Inception report and state-of-the-art review

ECOSTAND

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Abbreviations and definitions

Abbreviation	Definition
CEN	Comité Européen de Normalisation (European Committee for Standardisation)
CO_2	Carbon dioxide
ETSI	European Telecommunications Standards Institute
EU	European Union
FOT	Field operational test
FP7	European Commission Seventh Framework Programme
I2V	Infrastructure-to-vehicle
ICT	Information and communication technology
ISO	International Standards Organisation
ITS	Intelligent transport systems
METI	Japanese Ministry of Economy, Trade and Industry
MLIT	Japanese Ministry of Land, Infrastructure, Transport and Tourism
PAYD	Pay-as-you-drive
RITA-DOT	Research and Innovative Technology Administration (division of US DOT)
TERN	Trans-European Road Network
TRB	Transportation Research Board
US	United States of America
US-DOT	United States-Department Of Transportation
V2I	Vehicle-to-infrastructure
V2V	Vehicle-to-vehicle

Executive summary

The objective ECOSTAND is to provide support for an agreement between three regions – the EU, Japan and the US – on a common assessment methodology for determining the impacts of ITS on energy efficiency and CO_2 emissions. This support will involve the formulation of (i) policy advice, in the form of a 'roadmap' and (ii) a joint research agenda to identify gaps in the understanding and to propose solutions to enable the methodology to be developed.

There are numerous recent or ongoing initiatives and projects which deal with ITS and CO_2 emissions. We have identified the following types of activity:

- Bilateral initiatives
- An initiative in Japan (Energy-ITS)
- An initiative in the US (AERIS)
- Initiatives in the EU
- Selected European projects

The participants in the projects and initiatives are potential contributors to the ECOSTAND symposia, and their reports will be valuable sources of information

The ITS applications have been divided into six categories:

- Navigation and travel information.
- Traffic management and control.
- Demand and access management.
- Driver behaviour change and eco-driving.
- Logistics and fleet management.
- Safety and emergency systems.

The nomenclature is specific to ECOSTAND, but the categories are based on those already put forward in the EC-METI report (Spence *et al.*, 2009), and correspond broadly to the classification used by the Working Group on ICT for Clean and Efficient Mobility (Kompfner *et al.*, 2008), with the addition of a sixth category consisting of safety and emergency systems. They also have a close correlation with the categories identified by the ISO Technical Committee TC204.

In emission models the various factors affecting emissions are commonly taken into account using the following parameters (Boulter and McCrae, 2007):

- *Road characteristics*: Some emission models require a description of the road characteristics, such as the area type (urban or rural) and the speed limit. The road segment length is an essential parameter in any model, and another important factor is the road gradient, which has a large effect on emissions especially from heavy-duty vehicles.

- *Traffic flow (volume):* To a first approximation, emissions are proportional to the total amount of traffic on a road, or the total vehicle-km travelled in an area or during a period of time.
- *Traffic composition:* Emission factors for different categories of vehicle are normally presented in grammes per vehicle-kilometre travelled or grammes per litre of fuel consumed. In addition to the primary division by vehicle type (*i.e.* motorcycles, passenger cars, buses, HGVs), sub-division by engine size, number of axles or vehicle weight is common. There is then usually a further separation of vehicles by emission standard. A common approach is to weight each emission factor by the proportion of vehicles in the relevant category and the total traffic flow during a given time period[1].
- *Vehicle operation.* The treatment of vehicle operation is one of the most complex aspects of emission modelling. Vehicle operation may be represented using average speed alone, or using other methods which explicitly allow for driving dynamics (see section 4.3).

The following chain of models or information is usually needed to provide an accurate estimate of the impacts of an ITS application on CO_2 emissions (Spence *et al.,* 2009; Klunder *et al.*, 2009):

- A representation of the infrastructure within which the ITS application will be implemented.
- A representation of the ITS application.
- A traffic model[2] to represent changes in driver behaviour resulting from the infrastructure and the ITS application. Traffic simulation models need to generate realistic data (including speed-time profiles where appropriate) to ensure accurate input data for the emission models.
- An emission model which can be used to evaluate the effects per vehicle type of the ITS application.
- A model for translating the CO_2 impacts per vehicle type into the CO_2 impacts on a larger geographical scale.

The assessment methodology will be based on the above mentioned chain. Furthermore the availability of data is an important aspect that needs to be taken into account. A specific section in the document is related to the availability and use of different sources of data.

The report has summarised the key issues which are considered to be relevant to the development of a common assessment methodology, and therefore need to be addressed within the

[1] Clearly, one only actually needs the *number* of vehicles in each category during the time period. However, it is useful conceptually to treat the total flow and the composition separately, such as when assessing the effects of transport measures and policies.

[2] For small-scale ITS applications it may be possible to use direct measurement.

ECOSTAND project. By means of the aforementioned symposia these different issues will be addressed according to the sub-topics that have been identified. Besides the sub-topic oriented issues general questions are posed as well which need to be solved before the end of the project. The six-subtopics for which the issues are identified are the following:

Sub-topic	Description	Main aim
1	ITS applications	To reach agreement on the main categories and types of ITS application which the methodology needs to be able to assess.
2	Traffic simulation	To identify traffic modelling approaches which enable CO_2 emissions to be estimated for baseline conditions and for various ITS implementation scenarios.
3	Emission modelling	To identify the key requirements of CO_2 emission models required to calculate the impacts of ITS.
4	Monitoring using probe vehicles	To arrive at a common understanding of the contribution of probe data to 'real-time' CO_2 monitoring.
5	Validation methodology	To establish a common validation framework for both traffic simulation and CO_2 emission models.
6	International traffic database	To provide easy access to the data required for estimating the impacts of ITS applications on CO_2 emissions, and for validating models, and to enhance current international traffic databases.

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1 Introduction

1.1 Overview of report

The objective of the ECOSTAND project is to provide support for an agreement between three regions – the European Union (EU), Japan and the United States (US) – on a common assessment methodology for determining the impacts of Intelligent Transport Systems on energy efficiency and CO_2 emissions. This support will involve the formulation of (i) policy advice, in the form of a 'roadmap' and (ii) a joint research agenda to identify gaps in the understanding and to propose solutions to enable the methodology to be developed.

This document is the first output of the project, and serves as both an inception report and a state-of-the art review. It sets the scene for the work to be undertaken and describes the general approach to be followed. The intention of the report is to provide an initial basis for trilateral discussions to determine the scope and content of the roadmap and research agenda.

International cooperation in this field between the EU and the US, and between the EU and Japan, did not begin with the ECOSTAND project, but is an ongoing process which ECOSTAND aims to support (*i.e*. the move from separate bilateral discussions to a trilateral forum). Thus, this report summarises the international cooperation to date. It also addresses the key topics which are relevant to the development of a common assessment methodology, and provides an initial list of 'open'[3] issues to be addressed in the trilateral discussions.

1.2 The ECOSTAND project

1.2.1 Background

In current policies and research frameworks of the EU considerable emphasis is placed upon the environmental impacts of road transport and the promotion of measures which can help to reduce these impacts. One of the primary concerns is climate change, and therefore reducing emissions of carbon dioxide (CO_2) and other greenhouse gases.

Policy makers in Europe, Japan and the US share a conviction that applications of information and communication technology (ICT) in the field of road transport, commonly referred to as Intelligent Transport Systems (ITS)[4] can, as part of an integrated strategy, make a significant contribution to improving energy efficiency and reducing CO_2 emissions from the transport sector. Growing numbers of so-called 'Green ITS' applications and services are currently being developed. These are specifically designed to reduce emissions or other environmental impacts and include, for

[3] The word 'open' is used in a general sense here to refer to questions which are either unresolved within regions or to aspects which cannot, at present, considered to be 'harmonised' in the three regions.

[4] For simplicity, ICT and ITS are referred to in this report as ITS, unless specific reference to ICT is required.

example, specially adapted traffic management strategies, information and routing services, and traffic access restrictions. Such ITS applications are often made possible through the deployment of ‘cooperative systems’ which involve data exchange between vehicles, or between vehicles and the infrastructure. Nevertheless, many intelligent transport systems developed with other primary objectives (*e.g.* improving traffic efficiency or enhancing safety) may also have an impact on emissions.

If future ITS investment and policy decisions are to be taken on the basis of sound and detailed knowledge, then it will be essential to understand *which* applications are the most effective at reducing CO_2 emissions, and in which context (and combination) they have the most beneficial effect. Such an understanding would enable effective ITS deployment strategies to be designed and promoted.

It will also be important to identify the stakeholders for whom information on energy efficiency and emissions will be of interest at different stages in the lifecycles of ITS applications. These stakeholders, and their tasks, are likely to include:

- Customers and their advisors, who wish to select the best possible ITS solution for a specific requirement or location.
- Policy makers who steer the development and deployment of systems.
- Researchers and engineers involved in the development and testing of new systems.
- System producers, who need to track performance and keep systems up to date.

Detailed and reliable information on the environmental impacts of different types of ITS application, and recommendations on the most appropriate ways of implementing them, would greatly facilitate such tasks. Unfortunately, comprehensive and universally accepted data on the impacts of different ITS applications are currently unavailable. Different assessment methodologies and models are in use in several countries and regions, but this renders the comparison of results from different studies difficult and hampers decision making. A standard international assessment methodology would ensure that knowledge on ITS impacts is acquired using a rigorous, systematic approach. In addition, if a given methodology were agreed and accepted internationally then it would be all the more useful and powerful. A standard methodology would require suitable frameworks and tools, and these would have to be tested and validated. Once available, they would be valuable for promoting energy efficiency in the road sector. It is worth noting that a similar shift towards harmonisation is also taking place in legislation, such as in the regulation of exhaust emissions from road vehicles.

Ideally, a standard methodology for assessing the impacts of ITS on CO_2 emissions would have the following characteristics:

- It would be suitable for comparing different ITS solutions under the same circumstances.
- It would give an accurate and reliable estimate of emissions.
- It would give estimates of other relevant system parameters (travel-times, capacity, *etc*.),
- It would be cost effective and easy to use.
- It would be repeatable.
- It would also be necessary to have a clear awareness of the limitations of the methodology.

In fact, practical work on the definition of a common methodology for assessing the impacts of ITS on CO_2 emissions has already begun. In March 2008 a 'Cooperation Agreement' with this objective was endorsed by the European Commission (DG INFSO) and the Japanese Ministry of Economy, Trade and Industry (METI). This Agreement promoted a continuous dialogue between the two regions, as well as collaborative research, and was supported by a joint EC-METI Task Force. In January 2009 a similar agreement was signed between the European Commission and the Research and Innovative Technology Administration (RITA) of the US Department of Transport (DoT).

The ECOSTAND project was established to unify these bilateral activities[5] and to enhance trilateral co-operation in working towards standardisation. It is a three-year Coordination and Support Action funded by the European Commission (EC) under its Seventh Framework programme (FP7). The project is supported by the EC's Directorate General for Information Society and Media (DG-INFSO).

1.2.2 Objectives

ECOSTAND will provide support and expert knowledge to enable European representatives to play an active and effective role in international collaboration - as part of a Joint Research Task Force - on the topic of the impact of ITS on CO_2 emissions.

The initial objectives of the project are twofold:

- *To promote and facilitate co-operation between the EU, Japan and the US on the assessment of ITS and CO_2 emissions*. Here, the main contribution of ECOSTAND will be to encourage a continuous dialogue and agreement between the three regions on relevant themes. ECOSTAND will stimulate the exchange of information on state-of-the-art modelling techniques and simulation tools, and will permit a high quality EU contribution to discussions.
- *To provide trilateral agreement on a framework within which a common assessment methodology can be defined*. The framework will pave the way towards the international standardisation of the methodology. It should be stressed that while it is not in the remit of

[5] ECOSTAND effectively replaces, and continues the work of, the EC-METI Task Force.

ECOSTAND to *produce* the methodology; the project aims to formulate a **roadmap** and **joint research agenda** to identify gaps in the research and propose solutions to enable the methodology to be developed.

These two objectives are rather general at present, and it is anticipated that during the project they will be systematically refined.

1.2.3 Approach

The ECOSTAND project will be conducted in three main stages:

- A short *preparation phase*. This will involve a state-of-the-art review (the present report) and a relationship-building exercise in order to ensure the cooperation and participation of key experts in the three regions.
- Two *international symposia,* to be organised in Europe. Each symposium will serve as a forum for presenting the results of ECOSTAND to participants from the three regions (and thus combining two separate bilateral streams into one trilateral event). Each symposium will culminate in the production of a separate report. The first report will contain the preliminary findings and initial recommendations concerning the research agenda. The second report will update the first, and will result in a roadmap and more extensive recommendations. The two European symposia will be interlined by American and Japanese events where ECOSTAND will be present, allowing for a further scrutiny on discussion points. Active participation from European side is foreseen here.
- A joint *technical report*. This report will summarise all the work on ECOSTAND, and will contain contributions from all three regions. It will mark the starting point for further research.

The general relationships between the three regions are shown in Figure 1. The European symposia will promote interaction with other relevant EU-funded activities, including FP7 projects such as eCoMove.

At the technical level the first step will be to find common ground (between the EU, Japan and the US) with regard to the types of ITS application which need to be taken into consideration. The next steps will be to identify the various methodologies and assessment tools that are available in the three regions, and to reach a common agreement on how the validation of these tools can be carried out. Any gaps in the understanding will need to be identified and, by means of joint symposia, ‘convergence’ achieved on the aspects to be included in future research agendas.

The EC-METI Task Force has already identified six different themes (referred to as ‘sub-topics’) which will form the basis for discussion and will be considered in depth in ECOSTAND. These sub-topics are shown in Table 1. The appointed ECOSTAND experts on these sub-topics will work with the respective experts from Japan and the US by participating in the workshops and actively contributing to the discussion and the delivery of reports.

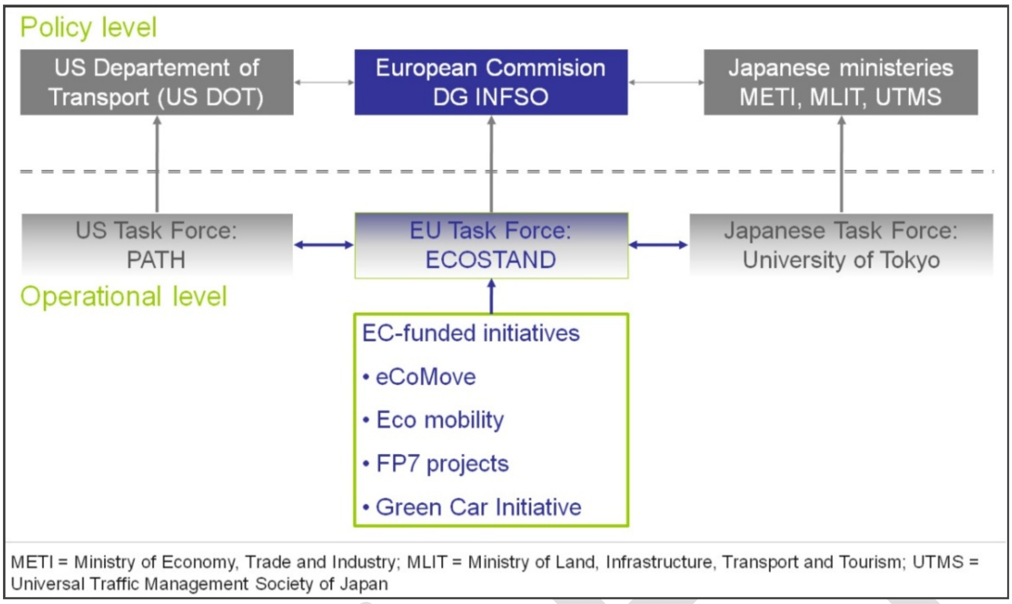

Figure 1: General relationships in ECOSTAND.

Table 1: Sub-topics for discussion.

Sub-topic	Description	Main aim
1	ITS applications	To reach agreement on the main categories and types of ITS application which the methodology needs to be able to assess.
2	Traffic simulation	To identify traffic modelling approaches which enable CO_2 emissions to be estimated for baseline conditions and for various ITS implementation scenarios.
3	Emission modelling	To identify the key requirements of CO_2 emission models required to calculate the impacts of ITS.
4	Monitoring using probe vehicles	To arrive at a common understanding of the contribution of probe data to 'real-time' CO_2 monitoring.
5	Validation methodology	To establish a common validation framework for both traffic simulation and CO_2 emission models.
6	International traffic database	To provide easy access to the data required for estimating the impacts of ITS applications on CO_2 emissions, and for validating models, and to enhance current international traffic databases.

It is the intention of this report to begin the process by identifying specific issues and priorities to be discussed. Initial topics of discussion are likely to include, for example, the different transport modes which should be included, the vehicle types (private car, commercial vehicles, public transport, *etc*), as well as the types of traffic and emission model which are relevant. Although the focus will be on energy efficiency and CO_2 emissions, ECOSTAND will also – where appropriate – consider other types of environmental impact.

1.3 Structure of report

The report is structured as follows:

- Chapter 2 summarises and categorises the ITS applications commonly used in Europe.
- Chapter 3 summarises initiatives and projects which address (or have addressed) the impacts of ITS on energy efficiency and/or CO_2 emissions.
- Chapter 4 provides information on methodologies relating to the assessment of ITS applications and CO_2 emissions (traffic modelling, emission modelling and traffic data).
- Chapter 5 provides an initial list of the key topics which are relevant to the development of a common assessment methodology, and identifies 'open' issues to be addressed within ECOSTAND. These issues will be discussed at the symposia and will feed directly into the policy advice for the roadmap and research agenda.
- Chapter 6 provides a summary of the report and puts forward some recommendations for the future work of the project, especially for the first round of symposia and discussions.

2 ITS applications

This chapter provides an overview of the types of ITS application which are most commonly employed today. However, reference is also made to innovative applications - such as those involving cooperative systems - which are not yet widely used at present but are expected to be deployed on a larger scale in the near future. These systems exploit the potential of both vehicle-based and roadside sensing technologies to gather detailed information about the driving environment, including road and weather conditions, traffic behaviour, and individual vehicle trajectories. By means of communication networks such information can be exchanged between vehicles, and also between vehicles and the infrastructure. In the context of CO_2 reduction, cooperative systems can be considered 'enablers' for green versions of ITS applications. They permit enhanced monitoring of the road network and also direct communication with individual drivers, providing, for example, recommended speeds or suggested routes. The information can be 'targeted' more precisely than is possible with the existing collective messages sent, for example, through variable message signs or radio broadcasts, and can affect driving behaviour in rapid response to changing environmental or traffic conditions (Spence *et al*., 2009). In addition, these technologies have been the subject of substantial investment and intensive research efforts in recent years in the three regions. The ability to make reliable measurements of their potential impact on emissions will therefore be of considerable interest.

The ITS applications are presented in Table 2. The list does not claim to be exhaustive, but should cover the principal categories of ITS. As such, it gives an indication of the range of systems which will need to be taken into consideration in the definition of the common methodology.

The ITS applications have been divided into six categories:

- Navigation and travel information (category *i*-1)
- Traffic management and control (category *i*-2)
- Demand and access management (category *i*-3)
- Driver behaviour change and eco-driving (category *i*-4)
- Logistics and fleet management (category *i*-5)
- Safety and emergency systems (category *i*-6)

The nomenclature is specific to ECOSTAND, but the categories are based on those already put forward in the EC-METI report (Spence *et al.*, 2009), and correspond broadly to the classification used by the Working Group on ICT for Clean and Efficient Mobility (Kompfner *et al*., 2008), with the addition of a sixth category consisting of safety and emergency systems. They also have a close correlation with the categories identified by the ISO Technical Committee TC204.

Table 2: ITS applications (adapted from Spence *et al*., 2009).

Code	ITS application	Brief description
***i*-1**	**Navigation and travel information**	
i-1.1	On-board navigation systems	Routing recommendations based on calculation of fastest route, environmental impact and real-time traffic situation. Information may be provided via a PDA or mobile phone. Other terms in use include ‘green navigation’, ‘enhanced navigation’ and ‘dynamic on-trip routing’.
i-1.2	Intelligent parking	Recommendations for best route to parking spaces, taking into account parking availability, environmental status, network characteristics and in some cases also CAN-bus data.
i-1.3	Web-based pre-trip information services	Route planning for given destination consulted before trip.
***i*-2**	**Traffic management and control**	
i-2.1	Isolated controlled intersections	Generally used for safety. The specifics of the control are different from place to place.
i-2.2	Plan-based control, including ‘green wave’ strategy	Synchronisation of lights to favour traffic flows on specific routes. Optimisation criteria can be overall minimum delay or number of stops.
i-2.3	Traffic-adaptive urban traffic control (UTC)	System which can measure and forecast queue length and adjust phases to optimise efficiency (not fixed plan). Some systems also give (absolute or selective) priority to PT vehicles. A new evolving functionality gives forms of priority to different types of road users (*e.g.* heavy/freight vehicles).
i-2.4	Ramp metering	Traffic lights to manage influx of vehicles to ring road or motorway system.
i-2.5	Point-to-point speed control	System of speed monitoring, using speed cameras, in which average speed between two points is calculated.
i-2.6	Dynamic speed limits	Traffic regulation to impose a given speed (on motorways) according to real-time flow conditions, usually through variable message signs. Also known as ‘variable speed limits’.
i-2.7	Cooperative driver assistance	With a combination of V2V and I2V, more efficient functions like efficient merging of motorway lanes and safe and efficient adaptive cruise control can be achieved. There is some overlap here with category *i*-4.1.
***i*-3**	**Demand and access management**	
i-3.1	Infrastructure use pricing.	Automatic fee collection at road barriers, for specific zones and congestion situations. Other terms include ‘electronic fee collection’, ‘road pricing’, ‘cordon pricing’ and ‘congestion charging’.
i-3.2	‘Carbon credit’ scheme	Management of a system based on carbon assessment of trips, which can be bought and sold.

Code	ITS application	Brief description
i-3.3	Restricted traffic zones	Entry restrictions to given area. Criteria can be vehicle type, socio-economic necessity, vehicle registration plate, credits, *etc*. Also known as 'low-emission zones', 'low-noise zones', 'environmental zones', 'green zones' and 'clear zones'.
i-3.4	Pay-as-you-drive strategy	Onboard black box to charge according to infrastructure use. Can potentially be made very complex, to include dynamic congestion charge functionality, additional fees for environmental zones, time of day etc.
***i*-4**	**Driver behaviour change and eco-driving**	
i-4.1	Support for an energy-efficient style of driving	ITS can improve the driver's information needed to improve an energy driving style on all phases of a trip (pre-trip, on-trip and evaluation post-trip)
***i*-5**	**Logistics and fleet management (commercial and public transport fleets)**	
i-5.1	Commercial fleet management services	Automated tools for supporting the logistics and operation of commercial vehicle fleets.
i-5.2	Parking/loading /delivery management	Allocation of parking spaces and loading/unloading areas in busy urban environments.
i-5.3	Demand-responsive systems for PT	Systems for organising a flexible use of vehicles and vehicle-types on flexible routes based on actual demand.
i-5.4	Slot management	The objective of slot management is to improve the use of the existing road capacity, and thereby to reduce congestion. Time slots are allocated for access to motorway entrances, usually for heavy goods vehicles. Vehicle operators can book slots in advance using an appropriate web site. Vehicles without bookings are not allowed access to the road.
i-5.5	Automated vehicle management systems for public transport (AVM).	Automated tools which permit increased service regularity and greater efficiency. These systems indirectly make public transport more attractive, affecting the modal split and can also result in the need for fewer vehicles for the same service. When combined with traffic light priority, they also result in fewer stops.
***i*-6**	**Safety and emergency systems**	
i-6.1	On-board accident prevention systems	Accidents often result in a build up of queues, especially when traffic densiy is high. . A reduction in the number of accidents leads to less congestion and reduced emissions.
i-6.2	Infrastructure-based incident prevention systems	By prevention of incidents, congestion is reduced. Can be combined with on-board accident prevention.
i-6.3	Incident management systems	Systems which organise the response to incidents (emergency vehicles, clearing of the incident, avoiding secondary incidents)

Although compiled from a European perspective, the list of applications should also reflect the situation in Japan and the United States. There are, however, differences between the three regions in the categories and nomenclature used. In previous exchanges within the EC-METI initiative, it emerged that - in the context of environmental sustainability - Japan and Europe tend to give importance to different areas of ITS. In other words, despite a considerable degree of overlap, there are nevertheless some differences of focus.

While such variations in terminology and focus can be considered inevitable, it is important - in the interest of achieving convergence on a common methodology - that some degree of alignment is achieved. One of the priorities of ECOSTAND should therefore be to reach a trilateral agreement on the *categories of ITS* which need to be covered by the common methodology and also, as far as possible, the applications included in each category. This will have important implications for the methodology itself.

Useful progress in this direction was made in the EC-METI meeting held in Amsterdam in March 2010, in which the Japanese delegation provided a very good starting point for the discussion. These efforts need to be built upon in the first trilateral symposium, so that alignment on these fundamental issues can be reached as soon as possible. It is the intention that Table 2 will provide a helpful basis for this work.

Harmonisation must also be sought in the *terminology* used, since it is essential that there is no misunderstanding between the regions regarding the ITS applications in question. To avoid any ambiguity, it would be useful to produce clear and a detailed description of each ITS application, including distinguishing features. If the individual regions prefer (at least locally) to continue using their own nomenclature, it would be helpful to compile a glossary of equivalent terms. Also the connection with existing standardisation activities like ISO TC 204 will be taken into account.

Once it has been established *which* ITS applications should be covered by the methodology, the next step is to determine the most appropriate geographical and temporal scales at which each one should be assessed, and the modelling implications. It should also be noted that the impacts of different applications on CO_2 emissions arise in very different ways: through their effect on traffic flows, on the distribution of traffic across the road network, on individual driving styles, on traffic composition and so on. It is clear that, as a result, the assessment of different types of ITS application poses very different requirements on the methodology. These aspects are examined in more detail in chapter 4.

3 Initiatives and projects

This chapter of the report summarises recent or ongoing initiatives and projects dealing with ITS and CO_2 emissions. This represents a continuation of the work which was undertaken by the EC-METI Task Force. We have identified the following types of activity:

- Bilateral initiatives
- An initiative in Japan (Energy-ITS)
- An initiative in the US (AERIS)
- Initiatives in the EU
- Selected European projects
- Selected national projects

3.1 Bilateral initiatives

3.1.1 The EC-METI Task Force

Overview

The EC-METI Cooperation Agreement and Task Force were mentioned earlier in the report. The parties involved have initiated a number of activities aimed at the definition of a common assessment methodology. The EC-METI meetings have led in the subjects to be tackled, and serve as a platform for finalising discussions on emerging difficulties.

Activities

The first activity consisted of a survey of existing methodologies and approaches to traffic and emissions modelling. The EC-METI Technical Report (Spence *et al.*, 2009) summarised the status in Europe with regard to methodologies for assessing the impacts of road transport on CO_2 emissions. It discussed traffic simulation models which operate at the 'micro', 'meso' and 'macro' levels, and their use in conjunction with models for estimating emissions. The emphasis was on exhaust emissions; emissions associated with the building of infrastructure were not considered. The data requirements of models were also described. A number of general conclusions were provided in relation to the suitability of different models. The report also identified the main shortcomings of methodologies and provided extensive recommendations for future research. It also proposed some possible steps towards achieving a harmonised approach.

The recommendations[6] of the Technical Report were as follows:

1. *The core ITS applications, and scales of application, should be identified*

   The categories of ITS proposed by EC-METI were, as stated earlier, broadly analogous to those listed in Table 2. It was noted that in order to establish appropriate methods for each context, the ITS applications could also be associated with the type of road environment or specific geographical areas (*e.g.* urban areas, motorways, regional/national networks). The appropriate scale for the assessment of each ITS application should also be agreed in order to include network-level effects.

2. *The fundamental elements of the common assessment methodology should be agreed*

   Four core elements were identified:

   - Traffic Simulation Models (including communication simulation models)
   - Emission models
   - Probe information
   - Traffic databases

   Agreement should be sought on the purpose and scope of these elements. The methodology should cover the assessment of CO_2 reductions associated with changes in transport demand, changes in the behaviour and routing of traffic on the road network, and changes in the driving characteristics of single vehicles.

3. *A roadmap for the development of the required modelling technologies should be defined*

   Whilst several simulation models have useful features for supporting the evaluation of ITS applications in terms of fuel efficiency and emissions, they also have serious shortcomings. The following gaps and issues were identified:

   - There is a need to develop new 'driving cycle' models, taking into account driving behaviour relevant to CO_2 emissions, such as responses to traffic signals, acceleration patterns, gear changes, eco-driving advice, *etc*.
   - There is a need to decide whether and how models should take into account regional differences in behaviour and external conditions (*e.g.* weather, road conditions, visibility, *etc*).
   - The vehicle categories in models need to be defined.
   - Standard tools are required for the calibration/validation of models.
   - Standardised (open) interfaces are required between the different modules (*e.g.* between emission models and micro simulation models).

[6] It should be noted that these have, in some cases, been paraphrased to take into account the developments in ECOSTAND.

- The potential of cooperative systems to provide data input for simulation models should be established, and the most promising types of data source should be identified.

4. *Improved databases should be developed and probe vehicle data obtained*

A clear definition of data needs and availability is of major importance. The following actions were recommended:

- Clarify the implications of data protection and privacy legislation in both Europe and Japan in relation to the collection of data for modelling and validation, especially with regard to probe information.
- Make a detailed analysis of the availability of relevant traffic databases (public and private) in the various Member States of Europe, and in Japan.
- Develop a common access tool for traffic databases in EU and Japan.
- Develop of a standard database for calibration and validation purposes.
- Agree on common parameters for information used to characterise roads (curvature, slope, traffic calming measures).
- Agree on the most appropriate approaches to the collection of probe vehicle data for use in validating traffic models and emissions monitoring systems.
- Investigate the potential of using instrumented fleet vehicles (buses, taxis, public service vehicles, etc) as probe vehicles.
- Compile a common database with representative vehicle mixes for use in simulations. This database should enable predictions to be made for future vehicle mixes (in which hybrid and electric vehicles will play a larger part).

The last EC-METI Task Force meeting took place in Amsterdam on 23 March 2010. The meeting included also US representatives bringing together various experts from the three regions.

Implications for ECOSTAND

ECOSTAND effectively replaces, and continues the work of, the EC-METI Task Force. The ECOSTAND project organisation and work has been based on the decisions taken and suggestions made at the Amsterdam EC-METI meeting. The recommendations of EC-METI have been carried forward into ECOSTAND.

3.1.2 EU-US Task Force on Technical Roadmap for Cooperative Systems

Overview

Future research in road transport applications of ICT will be enhanced under the EU-US Implementing Arrangement signed in Washington in January 2009 and endorsed by the Joint Declaration signed in November 2009 by EC DG INFSO and USA DoT. This EU-US cooperation aims to coordinate research activities, maintain a periodic dialogue, share research results, exchange information and documentation, co-ordinate studies/programmes/activities, conduct joint analyses and evaluations, conduct synchronised research, and participate in joint working groups.

Key coordination areas include assessment tools, methodologies for field operational tests (FOTs)[7], the definition of applications, support for standardisation, and harmonisation of data formats and parameters.

Activities

The EU-US Task Force comprises an American and a European working group. The European group is made up of representatives of the main current and recent projects in the domain of cooperative systems. The European group meets three or four times per year, while the full EU-US group meets on average twice – once during the World ITS Congress, and once during the TRB meeting in Washington. The last meeting took place in Washington in January 2011. A full European delegation as well as a few Japanese observers were invited, with a view to better coordinating the EU-Japan work with that of the EU-US Task Force.

The Task Force addresses the following areas for international cooperation between Europe and the United States:

- Definition of a common roadmap for technical development.
- Common definition/concept of cooperative applications (safety, sustainability).
- Identify further research needs.
- Harmonisation of standardisation for cooperative systems.
- Share common practice in specific areas:
    - Glossary of terms.
    - Human-machine interface and driver distraction.
    - Assessment tools (including simulation).

The European group has already produced a first version of the joint document and a work plan, based on input from the following projects: CVIS, PRE-DRIVE C2X, DRIVE C2X, COOPERS, SAFESPOT, FESTA, iTETRIS, COMeSafety and FOT-net.

One of the teams under the Agreement is dealing with assessment tools, and is compiling an inventory, with comparisons between tools available in Europe and the USA. Other teams are working on the definition of V2V safety applications (two applications) and a sustainability application. The eCoMove project has already contributed a draft for this sustainability application, “the energy-efficient intersection”, taken as the basis for a jointly agreed definition. The joint group is currently examining the possibility of a joint demonstration of this application at a suitable future event.

[7] Field operational tests are large-scale test programmes aimed at providing a comprehensive assessment of the efficiency, quality, robustness and acceptance of ICT solutions.

Implications for ECOSTAND

Some ECOSTAND partners have already participated in the work under the Implementing Agreement, and ECOSTAND will serve as a platform for the continuation and expansion the EU-US collaboration. This work needs to be coordinated with COMeSafety2, which has been providing support to the Task Force since 1 January 2011. COMeSafety2 will be organising a number of workshops on different topics in the course of its work on intercontinental FOT synergies, architecture maintenance, R&D priorities and requirements, EU-US cooperation, standardisation and dissemination/awareness. COMeSafety2 could provide support directly, or could help to include ECOSTAND in a planned event.

Contacts

The principal individuals involved in the EU-US Task Force are shown in Figure 2. The European organisations involved include the European Commission, BMW Research and Technology, Hess Consulting, Renault, Siemens, TSE Consult, PTV, Q-Free and Efkon.

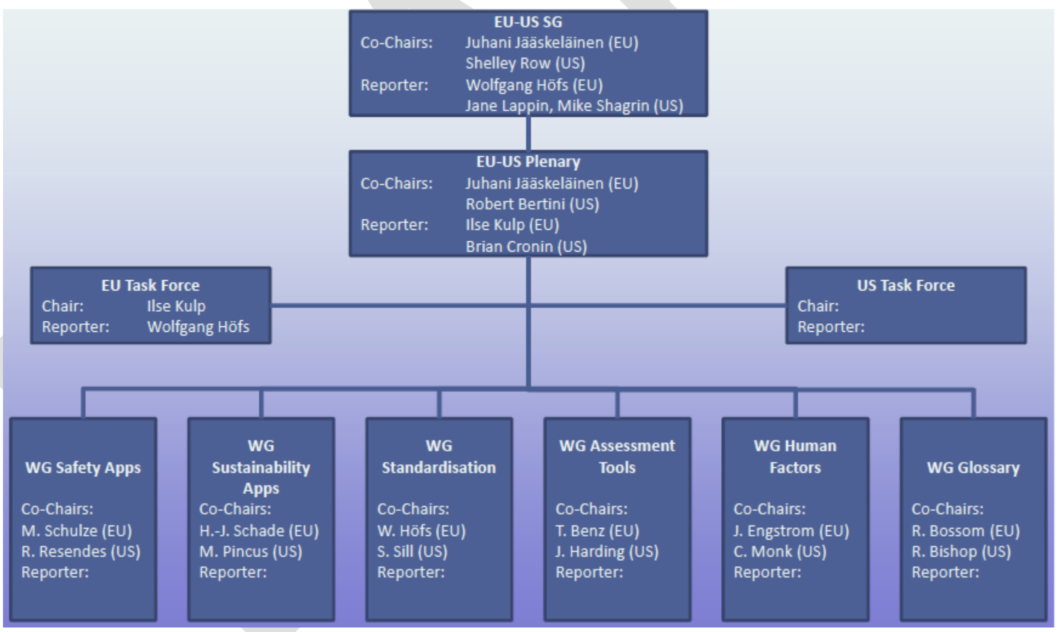

Figure 2: Organisation of the EU-US Task Force.

3.1.3 US-Japan agreement

The ITS Joint Program Office of RITA also has a formal bilateral agreement with the Japanese Ministry of Land, Infrastructure, Transportation, and Tourism (MLIT). On October 21, 2010, RITA and the Road Bureau of MLIT signed a Memorandum of Cooperation to promote research collaboration in the field of ITS for surface transport. This Memorandum is expected to enhance bilateral cooperation between the agencies and further the development and implementation of global ITS activities for safer, more energy-efficient and environmentally-friendly surface transport. The MOC activities are carried out by a Task Force that formally meets at least twice annually. At the Task Force Meeting held in Tokyo in October, 2010, research areas for cooperation were considered and prioritized. The Task Force identified the following three areas as priorities:

- International ITS Standards
- Evaluation Tools and Methods
- Probe Data

The Task Force will share information in the following research areas:

- Driver Distraction
- Environmental Issues
- Communications Security
- Certification
- Open Platform RSE
- Open Source Software Environment using probe data

Contacts

Jane Lappin, US Department of Transportation.

3.2 Initiative in Japan: METI Energy ITS project

In Japan METI launched the Energy ITS project in 2008. This five-year project aims to establish an international standardised assessment methodology for measuring the effects of ITS.

The initial results were presented at a symposium held in Tokyo in February 2008. Furthermore, the work from the Japanese Energy ITS Initiative has been further integrated within the EC-METI Task Force. In addition, an workshop on energy efficiency and CO_2 emissions was hosted by METI and NEDO (New Energy and industrial Technology Development Organisation) on 22-23 October 2010 in Tokyo, with experts from Japan, USA and Europe attending (including an ECOSTAND representative). The topics covered included emission models, ITS applications, traffic simulation models and databases.

More information is available from the following web sites:

http://www.meti.go.jp/english/policy/GreenITInitiativeInJapan.pdf
http://www.scribd.com/doc/46636895/Green-IT-Initiative

3.3 Initiative in the US: Applications for the Environment: Real-Time Information Synthesis (AERIS)

The objectives of the AERIS research programme are to generate and acquire environmentally-relevant real-time transport data, and to use these data to create actionable information that supports and facilitates ‘green’ transportation choices by users and operators. Employing a multi-modal approach, the AERIS program will work in partnership with the vehicle-to-vehicle communications research effort to better define how connected vehicle data and applications might contribute to mitigating some of the negative environmental impacts of surface transportation.

The AERIS research program is structured around research questions that encompass both the issue of information availability as well as the feasibility of providing greater ‘choice’ to decision makers. These questions include:

- What vehicle-based data are available?
- What is the data quality and validity?
- How can vehicle-based data be integrated with existing traffic and emissions data?
- What cross-modal public sector applications are needed, and what are their benefits?

AERIS tasks which are relevant for ECOSTAND include the following:

- *State of the Practice Scan (International) and Site Visits*. Several international trips are being made to relevant ITS deployments or research sites. A gap analysis is being undertaken to determine how the US compares with the rest of the world, and to begin the process of reaching out to international stakeholder groups and governments. These activities will seek to identify opportunities to influence international research to reduce costs, risks and/or schedule requirements associated with AERIS research requirements. A plan for extended international cooperation and joint research will be developed. Cooperative research with the EU will be conducted within the framework of the existing USDOT/RITA-EU cooperative research agreement, and will be coordinated with the US-EU ITS research task force.

- *Evaluation techniques*. There will be an examination of techniques for evaluating the performance of technologies and integrated systems that are designed to mitigate the negative impacts of transportation on the environment. What are the different evaluation options and what results do they yield? Are the results accurate and robust? Are they actual measurements or from models?

Contacts

Marcia Pincus, Program Manager, Environment (AERIS) and ITS Evaluation, ITS Joint Program Office, RITA.
Website: http://www.its.dot.gov/aeris/index.htm

3.4 Initiatives in the EU

3.4.1 FP7 Research topic ICT for Clean and Efficient Mobility

Overview

The topic of research in 'ICT for Clean and Efficient Mobility' for all modes of transport was opened in November 2008 under the ICT priority of the European Commission's Seventh Framework Programme. Calls have invited proposals for new tools, systems and services to support energy-efficient driving (eco-driving). These include on-board systems and/or cooperative infrastructure and energy-optimised, adaptive traffic management for urban areas and inter-urban roads.

The final report on ICT for Clean & Efficient Mobility (ICT4EE) was presented to the eSafety Forum on 6 Nov. 2008. The iCAR Thematic Network report on ICT4EE was delivered in June 2010.

Activities

This R&D topic has led to the successful start of several projects on the theme of ICT (or ITS) for clean and efficient mobility. To name a few: eCoMove and ELVIRE grew out of ICT Call 4, and ECOGEM (ICT for fully electric vehicle) from the Green Car initiative. Projects will be discussed in more detail in section 3.5.

Implications for ECOSTAND

ECOSTAND should look at the evaluation methodology used in relevant projects, and also at any field operational tests for the results on impacts, costs, benefits, *etc*, of ICT for sustainable mobility.

The eSafety Forum Steering Group has decided to re-establish the work of the WG ICT4EE in a similar form (*i.e.* the eSafety Working group on ICT for Clean and Efficient Mobility - WG4CEM), for which Terms of Reference are being established (June 2011).

The following Green ITS Areas will be addressed in the WG4CEM:

- Eco-driving and eco-driving support
- Eco-traffic management, urban traffic management
- Eco-mobility services
- Eco-information, navigation and guidance
- Eco-demand and access management
- Eco-freight and logistics management
- Eco-monitoring and modelling

The work of the WG4CEM is intended to be based on inputs from recent and ongoing projects, e.g. eCoMove and ECOSTAND. Membership of the WG4CEM is also open to ECOSTAND partners who could contribute to its work.

Contacts

Jean-Charles Pandazis, Head of Sector – EcoMobility, ERTICO – ITS Europe, (eCoMove).
Burak Onur, R&D Support Executive, Temsa Global, Turkey.
Hannes Luettringhaus, Continental Automotive GmbH (ELVIRE).
Web site: http://www.icarsupport.eu/esafety-forum/esafety-working-groups/?menu=4

3.4.2 eSafety Forum Working Group on ICT for Clean & Efficient Mobility

Overview

In December 2006 the eSafety Forum established a Working Group for ICT for Clean and Efficient Mobility. This Working Group has identified seven types of ITS measure which offer the greatest potential for energy efficiency and reduction of CO_2 emissions. Detailed recommendations are offered to industry, the Member States and the European Commission concerning the deployment of measures. The measures identified by the Working Group were also considered in the review of ITS applications in chapter 2.

Activities

The Working Group functioned for two years and presented its final report in November 2008, during the eSafety Forum plenary meeting. Its results were an important input to 7th Framework Programme R&D planning by DG INFSO, and to projects such as eCoMove that began in 2010. In 2010 the eSafety Forum Steering Group also considered establishing a new working group in the area of ICT for energy efficiency and the environment, but no decision has yet been taken.

Implications for ECOSTAND

The final report contains an extensive list of recommendations, including requirements for further research and evaluation methodologies. An annex contains a summary of known research results on the impacts of ITS on energy efficiency and the environment.

Contacts

Irmgard Heiber, EC contact for Working Group, EC DG INFSO, Unit G4.
Paul Kompfner, Co-Chair of Working Group, ERTICO – ITS Europe.
Web site: http://www.esafetysupport.org/

3.4.3 EC Intelligent Car Initiative

The Intelligent Car initiative was launched by the European Commission in February 2006 as one of the flagship projects of the i2010 programme to boost Europe's digital economy and improve the take-up of ICT in road transport.

One of its main objectives, with the help of the eSafety Forum, is to support ICT-based research and development in the area of smarter, cleaner and safer vehicles, to be achieved by establishing the Working Group for ICT for Clean and Efficient Mobility.

The EC-METI Task Force (see section 3.1.1) was appointed under the aegis of the Intelligent Car Initiative to pave the way towards international harmonisation and standardisation.

Contacts

Web site: http://ec.europa.eu/intelligentcar

3.4.4 The Energy Efficiency Task Force

In 2008 the European Commission adopted its first 'Communication on ICT for Energy Efficiency'. This document was subjected to wide public consultation, and a Stakeholder Group called the 'Energy Efficiency Task Force' was also established. On the basis of the conclusions of the Stakeholder Group, in October 2009 the Commission issued a 'Recommendation on mobilising ICT to facilitate the transition to an energy-efficient low-carbon economy', addressed to the Member States and the ICT sector. This identifies actions to enable energy-efficient behaviour and economic benefits at all levels of society, with the aim of facilitating and accelerating the deployment of innovative ICT applications.

The main political message is that ICTs and ICT-based innovations potentially offer some of the most cost-effective means of helping Member States to reach their 2020 target for reducing carbon emissions. ICTs can also help to induce behavioural change, which will be essential for going beyond the 2020 targets, as will undoubtedly be necessary. There are opportunities not just to enable energy savings (and thus cost savings), but also to open up new markets.

Following on the Recommendation (SEC(2009) 1315 of 9th October 2009), in a Memorandum of Understanding DIGITALEUROPE, GeSI, JBCE and TechAmerica Europe agreed to establish an ICT for Energy Efficiency (ICT4EE) industry Forum. The aims of the Forum are to help ensure a coordinated global approach from the ICT sector to support coordinated EU policy making on climate and energy efficiency.

Implications for ECOSTAND

Accompanying the Recommendation will be an Impact Assessment and a detailed report covering multiple sectors, including transport.

The Green IT Promotion Council in Japan and the Digital Energy Solutions Campaign (DESC) in the US, India and China are going to provide the results of their activities and cooperate with the ICT4EE Forum.

Contacts

Web sites:

- First European Commission Communication on ICT for Energy Efficiency: http://ec.europa.eu/information_society/activities/sustainable_growth/docs/com_2008_241_all_lang/com_2008_241_1_en.pdf
- Recommendation on mobilising ICT to facilitate the transition to an energy-efficient low-carbon economy: http://ec.europa.eu/information_society/activities/sustainable_growth/docs/recommendation_d_vista.pdf

  and accompanying Communication: http://ec.europa.eu/information_society/activities/sustainable_growth/docs/com_2009_111/com2009-111-en.pdf

  and accompanying impact assessment report http://ec.europa.eu/energy/technology/set_plan/doc/2009_comm_investing_development_low_carbon_technologies_impact_assessement.pdf
- Impact Assessment report accompanying the WHITE PAPER 'Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system' http://ec.europa.eu/transport/strategies/doc/2011_white_paper/white_paper_2011_ia_full_en.pdf

3.5 European projects and studies

In this section of the report we have listed a number of EC-funded projects and national initiatives which are relevant to the work of ECOSTAND, in the sense that at least one of the activities involves the assessment of ITS applications on energy efficiency and/or CO_2 emissions. As such, the participants in the projects and initiatives are potential contributors to the ECOSTAND symposia, and their reports will be valuable sources of information. We have also included support actions dedicated to international cooperation, as these are also potential sources of relevant contacts for the ECOSTAND symposia. The ECOSTAND partners are also aware of a number of new project developments which, if approved for EC funding, would develop a framework for the evaluation of the effects of ICT measures in traffic and transport on energy efficiency and CO_2 emissions (as well as other performance indicators).

ICT & Energy Efficiency study

<u>Project details</u>

Start Date: 2009

End date: 2009

Duration: 6 months

Coordinator: TNO

Funding: EC DG INFSO

<u>Summary</u>

In 2009 a consortium led by TNO conducted a study for the European Commission in which the effects of different ITS and ICT measures on CO_2 emissions were compared (Klunder *et al.*, 2009).

Three types of ICT solution were investigated: traffic management, advanced driver assistance systems and eco-driving. More than 50 systems were initially assessed, and several of the more effective systems were subjected to an extended analysis. The authors estimated the potential for CO_2 reduction of each system at the EU-27 level, with the emission factors being derived from TNO's VERSIT+ model. The potential CO_2 reduction of each system was based on a 100% penetration rate, or application on all suitable roads. The results are summarised in Table 3, which gives an overview of the estimated potential CO_2 reductions per measure. This reduction is given as a percentage of the total CO_2 emission by road transport in the EU-27.

The measures which were found to have a 'very large' CO_2 reduction at the EU-27 level were eco-driver coaching and eco-driver assistance (Including support by a number of tools such as gear-shift indicator, speed profile recommendations, using enhanced map data) For both systems, the effect is highly dependent on the willingness of the driver to comply with the most energy efficient driving style.

Pay-as-you-drive (PAYD) and platooning were found to have a large CO_2 reduction. The effect of PAYD is due to the fact that the amount of vehicle kilometres (vkm) driven will decrease significantly. The CO_2 reduction of platooning is mostly due to drag reduction, but its implementation could also require infrastructural changes.

Measures with a medium CO_2 reduction at the EU-27 level were adaptive cruise control, dynamic traffic light synchronization, fuel-efficient route choice, automatic engine shutdown, trip-departure planning, and tyre pressure indicators.

Measures such as congestion charging and slot management were found to have low CO_2-reduction potential because they are applicable in fewer situations (*e.g*. only large cities and main transport corridors).

The TNO study provides some very useful information for ECOSTAND, such as a substantial inventory of emission models, a discussion on the relevance of different emission models to the assessment of ICT and ITS, and an approach for taking into account differences in the geographical and temporal scale of operation of different ITS/ICT (*i.e.* scaling up impacts to the EU-27 level).

Table 3: Potential effect on CO_2, ease of implementation, compliance and future use for selected measures (Klunder *et al*., 2009).

System	Potential CO_2 effect in EU-27	Ease of implem-entation	Compliance	Expected future use
Eco-driver coaching	15%	Medium	Medium	Large
Eco-driver assisstance	10%	Easy	Med./hard	Large
PAYD	7%	Medium	Medium	Medium
Platooning	6%	Very hard	Hard	Small
CC/ACC	3%	Easy	Easy	Large
Fuel-efficient route choice	2%	Med./hard	Mediun	Medium
Dynamic traffic light synchronisation	2%	Medium	No issue	Large
Automatic engine shutdown	2%	Easy	Easy	Large
Trip departure planning (freight)	2%	Medium	Medium	Large
Tyre pressure indicator	1%	Easy	Medium	Large
Congestion charging	0.5%	Medium	No issue	Medium
Slot management	<0.1%	Hard	No ssue	Small
Lane keeping	0.1%	Easy	Easy	Large
Emergency braking	<0.1%	Easy	No issue	Large

Intelligent Cars Thematic Network

Project details

Start Date: 2008-07-01

Duration: 24 months

Coordinator: FIA European Bureau

Funding: EC FP7 CIP ICT-PSP

Summary

The iCars Network was a two-year project which contributed to the deployment of transport ICT/ITS technologies by exchanging knowledge and experience on a number of specific topics.

The iCars Network had a Thematic Group on Impact Assessment Methods that drew up a catalogue of assessment methods for faster take-up of technologies that contribute most to improvement of road safety, mobility, efficiency and CO_2 output. A second Thematic Group on Energy Efficiency drew up a roadmap on the implementation of new ITS technologies with potential to reduce the CO_2 output of road transport.

The outputs are available online at http://www.icarsnetwork.eu/download/TGs/d35_1_webpage.pdf (catalogue) and http://www.icarsnetwork.eu/download/TGs/d44_1_webpage.pdf (roadmap). In each Thematic Group a substantial amount of background documentation is also available online.

Cooperative Mobility Systems and Services for Energy Efficiency (eCoMove)

Project details

Start Date: 2010-04-01

Duration: 36 months

Coordinator: ERTICO – ITS Europe

Funding: EC FP7 ICT for Safety and Energy Efficiency in Mobility (ICT-2009.6.1)

Summary

The eCoMove project will create an integrated solution using vehicle-infrastructure communication to improve road transport energy efficiency by:

- Saving unnecessary kilometres driven (optimising routes)
- Helping driver to save fuel (optimising driver behaviour)
- Managing traffic more efficiently (optimising network management)

The combination of applications targeting these three areas - *i.e.* supporting eco-driving for both private and professional drivers, eco-tour planning for the freight & logistics sector, as well as eco traffic balancing & control measures - will deliver an overall reduction in fuel consumption (and thus CO_2 emissions) of up to 20%.

These important eCoMove innovations are being enabled by the use of cooperative information exchange, such as vehicle fuel consumption data and traffic information, in order to formulate speed and route recommendations to minimise the energy use and carbon footprint of individual vehicles, as well as the overall network.

An integrated validation, impact assessment and evaluation of the eCoMove system and its individual applications will be performed. Therefore drivers, barriers and requirements of all stakeholders of the eCoMove system have to be identified before the design of eCoMove applications.

eCoMove applications will be later tested in different traffic environments. Both technical and non-technical achievements will be evaluated. The overall impact of eCoMove applications on traffic efficiency and environment will be assessed using a cost-benefit analysis. The project includes development of models for both model-based traffic management and for assessment. Core of the modelling will be VISSIM+ENVIVER.

DRIVing implementation and Evaluation of C2X communication technology in Europe (DRIVE C2X)

Project details

Start Date: 2011-01-01

Duration: 36 months

Coordinator: Daimler

Funding: EC FP7 ICT for Mobility of the Future (ICT-2009.6.2)

Summary

The objective of the project is to carry out large-scale field operational tests of cooperative systems to evaluate their impact on user behaviour, traffic flow, safety, the environment and society. In addition to impacts, other important areas of testing are technical functionality and the robustness of the systems under adverse conditions. The user feedback and the results from technical tests will enable the creation of realistic business models to pave the way for market implementation.

The project will bind together and harmonise existing European test sites according to mutually agreed methodological and operational procedures. To develop and implement its methodology, the project will build on previous work carried out in PRE-DRIVE C2X (completed in 2010), which developed an integrated simulation model for cooperative systems enabling a holistic approach for the estimation of the expected benefits in terms of safety, efficiency and the environment.

Cooperative systems for Sustainable Mobility and Energy Efficiency (COSMO)

Project details

Start Date: 2010-11-01

Duration: 32 months

Coordinator: Mizar Automazione

Funding: EC FP7 CIP ICT-PSP

Summary

COSMO is a pilot project which aims to demonstrate the benefits of cooperative traffic management services and to quantify their potential to improve energy efficiency and reducing the carbon footprint.

While the principal focus of COSMO is in the area of environmentally sustainable traffic management, the services cover a range of application areas involving different technologies and scenarios: 'luminous path' system (traffic-adaptive street lighting), public transport priority at intersection, eco-driving support (for private cars and also buses), eco-navigation, eco-access management The scenarios to be developed and explored by COSMO involve prototypes developed during the recent EC-funded research projects COOPERS, CVIS and SAFESPOT.

Their effectiveness will be tested in practical demonstrations to be carried out at three pilot sites: Salerno (Italy), Vienna (Austria) and Gothenburg (Sweden). The Italian and Swedish pilot sites consist of urban scenarios, while the Austrian pilot is testing an inter-urban use case on a highway.

COSMO is adopting a system-wide approach to the assessment of energy efficiency, measuring the effect of a range of innovative traffic management systems not only on fuel consumption and traffic emissions, but also considering the impact of the energy used by the equipment itself and the product lifecycle.

The principal result will be a set of quantified specifications for their practical deployment, covering technical, legal and organisational issues, as well as indications on the procurement, installation, operation and maintenance.

Urban Freight Energy Efficiency Pilot (FREILOT)

Project details

Start Date: 2009-04-01

Duration: 30 months

Coordinator: ERTICO – ITS Europe

Funding: EC FP7 CIP ICT-PSP

Summary

The FREILOT pilot aims to increase energy efficiency in urban freight transport and to demonstrate (at four linked pilot locations) that a reduction in fuel consumption and CO_2 emissions in urban areas of up to 25% is achievable through FREILOT services: selective priority for eligible goods vehicles, acceleration/adaptive speed limiters, eco-driving support and real-time loading/delivery space booking.

Intelligent and Efficient Travel Management for European Cities (In-Time)

Project details

Start Date: 2009-04-01

Duration: 36 months

Coordinator: AustriaTech

Funding: EC FP7 CIP ICT-PSP

Summary

In-Time focuses on Multi-modal Real Time Traffic and Travel Information (RTTI) services, with the goal of reducing the overall energy consumption of transport in urban areas by encouraging changes in travel behaviour. In-Time will be piloted in the cities of Brno (CZ), Bucharest (RO), Florence (IT), Munich (DE), Oslo (NO), and Vienna (AT).

In-Time provides three main services:

- Business-to-business services enabling Europe-wide Traffic Information Service Providers (TISPs) to have access to regional traffic and travel data and services in the pilot cities via a standardised open interface.
- Interoperable and multi-modal RTTI services or *e*-services, provided by the TISPs to end-users (typically mobile devices or navigational devices users).
- Web based interoperable and inter-modal pre-trip information provided by the pilot operators.

These services have the potential to influence the travel behaviour and optimise journeys while taking environmental aspects into account.

The estimated impacts of these energy saving measures include the following:

- Modal shift away from individual traffic: private users will be able to compare transport modes and make a choice.
- Using modern traffic management equipment will achieve drastic cuts in energy consumption through optimised traffic control (eco-flow), enhanced product life-cycle, and reduced power consumption by using LED technologies.

Coordination of Network Descriptors for Urban Intelligent Transport Systems (CONDUITS)

Project details

Start Date: 2009-05-01

Duration: 24 months

Coordinator: Istituto Di Studi Per L'integrazione Dei Sistemi (ISIS)

Funding: EC FP7 Intelligent mobility systems and multi-modal interfaces for transport of passengers (SST-2007-3.1-02)

Summary

The main objective of this project is to develop key performance indicators which will represent internationally-recognised standard measures for quantifying the benefits of ITS in urban areas from efficiency, environment, energy, safety and spatial perspectives. The indicators will assist European municipalities in making informed decisions on ITS investments.

Toolkit for sustainable decision making in ITS deployment (2DECIDE)

Project details

Start Date: 2009-10-01

Duration: 24 months

Coordinator: AustriaTech - Federal Agency For Technological Measures Ltd

Funding: EC FP7 Assessment of ITS tools for better decision making (SST.2008.2.7.6)

Summary

The objective of 2DECIDE is to develop an 'ITS Toolkit' which will assist transport authorities in the deployment of ITS, and will help them solve traffic and transport problems and address policy objectives.

The ITS toolkit will be free to users, and aims to provide:

- Best practice examples of ITS deployment.
- Information about costs, benefits and impacts of ITS solutions.
- A database of evaluation reports on ITS projects.
- Information on technical and legal aspects for ITS solutions.
- Targeted information in response to user queries.

European Field Operational Test on active safety functions in vehicles (euroFOT)

Project details

Start Date: 2008-05-01

Duration: 40 months

Coordinator: Ford Forschungszentrum Aachen

Funding: EC FP7 ICT for cooperative systems (ICT-2007.6.2)

Summary

euroFOT is a field operational test that will examine a variety of intelligent vehicle systems (IVS) on a large scale and under real-world driving conditions. The assessments will cover safety, the environment and driver behaviour.

The FOTs are focusing in particular on eight distinct functions that assist the driver in detecting hazards, preventing accidents and make driving more efficient. Over the course of one year, more than 1,000 cars and trucks equipped with a range of different intelligent technologies are being tested on European roads across France, Germany, Italy and Sweden.

The analysis of the data gathered in real-world traffic conditions with ordinary drivers is expected to highlight several crucial aspects of intelligent vehicle systems:

- What are the performance and capability of the systems?
- How does the driver interact with and react to the systems?
- What are the impacts on safety, efficiency, and on the environment?

The insights gained during the project will help policymakers decide on the right policy framework, and business leaders to make informed decisions on the best way to bring these technologies to the market.

SUstainable social Network SErvices for Transport (SUNSET)

Project details

Start Date: 2011-02-01

Duration: 36 months

Coordinator: Stichting Novay

Funding: EC FP7 ICT for Mobility of the Future (ICT-2009.6.2)

Summary

SUNSET will develop and evaluate a set of services that use social networks and incentives to encourage people to travel more sustainably in urban environments. The project will focus on services that reduce the impact of mobility on the environment, for instance in terms of reduced CO_2 emissions, improved air quality and reduced noise pollution.

The SUNSET services will be evaluated in two 'living labs', one in Enschede (NL) and one in Göteborg (SE) or Leeds (UK). The goal of the living labs is to assess how the SUNSET services contribute to the project objectives.

The expected outputs of SUNSET are evaluation methodologies and an impact analysis based on the living lab evaluations.

Field operational tests of aftermarket and nomadic devices in vehicles (TeleFOT)

Project details

Start Date: 2008-06-01

Duration: 48 months

Coordinator: VTT Technical Research Centre of Finland

Funding: EC FP7 ICT for cooperative systems (ICT-2007.6.2)

Summary

TeleFOT is assessing the impacts of the functions provided by aftermarket and nomadic devices in vehicles through large-scale field operational tests, and is raising awareness of these impacts. The FOTs developed in TeleFOT aim at a comprehensive assessment of the efficiency, quality, robustness and user friendliness of in-vehicle systems, such as ICT for smarter, safer and cleaner driving.

The functions to be tested cover two broad areas, promoting (i) safe driving and (ii) economic and fuel efficient driving. The impacts are assessed in terms of usability, behaviour/incidents, safety, 'green driving', and efficiency, as well as impacts on the transport system.

Up to 3,000 drivers in TeleFOT-equipped vehicles will be driving around in eight of the Member Countries involved in the project (Finland, Sweden, Germany, UK, France, Greece, Italy and Spain).

Network of Excellence for Advanced Road Co-operative Traffic management in the Information Society (NEARCTIS)

Project details

Start Date: 2008-07-01

Duration: 48 months

Coordinator: EUROPE RECHERCHE TRANSPORT – www.nearctis.org

Funding: EC FP7 ICT for cooperative systems (ICT-2007.6.2)

Summary

The project aims at bringing together most of the European academic community working on road traffic management - *i.e.* traffic modelling, traffic control, communications and location technologies - to constitute a virtual research institute that is setting up a common and consistent research programme.

This will involve descriptions of the state of art in science and deployment activities, and of existing research capacities and resources, as well as the identification of areas where further research and/or deployment activities are needed to fill current gaps, namely:

- Traffic models and impact estimation models: traffic flow, safety, environment and energy.
- Evaluation methods (economic, technical, environmental, safety-related).

Logistics Industry Coalition for Long-term, ICT-based Freight Transport Efficiency (LOGISTICS FOR LIFE)

Project details

Start Date: 2010-01-01

Duration: 30 months

Coordinator: INSIEL - INFORMATICA PER IL SISTEMA DEGLI ENTI LOCALI S.P.A.

Funding: EC FP7 ICT for Safety and Energy Efficiency in Mobility (ICT-2009.6.1)

Summary

Logistics for LIFE has the general goal of driving European ICT for transport research in the direction of making logistic operations more efficient, and thus more environmentally friendly, financially sustainable and socially sustainable in the long term. It will bring together leading logistic companies, technology providers and research organisations working on innovative ICT solutions.

The specific objectives include the following:

- To establish a reference framework where logistic efficiency requirements from different stakeholders are related to sustainability strategic objectives on the one side, and, on the other side, to existing and future ICT solutions.
- To develop a strategic roadmap, including concrete actions and strategies that will guide and facilitate the effective implementation of ICT solutions identified in the reference framework

for energy efficiency in logistics. Both the framework and the related roadmap will be periodically updated with stakeholders input, collected through the Logistics for LIFE activities, and aligned with Commission programmes as well as with inputs from other forums and EU projects.

Highly Automated Vehicles for Intelligent Transport (HAVEit)

Project details

Start Date: 1 February 2008

Duration: 42 months

Coordinator: Continental Automotive GmbH

Funding: ICT for Intelligent Vehicles and Mobility Services (ICT-2007.6.1)

Summary

The aim of HAVEit is to realise the long-term vision of highly automated driving for intelligent transport by optimising the division of tasks between the driver and the co-driving system (*i.e.* ADAS). A step-by-step-approach will be used to transfer the driving task back from the automated system to the driver.

Comfort, safety and the efficient usage of energy will be addressed for the following applications in both passenger cars and heavy-duty trucks:

- Automated queue assistance
- Construction site assistance
- Temporary auto-pilot
- Active green driving

After implementing the aforementioned applications, their benefit and impact will be assessed in relevant scenarios.

The 'active green driving' application aims at increasing energy efficiency. Impacts on efficiency will be assessed by comparing the active green system performance in pre-defined cases with a baseline system. This assessment can be performed by measuring a set of key indicators such as fuel consumption or change of battery state of charge for some specified uses. These indicators and cases will be precisely defined.

Communications for eSafety2 (COMeSafety2)

Project details

Start Date: 2011-01-01

Duration: 36 months

Coordinator: BMW FORSCHUNG UND TECHNIK GMBH

Funding: EC FP7 ICT for Mobility of the Future (ICT-2009.6.2)

Summary

The project will support and coordinate the development of the necessary standards for the realisation of cooperative systems on European roads, under the ITS standardisation mandate at ETSI and CEN.

It will support the mutual validation and exploitation of programme results under the EU-US cooperation agreement. The project will target international and especially intercontinental synergies of FOTs. The project will develop roadmaps for realising and implementing research results in a developing real-world cooperative system environment. It will also support the creation of the corresponding research agendas to address open technical issues, explore new fields and develop further innovations.

An important objective that will be addressed by COMeSafety2 is the specification of common EU-US compatible applications, both for safety and sustainability. These specifications may then be used for inter-operable implementations on either continent, and will be targeted towards standardisation. This will support the synergies that can be achieved by coordinated FOT testing. The exchange of test tools and methodologies between EU and US, and later possibly with Japan and other countries, will allow the production of comparable test data, thereby reducing test efforts for the individual FOTs, providing larger data sets, and leading to the possibility of comparing test outcomes.

Intelligent Car Support (iCar Support)

Project details

Start Date: 2009-12-01

Duration: 36 months

Coordinator: ERTICO – ITS Europe

Funding: EC FP7 ICT for Safety and Energy Efficiency in Mobility (ICT-2009.6.1)

Summary

iCar Support aims to support the implementation of the actions and recommendations of the eSafety Forum and the Intelligent Car Initiative. This includes supporting the eSafety Forum and its various elements, including its Working Groups and Task Forces. For example, the Working Group on International Cooperation aims to improve the implementation of the recommendations made by other eSafety Forum Working Groups by supporting a dialogue at the international level and by identifying working items from other Groups where this type of cooperation is lacking or should be strengthened.

These include:

- Research to use eSafety techniques for energy efficiency/environmental benefit.
- A register of field operational tests and assessment processes.

Field Operational Test Networking and Methodology Promotion (FOT-Net 2)

Project details

Start Date: 2011-01-01

Duration: 36 months

Coordinator: ERTICO – ITS Europe

Funding: EC FP7 ICT for Mobility of the Future (ICT-2009.6.2)

Summary

The FOT-Net Support Action provides a platform of knowledge exchange in order to allow individual FOTs to benefit from each other's experiences. The prime goal of FOT-Net 2 is to increase the momentum achieved in FOT-Net 1 and further develop the strategic networking of existing and future national, European and global FOTs (*e.g.* strengthening international cooperation with US and Japan). FOT-Net 2 will create five new expert working groups in order to clarify critical topics related to the legal and ethical issues, data analysis, incident definition, data sharing and impact assessment.

In the impact assessment Working Group specific tools will be listed in an inventory in order to cover the complete chain of data analysis.

EasyWay Evaluation Expert Group (EW EEG)

Project details

Duration: Three stages (2007- 2009, 2010-2011 and 2012-2013)

Leader: Ian Davies (EW EEG)

Funding: EC DG TREN TEN-T Programme

Summary

The EasyWay project focuses on a Europe-wide harmonised deployment on the Trans-European Road Network (TERN) of a set of core ITS services in traveller information, traffic management, and freight and logistic areas (plus supporting ICT infrastructure). The main objectives are to increase road safety, to increase mobility, to decrease congestion, and to decrease the transport burden on the environment.

Driven by national road authorities and operators with associated partners including the automotive industry, telecom operators and public transport stakeholders, Easyway incorporates all current Euro Regions and facilitates the integration of new Member States.

The Evaluation Expert Group (EEG) constitutes an independent body within EasyWay. The EEG is responsible for developing evaluation procedures to collect and process evaluation results from study and implementation activities within the EasyWay programme. The objectives of the EEG are to evaluate impacts on the TERN of the co-ordinated delivery of integrated services, and to demonstrate their benefits in terms of safety, network efficiency and the environment.

EasyWay offers a bank of evaluation reports across a wide variety of different implementation types and sites across Europe. Together with resources such as the US Benefits Database, IBEC's[8] own website, the UK's ITS Toolkit site, and the EU-wide '2DECIDE' resource, there is a wealth of international best practice and benchmarked results to assist decision makers and practitioners within the Programme[9].

3.6 Selection of national projects and initiatives

ITS UK Carbon Working Group

Project details

Start Date: 05-2009

Coordinator: Keith McCabe, Atkins; Ian Routledge of the Ian Routledge Consultancy (www.irconsultancy.co.uk)

Summary

The ITS United Kingdom Carbon Working Group has been set up to explore how ITS can play a role in transportation greenhouse gas reduction, with the aim of producing a roadmap for a 'Low Carbon ITS Industry'. The Carbon Working Group is a sub-group of the Smart Environment Interest Group (SEIG), which provides a forum for all ITS United Kingdom members with an interest in transportation and the environment to meet, discuss their views and study the uses of ITS to benefit the environment.

[8] International Benefits, Evaluation and Costs (IBEC) Working Group.

[9] EasyWay Evaluation Expert Group (EW EEG) Document – EEG/11/10, Synthesis of Project Evaluation Results 2007-9, February 2011, Page 9.

The Carbon Working Group has identified several ITS applications that have been shown to result in reduced CO_2 emissions, or have a significant potential to do so:

Already used:

- Internet-based maps to guide freight drivers accurately.
- Managed motorways: benefits of reduced emissions due to smoother traffic flow, of the removal of the need for additional road building (a carbon intensive activity), and of better design of road side equipment reducing energy consumption.
- Systems to support cycling and walking.
- Adaptive signal control to reduce braking, acceleration, and idling.
- Information services to support travel planning - for towns, workplaces, other activity centres, and individuals.
- Road user charging.
- Point-to-point speed enforcement, which smoothes traffic flows.

Ready, or close to being ready, for implementation:

- Infrastructure to support the use of low-carbon vehicles, such as mapping and navigation for charging points.
- Systems to support eco-driving.

Co-operative Networked Concept for Emission Responsive Traffic Operations (CoNCERTO) (UK)

Project details

Start Date: Autumn 2010

Duration: 36 months

Coordinator: Centre for Transport Studies, Imperial College London

Summary

The vision of the project is to utilise real-time information on air pollutant concentrations measured at the roadside and information on vehicles as inputs to traffic control and driver information systems, and to investigate and demonstrate the potential effectiveness of 'green' traffic management techniques.

The project will establish a small fleet of equipped vehicles and an equivalent infrastructure-based system will be deployed on the innovITS ADVANCE test track.

The anticipated outcomes are quantified measures of the system and traffic performance of a range of cooperative systems approaches to reduce emissions from road traffic.

Truck of the Future (NL)

Project details

Start Date: 2011-2013

Coordinator: TNO

Funding: Dutch Ministry of Infrastructure and Environment

Summary

Part of the national Truck of the Future initiative is a demonstration programme carried out by TNO, which focuses on systems that lower tractive resistance, systems that bring down air resistance and ICT-systems that influence driver behaviour.

Two hundred trucks will be equipped with fuel saving systems already available on the market. By monitoring their fuel consumption for a year and by comparing the data with those of reference trucks, a detailed picture will be established of which systems leads to what reductions, and under which circumstances. In order to translate this knowledge into savings at national level, a model will be developed that can calculate the CO_2 reductions and fuel savings in Dutch transport for various future scenarios.

In addition to the demonstration programme, Agentschap NL will be carrying out a 'Truck of the Future' subsidy programme in which innovative methods of hybrid drive, alternative fuels and systems for assisted power (as in refrigerated transport) will be put into practice. TNO will be assessing the fuel savings.

Strategic platform for intelligent traffic systems (SPITS) (NL)

Project details

Start Date: July 2009

Duration: 2 years

Coordinator: NXP

Funding: Dutch Ministry of Economic Affairs

Summary

SPITS is a Dutch project in which new techniques and services for cooperative driving and mobility will be investigated. These include the following[10]:

[10] From https://spits-project.com/index.php?option=com_content&view=article&id=59&Itemid=59

- Parking services
- Contextual infotainment
- CVIS/SafeSpot apps
- World Map
- E-Call/B-Call
- Stolen vehicle tracking
- Pay-as-you-drive
- Sync route planner
- Remote diagnostics
- ADAS
- Infotainment
- Road Pricing (ABvM)

The goal of SPITS is to develop an open platform called Strategic Platform for Intelligent Traffic Systems. This platform has been developed over a period of 2 years with a budget of 63 million Euro. The project was started off with the end result of the CVIS project, tasked with creating Intelligent Traffic Systems (ITS) concepts that can improve mobility and safety. The focus of SPITS was on three areas: traffic management, in-vehicle solutions and service download & management solutions. Effect studies will quantify the impacts of applications on throughput, comfort, safety and the environment.

3.7 Summary

The information presented in this chapter shows that a substantial number of initiatives and projects have dealt with the assessment of ITS and CO_2 emissions or energy efficiency. Each of these initiatives and projects will be relevant to ECOSTAND, and will give insight in an interesting variety of assessment approaches developed by different project consortia.. In Table 4 we have considered each EU project in turn, and its potential contribution to ECOSTAND (the table is in alphabetical order instead of the order used in the previous sections).

Table 4: European projects and their likely contributions in terms of ECOSTAND (* = completed studies).

Project/initiative	Potential contribution to ECOSTAND
2DECIDE	Project ITS toolkit containing best practice examples of ITS deployments, information about costs, benefits and impacts of ITS solutions, and a database of evaluation reports on ITS projects.
COMeSafety2	Specifications of common EU-US compatible sustainability applications targeted towards standardisation and creation of corresponding research agendas to address open issues. Exchange of test tools and methodologies between EU and US from FOT testing.
CoNCERTO	Methodology for estimation of the impact of tested ITS applications in improving energy efficiency and reducing the carbon footprint.
CONDUITS	Key Performance Indicators for an internationally-recognised standard measure for quantifying ITS benefits on environment.

Project/initiative	Potential contribution to ECOSTAND
COSMO	Methodology for estimation of the impact of tested ITS applications in improving energy efficiency and reducing the carbon footprint.
DRIVE C2X	Methodology for estimation of the impact of tested ITS applications in improving energy efficiency and reducing the carbon footprint.
EasyWay EEG	• The Evaluation Expert Group is responsible for developing evaluation procedures to process evaluation results from EasyWay implementation. • Bank of evaluation reports across different implementation sites across Europe together with resources such as the US Benefits database.
eCoMove	Methodology for estimation of the impact of tested ITS applications in improving energy efficiency and reducing the carbon footprint.
euroFOT	Methodology for estimation of the impact of tested ITS applications in improving energy efficiency and reducing the carbon footprint.
FOT-Net 2	Networking platform for existing and future National, European and Global FOTs in order to strengthen international cooperation with US and Japan.
FREILOT	Methodology for estimation of the impact of tested ITS applications in improving energy efficiency and reducing the carbon footprint.
HAVEit	Methodology for estimation of the impact of tested ITS applications in improving energy efficiency and reducing the carbon footprint.
ICT and energy efficiency study*	An inventory of emission models, a classification of applications, a discussion on the relevance of different emission models to the assessment of ICT and ITS, and an approach for taking into account differences in the geographical and temporal scale of operation of different ITS/ICT.
iCars Network*	A catalogue of assessment methods for faster take-up of technologies that contribute most to improvement of road safety, mobility, efficiency and CO_2 output. A roadmap on the implementation of new ITS technologies with potential to reduce the CO_2 output of road transport.
iCar Support	International Cooperation Working Group supporting dialogue at international level on working items identified by other Groups, namely eSafety techniques for energy efficiency / environmental benefit and field operational trials and assessment processes.
In-Time	Methodology for estimation of the impact of tested ITS applications in improving energy efficiency and reducing the carbon footprint.
ITS UK Carbon Working Group	Forum for all ITS UK members with an interest in transportation and the environment to meet, discuss their views and study the uses ITS to benefit greenhouse gas reduction with the aim of producing road map for a “Low Carbon ITS Industry.
Logistics for LIFE	Strategic roadmap including concrete actions and strategies to facilitate deployment of ICT solutions identified in the reference framework for energy efficiency in logistics.

Project/initiative	Potential contribution to ECOSTAND
NEARCTIS	Future research agenda proposed in terms of Traffic modelling and impact estimation models (traffic flow, safety, environmental and energy), but also evaluation methods (economic, technical, environmental, safety related).
SPITS	Methodology for effect studies quantifying the impact of tested ITS applications in improving energy efficiency and reducing the carbon footprint.
SUNSET	Evaluation methodologies and impact analysis based on living lab evaluations to assess how the SUNSET services contribute to the project objectives of reduced CO2 emissions, improved air quality management and reduced noise pollution.
TeleFOT	Methodology for estimation of the impact of tested ITS applications in improving energy efficiency and reducing the carbon footprint.
Truck of the Future	Model developed that can calculate the CO_2 reductions and fuel savings in Dutch transport for various future scenarios.

4 Evaluation methodologies

4.1 Overview

Given the large numbers of vehicles operating on road networks, the wide range of vehicle types, and the large number of influencing factors, direct measurement is an impractical proposition for the evaluation of exhaust emissions. Some form of simplification and modelling is therefore required. Nevertheless, for the assessment of ITS applications a great deal of work is still necessary to set up a simulation on a useful scale (area, city or region). To perform a detailed simulation of a single controlled intersection can require several days of work. Extrapolating this to a city scale (several hundred intersections), could amount to a great deal of effort. To effectively simulate emissions for a large network approximation or extrapolation is therefore essential (Spence *et al.*, 2009).

In emission models the various factors affecting emissions are commonly taken into account using the following parameters (Boulter and McCrae, 2007):

- *Road characteristics*: Some emission models require a description of the road characteristics, such as the area type (urban or rural) and the speed limit. The road segment length is an essential parameter in any model, and another important factor is the road gradient, which has a large effect on emissions especially from heavy-duty vehicles.
- *Traffic flow (volume):* To a first approximation, emissions are proportional to the total amount of traffic on a road, or the total vehicle-km travelled in an area or during a period of time.
- *Traffic composition:* Emission factors for different categories of vehicle are normally presented in grammes per vehicle-kilometre travelled or grammes per litre of fuel consumed. In addition to the primary division by vehicle type (*i.e.* motorcycles, passenger cars, buses, HGVs), sub-division by engine size, number of axles or vehicle weight is common. There is then usually a further separation of vehicles by emission standard. A common approach is to weight each emission factor by the proportion of vehicles in the relevant category and the total traffic flow during a given time period[11].
- *Vehicle operation.* The treatment of vehicle operation is one of the most complex aspects of emission modelling. Vehicle operation may be represented using average speed alone, or using other methods which explicitly allow for driving dynamics (see section 4.3).

[11] Clearly, one only actually needs the *number* of vehicles in each category during the time period. However, it is useful conceptually to treat the total flow and the composition separately, such as when assessing the effects of transport measures and policies.

Any changes in these parameters will result in a change in emissions, and clearly ITS applications can lead to a reduction in emissions by influencing them. Whether or not this is the primary goal of an ITS application (as noted earlier, such applications are sometimes called 'Green ITS') is irrelevant.

The following chain of models or information is usually needed to provide an accurate estimate of the impacts of an ITS application on CO_2 emissions (Spence *et al.,* 2009; Klunder *et al.*, 2009):

- A representation of the infrastructure within which the ITS application will be implemented.
- A representation of the ITS application.
- A traffic model[12] to represent changes in driver behaviour resulting from the infrastructure and the ITS application. Traffic simulation models need to generate realistic data (including speed-time profiles where appropriate) to ensure accurate input data for the emission models.
- An emission model which can be used to evaluate the effects per vehicle type of the ITS application.
- A model for translating the CO_2 impacts per vehicle type into the CO_2 impacts on a larger geographical scale.

However, this may not be the best approach in all cases. For example, where ITS is used to manage a 'captive fleet' (*i.e.* buses or HGVs which are run by one operator), there might be monitoring of fuel consumption via the CAN-bus and positional info using GPS, then transmission of data by GRPS to a hub where the operator can monitor driver/vehicle performance using bespoke software. Hence, all the data are for the captive fleet only, and there are no 'spatial' or 'traffic' aspects in the sense that these terms used for other ITS applications.

The errors in each modelling (or measurement) step also need to be understood, and a number of related questions were introduced by Klunder *et al.* (2009). For example:

- Are existing traffic simulation models sufficiently accurate to allow the effects of ITS applications on emissions to be determined?
- Are the vehicle fleet data adequate for the applications being modelled?
- Are validated vehicle emission models available?

The remaining sections of this chapter provide information on methodologies relating to the assessment of ITS applications and CO_2 emissions, and specifically traffic modelling (section 4.2), emission modelling (section 4.3), the applicability of different types of model to ITS (section 4.4), and the provision of traffic data for model input/validation (section 4,5).

[12] For small-scale ITS applications it may be possible to use direct measurement.

4.2 Traffic modelling

The task of a traffic model is to describe the behaviour of the vehicles which make up the traffic streams on a road network. Ideally, a traffic model would produce all the outputs required for emission modelling. However, traffic is affected by various stochastic influences, and traffic models need to produce statistically sound representations of the real-world.

Classically, two different basic types of traffic model exist: macroscopic and microscopic. These are described briefly below.

Macroscopic models do not simulate the movements of individual vehicles, but are based on macroscopic parameters of the traffic: traffic flow (or volume), density and average speed. Starting from the traffic demand in terms of number of trips between areas - so-called 'traffic cells', expressed as origin-destination (OD) matrices - they follow the classical traffic planning process. The demand is split into the traffic modes (cars, bicycles, public transport, *etc.*). The resulting numbers of private vehicles are then assigned to routes on the traffic network according to modelling approaches derived from economical decision processes. The typical output of a macroscopic model is therefore a road network with assigned traffic volumes on the links. Important intermediate results are the speeds on the links, which not only determine the journey times (and thus the 'resistance' of a link) but also indicate the traffic situation on a link. Such models do not provide any insight into the actual movement of vehicles on links. They are typically used in transport planning applications to determine the future traffic volumes on the links of the network.

Macroscopic models were originally 'time-independent'. This means they only had an implicit time dimension by looking at average days. Today, such models can deal with time-depend traffic volumes on links using dynamic OD matrices; they can be split into one-hour intervals or even shorter time periods. Where time-dependent matrices of traffic demand are used, the resulting traffic volumes are also time-dependent.

In contrast, microscopic models simulate the movement of individual vehicles. There are different approaches to determine the movements: examples include 'follow-the-leader' models using psycho-physical approaches, or other simpler alternatives. Their main purpose was originally to examine small-scale traffic engineering problems, such as the effects of changing traffic signal timing. With increasing computer power and available memory, these models can now be applied to large-scale networks (up to medium-sized cities). They are able to produce the trajectories (*i.e*. speed-time profiles) for individual vehicles with good accuracy if they are properly calibrated. From the individual trajectories, other parameters – such as average speed - can be derived. However, some concerns have been raised about the suitability of micro-simulation traffic model ouputs for emission modelling (Klunder *et al*., 2009).

It must be noted that a number of models fall between the two categories mentioned above. These are termed 'mesoscopic' models. Such models generally deal with individual vehicles, although their movements are determined by macroscopic relationships.

In order to include vehicles equipped with ITS measures in the traffic models, their behaviour has to be established and then modelled. Depending on the intended effect of the ITS measure (*e.g.* navigation or longitudinal driving behaviour) and the spatial scale (*e.g.* individual intersection or city network), a microscopic or macroscopic model is the one of choice. Generally, the effects on macroscopic relationships (volume - density - speed) of ITS-equipped vehicles are not known, and cannot be measured in reality. To overcome this, a suitable solution is to establish the macroscopic relationships through the application of a microscopic model, although there will be a loss of accuracy. Microscopic models are generally easier to adapt because they include driver behaviour explicitly. Thus, any changes in behaviour which are induced by ITS can be modelled in a rather straightforward manner; changes in driver behaviour can be determined using assumptions, simulator studies, or real-world measurements (field operational tests).

4.3 Emission modelling

Various atmospheric pollutants are emitted from road vehicles as a result of combustion and other processes. As noted earlier, emissions are dependent upon many factors, including vehicle-related ones such as model, size, fuel type, technology level and mileage, and operational ones such as speed, acceleration, gear selection, road gradient and ambient temperature. Models must take into account these various factors affecting emissions, although the manner in which they do so, and the level of detail involved, can vary substantially.

Emission models can be classified in several different ways, with typical criteria including the geographical scale or the type of application. Perhaps the most important distinction between models is the way in which vehicle operation is taken into account. A typical categorisation is provided below.

- *Aggregated emission factor models*. In aggregated emission factors vehicle operation is only taken into account at a rudimentary level (*e.g.* for urban, rural or motorway conditions).
- *Average-speed models*. The average-speed approach is more flexible and has a number of advantages – such as ease of use and the reasonably close correspondence between the model inputs and the data available to users. However, such models cannot account for the variation in vehicle operation and emission behaviour that can be observed for a given average speed. The concept of 'cycle dynamics' has therefore become useful for explaining this variation, usually by reference to statistical descriptors of a vehicle speed-time profile.
- *Traffic situation models*. In 'traffic situation' models average emission factors are correlated with various driving cycle parameters. These, in turn, are referenced to specific traffic

situations which are known by the model user. However, asking the user to define the traffic situation using a textual description of speed variation or dynamics may lead to inconsistencies in interpretation. Also, there are likely significant differences between the absolute characteristics of traffic in different cities and, importantly, there are few data (traffic and emissions) which correspond directly to real-world ITS implementation.

- *Multiple linear regression (MLR) models*. In an MLR model each driving cycle used in its development is characterised by a large number of descriptive parameters (*e.g.* average speed, number of stops per km). For each pollutant and vehicle category a regression model is used to determine the descriptive parameters which are the best predictors of emissions (the group of descriptors being different in each case). A MLR model requires a driving pattern as the input, from which it calculates the same range of descriptive variables and estimates emissions for the driving pattern.
- *Modal models*. In modal models emission factors are allocated to the specific modes of vehicle operation encountered during a trip. In simple type of modal model vehicle operation is defined in terms of a relatively small number of modes - typically ‘idle’, ‘acceleration’, ‘deceleration’ and ‘cruise’.
- *Instantaneous*[13] *models (speed- or power-based)*. A number of more detailed modal models relate emission rates to vehicle operation, typically during one-second steps. In theory, the advantages of instantaneous models include the following:
    - o Emissions can be calculated for any vehicle operation profile specified by the model user, and thus new emission factors can be generated without further testing.
    - o The models inherently take into account the dynamics of driving cycles.
    - o The models allow emissions to be resolved spatially, and thus have the potential to lead to improvements in the prediction of air pollution.

Some instantaneous models, especially the older ones, relate fuel consumption and/or emissions to vehicle speed and acceleration during a driving cycle, typically at one-second intervals. Other models use some description of the engine power requirement. Another approach is presented by Carslaw *et al*. (2010), who used Generalized Additive Models[14] to describe how instantaneous CO_2 emissions from individual vehicles varied depending on the driving conditions, taking account of variable interactions and time-lag effects. However, instantaneous models have tended only to be validated for trips, and not on the very local

[13] Several other terms have been used to describe the more detailed type of model, including ‘microscale’, ‘continuous’ and ‘on-line’.
[14] Generalized Additive Models are statistical models which maximise the quality of prediction of a dependent variable from various distributions, by estimating unspecific (non-parametric) functions of the predictor variables which are connected to the dependent variable via a link function.

scale, and the information they contain may not fully represent the driving behaviour[15] associated with all types of ITS.

Some specific emission models in current use are listed in Table 5. The list is not comprehensive, and models which no longer appear to be in use are not included. A larger inventory of emission models was compiled by Klunder *et al.* (2009). These models have also been described in more detail elsewhere, such as the review by the EC-METI Task Force (Spence *et al*., 2009).

Table 5: Examples of emission models in current use.

Model type	Model	
	Name	Country/region
Aggregated emission factors	TREMOD	D
Average-speed	COPERT	EU
	ARTEMIS	EU
	DMRB	UK
	MOBILE	US
Traffic situation	HBEFA	D, A, CH, S
	ARTEMIS	EU
MLR	VERSIT+	NL
Modal	MOVES	US
Instantaneous	CMEM	US
	PHEM	EU
	VeTESS	B
	ADVISOR	US

It should also be borne in mind that other aspects of ITS applications lead to 'life cycle' greenhouse gas emissions, such as the extraction, processing and transport of materials which are used in applications, construction activities (which could include off-road transport) and power consumption of electrical equipment during the operational phase. The inclusion (or exclusion) and significance of emissions from such sources will be one of the topics which will be addressed in the technical discussions in ECOSTAND.

4.4 Evaluation of ITS – general considerations

Because ITS applications operate on various spatial scales and affect a range of vehicle and traffic parameters, no single traffic or emission model can be used universally. This section of the report

[15] In other words, ITS operation may be 'outside the envelope' of the emission data contained in an emission model.

suggests how different types of model can be used to evaluate different ITS applications. The discussion is limited to exhaust emissions from road traffic associated with the operational phase of an ITS application, but taking into account both direct and indirect effects.

It was observed by Klunder *et al*. (2009) that the mechanisms by which ITS measures influence CO_2 emissions are complex. Since energy consumption - and hence CO_2 emissions - depend on the detailed features of driving behaviour, and vary considerably from vehicle to vehicle, estimating the environmental impact of a given ITS application is not a straightforward task. ITS can affect the nature of the transport demand - affecting the modal split as well as the quantities and types of vehicle using the transport network. ITS services can also affect the way vehicles are distributed across the network, and there are likely to be numerous 'micro-effects' caused by changes in the behaviour of individual drivers. Moreover, the effects will be dynamic; ITS tools provide real-time information on which travellers can base their decisions regarding trip timing, mode, route, and other behavioural choices. These will therefore adapt dynamically to conditions on the networks, changing from hour to hour and even minute to minute.

The types of model which are needed for the evaluation of a given ITS application depend upon:

- The mechanism of the application and how it affects the parameters noted earlier (*e.g.* road characteristics, traffic volume, driver behaviour, *etc.*)
- Where the application is being introduced (*e.g.* which country, which type of road, *etc.*)
- The geographical scale of the application.
- The available data (*e.g.* traffic model output, traffic measurements).

For example, where an ITS application only affects the composition of the traffic, the total vehicle kilometres travelled, or the spatial distribution of the traffic then a more 'aggregated' approach can be used. It can be assumed that driving behaviour is not significantly affected. On a regional scale, the use of average-speed emission models is usually appropriate. However, for the assessment of local measures that influence driving characteristics along specific links, where vehicle dynamics and engine efficiency are affected, approaches based on predefined trip assignment rules, average vehicle speeds, trip times, and standard driving cycles are likely, in many cases, to be inadequate. In such cases a very detailed model which simulates the engine power demand of the vehicle or an instantaneous emission model is needed (Klunder *et al*., 2009), or otherwise existing models would have be extended to cover the relevant situations[16].

Specific emission models also tend to be applicable to specific countries or regions. This is usually because the emission data used in their development are ascribed to emission standards, and these vary around the world. Moreover, types of road and driving conditions vary from country to

[16] It is likely that this would require new real-world driving data. Such data could be collected in field experiments. An example of a framework which might support such activities is ITS Bretagne (http://www.itsbretagne.net/).

country. One example is this is the traffic situation model HBEFA, which is used in several European countries. However, it is not directly applicable to the UK, as the traffic situations are provided for roads with speed limits which are stated in km/h, whereas in the UK the speed limits are stated in mph.

To simplify matters, we have considered the following three modelling approaches (simplified and extended from the EC-METI report):

- ***Fine-grained**.* Detailed engine and/or driver behaviour must be modelled to accurately assess the impact of the application on CO_2 production. Micro-simulation is needed.
- ***Stops, speed, class**.* Modelling the number of stops and the speed per vehicles class is sufficient to quantify the impact of the application on CO_2 production. Micro-simulation is preferred, but on large networks mesoscopic simulation can be sufficient.
- ***Trip-motives**.* A key necessity for this type of application is the possibility to model the effects on user behaviour with regard to route-choice, modal-choice and/or moment-of-trip.

The last category currently is only addressed in simple models without any learning effects by the virtual user. Realistic modelling might benefit from virtual users that learn new behaviours during the runtime of a simulation. The simulation might need to simulate many days or months of real-world time.

Moreover, every application that has a significant impact on the road network – such as relieving congestion or changing travel-times on certain routes – will have an impact on the future demand. Applications can initially be very successful, but by attracting the latent demand will show deteriorating performance after weeks or months. A simulation environment that could take this into account would be useful. It would, however, also be complicated as it would need to model the latent demand (which will probably need a larger geographical network with knowledge about mobility patterns and trip motives).

In the following sections we have also considered the suitability of different types of model for estimating the effects of the general categories of ITS application which are listed in Table 2. Some specific applications are mentioned as examples.

4.4.1 Navigation and travel information

Navigation and travel information, whether provided before or during a trip, should lead to the selection of a more fuel-efficient route. It is possible to optimise route choice based on the lowest total fuel consumption rather than, for instance, the shortest time or distance, taking into account information like trip length, speed limits, road gradients, curvatures and dynamic real-time information about congestion and traffic incidents (Klunder *et al.*, 2009). In the case of freight transport the optimisation of a journey also involves the assignment of vehicles to locations and load capacity constraints.

Such systems could lead to a reduction in vehicle kilometres (vkm), and hence traffic volume, and modal shift. The main operational effect in terms of CO_2 emissions per vehicle is likely to arrive from a change in average speed (which may be an increase or a decrease). Consequently, an average-speed emission model would be appropriate. However, changes in driving dynamics could occur, and so other types of emission model may be needed.

4.4.2 Traffic management and control

Traffic management measures can influence many different aspects of traffic, including vkm, modal split, traffic intensity and the amount of congestion. The vehicle operation effects can often be evaluated using emission models which require relatively simple input data, such as traffic situation models. However, most of the models currently available do not include enough traffic situations (Klunder *et al.*, 2009), and there are no ITS-specific traffic situations. Instantaneous emission models - in combination with microscopic traffic models - are also suitable for evaluating measures which have detailed local effects on vehicle operation and driving dynamics. Consequently, either ‘fine-grained’ or ‘stops, speed, class’ traffic modelling approaches would be used.

Platooning - the synchronised movement of two or more vehicles driving one after the other, travelling at the same speed with relatively small inter-vehicle spacing - significantly reduces the aerodynamic drag on each vehicle, thus reducing fuel consumption and emissions. It also leads to fewer changes in acceleration, which again brings down fuel consumption and emissions. This suggests that the use of an instantaneous emission model would be preferable. It is worth noting that increasing the amount of available space on a road could have the undesirable effect of attracting additional traffic, resulting in higher overall emissions.

4.4.3 Demand and access management

Congestion charging schemes can affect emissions in several different ways, and therefore different types of modelling may be required. Primary effects (in the charging zone) include a reduction in vkm, a congestion reduction that leads to a reduction in driving dynamics, and an increase in average speed. This is one of the few measures that can improve throughput without inducing extra traffic. Secondary effects might include an increase in vkm outside the charged area. Also, there may be a shift towards less polluting vehicles that are often exempt from the fees or have reduced fees (Klunder *et al.*, 2009). Johansson *et al*. (2009) described the effects of a trial road charging system in Stockholm on emissions and levels of air pollutants between January and July 2006. The system consisted of three parts: extended public transport (16 new bus lines), a congestion tax, and more park-and-ride sites in the city and the county. Based on measured and modelled changes in road traffic it was estimated that CO_2 emissions were reduced by 13% in the inner city and by 3% in the Greater Stockholm area. The reductions were mainly due to decreased traffic flow; reduced congestion had little effect.

Pay-as-you-drive (PAYD) schemes ought to lead to a reduction in vkm. Schemes might also have an effect on traffic composition through increased vehicle sharing and teleworking. Moreover, PAYD probably increases the use of public transport as well as walking and cycling. However, it is estimated to have minimal effect on commercial traffic (Klunder *et al.*, 2009). In this case, an aggregated model would probably be sufficient.

4.4.4 Driver behaviour change and eco-driving

Eco-driving has been widely publicised as a means of reducing fuel consumption and emissions of air pollutants. It is aimed at both private motorists and fleet operators. Eco-driving can either be promoted using traditional methods (*e.g.* either a simple set of written 'rules' to be followed or a programme of training), encouraged using in-vehicle technology (*e.g*. a gear-shift indicator, econometer), or actively imposed using cooperative systems which enable the speed of vehicles to be regulated externally. Various terms are used in relation to the latter approach, including 'intelligent speed control', 'intelligent speed adaptation', 'active speed management', and 'dynamic eco-driving'. These are sometimes referred to collectively as 'advanced driver assistance systems' (ADAS), although ADAS can include a wider range of applications (e.g. related to safety).

Because eco-driving and ADAS affect driving dynamics, in general they need to be assessed using emission models which require driving patterns as input, such as instantaneous emission models (such as CMEM or PHEM) or the MLR model VERSIT+. The driving patterns can be derived from traffic simulation models or from real-world driving data, although the results will be specific to the local situation. ITS applications that interfere directly with the vehicle powertrain have to be modelled with more detailed engine power demand models and vehicle design models (*e.g.* PHEM). For example, to calculate the effects of a gear-shift indicator the model needs to have gear-shifting as input, and use it in its emission calculations (Klunder *et al*., 2009).

According to SenterNovem (2005), in several field tests devices such as econometers, on-board computers, cruise controls and speed and revolution limiters drivers were able to save 5% fuel on average. Individual savings sometimes exceeded 10%. Field tests with more sophisticated experimental feedback instruments resulted in fuel-efficiency improvements of even up to 20%.

Int Panis *et al.* (2006) examined the effects of intelligent speed control (termed 'active speed management') using a traffic micro-simulation model in conjunction with an instantaneous emissions model based on empirical (on-vehicle) measurements. It was found that, whilst the speed management reduced the average speed of the traffic, the impacts on vehicle emissions were complex due to changes in acceleration and deceleration. For the simulated urban network the modelling suggested that the active speed management had no significant impact on pollutant emissions, including CO_2. On the other hand, Barth and Boriboonsomsin (2009) showed that significant benefits could result from the introduction of 'dynamic eco-driving', whereby advice is given to the driver in real-time in response to changing traffic conditions in the vicinity of the vehicle. This strategy took advantage of real-time traffic sensing and telematics, allowing for a traffic management system to monitor traffic speed, density, and flow, and then communicates advice in real-time back to the vehicle. The PARAMICS microscopic traffic simulation tool was applied to the Comprehensive Modal Emissions Model (CMEM) to examine vehicle performance under a variety of traffic conditions. It was found that by providing dynamic advice to drivers, approximately 10–20% in fuel savings and lower CO_2 emissions were possible without a significant increase in travel time. The author noted that the benefits are dependent on level of service; in general, larger reductions in fuel consumption and CO_2 emissions were observed during severely congested conditions than during light congestion. Under free flow conditions benefits would be minimal.

A thorough assessment of the impacts of intelligent speed control on CO_2 emissions was undertaken by Carslaw *et al.* (2010). The authors developed individual vehicle modal emissions models for CO_2 for 30 Euro 3 and Euro 4 cars. Generalized Additive Models were used to describe how emissions from individual vehicles varied depending on their driving conditions, taking account of variable interactions and time-lag effects. The impacts of vehicle speed control on CO_2 emissions were examined by road type, fuel type, and type of driver behaviour. Savings in CO_2 of ~6% were found on average for motorways when mandatory speed control was used compared with base case conditions. For most other types of road, speed control had very little effect on emissions of CO_2 and in some cases can result in increased emissions for low-speed limit urban roads. In addition, there was, on average, a 20% difference in CO_2 emissions between the lowest and highest emitting driver, which highlighted the importance of driver behaviour in general as a means of reducing emissions of CO_2.

4.4.5 Logistics and fleet management

A number of telematics systems are available which use remote devices on freight vehicles, real-time traffic data and communication links between the vehicles and a control centre in order to control and monitor freight operations and present this data in a useable format to freight managers. Different traffic and emission modelling approaches will be required, depending on the actual application. If the fuel consumption of a captive fleet is actually being monitored - which is often the case - then there is no need for any detailed modelling. Emissions of CO_2 (and other pollutants) from the fleet can be determined using fuel-specific emission factors.

Slot management (pre-booking of road use) is typically applicable to heavy-duty vehicles. The aim is to improve the use of the existing road capacity and to reduce congestion. Slot management can have significant impacts on traffic composition and speed. There may also be an effect on driving dynamics (Klunder *et al*., 2009). Depending on the primary effect, either an average speed model or an instantaneous model would be appropriate.

4.4.6 Safety and emergency systems

As stated before most systems don't just have an impact on of the three policy goals (traffic efficiency, safety or environment) but are interrelated. Although for safety and emergency systems no information was found on CO_2 emissions there is potentially an effect to be expected. These effects will be taken into account with the models that are discussed and described, but are not the main focus of this project.

4.4.7 Co-operative systems

Although not a specific type of application, but more an technique, cooperative systems are briefly discussed here due the amount of information that is available with this technique as main focal point. The CODIA (Co-operative Systems Deployment Impact Assessment) study provided an assessment of direct and indirect impacts, costs and benefits of a set of chosen co-operative systems up to 2030 (Kulmala *et al*., 2009). The co-operative systems studied were:

- Speed adaptation due to weather conditions, obstacles or congestion (V2I and I2Vcommunication).
- Reversible lanes due to traffic flow (V2I and I2V).
- Local danger / hazard warning (V2V).
- Post crash warning (V2V).
- Cooperative intersection collision warning (V2V and V2I).

With the exception of intersection collision warning, the effects on emissions (NO_x, PM and carbon) of each type of system were assessed using an instantaneous emission model (TRL's prototype Instantaneous Emissions Module - IEM[17]) in conjunction with a micro-simulation traffic model (SISTM).

The direct emission effects were found to be negligible for all systems. The indirect emission effects were expected to be somewhat larger, indicating lower emissions due to reduced congestion caused by decreases in the number of accidents.

4.4.8 Summary

A summary of the modelling requirements by ITS application is provided in Table 6. The Table includes the type of road environment or scale affected by the application, observations on the possibilities of applying simulation and validation methods for estimating the CO_2 emissions impact of the system, and the traffic parameters which are likely to be affected.

[17] The IEM emissions model (which is based upon the PHEM model originally developed within the 5FP ARTEMIS project and under COST Action 346, coordinated by the Technical University of Graz) is linked to a series of speed and speed times acceleration look-up tables. There are many hundreds of look-up tables – one for each vehicle type, vehicle size and Euro emission specification.

Table 6: Modelling implications of ITS applications (adapted from Spence *et al*., 2009).

Code	System	Scale/ road type	Parameters affected					Modelling implications	
			Road (*e.g.* speed limit)	Traffic volume	Traffic composition	Average speed	Driving dynamics	Comments	Type
i-1	**Navigation & travel information**								
i-1.1	On-board navigation systems	Urban, regional, national	No	Possible reduction in vkm	No	Yes	Possible		Trip motives
i-1.2	Intelligent parking	Urban	No	Reduction in vkm for vehicles searching parking	No	No	No		Trip motives
i-1.3	Web-based pre-trip information services	Urban, regional, national	No	Possible reduction in vkm	No	Yes	Possible		Trip motives
***i*-2**	**Traffic management and control**								
i-2.1	Isolated controlled intersections	Urban, inter-urban	No	No	No	Yes	Yes	Details are important, resulting in labour intensive simulation. Validation can be local and detailed (at a cost). Validation is difficult to generalise to other situations.	Fine-grained
i-2.2	Plan-based control, including 'green wave' strategy	Urban, inter-urban	No	Yes, but effect unclear. Possible increase in demand due to improved conditions.	No	Yes	Yes	The control is generally simple (with exceptions), so the effort for building a simulation is limited. Validation could be done in a few typical situations. Probably giving transferable results (need to be 'meta-validated').	Stops, speed, class

Code	System	Scale/ road type	Parameters affected					Modelling implications	
			Road (*e.g.* speed limit)	Traffic volume	Traffic composition	Average speed	Driving dynamics	Comments	Type
i-2.3	Traffic-adaptive urban traffic control (UTC)	Urban	No	Yes, but effect unclear. Possible increase in demand due to improved conditions.	No	Yes	Yes	The specification of the control is generally simple, which makes setting up a simulation easy. Behaviour, however, is very flexible which makes simulation and validation time consuming. Results are probably difficult to transfer.	Stops, speed, class/fine-grained
i-2.4	Ramp metering	Motorway	No	Yes	Possible	Yes	No	Easy to simulate. Validation could be limited to a number of typical scenarios. Results would be transferable.	Fine-grained
i-2.5	Point-to-point speed control		Yes	No	No	Yes	Yes		
i-2.6	Dynamic speed limits	Inter-urban, motorway	Yes	Yes	No	Yes	No	Easy to simulate. Validation could be limited to a number of typical scenarios. Results would be transferable.	Stops, speed, class
i-2.7	Cooperative adaptive cruise control, lane merging assistance	Inter-urban, motorway						Difficult to simulate. Interaction of vehicle detailed behaviour and their environment.	Fine-grained
***i*-3**	**Demand & access management**								
i-3.1	Infrastructure use pricing	Urban, inter-urban, motorway	No	Yes	Possible	Possible indirect effect	Possible indirect effect	Macroscopic modelling with strong behavioural aspects. Validation only possible in 'real' systems.	Trip motives
i-3.2	'Carbon credit' scheme	Urban, regional, national	No	Possible	Possible	Possible indirect effect	Possible indirect effect		Trip motives

Code	System	Scale/ road type	Parameters affected					Modelling implications	
			Road (*e.g.* speed limit)	Traffic volume	Traffic composition	Average speed	Driving dynamics	Comments	Type
i-3.3	Restricted traffic zones	Urban	No	Yes[18]	Possible	Possible indirect effect	Possible indirect effect		Trip motives
i-3.4	Pay-as-you-drive strategy	Urban, regional, national	No	Possible	Possible	Possible indirect effect	Possible indirect effect	Simulation needs to include a behavioural model. Probably difficult to validate?	Trip-motives
***i*-4**	**Driver behaviour change & eco driving**								
i-4.1	Promotion of an energy-efficient style of driving	Urban, regional, national	No	Possible	Possible	Possible	Possible	Needs detailed behavioural model for simulation. Validation through logging of individual trips.	Fine-grained
***i*-5**	**Logistics & fleet management**								
i-5.1	Commercial fleet management services	Urban, regional, national	No	Possible reduction in vkm.	No	Possible	Possible		Stops, speed, class
i-5.2	Parking/loading /de livery management	Urban	No	Possible reduction in vkm					Fine-grained
i-5.3	Demand-responsive systems for PT	Urban, inter-urban	No	Possible reduction in vkm					Trip-motives
i-5.4	Slot management		No	?	Yes	Yes	Possible		
i-5.5	Automated vehicle management systems for public transport (AVM).	Urban, inter-urban	No	Possible reduction in vkm	Yes				Fine-grained

[18] However, through-traffic is diverted around such zones; their vkm increase

Code	System	Scale/ road type	Parameters affected					Modelling implications	
			Road (*e.g.* speed limit)	Traffic volume	Traffic composition	Average speed	Driving dynamics	Comments	Type
***i*-6**	**Safety & emergency systems**								
i-6.1	On-board accident prevention systems	Urban, regional, national	No						Stops, speed, class
i-6.2	Infrastructure based incident prevention systems	Urban, regional, national	No						Stops, speed, class
i-6.3	Incident management systems	Urban, regional, national	No						Stops, speed, class

4.5 Data needs and sources

Field data are essential for the assessment of ITS measures and for realistic estimates of traffic emissions. Indeed, for deriving traffic dynamics (*e.g.* speed, acceleration, trajectories) to be used as input to emission models, a well-calibrated and validated traffic simulation model is necessary. Indeed, microscopic simulation models are very useful for generating traffic data, and offer the advantage of generating totally disaggregated data on the relative position of vehicles in a traffic flow. Data of this kind are quite costly to gather from real-life test beds. If such models are correctly calibrated and validated, they can be used to provide trajectory-based data and other microscopic parameters based on real cases. These can then be used to “feed” the emissions models, providing consistency in the traffic and emission modelling approaches as regards parameters definition, scales, *etc*. For other traffic simulation models different kind of data will be necessary.

4.5.1 Traffic model data needs

The data needed to support model validation (*i.e*., the process of checking to what extent the model replicates reality)[19] of the modelling chain can be divided into two main categories: (i) input data, (ii) calibration and test data.

With regard to input data, the requirements include items such as network geometry, road capacities, traffic composition, traffic signal data (for urban networks), and traffic demand data (*e.g*. turning counts, origin-destination tables). Because of the random variation of the traffic arriving at nodes on a network (*e.g*. signalised intersections), a large number of observations are necessary to cover a wide range traffic conditions: degrees of saturation, cycle lengths, types of flow, and ratios of the variation in the mean of the number of arrivals per cycle. To obviate the collection of this large amount of data, some sampling and resampling statistical techniques (*e.g.* Bootstrap technique) can be applied to a limited amount of field data.

For model calibration purposes, the needs include traffic count data (traffic volume, occupancy rate and speed), time headway distribution, travel times, queuing information and also acceleration. Such information can be obtained from individual (microscopic) traffic data (*i.e.* data collected at the individual vehicle level). This can be partly delivered by inductive loop detectors (ILDs). However, advanced models (those representing driver behaviour, lane selection/changing mechanisms, traffic merging, *etc*) need very precise information which can be provided only by trajectory-based data. These trajectories are routinely extracted from video data by mean of image processing tools (*e.g.* NGSIM data, Alexiadis *et al*., 2004).

[19] The FHWA’s Validation Manual defines the purpose of model validation as follows: In order to test the ability of the model to predict future behaviour, validation requires comparing the model predictions with information other than that used in estimating the model. This step is typically an iterative process linked to model calibration. It involves checking the model results against observed data and adjusting parameters until model results fall within an acceptable range of error.

Trajectory samples can also be provided by high resolution probe data recorded directly by equipped vehicles (FCD or xFCD). This brings up some important issues regarding probe vehicles, examined in the next section.

4.5.2 Emission models data needs

For CO_2 emission estimates, traffic dynamics have less impact than they do for other pollutants, although the relationship is nevertheless significant (of the same order of magnitude as the sensitivity to vehicle speed). Macroscopic approaches using the average speed, for instance, would therefore be insufficient to reflect the impact of ITS on driver behaviour.

To estimate CO_2 for a single vehicle at a microscopic scale, using for example an instantaneous emission model such as PHEM (cf. Chapter 3), the necessary data input would be:

- Information on the vehicle (type, fuel, year or registration, mileage, engine power, vehicle weight, etc.).
- Instantaneous speed recording (chronologically), from which the acceleration and dynamic-related parameters can be derived.
- The road profile (gradient).
- The engine temperature (which could be determined from the speed or the time duration since the start of a trip), to assess the effect of cold starts.
- Whether or not air conditioning is used.
- Other parameters such as the vehicle load (particularly for heavy vehicles).

However, it should be borne in mind that such models assume average driver behaviour (gear changing, acceleration levels, vehicle usage, *etc*.) as a basis. ,Thiscan restrict its use for the evaluation of ITS applications that induce significant change in driver behaviour, unless this information is collected and changed manually.

Assuming that average traffic is considered (*i.e.* not considering individual vehicles but using data based on a given national or local fleet composition and structure), applying the same tools and limits of application, the following data would be satisfactory:

- the instantaneous speed recording (all other parameters being covered by national assumptions). Such data are, however, rarely available at a large scale.

To estimate CO_2 at the street level (*i.e.* a more macroscopic but still local scale), a "traffic situation" approach, such as that developed in ARTEMIS, would be adequate providing that:

- traffic composition information is available, based on national or regional assumptions (this could be improved using local data from video observation, loop information, surveys, *etc*). In this case, the traffic conditions should be estimated as a given share between congested (stop & go), saturated, free-flow, etc. as a percentage of the total traffic flow or vehicle km.

- traffic composition can be improved from local data (video observation, loop information, surveys).

The above approach can be applied to a whole city providing the road network and traffic are sufficiently well described. This would offer a sufficient level of detail, but requires data to be available at this scale.

For national or regional estimation, CO_2 can be estimated:

- by traffic situations based on assumptions regarding the mileage distribution on particular road types and traffic conditions (typical, but representative distributions can be calculated);
- using the average speed with the same kind of statistics (*i.e*. percentage of traffic by speed class, or at several given speeds). It should be noted that such statistics - although they may appear straightforward - are not in reality easy to establish. It is also likely that the CO_2 impact of ITS applications cannot be satisfactorily assessed at this geographical scale.

4.5.3 Traffic data sources

Technological advances in the area of road transport have favoured a significant enhancement in the ability to collect cost-effective and detailed traffic data. Indeed, in recent years we have been witnessing the emergence of alternative data sources in addition to roadside sensing equipment such as on-board sensors able to offer data on engine status, driver behaviour, the situation 'surrounding' the vehicle, environmental conditions and so on, crowd sourcing alternatives, etc...

Data collection technologies can therefore be gathered into the two broad categories:

- *Infrastructure-based sensors*: inductive loops, ultrasonic detectors, compact wireless magnetometers, Bluetooth scanner, video data, *etc.*
- *Vehicle-based sensors*: including radar, lasers canners, infrared cameras used for diagnostics purposes or Automatic Driver Assistance Systems (ADAS), GPS-enable equipment (*e.g.* smart phones), *etc.*

These technologies, based on those already put forward in the EC-METI report (Spence *et al.*, 2009), enable the collection of basic macroscopic traffic characteristics such as flows, speeds, occupancies, and for some of them also path travel time, queues and vehicle trajectories. On-board instrumentation with access to the OBD (on-board diagnostics) can also provide detailed information on the engine and vehicle operations, which could be valuable for the driving behaviour characterisation.

Electronic Toll Collection (ETC), a mature technology for the payment of motorway tolls, can also be viewed as a potential source of traffic information. ETC data is recorded in two main ways: automatic toll systems in which coin machines or credit cards are utilised, and Automatic Vehicle Identification (AVI) systems using vehicle-mounted tags. Such a source could provide speed or travel time as well as origin-destination matrices for the entry-exit ramps, and total traffic flows, which could be divided into classes to give traffic composition.

Furthermore, the advent of co-operative systems will deliver new concepts of combining data provision both from the vehicle and the road infrastructure.

The communication network for the co-operative systems would allow for any subsystem component to communicate with any other subsystem component (C2X and X2C). The communication could be performed directly between two sub-system components, or indirectly 'multi-hopping' via intermediate sub-system components. For instance, vehicles could communicate with servers either directly reachable through the communication network or reachable through the roadside or even another vehicle, as well between each other.

The data provided by the co-operative systems can therefore be very complex, including not only traffic data but also origin-destination data, segment by segment travel time analysis, *etc*.

Table 7 summarises traffic data sources and key applications.

Table 7: Traffic data sources and key applications.

Traffic data type	Traffic characteristics	Key applications
Inductive Loop Detectors, Ultrasonic Detectors		
Aggregated data (*e.g.* aggregation period 5 min).	Volume, occupancy, spot speed (temporal mean speed), traffic composition.	Core data: traffic flow status, management decision support, real-time traffic information, traffic composition, macroscopic traffic model calibration.
Individual vehicle data.	Speed, occupancy, time headway, class of vehicle.	Same as above, plus microscopic traffic model calibration, risk-based indicators.
Probe data (FCD, xFCD FMD)		
Individual data derived from high resolution probes (*e.g.* xFCD).	Fine grained vehicle position, speed (trajectory), OD, travel time, queue detection, acceleration, weather.	Same as above, plus road friction Indicators and location-based services.
Individual data from unidentified probes (low resolution data).	Vehicle position, speed.	Real-time traffic information (travel time) and fleet management. Location-based services.
ETC Data		
Individual data from Electronic Toll Collection.	Vehicle position, speed, OD information, traffic composition.	Real-time traffic information (travel time), OD analysis, traffic flows and traffic composition.

4.5.4 FOT data collection

One of the primary aims of Field Operational Tests (FOT) is the assessment of the behaviour of road users in traffic environments equipped with new ICT-based systems. They represent another valuable source of information as they involve data collection in real-world settings (cf. SmartWay in Japan, IntelliDrive in USA). Experiments have demonstrated the potential of vehicle-based sensors for analysing driver behaviour, characterising fuel consumption and emissions, as well as vehicle and engine operation, or designing mission profiles. Until now, FOTs have mostly involved passenger cars, but significant work is now being carried out with commercial and heavy duty vehicles too through the use of electronic engine control units. The operational data from FOTs, collected for sufficiently large fleets of vehicles, deliver not only data relating to the prevailing traffic conditions, but also valuable information on the impact of ICT-based systems (including ADAS and cooperative systems). This, as well as data on driver behaviour, is of great interest for the development of methodologies for assessing energy consumption and CO_2 emissions of vehicles. Among such tests is a study undertaken in the US with extensive on-board instrumentation, including video and radar, and the large-scale mobility studies using data loggers and GPS. Several pilot experiments have also been conducted to implement integrated solutions for traffic management though advanced vehicles and telematic tools (probe vehicles providing real-time information on the traffic, traffic control and management, see the ATENA project. Large-scale FOTs are currently being promoted by the European Commission.

The necessary vehicle instrumentation can now be quite simple and provided at low cost (use of the OBD information, GPS, transmission through GSM/GPRS). “Equipped” cities, as envisaged by Virginia Tech[20] or Leeds University[21], also constitute a promising way of combining traffic and vehicle-based information through a large-scale deployment of instrumentation, and hence also for the assessment of ITS applications.

4.5.5 CO_2 emissions data

On-board instrumentation with access to OBD (on-board diagnostics) can provide accurate information on fuel consumption as well as engine operation which can be used to derive an estimate of CO_2 emissions.

By itself, the continuous monitoring of vehicle speed (from equipped vehicles or probe cars) can also provide a valid basis for the calculation of CO_2 emissions. Combined with the vehicle position (obtained from GPS information), it can enable an assessment of the influence of the context (local traffic management, traffic conditions, *etc*.) as well as other impacts (*e.g.* health effects from pollutants).

With regard to speed measurements:

[20] http://www.vtti.vt.edu
[21] http://www.its.leeds.ac.uk/facilities/icity

- The speed detected by radar systems, video, or loops is not satisfactory for assessing CO_2 emissions as it does not take into account stops, acceleration/deceleration, and other transient driving behaviour. Integrated speed information is necessary (over a trip, over a certain distance, *etc*.).
- Speed which is continuously measured or monitored by vehicles, probe cars, *etc*. is ideal.
- It is better if it is localised (*i.e.* combined with GPS information) to assess the influence of the context, and to assess the local impacts (for pollutants, not for CO_2)
- The FOTs supported by the European Commission, such as the FOT-NET initiative[22] are of great interest in this respect.

With regard to the use of probe information for estimating CO_2 emissions, existing initiatives in Europe, Australia and elsewhere show potential. It is however important to be aware that the use of operational data from private vehicles (when individual identification is possible) requires permission from the vehicle owner. In the case of private drivers this is clearly a serious drawback.

It therefore seems more practical, at least in current conditions, to gather probe data from fleet vehicles (bus, coaches, trucks, taxis, *etc*.). A growing number of fleet managers appear willing to install the equipment necessary to enable the monitoring of vehicle behaviour to enable the fuel consumption estimates as well as environmental information, including CO_2 modelling. It would be of great interest to have such information for hybrid and electric vehicles as well as conventional fuels.

4.5.6 Data fusion

The data needs of traffic operators and managers have until now generally been met through conventional measurement techniques, and have involved a single or small number of sensing systems. However, in the present context, where highly accurate information is needed, it is likely that a number of data sources may need to be integrated to provide information of sufficient quality. In fact, as explained above, a wide spectrum of different data sources can be potentially used for building the models required for assessing CO_2 emissions. This suggests that new data fusion techniques will possibly have to be developed.

Several methodologies of data fusion have been proposed in the literature for the purpose of multi-sensor fusion and aggregation under heterogeneous data configurations. Due to the different types of sensors that are used and the heterogeneous nature of information that needs to be combined, different data fusion techniques are being developed to suit the applications and data. These techniques were drawn from a wide range of areas including artificial intelligence, pattern recognition, statistical estimation, and other areas. Traffic engineering field has naturally benefited from this abundant literature. For instance, independent of specific application a variety of

[22] http://www.fot-net.eu

techniques can be used for ranging from a sample arithmetic mean to a more complex data fusion approach. More precisely, a three-way split could be suggested:

- Statistical approaches: weighted combination, multivariate statistical analysis and its most up-to-date form data mining engine. Among statistical techniques, the arithmetic mean approach is the simplest which is used for information combination. This approach is not suitable when the information at hand is not exchangeable or when estimators/classifiers have dissimilar performances.
- Probabilistic approaches: For instance, Bayesian approach with Bayesian network and state-space models, maximum likelihood methods and Kalman filter, possibility theory, evidential reasoning and more specifically evidence theory are widely used for the multi sensor data fusion. This later technique could be viewed as a generalization of Bayesian approach.
- Artificial Intelligence: Neural networks and artificial cognition including artificial intelligence, genetic algorithms and neural networks. In many applications, this later approach serves both as a tool to derive classifiers or estimators and as a fusion framework of classifiers/estimators.

4.5.7 Data quality

Data quality is of central importance and traffic management agencies and traffic operators as well as data collectors are putting great emphasis on the improvement of quality assurance / quality control (QA/QC). Finding ways of ensuring high data quality is therefore a critical issue as it will also affect the consistency and validity of model-based estimates of CO_2 emissions.

Since the data can be provided by several sources, there can be variations in the data collection methods, data recorded, location description or naming conventions. Some standardization has been already achieved in this respect. Nevertheless, due to the impact on the model validation, a consistent set of QA/QC criteria and guidelines are needed.

There are frameworks which present such guidelines and standards for calculating data quality measures quality that are intended to address the following key traffic data quality issues:

- Defining and measuring traffic data quality
- Quantitative and qualitative metrics of traffic data quality
- Acceptable levels of quality

The data quality is usually defined on the basis of the following fundamental measures:

- *Accuracy*: The measure or degree of agreement between a data value or set of values and a source assumed to be correct. It is also defined as a qualitative assessment of freedom from error, with a high assessment corresponding to a small error.
- *Completeness* (also referred to as availability): The degree to which data values are present in the attributes (*e.g.*, volume and speed are attributes of traffic) that require them. Completeness is typically described in terms of percentages or number of data values. Completeness can refer to both the temporal and spatial aspect of data quality, in the sense that completeness measures how much data is available compared to how much data should be available.
- *Validity*: The degree to which data values satisfy acceptance requirements of the validation criteria or fall within the respective domain of acceptable values. Data validity can be expressed in numerous ways. One common way is to indicate the percentage of data values that either pass or fail data validity checks.
- *Timeliness*: The degree to which data values or a set of values are provided at the time required or specified. Timeliness can be expressed in absolute or relative terms.
- *Coverage*: The degree to which data values in a sample accurately represent the whole of that which is to be measured. As with other measures, coverage can be expressed in absolute or relative units.
- *Accessibility* (also referred to as usability): The relative ease with which data can be retrieved and manipulated by data consumers to meet their needs. Accessibility can be expressed in qualitative or quantitative terms.

4.5.8 Need for a data warehouse

In order to facilitate the 'extraction' of information coming from heterogeneous data sources (e.g. via data mining or data fusion techniques), it could be very useful to implement a data base specifically conceived for this purpose. More precisely, a data warehouse would offer an extremely valuable basis for evaluating ITS applications. Such a warehouse could serve as a repository of integrated information available for queries and analysis.

Among the benefits of a data warehouse is the fact that it could:

- Facilitate reporting as well as analysis.
- Provide well organised historical information.
- Serve as an adaptive and resilient source of information.
- Offer a good basis for decision making.

Significant efforts to initiate the development of a comprehensive traffic data warehouse with an international dimension have already been made by the University of Tokyo.

4.5.9 Data ownership, protection and privacy

The availability of many of the data items described in this section relies in many cases on having open access to databases used for other purposes. This raises the major issue of data ownership. For a warehouse to be set up, strategic partnerships would need to be forged between transport managers and road traffic operators. In other words, a model for public-private cooperation would be required for the development and deployment of a large traffic data platform.

Another critical issue to be resolved concerns data protection and privacy. Access to vehicle registration data (especially when cross-border), involves different national legislation. Indeed, location data (from GPS-enabled mobile devices, phone tracking, probes etc) as well as vehicle registration data is very sensitive and has to be recorded anonymously, i.e. with appropriate privacy filters. This concern is linked to EU Data Protection Directive23 and more precisely the Article 29 Working Party Data Protection.

[23] http://ec.europa.eu/justice_home/fsj/privacy/workinggroup/index_en.htm

5 Issues to be addressed

This chapter of the report brings together the key issues which we consider to be relevant to the development of a common assessment methodology, and presents the principal open issues and questions which need to be addressed within the ECOSTAND project.

Standardisation requires an understanding of not only the EU perspective, but also the Japanese and US perspectives. The questions will therefore be put forward for discussion in the trilateral symposia to ensure that these are well informed and well targeted. The conclusions and agreements reached will directly feed into the policy advice on the roadmap and research agenda.

Once again, this work builds upon the Technical Report of the EC-METI Task Force and subsequent work, and it is intended that this initial approach will evolve and will be refined during ECOSTAND. In the EC-METI workshop in Amsterdam representatives for each of the three regions were identified for the sub-topics, as shown in Table 8.

Table 8 Sub-topics and key experts from the three regions.

Sub-topic	Description	Japan: Energy ITS	EU: ECOSTAND	US[a]
1	ITS applications	R. Horiguchi (i-Transport Lab. Co.)	A. Spence (MIZAR) S. Turksma (PEEK)	J. Misener (University of California)
2	Traffic simulation	R. Horiguchi (i-Transport Lab. Co.)	T. Benz (PTV)	A. Skarbadonis (PATH)
3	Emission modelling	H. Hirai (JARI)	S. Maerivoet/ K. Vanherle (TML) P. Boulter (TRL)	M. Barth (University of California)
4	Monitoring using probe vehicles	R. Horiguchi (i-Transport Lab. Co.)	J-P. Medevielle (IFSTTAR).	A. Skarbadonis
5	Validation methodology	S. Tanaka (University of Tokyo)	J-C. Pandazis (ERTICO) M. de Kievit (TNO)	J. Misener (University of California)
6	International traffic database	M. Miska (University of Tokyo)	J-P. Medevielle (IFSTTAR)	M. Barth (University of California)

(a) Provisional

The purpose here is to provide a clear statement of the relevant issues rather than to attempt to offer answers. Given the large number of open questions, it will nevertheless be helpful if indications can be given of their relative priority. There are certain fundamental issues which will need to be agreed between the three regions at an early stage, as they will be fundamental to the later work.

The questions are diverse in nature, but typically relate to the scope and boundary conditions of the methodology and/or standardisation. The scope of the assessment methodology (which items are to be included) and the boundary conditions (the extent to which these items are included) will need to be defined clearly and unambiguously.

A number of 'general' issues which need to be addressed are presented in Table 9.The issues and questions for ECOSTAND relating to the six sub-topics are presented in Table 10 to

Table 15.

Table 9: General issues.

No.	Issue/question	Observations
G1	Which types of user is the common methodology aimed at?	Several types of user were identified in chapter 1. The types of user will influence the characteristics of the common methodology.
G2	What are the precise aims of the methodology? In other words, what will it be used to assess?	The aims of the methodology should be clarified.
G3	What are the required characteristics of the methodology	Some likely characteristics were mentioned in chapter 1. These include accuracy, reliability, cost-effectiveness, etc.
G4	Does the methodology aim at single ITS applications or also at bundles?	
G5	How do we deal with cultural differences between the three regions	
G6	Should a distinction be made between commercial and non-commercial models?	
G7	Is cost an issue when taken into account the applicability of the methodology for an identified end-user?	

Table 10: Issues relating to sub-topic 1 - Identification and definition of ITS applications and reference models.

No.	Issue/question	Observations
1.1	Classification of ITS applications: are the six categories proposed in Chapter 2 appropriate for the purpose of the present initiative?	At present different ITS classifications are used in the three regions (and in some cases also within the regions), as well as in various working groups (*e.g.* ISO). Agreement on a single classification would be highly desirable.
1.2	ITS applications in each category: are the applications currently grouped under each category appropriate?	As above.
1.3	Should the common methodology be able to assess all the ITS applications listed?	It would be useful to define the criteria to be applied in the selection of ITS applications which the methodology needs to cover.
1.4	Geographical/ temporal scales of operation of the ITS applications: how should these be addressed?	Different ITS applications operate on different geographical and temporal scales. A 'fair' approach to their assessment is therefore required when making comparisons.
1.5	Are the spatial and temporal boundaries valid for estimating CO_2 emissions the same as those of the operation of the ITS?	It would be very useful to be able to agree on a suitable geographical/temporal scale for the assessment of each ITS application.
1.6	Are emissions estimations required for captive fleets?	For certain applications (*e.g.* eco-driving schemes) there may be no specific spatial boundary. Consideration therefore needs to be given to how such schemes can be compared with other ITS applications.
1.7	Modes of transport: Will the methodology address road transport only?	Even if the focus is on road transport, one issue which arises is how to measure the full impact of changes in modal spilt.
1.8	Will the methodology address emissions associated with the infrastructure (*e.g.* street-lighting, the operation of the ITS)?	The inclusion or exclusion of infrastructure effects must be addressed. These are likely to be more important for some ITS applications than others.
1.9	What is the most appropriate reference situation for each ITS application?	

Table 11: Issues relating to sub-topic 2 – Traffic simulation.

No.	Issue/question	Observations
2.1	Should traffic simulation be used as standard, or should there be the possibility of basing assessments on direct measurement?	Some ITS applications operate on small spatial scales, and real-world traffic data may be available from surveys.
2.2	If direct measurement is possible then what techniques should be used?	Appropriate methods will need to be defined.
2.3	What *types* of traffic model are available in each of the three regions?	It is important to understand the different types of model being used in the three regions. If a given type of model is rarely used in one region, then it would be difficult to recommend it in the standard methodology.
2.4	What *specific* traffic models are available in each of the three regions?	As above, but for specific models.
2.5	What criteria should be used for selecting traffic models?	The most important criteria will need to be identified.
2.6	Define the optimum granularity for traffic simulation modelling?	This depends on the nature of the ITS under investigation
2.7	How to get the vehicle trajectory based data, and to establish the human behaviour modelling?	
2.8	How to perform the model parameter calibration and validity check?	
2.9	What kinds of output data are required from the traffic models or measurements?	The outputs from traffic models are well established and are not likely to change.
2.10	Are existing traffic simulation models sufficiently accurate to allow the effects of ITS applications on emissions to be determined?	
2.11	What road and traffic parameters do different ITS applications affect, and are these relevant to traffic and emissions modelling?	
2.12	Is the structure of available driver behaviour models sufficient to describe new behaviour?	If the driver behaviour can be expressed using parameters, and the changes in these parameters resulting from ITS, then such models are sufficient. ITS which results in, for example, a change in tactical driving might be different.

Table 12: Issues relating to sub-topic 3 – Emission modelling.

No.	Issue/question	Observations
3.1	What *types* of emission model are available in each of the three regions?	It is important to understand the different types of model being used in the three regions. If a given type of model is rarely used in one region, then it would be difficult to recommend it in the standard methodology.
3.2	What *specific* emission models are available in each of the three regions?	As above, but for specific models.
3.3	Are validated models available?	Some emission models have been partly validated using different techniques (e.g. tunnel studies, inverse modelling, or remote sensing). For CO_2 validation is possible if fuel consumption data are available, but this is generally only the case for large areas (*e.g.* national fuel sales).
3.4	Do similar types of model in the EU, the US or Japan operate on exactly the same principles, or are there important differences?	Slightly different approaches are used in the three regions, but there are some common elements.
3.5	What criteria should be used for selecting models?	For example, different emission models work on different geographical scales. The most appropriate scale for calculating the effects of a given type of ITS application needs to be established.
3.6	Which pollutants should be included?	Different models cover different pollutants. Again, it is important to understand the coverage of different models.
3.7	Which emission models are best suited to specific types of ITS, and where might difficulties arrive?	There is clearly a need for any universal assessment methodology to be comprehensive in terms of its ability to deal with different types of ITS. The methodology therefore needs to refer to different types of emission model.
3.8	What kinds of input data are required from the traffic models or measurements?	Different emission models require different types of input. However, these are generally well established. Moreover, the outputs from traffic models are also well established and are not likely to change.
3.9	Which vehicle categories (fleet structure) will be used, and how will these be defined?	For example, vehicles in European emission models are generally classified by European emission standards, engine size, GVW, etc., whereas in the US and Japan they will be categorised differently. Such differences will need to be taken into account.
3.10	Are the vehicle fleet data adequate for the applications being modelled?	The fleet data should have a level of detail which is appropriate to the assessment. For example, there is little point in having a very detailed approach to modelling vehicle operation if the fleet data are very coarse, or inappropriate in other ways (*e.g.* wrong year).
3.11	How are future conditions treated in different models?	It seems probable that the composition of the traffic - in terms of type of fuel/powertrain - will change significantly in the future.
3.12	Are any improvements to models required?	Some models may be appropriate for evaluating ITS, but improvements may be required (e.g. amount of data contained in model, coverage of pollutants, coverage of vehicle categories).

Table 13: Issues relating to sub-topic 4 – Monitoring using probe vehicles.

No.	Issue/question	Observations
4.1	What are the available probe data sources in each region?	
4.2	What is the required quality for these sources, and what are the quality criteria?	
4.3	What are the criteria for accepting data (such as the minimum number of vehicles)?	
4.4	How should the probe data be expanded to give region-wide results?	
4.5	How can cooperative systems add to the use of probe-data?	

Table 14: Issues relating to sub-topic 5 – Validation methodology.

No.	Issue/question	Observations
5.1	What are typical validation points for both traffic simulation models and CO_2 emission models?	
5.2	Which validation processes are common between regions?	
5.3	How strictly should models be certified?	
5.4	What kind of benchmark dataset is required for validation?	
5.5	How are validation results and errors to be treated?	

Table 15: Issues relating to sub-topic 6 – International traffic database.

No.	Issue/question	Observations
6.1	What are the necessary parameters for traffic modelling ('wish-list')?	
6.2	What are the essential parameters for emission modelling?	
6.3	What are the requirements for the baseline dataset in the traffic and emission modelling?	
6.4	What meta-information is required for specific problems?	
6.5	What are the requirements to trust the third party data (quality check)?	

6 Summary and recommendations

6.1 Overview

The objective ECOSTAND is to provide support for an agreement between three regions – the EU, Japan and the US – on a common assessment methodology for determining the impacts of ITS on energy efficiency and CO_2 emissions. This support will involve the formulation of (i) policy advice, in the form of a 'roadmap' and (ii) a joint research agenda to identify gaps in the understanding and to propose solutions to enable the methodology to be developed.

This report has set the scene for the work to be undertaken and has described the general approach to be followed. The intention of the report was to provide an initial basis for trilateral discussions to determine the scope and content of the roadmap and research agenda.

6.2 ITS applications

This report provided an overview of the types of ITS application which are most commonly employed today. The ITS applications have been divided into six categories:

- Navigation and travel information.
- Traffic management and control.
- Demand and access management.
- Driver behaviour change and eco-driving.
- Logistics and fleet management.
- Safety and emergency systems.

Although compiled from a European perspective, the list of applications should also reflect the situation in Japan and the United States. There are, however, differences between the three regions in the categories and nomenclature used.

One of the first priorities of ECOSTAND should be to reach a trilateral agreement on the ***categories of ITS*** which need to be covered by the common methodology and, as far as possible, the applications included in each category. This will have important implications for the methodology itself.

Harmonisation must also be sought in the ***terminology*** used, since it is essential that there is no misunderstanding between the regions regarding the ITS applications in question. To avoid any ambiguity, it would be useful to produce clear and a detailed description of each ITS application, including distinguishing features. If the individual regions prefer (at least locally) to continue using their own nomenclature, it would be helpful to compile a glossary of equivalent terms.

Once it has been established which ITS applications should be covered by the methodology, the next step is to determine the most appropriate geographical and temporal scales at which each one should be assessed, and the modelling implications.

6.3 Initiatives and projects

There are numerous recent or ongoing initiatives and projects which deal with ITS and CO_2 emissions. We have identified the following types of activity:

- Bilateral initiatives
- An initiative in Japan (Energy-ITS)
- An initiative in the US (AERIS)
- Initiatives in the EU
- Selected European projects

The participants in the projects and initiatives are potential contributors to the ECOSTAND symposia, and their reports will be valuable sources of information.

6.4 Evaluation methodologies

The methodologies which are currently used for evaluating road traffic and emissions also have a long history in the assessment of ITS. These methodologies mainly involve a combination of traffic simulation and emission modelling, and over the years the models have been adapted and improved, so that they can now be used to effectively evaluate a wide range of ITS measures.

Experience from the different regions suggests that the methodologies available are suitable for assessing ITS, but they require adequate data to reflect the changes that ITS measures introduce.

A suitable evaluation methodology depends on the measures under investigation. The mechanisms that are affected must be adequately represented by the evaluation methodology; e.g. an ITS application targeting driver behaviour while driving by changing speed behaviour needs to be investigated by a methodology that explicitly includes such behaviour; optimally in a causal model.

6.5 Issues to be addressed

The report has summarised the key issues which are considered to be relevant to the development of a common assessment methodology, and therefore need to be addressed within the ECOSTAND project. By means of the aforementioned symposia these different issues will be addressed according to the sub-topics that have been identified. Besides the sub-topic oriented issues general questions are posed as well which need to be solved before the end of the project. The six-subtopics for which the issues are identified are the following:

Sub-topic	Description	Main aim
1	ITS applications	To reach agreement on the main categories and types of ITS application which the methodology needs to be able to assess.
2	Traffic simulation	To identify traffic modelling approaches which enable CO_2 emissions to be estimated for baseline conditions and for various ITS implementation scenarios.
3	Emission modelling	To identify the key requirements of CO_2 emission models required to calculate the impacts of ITS.
4	Monitoring using probe vehicles	To arrive at a common understanding of the contribution of probe data to 'real-time' CO_2 monitoring.
5	Validation methodology	To establish a common validation framework for both traffic simulation and CO_2 emission models.
6	International traffic database	To provide easy access to the data required for estimating the impacts of ITS applications on CO_2 emissions, and for validating models, and to enhance current international traffic databases.

6.6 Next steps

The list of issues will be put forward for discussion in the trilateral symposia to ensure that these are well informed and well targeted. The conclusions and agreements reached will directly feed into the policy advice on the roadmap and research agenda.

Given the large number of open questions, it will be helpful if indications can be given of their relative priority. There are certain fundamental issues which will need to be agreed between the three regions at an early stage, as they will be fundamental to the later work.

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Annex A: ECOSTAND management

A1 Overall strategy

The ECOSTAND project will define a common research agenda and will develop a roadmap on how to plan and promote cooperation in research and development work on ICT for sustainable mobility in the three regions. This will be mainly achieved through the organisation of a series of symposia in the regions with key experts, followed by the publication of policy advice papers.

The ECOSTAND symposia will be organised in conjunction with other major international events in order to facilitate attendance. The symposia will be coordinated by the ECOSTAND consortium, including setting the agenda, choosing presentation/session topics, and specific discussion formats (*e.g.* panel discussions or exercises in smaller break-out groups). Specific policy advice will be produced, including road maps and recommendation for further work in this area.

A2 Work Packages

The ECOSTAND activities will be split into the five Work Packages listed in Table A1. The objectives and content of each Work Package are briefly summarised below.

Table A1: Work Package list

Work Package		Leader
No.	Title	
WP1	Project management	TNO
WP2	Assessment methodology and relationship building	PTV
WP3	Symposium organisation	TML
WP4	Roadmap development	MIZAR
WP5	Dissemination and exploitation	ERTICO

WP1 Project management (WP leader TNO): The main objective is to ensure an effective and timely management of the project activities. TNO will be responsible for the project coordination between partners and for the liaison between the EC and ECOSTAND partners. WP1 also includes the management of project resources and quality assurance. The main activities include information management, administrative and financial management, quality assurance, liaison with the Japanese and US partners, coordination of project activities, and producing project management reports and the final report. Furthermore, TNO will be responsible for the consortium meetings between the symposia.

WP2 Assessment methodology and relationship-building (WP leader PTV): The main objectives are to understand the best practice in the area of international cooperation on ICT for sustainable mobility, and to build up a network of international experts and organisations who will attend and actively contribute to the working groups and symposia, as well as the policy papers to be produced based on the discussions and presentations at the symposia. The sub-topics for the working groups have been identified prior to the ECOSTAND project. The working groups have been established and the output from these working groups will aid the setting of the agendas. The main results of this WP will be twofold: (i) a collection of procedures that guarantee a good and results-oriented cooperation between the people and organisations involved, and (ii) a “base network” of people forming the core group for cooperation in the envisaged symposia. Furthermore a first outline of the assessment methodology will be delivered.

WP3 Workshop organisation (WP leader TML): The main objective is the organisation of the two rounds of three symposia in the EU, Japan and the USA. For the EU events the symposium organisation will include activities such as setting dates in conjunction with other key events, booking venues, invitations, providing food/breaks, setting the agenda, identifying speakers and presentations, etc. For the non-EU events the work will involve liaising with Japanese and US working group members to assist in the planning.

WP4 Roadmap development (WP leader MIZAR): The objective is to define the “roadmap” setting out the main steps which will permit the establishment of a common research agenda and the definition of a common methodology – fully endorsed by the three regions – for assessing the impact of ITS applications on energy efficiency and CO2 emissions. This will involve formulating the recommended actions and providing technical guidelines on the basis of the discussions held during the two rounds of symposia and other information gathered from experts and stakeholders. As work in the working groups within WP2 progresses a similar division of the work might occur in this Work Package (although the contents of these working groups might change due to progression of knowledge and agreement).

WP5 Dissemination and exploitation (WP leader ERTICO): The objectives of the dissemination plan are to create awareness about the project and its specific research area, to promote the project results to the different target groups, and to encourage the exploitation of the results. This WP will ensure that the knowledge accumulated in this project is properly presented and complements other international initiatives. There will be an extensive dissemination process within ECOSTAND which will use communication methods across various channels. To address the widest possible audience the dissemination strategy has to be flexible enough to encompass public bodies, expert networks, companies and other organisations.

A3 Deliverables and milestones

Table A2: Deliverable list

Deliverable		WP	Nature	Dissemination level	Delivery date (month)
No.	Name				
D1.1	Final project report	WP1	R	PU	M36
D1.2	Yearly management reports	WP1	R	PU	M18
D2.1	State of the Art report	WP2	R	PU	M3
D2.2	Report on assessment methodologies	WP2	R	PU	M14
D3.1	Report on outcomes of round one of symposia	WP3	R	PU	M18
D3.2	Report on outcomes of round two of symposia	WP3	R	PU	M30
D4.1	Preliminary findings and identification of main issues	WP4	R	PU	M21
D4.2	Joint research agenda and roadmap	WP4	R	PU	M36
D4.3	European contribution to the Joint Technical Report EU/US/Japan	WP4	R	PU	M36
D5.1	Project website	WP5	O	PU	M3
D5.2	Project newsletter	WP5	O	PU	M3/18/36
D5.3	Communication and Dissemination plan	WP5	O	PU	M3/M15/ M27

Table A3: List of milestones.

Milestone		Work Package(s) involved	Expected date	Means of verification
No.	Name			
MS1	Submission of final project report	WP1	M36	Peer review process
MS2	First round of workshops completed	WP3	M18	Event carried out, attendance of key invitees
MS3	Second round of workshops completed	WP3	M30	Event carried out, attendance of key invitees
MS4	Project website online	WP5	M3	Website accessible