction potential. Cities need appropriate tools to form a GHG emissions inventory.

State of the Art and Practice

One of the first tools to support environmental impact assessment within the traffic and logistic domain was developed during the Model Base for Integrative view of Logistic and Environment project (MOBILE)[2].
The MOBILE system followed an eco-logistic approach which focused on reducing resource consumption and environmental pollution generated from the start.

The EU project Impact of ICT on Transport and Mobility - ICTRANS[3] has tackled the CO_2 assessment for ICT measures. To define the different impacts of ICT on transport and mobility, a systematic analysis was conducted along four main types of impacts, namely, (i) frequency of travel, (ii) travel distances, (iii) travel mode and (iv) the ratio between freight and passenger transport. It was concluded that the overall impact of ICT will likely be minor, but more significant impact can be expected on the spatial and temporal distribution of transport flows, if flexible information society technology concepts for working, living and producing are implemented.
In March 2008, the European Commission agreed with the Japanese Ministry of Economy, Trade and Industry (METI) to develop a common methodology for assessing the impact of ICT for transport on CO_2 emissions. The first step for such methodology was to conduct a survey of existing methodologies and approaches to traffic and emission modelling in the EU and Japan. For the EU, the EC-METI Task Force[4] summarised the status and defined some recommendations for further joint discussion with the Japanese METI.

The recommendations included:

1. identifying the core green ITS applications, where six categories were proposed;
2. defining the main elements of the common methodology as: traffic simulation models, emission models, probe information and traffic database;
3. defining a roadmap for developing the required modelling technologies; and
4. explaining the requirement to have a clear definition of data needs and availability.

In Japan, the Energy ITS project was conducted from 2008 to 2012 to establish a reliable international evaluation method for ITS and to develop a technology for automated driving and platooning. For the methodology, hybrid simulation tools were developed, which include traffic networks from metropolitan to rural areas as well as an emission model to calculate vehicular emissions[5]. Moreover, technology to monitor CO_2 emissions using probes was developed and a comprehensive technology to estimate CO_2 emissions was examined.

In January 2009, an agreement was signed between the European Commission and the Research and Innovative Technology Administration of the US Department of Transportation. As a result of the two European agreements with Japan and the US, the three-year ECOSTAND project was established in December 2010 to provide support for an agreement between the three regions (EU, Japan and US) on a common assessment methodology. ECOSTAND did not

[2] - Hilty, L.M., Meyer, R.: 'A flexible modelling and simulation system for environmental impact analysis in traffic planning'. Proc. of the Second Int. Conf. on Urban Transport and the Environment for the 21st Century (UT 1996), Barcelona, 2–4 October 1996, pp. 221–230
[3] - ESTO: 'Impact of ICTs on transport and mobility (ICTRANS)'. The ESTO Research Report, Seville, 2003
[4] - Spence, A., Turksma, S., Schelling, Ab., Benz, T., Medevielle, J., McCare, I.: 'Methodologies for assessing the impact of ITS applications on CO2 emissions'. EC-METI Task Force, Technical Report v1.0, 2009

aim to produce a methodology, but rather to develop a standardised framework, a roadmap and joint research agenda to identify gaps in the research and propose solutions to enable the development of the methodology[6]. To achieve this goal, ECOSTAND developed a roadmap with actions to be undertaken to conclude the development of the methodology and the supporting tools. The developed roadmap covers the period up to 2020[7].
The global e-sustainability initiative started a study in 2010 to establish a methodological framework for assessing the enabling effect of ICT[8].
The methodology uses a life cycle assessment (LCA) approach to guide the assessment of the changes to the business-as-usual (BAU) system resulting from the adoption of an ICT solution (BAU refers to the components in the existing manual, mechanical or physical processes that are impacted by the implementation of the ICT system). It consists of three steps: (i) defining the goal and the scope of the study, (ii) limiting the assessment by excluding life cycle processes that have no significant impact on the conclusion and (iii) determining the net enabling effect by assessing life cycle processes chosen in step 2.

Integrated Methodology Proposal

Developing an integrated methodology to assess the CO_2 impact of road transport was targeted in some of projects aforementioned. For instance, ECOSTAND and ICT-emissions have proposed a methodology to evaluate the impact of ICT-related measures on mobility, and vehicle energy consumption of vehicle fleets at local scale. Attention was particularly given to a set of ITS measures for the former and new vehicle technologies including start–stop systems, hybrids, plug-in hybrid and electric vehicles for the latter. The results from the local scale level can be extrapolated to the macro level to calculate impact in terms of energy consumption and emissions from all passenger road transports. In this way, the methodology combines benefits from both micro and macro modelling. More information about the methodology can be found in [6] and [9].

step 1.	*Selection of a target city and target ITS applications*
step 2.	*Data collection for the estimation*
step 3.	*Modeling of CO2 reduction mechanism*
step 4.	*Selection of an evaluation tool*
step 5.	*Calibration of the evaluation tool for the target city*
step 6.	*What-if study*
step 7.	*Scaling up (to the whole city and to the annual reduction volume)*

Figure 7 - Steps of CO2-emission assessment framework developed in Ecostand
Source : ECOSTAND Project, Deliverable 2.1: 'Inception report and state-of-the-art review', Version 1.7, 2011

[5] - Kuwahara, M., de Kievit, M., Shladover, S., et al.: 'Guidelines for assessing the effects of ITS on CO_2 emissions'. International Joint Report. Available at http://www.nedo.go.jp/content/100521807.pdf
[6] - ECOSTAND Project, Deliverable 2.1: 'Inception report and state-of-the-art review', Version 1.7, 2011
[7] - ECOSTAND Project, Deliverable 4.2: 'Roadmap & Research Agenda', Version 1.0, 2012

Methodology for Evaluating GHG/CO2 Emission

Another effort undertaken within the **Amitran European project**[11], aimed at developing a methodology framework for evaluating the effects of ICT measures in traffic and transport on energy efficiency and CO_2 emissions.

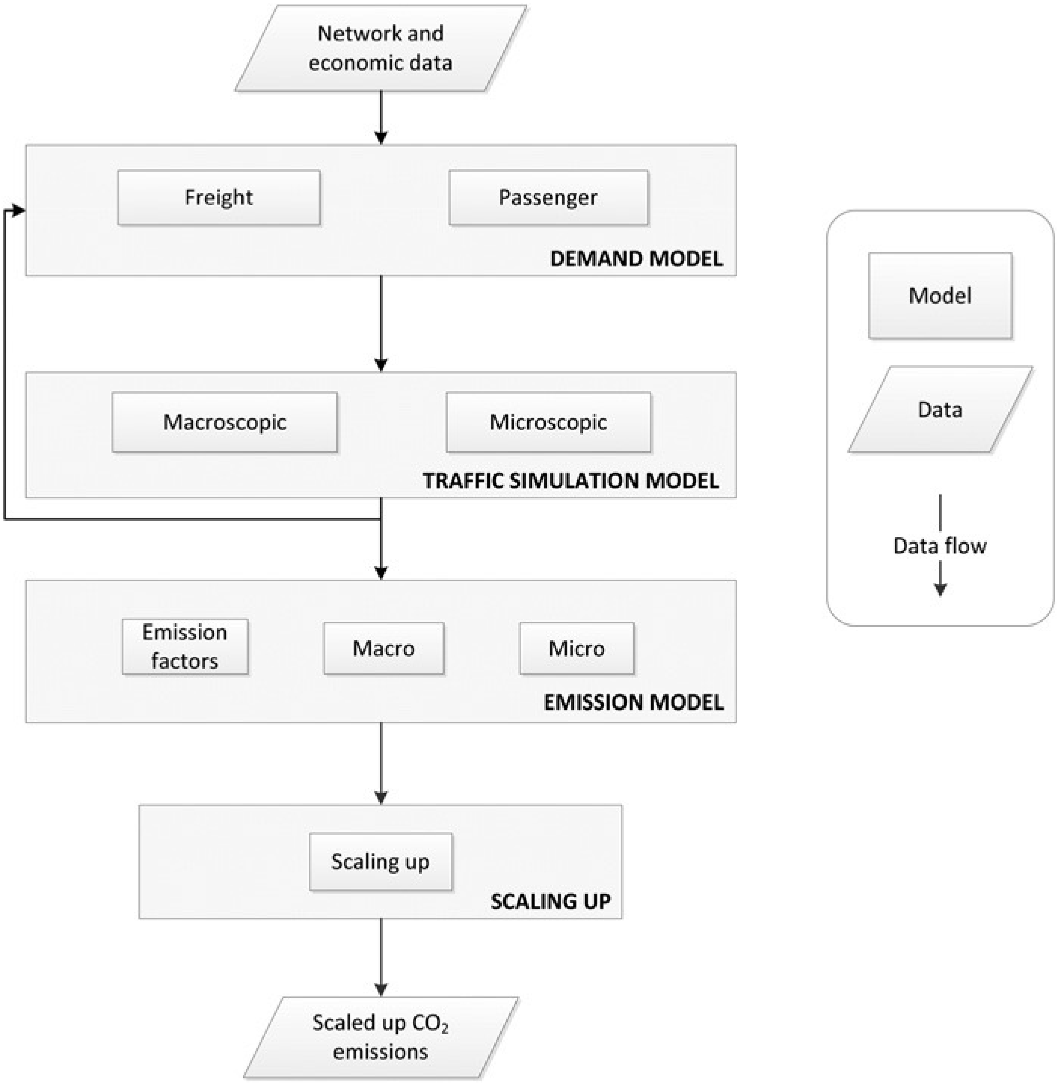


Figure 8 - General overview of Amitran framework architecture
Source : 'Amitran Guidance Knowledge Base'. Available at http://www.amitran. eu/knowledge-base, accessed August 2014

[8] - GeSI: 'Evaluating the carbon-reducing impacts of ICT An assessment Methodology', September, 2010.
Available at http://www.gesi.org/ files/Reports/Evaluating%20the%20carbon-reducing%20impacts%20of %20ICT_September2010.pdf
[9] - ICT-Emissions, Deliverable 2.1: Methodology', Version 3.0., 2013 11 ITU-T: 'Methodology for the assessment of the environmental impact of information and communication technology goods, networks and services, Recommendation ITU-T L. 1410, 3/2012
[11] - Amitran Project, Deliverable 4.1: 'Requirements and design of the methodology', Version 9, 2013

Methodology for Evaluating GHG/CO2 Emission

Although both **ECOSTAND** and **ICT-emissions** focus on road vehicles, **Amitran** addresses both passenger and freight traffic including different modes: road, rail as well as short sea and inland shipping. A well-to-tank approach is followed in Amitran meaning that not only direct CO_2 emissions are considered, but also the additional emissions needed for energy production. The geographic scope for Amitran is the EU countries allowing the users of the methodology to scale their local results to a larger region (e.g. country or EU level)[12], [13].

As an effort of enhancing international cooperation and planning towards sustainable transport policies, with a particular aim of facilitating climate change mitigation, a **ForFITS three-year project** was launched in 2011. This project was funded by the UN Development Agency (UNDA) and it involved all United Nations Regional Commissions.

This model is meant to foster **sustainable transport policies For Future Inland Transport Systems** (and therefore named ForFITS) and is capable of assisting users in making informed decisions about measures available for the reduction of CO2 emissions in the transport sector. Users of the tool can compare the projections between a baseline scenario and scenarios where proposed transport policies are implemented and estimate the amount of emissions that can be "saved" by their implementation in the future. Results of these analyses can be used to support the implementation of future transport policies that are likely to be effective in reducing CO_2 emissions. ForFITS is primarily focused on CO_2 emissions from transport, including road, rail and inland waterways, and predicts future emissions based on current patterns[14].

Lessons learned

Simulation of ITS measures is a demanding process that requires simulation advancements beyond the current state of the art, with respect to vehicle, traffic and emission modelling. The ECOSTAND and ICT -Emissions projects made a number of steps in this direction. Most importantly[14], [34]:

- **ADAS** modelling requires a completely new approach so that specific control algorithms are taken into account in the car following sub models of micro traffic models.

- Eco-driving demands a new car following submodule to account for the smoother driving performance of eco-drivers.

- Moving from the micro to the macro scale requires a fully calibrated interface, e.g. through specifically developed speed-intensity functions.

- Macro emission modelling requires improvements so that emission factors take into account the impacts of traffic level, eco-driving and ADAS on a link-by-link basis.

- Combination of emission models with traffic simulation tool. Indeed, there are different classes of traffic simulation tool in terms of the granularity of vehicle trajectories. Accordingly, they should be combined with an adequate type of emission model to feed the trajectories.

[12] - Amitran Project, Deliverable 3.1: 'Methodology for classification of ITS', Version 11, 2013
[13] - Amitran Project, Deliverable 5.1: 'Specification of interfaces', Version 1, 2013
[14] - ForFITS Project'. Available at http://www.unece.org/trans/theme_forfits.html , accessed July 2019
[34] - Canaud M., N.-E. El Faouzi. ECOSTAND: towards a standard methodology for environmental evaluation of ITS. Transportation Research Procedia 6 (2015) 377 – 390.

European and International initiatives & Harmonisation

As stated above, **any action to reduce GHG/CO2 emissions at any level, requires that the authority in change has a good overview on the emission sources and their respective reduction potential.** Cities need appropriate tools to form a GHG emissions inventory.

Cities & European initiatives: Illustrative Examples

The transition towards a more sustainable urban environment at the local level begins with a common understanding that there is significant potential to curb the city's CO_2 emissions. This understanding provides a basis upon which political leadership instigates a process of exploring possibilities and discussing different options with a wide range of stakeholders towards selecting, detailing, implementing and monitoring local action. In this process, local authorities (LAs) have the capacity to support and mobilize action for local energy generation investments through several modes of urban climate governance[15].

The **Covenant of Mayors (CoM) "2020 target" initiative** was launched in 2008 by the European Commission after the adoption of the 2007 EU Climate and Energy Package, to endorse and support the efforts deployed by local authorities in the implementation of sustainable energy policies towards a low-carbon future. The initiative aimed to convene local and regional authorities voluntarily committing to implementing sustainability policies on their territories and to providing them with harmonised data compilation, methodological and reporting framework, to translate their greenhouse gas (GHG) emissions reduction ambitions into reality.

As an illustrative effort, **MobiliseYourCity Partnership**, a multi-donor action, jointly co-financed by the European Commission's Directorate-General for International Cooperation and Development (DG DEVCO), the French Ministry of Ecological Transition and Solidarity (MTES), the French Facility for Global Environment (FFEM), and the German Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (BMUB).

The initiative is implemented by its founding partners ADEME, AFD, CEREMA, CODATU, and GIZ. Besides contribution to the international climate process, MobiliseYourCity contributes to the UN's Agenda 2030, specifically Sustainable Development Goal (SDG) 11: "Make cities inclusive, safe, resilient and sustainable".

The objectives of this initiative are:

- Enable transformational changes towards more inclusive, livable, and efficient cities.
- Foster more comprehensive, integrated and participatory urban mobility planning (local & national levels).
- Target reduction of transport-related GHG emissions in participating cities (> 50% until 2050).
- Link planning with agreement on investments and optional use of financial assistance.
- Make use of innovative planning techniques and digitalization and promote state-of-the-art mobility and transport technologies.

More specifically, MobiliseYourCity sets out the GHG monitoring and reporting principles for the MobiliseYourCity Partnership. A focus is placed on the ex-post monitoring of GHG emission developments in urban transport (Step 5 "implementation, monitoring and evaluation" of the SUMP cycle). That said, a rough ex-ante estimate of the initiative's potential GHG emission reductions is already required in order to:

a) inform the prioritisation of measures
b) make the implementation of SUMP (Sustainable Urban Mobility Planning) attractive to international climate finance donors. Figure 1 (p3) illustrates how the MRV process aligns with the main steps of the SUMP process.

[15] - 'eCoMove Project'. Available at http://www.ecomove-project.eu/, accessed January 2014

In the same vein, the Lyon Metropolis (France), in partnership with ATMO Auvergne-Rhône-Alpes and Caisse des Dépôts, set up an ambitious project called **[R] Challenge** aiming at proposing a real innovation approach to air quality issues. This initiative is part of the Oxygen Plan, created to encourage the advent of new solutions to promote air quality.

Through a system including call for projects, prototyping and experimentation, the [R] Challenge supports the emergence of innovative solutions. Thanks to this approach with a variety of actors from industry, health, urban planning, mobility, the environment, energy and digital technology, the objective is to be able to provide real environmental and societal solutions for the city of tomorrow.

Within the [R] project, 3 main challenges have been identified for air quality purposes[16]:

1. Develop urban monitoring capacities
2. Inducing citizens' behaviour change, and
3. Develop emission reduction technologies

Many projects have been launched within this initiative:

- **Airmap** and **Geoptis** targeting a dynamic real-time mapping of pollutant emissions, measured from probe data;
- **Togeth'Air** aiming at collecting different types of data related to air quality in order to promote mobility behaviour change;
- **Rsense** that helps to raise user's awareness in order to reduce the emission of pollutants in the city.

Standardisation and Harmonisation

To date, efforts to standardize and harmonize the quantification of GHG emissions and the tools to perform such quantification are struggling to materialize.
The SLoCaT (Sustainable Low Carbon Transport) partnership has collected more than 150 transport and GHG models and tools[32], showing the lack of coordination to harmonized and standardized tools.
The UNECE has developed the **ForFITS** (For Future Inland Transport Systems) aiming at providing a public, transparent and undisputed platform to perform forward looking projections of GHG emissions of the transport sector under user-defined scenarios[27].

The European Environment Agency (EEA) and UNECE also hosts the **Task Force on Emission Inventories and Projections** (TFEIP, under the Long Range Transboundary Air Pollution, LRTAP) that provides sectorial guidebooks, including for transport, on how to perform emission inventories for air pollution-related issues, similar to the IPCC guidebook to report on GHG emissions under a common framework and methodological approaches[28].

Nevertheless, such an emission inventories guidebook is mainly aimed at national level applications, and not always fit for smaller scale applications, as shown in Figure 5 (p6).

[16] - 'DRIVE C2X Project'. Available at http://www.drive-c2x.eu/project, accessed January 2014
[32] - SloCaT, 2017, SLoCaT Analysis of 150 Transport Emission Methodologies and Toolshttp://www.slocat.net/news/1452
[27] - UNECE, 2014, ForFITS, http://www.unece.org/trans/theme_forfits.html
[28] - UNECE, 2019, TFEIP emissions guidebooks updates, https://tfeip-secretariat.org/guidebook-updates-2/

Role of ITS and C-ITS in Mitigating GHG/CO2 Emissions

ITS in general and more specifically connected car technologies (Cooperative ITS – C-ITS), are instrumental in empowering drivers to make optimal decisions with regards to driving: real-time information that helps drivers make better decisions about routes to take, where to park and other driving decisions that are based on data provided by public and private providers. ITS and connected car technology can help lower fuel consumption, reduce costs and lower CO_2 emissions. Collectively, these systems bring together technologies that include several different strategies:

- **Strategies which aim to modify transport demand.** This can be achieved in a number of different ways, such as encouraging travellers to use low-polluting vehicles or transport modes or reducing the overall demand for mobility and the total distance travelled. In the case of commercial vehicles, results can be achieved through more efficient logistics. Other approaches include road charging or tolling schemes designed to favour low-CO_2 vehicles, to promote a modal shift or to discourage journeys altogether. Relevant strategies also include information services and management systems designed to increase the convenience and efficiency of public transport, as well as ITS platforms which support fleet management.

- **Strategies which promote a more CO_2-efficient use of the transport network.** This objective can be achieved through the numerous types of traffic management and control systems which act on traffic flows. The more sophisticated applications seek not only to increase throughput and reduce congestion but can be designed to promote optimum speeds for energy efficiency, reduce ''stop & go'' behaviour, and so on. They also include the management of dedicated lanes for specific vehicle types and real-time routing which can favour more energy-efficient traffic flows. Better use of the network can also result from changes in trip timing (i.e. using real-time traffic information to persuade travellers to modify their departure times) and information services which support drivers looking for parking places in urban areas.

- **Strategies which encourage optimum driving behaviour.** This category includes initiatives such as eco-driving campaigns which target individual drivers with the objective of promoting a driving style with lower CO_2 emissions. The strategy can be supported by internet-based and/or on-board instruments, as well as systems and tools embedded in the vehicle itself.

These technologies appear to have significant CO_2 reduction potential, which is shown by multiple recent projects and studies. A study carried out by ERTICO in 2015 provides a summary of various studies as the one presented in this document with a list of ITS solutions with a high-level assessment of fuel/CO_2 savings.
The overview in Table 1 and 2 extracted from the ITS4rCO_2 study carried out in 2015[33] provides a list of potential impacts of ITS related solutions with a high-level assessment of fuel/CO_2 savings:

- **Navigation and travel information category:** Personalised multi-modal navigation tools, as the focus of this report is on car transport only.

- **Traffic management and control category:** Dynamic lane allocation, which includes reversible (contraflow) lanes and the creation of peak hour lanes e.g. by hard shoulder running on motorways. These are essential to increase road capacity and reduce congestion, and not aimed at CO_2 reduction; in fact increasing capacity and therefore increasing traffic volumes would normally lead to increased emissions on the road treated with this measure, although some benefits could occur on alternative routes which could see a reduction in traffic.

- **Demand and access management category:** none of the applications here are considered in our study, as they focus on reducing the number of trips or the timing of them, which is not within the scope of ITS4rCO2. Tolling and other forms of demand management do not affect the driving dynamics of vehicles (how they are driven), but rather whether, when and where they are driven.

[33] - Pandazis J-.C. et A. Winder, 2015. Study of ITS for reducing CO_2 emissions, ERTICO 10/09/2015.

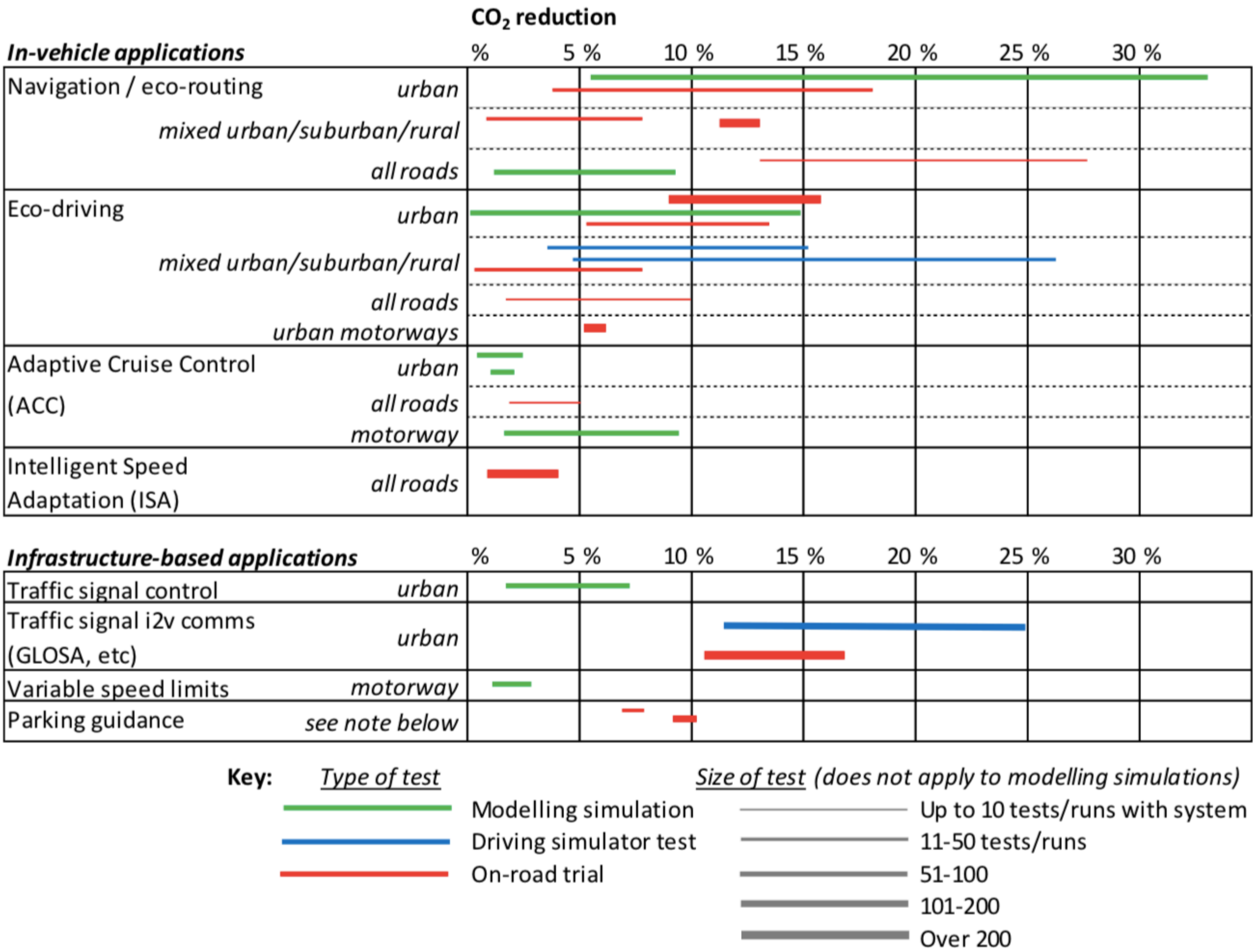
• **Driver behaviour and eco-driving category:** Mandatory ISA is not covered as we are not aware of any such trial having been done; also, car buyers are unlikely to purchase vehicles with such mandatory controls. On the other hand, voluntary ISA (where the advice can be overridden by the driver or the system turned off if desired) is included

These studies show that, several ITS/ICT measures can readily be implemented to address total CO_2 emissions of the existing on-road fleet. More precisely, ITS/ICT measures including, adaptive cruise control, eco-driving, green navigation, start and stop systems, traffic-adaptive urban traffic control, and variable speed limits can lead to traffic improvement with associated positive CO_2 impacts proven under real-world conditions.
Additional CO_2 emissions reductions require a more comprehensive approach. The evolving policy framework should therefore include and support a broader mix of technologies and approaches, including road infrastructure, alternative fuels, innovative in-car technologies and more environmentally friendly driving technique.

Table 1 - Summary of iMobility Working group for Clean and Efficient Mobility (WG4CEM) results : ITS applications with greatest potential for CO2 reduction
Source : Pandazis J-.C. et A. Winder, 2015. Study of ITS for reducing CO_2 emissions, ERTICO 10/09/2015

High level category (ECOSTAND/ Amitran classification)	ITS measure	Estimated possible CO_2 reduction (percentage reduction from current levels)	Implementation timeframe
Navigation and travel Information	Navigation and eco-routing	5-10%	Today
	Connected eco-routing (taking into account real-time information)	5-10%	Until 2020
	Personalised multi-modal navigation tools.	5-10%	Today
Traffic management and control	Traffic signal control and signal coordination (UTC – Urban Traffic Control)	5-10% reduction until 2020, >10% reduction after 2020	Today, but much improved by 2020
	Cooperative traffic signals (i2v / GLOSA - green light optimal speed advisory and green priority)	>10%	Until 2020
	Dynamic lane allocation	0-5%	Today
	Variable Speed Limits (VSL)	0-5%	Today
	Coordinated ramp metering (motorway access control)	0-5%	Today
	Parking guidance	0-5%	Today
	Cooperative parking guidance (i2v routing)	0-5%	Until 2020
Demand and access management	Variable road pricing – Distance-based	>10%	Today
	Variable road pricing – Congestion -based	5-10%	Today
	Pay-as-you-drive insurance	5-10%	Today
Driver behaviour and eco-driving	Eco-driving support	5-10% with mobile or aftermarket solution >10% with integrated (embedded) solution	Today (mobile) Beyond 2020 (integrated)
	Mandatory ISA (Intelligent Speed Adaptation)	5-10% (0-5% potential with voluntary ISA)	Beyond 2020 (Voluntary ISA possible today)
	Cooperative Adaptive Cruise Control (C-ACC)/ Automation (autonomous platooning)	5-10%	Beyond 2020

Table 2 - Maximum Potential for CO2 reduction of some ITS/C-ITS strategies
Source : Pandazis J-.C. et A. Winder, 2015. Study of ITS for reducing CO_2 emissions, ERTICO 10/09/2015



Conclusions and Recommendations

ITS to help Emission Assessments

Beyond the possibility to reduce emissions, ITS technology also offers substantial potential to assist with mobility data collection.
Always keeping privacy in consideration, digitalization of individuals and of the economy has already started to collect huge amount of data, not always with the aim of serving the public interest.

The cost of data collection is ultimately expected to drastically drop, with increased sampling and accuracy, for both measurement and survey, thanks to heavy ITS deployment in transport systems.

In exchange for a deployment in their constituencies, public authorities might want to request transport operators to share data collected through the mobility services offered.

This would help quantifying the potential emission reduction ITS can deliver, so ITS technologies can help reducing emissions and help measuring it.

New thinking & Transformative Actions

The need to reduce GHG emissions is fostering new thinking and transformative actions. A 2007 report from the IPCC presents some policy options to consider along with technology issues.
Transport Demand management is tackling the needs for improving transit options.

The order of mode shift magnitude is also crucial to achieve GHG emissions reduction objectives. On a more limited scale, one can note a study[2] conducted for the student and employee population of the campus of the University of Illinois Chicago (UIC). Mode shift alternatives were evaluated for the campus to predict the impact on greenhouse gas emissions. The scenario showing the highest reduction in CO_2 (13%) concerns a 30 % simulated mode shift from car to light rail.

The analysis of GHG emission trends is actually based on physical and chemical measurements, which have been detailed in the first part of the report. These trends are also relevant to cultural changes affecting transportation behaviours. The complete assessment of GHG emissions should take into account the major societal prospects describing the scope of the possible future. Dan Sperling suggests in a recent seminal book[23] about transportation that "For the first time in half a century, real transformative innovations are coming to our world of passenger transportation. The convergence of new shared mobility services with automated and electric vehicles promises to significantly reshape our lives and communities for the better—or for the worse". Each of the three major components highlighted by Sperling have an impact on GHG emissions, depending on their rate of deployment.

The research framework to evaluate and measure these impacts should be designed along a comprehensive organizational and systemic model interacting with mobility evaluation and transportation policies assessments.

Pongthanaisawan[24] illustrates a comprehensive model of these interactions, Figure 9.

[2] - Hilty, L.M., Meyer, R.: 'A flexible modelling and simulation system for environmental impact analysis in traffic planning'. Proc. of the Second Int. Conf. on Urban Transport and the Environment for the 21st Century (UT 1996), Barcelona, 2–4 October 1996, pp. 221–230
[23] - Dan Sperling, Three Revolutions : Steering Automated, Shared, and Electric Vehicles to a Better Future; 2ndedition, Island Press, Washington, April 2018
[24] - Jakapong Pongthanaisawan , Success with intelligent transport systems measures and improving energy efficiency, In : Shifting to more efficient public transport and increasing energy efficiency of vehicles, 23 May 2016 Bonn, Germany. (https://unfccc.int/sites/default/files/01_thailand_jakapong_pongthanaisawan.pdf)

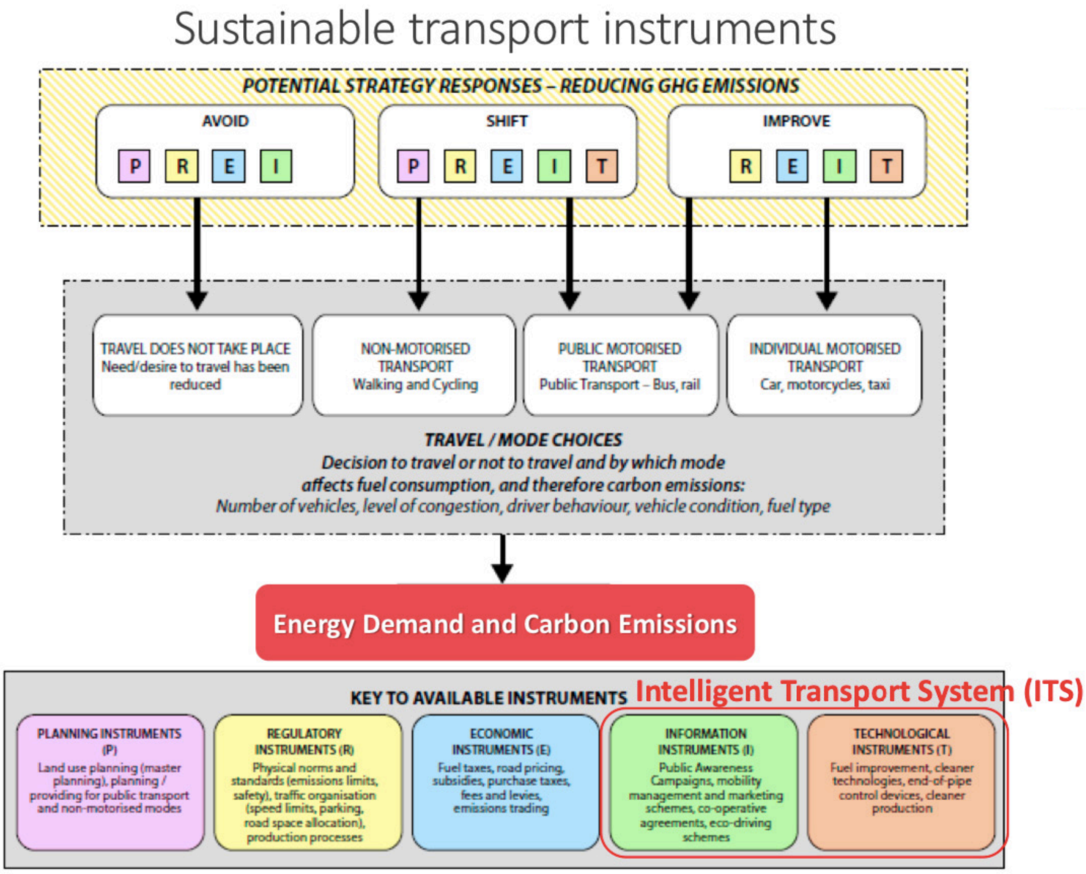


Figure 9 - Interactive Model for Analysing Mobility Trends
Source : GIZ (2010), Transport and Climate Change

One can illustrate the importance of the approach through two examples:

• **The modal shift impact:** The mode shift from one mode to another is not only an element of mobility measurement on specific territories but it is also a major factor for transportation planning. The mode shift factor was an important factor to justify the potential GHG impact of a new TGV line in France, called the LGV Rhin-Rhone. In 2009, The assessment of the GHG emissions due to construction, maintenance and operation of the LGV was showing a positive impact after 12 years., assuming a mode shift of 1.2 million travellers per year. from air and automobiles[25].

In 2017, six year after opening the new line, we count 9.5 million passengers a year, but there is no published data, to our knowledge, about the proportion of modal shifters among this population. They should be at least 1.2, to follow the initial prospect for a positive impact on GHG emissions at the horizon 2023.

• **The ride sharing impact:** Traffic flow analysis and congestion mitigation objectives usually consider vehicle flows instead of the flows of individuals. When car occupancy is close to 1 the two approaches are equivalent, but

[25] - Bilan Carbone® ferroviaire global : La Ligne à Grande Vitesse Rhin-Rhône au service d'une Europe durable, SNCF, 2009, Paris.

many possibilities for car occupancy variation rates allow various options for policy action and also for market innovation in order to shape a sustainable future for road transportation.

Everything being equal, an average car occupancy rate of 1.2, as observed for example today in Portugal or 1.3 in Sydney[26] just to quote a few cases, could have a very high impact on congestion and on Vehicle mile travelled (VMT) if increased to 2.0 or 3.0 persons per vehicle. Many policies and incentives try to achieve an increase in car occupancy rate in order to reduce GHG emissions due to road transport.

Recommendations

To manage GHG emissions from transport, it will be necessary to allocate targets at local as well as national and supra-national levels. An agreed approach is needed for allocation of high-level targets down to city, organisation and individual levels.

To verify that targets are met, it will be necessary to measure actual and detailed emissions, from individual vehicles, goods consignments and travellers. **An agreed approach is needed.**

Accurate and approved methods of measuring such individual and real emissions will be needed, using technologies such as connected vehicles, enhanced satellite positioning, IoT, short-range communications and smart personal devices.

[26] - A New Paradigm for Urban Mobility - © OECD/ITF 2015

Authors

Nour-Eddin EL FAOUZI,
Deputy head of Department, Univ. Lyon, IFSTTAR - France

Prof. Nour-Eddin EL FAOUZI has over 26 years of professional, academic and research experience in the areas of traffic Data Analytics, traffic modeling and management, intelligent transportation systems, multimodal systems modeling and optimization. He has served as principal investigator on various funded research projects sponsored by international, European, national, state, and metropolitan agencies and private industry. He is Deputy Director of IFSTTAR "Components and Systems" department, Head of the Transportation and Traffic Engineering Laboratory at IFSTTAR (The French Institute of Science and Technology for Transport and Networks), and Chair of the European Society of Traffic Management and Control – VCE NEARCTIS. Moreover, he is Adjunct Professor at Queensland University of Technology (QUT), Australia since 2013. He has served in an advisory capacity to various institutes and programs and has performed several program assessments of leading international research institutes and corporate R&D departments. He is member of Transportation Research Board committee on Surface Transportation Weather. He currently serves as an Associate Editor for International Journal of Intelligent Transportation Systems Research and acted as a guest editor for numerous special issues of top journals. Prof. Nour-Eddin EL FAOUZI received his Ph. D. in Applied Mathematics from Montpellier University in 1992 and a Post-Doctoral Degree (HDR) in Traffic modelling from Lyon University in 2008.

Annela ANGER-KRAAVI,
Senior Research Associate,
Cambridge Institute for Sustainability Leadership

Annela is a macroeconomist who enjoys working closely with industry, policymakers and environmental campaigners as well as with scientists from other disciplines.
Annela is Vice-Chair of the United Nations Framework Convention on Climate Change (UNFCCC) Subsidiary Body for Scientific and Technological Advice (SBSTA); an Adviser on international climate change policy and negotiations to the Estonian Ministry of the Environment; a College Research Associate in Economics at Emmanuel College in Cambridge; and Chief Executive of the Cambridge Trust of New Thinking in Economics.

Thamara VIEIRA DA ROCHA,
Project engineer, Citepa

Thamara VIEIRA DA ROCHA is PhD and engineer in air emissions from transport. Since 2015 at Citepa, she has been producing and contributing to studies and the French emissions inventories (UNECE and UNFCCC formats) of this sector.

Authors

François CUENOT,
Mechanical engineer, UNECE

Francois Cuenot is the Secretary of the Working Party on Pollution and Energy of the World Forum for Harmonization of vehicle regulations of the United Nations Economic Commission for Europe. He is supervising the activities on technical regulations related to vehicle emissions and energy efficiency. He is also leading the work of the ForFITS model developed at UNECE that helps policy makers choose the most appropriate transport policies to mitigate climate emissions from transport in the long term. Previously, he worked as Senior Transport and Energy Officer at the International Energy Agency (IEA) where he worked in fuel economy policy deployment and long-term strategy to improve energy use and lower carbon emissions of the transport sector globally. He also has been a consultant working on sustainable mobility in regulatory development at the European level and capacity building for sustainable urban mobility in developing countries.

Zissis SAMARAS,
Aristotle University of Thessaloniki

Zissis Samaras is Full Professor and Director of the Lab of Applied Thermodynamics, Dept. of Mechanical Engineering, Aristotle University, Thessaloniki, Greece. His research work deals primarily with engine and vehicle emissions testing and modeling and he has carried out a wide range of projects on modeling emissions from internal combustion engines. Dr. Samaras was involved in the development, testing and large-scale evaluation of Diesel particulate filters. He has provided expert advice to a number of organisations and private sector customers, including the European Commission, the European Environment Agency, the World Bank the Greek Ministry of Environment, Rhône-Poulenc, ACEA, CONCAWE. He was vice chairman of the management committee of COST action 319 (cordis.europa.eu/cost-transport/src/cost-319.htm) on the Estimation of Exhaust Gas Emissions and for many years co-Leader on behalf of the European Environment Agency of the Topic Group "Mobile Sources" of the UN-ECE Task Force on Emission Inventories (www.eea.europa.eu/publications/EMEPCORINAIR/page016.html). He coordinated a number of large European projects, including "Particulates, Characterisation of Exhaust Particulate Emissions from Road Vehicles", "Inspection & Maintenance of in-use Vehicles", "ICT-Emissions (www.ict-emissions.eu) Development of a methodology and tool to evaluate the impact of ICT measures on road transport emissions" and co-led "Artemis (http://www.trl.co.uk/ARTEMIS/), Assessment and Reliability of Transport Emission Models and Inventory Systems". He is elected Academic Member and Vice Chairman of the European Road Transport Research Advisory Council (ERTRAC - http://www.ertrac.org/?m=25) on "Energy, Environment and Resources". He is the author of more than 250 scientific publications, among them more than 120 in peer-reviewed journals, which received more than 700 citations in peer reviewed articles, reviews and technical notes.

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