

Engaging the International Community: Research on Intelligent Transportation Systems (ITS) Applications to Improve Environmental Performance

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16. Abstract This report seeks to build on the exposure that the authors have had during the past two years to the thinking of the Japanese and European thought leaders about how Intelligent Transportation System (ITS) can contribute toward meeting environmental goals (especially for reducing CO ₂). Carbon reduction has become a central element, and perhaps even THE central element, in the planning for future European and Japanese ITS research and development activities. Given the amount of thought that has been devoted to how ITS can support environmental goals in these other countries, there is an opportunity for the U.S. to learn from our international counterparts and to then determine how best to structure a program in the U.S. to complement the international activities and to focus on addressing the most important environmental concerns here.				
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1. Introduction

This project was proposed to build on the exposure that the authors of this report have had during the past two years to the thinking of the Japanese and European thought leaders about how Intelligent Transportation System (ITS) can contribute toward meeting environmental goals (especially for reducing CO₂). Carbon reduction has become a central element, and perhaps even THE central element, in the planning for future European and Japanese ITS research and development activities. Given the amount of thought that has been devoted to how ITS can support environmental goals in these other countries, there is an opportunity for the U.S. to learn from our international counterparts and to then determine how best to structure a program in the U.S. to complement the international activities and to focus on addressing the most important environmental concerns here.

Japan took on the leadership role in making carbon reduction central to its ITS activities. They created the “Energy ITS” program under the New Energy and Industrial Technology Development Organization (NEDO) of their Ministry of Economy, Trade and Industry (METI). This five-year program, funded at about ¥1 billion (\$12 million) per year, was started in 2008 with the explicit goal of reducing CO₂ emissions through use of ITS strategies. One of its activities has been focused on convening meetings of experts from Japan with their counterparts from Europe and the U.S. in order to achieve agreement on how to model and predict the CO₂ impacts that a wide range of ITS strategies will have when they are deployed.

The first of the international workshops on modeling the CO₂ impacts of ITS was convened in Tokyo in February 2009, in association with a major multi-agency demonstration of cooperative ITS systems and services. The only U.S. participants in that workshop were several of us from the University of California, while Europe was represented by people from the European Commission and some research institutes. A second workshop was held immediately after the ITS World Congress in Stockholm in September 2009, where Dr. Robert Bertini from RITA attended in addition to the University of California participants. This was followed by a third workshop during the Intertraffic exhibition and its associated conferences in Amsterdam in March 2010, where the only U.S. participants were again from the University of California. In October 2010, several U.S. DOT participants were able to join the next round of international Energy ITS program meetings in Tokyo and Busan, Korea, in addition to the University of California participants. In late June 2011, another international ITS program meeting is planned in Vienna Austria, again with participation from the U.S. DOT and researchers from the University of California and Virginia Tech.

Throughout these international workshops, the Japanese organizers have been eager to find the right counterparts from Europe and the U.S. to interact with on a regular basis between meetings, to exchange information and ideas and to build consensus on technical issues. By October 2010, Europe was finally able to identify its official representatives to

this international dialogue through its ECOSTAND project, while the U.S. representation has remained informal and unofficial until now.

This project and report are aimed at explaining the Energy ITS program from Japan, as well as its European counterpart projects, so that the U.S. DOT can determine how best to proceed within its AERIS program, both tactically and strategically.

2. Japan's Energy ITS Program Overview

The Energy ITS Program was created under the auspices of the Ministry of Economy, Trade and Industry (METI), which is mainly responsible for improving the international competitiveness of Japanese industry. This ministry has strong connections to the motor vehicle industry, and indeed its prime contractor for Energy ITS is the Japan Automobile Research Institute (JARI), which does testing and evaluation work for the vehicle industry and supports its standardization efforts. It is also worth noting that METI has no relationship to environmental regulations, transportation policy or transportation infrastructure, and it does not have close working relationships with the ministries that are responsible for those topics.

Within the Energy ITS Program, about 90% of the resources have been devoted to the development of an automated truck platooning system that can save energy and CO₂ by significantly reducing aerodynamic drag. The other 10% of the resources have been devoted to development of models and methodologies for estimating the extent to which a wide variety of ITS products and services could reduce energy and CO₂. This latter element of the program is the one that has so actively sought international cooperation and coordination through the series of meetings cited in the Introduction.

At first glance, it seems surprising that METI would tackle an issue like reducing CO₂ emissions from transportation. The most likely explanation is METI's interest in supporting the motor vehicle industry and its ability to continue to export its products internationally. If the growing international concerns about climate change lead to regulations limiting CO₂ emissions, it will be necessary to have a solid basis for determining how much CO₂ each new vehicle will be producing when driving in real traffic, not just on a test track. Japan would like to take the lead in defining the methodology for making these estimates, incorporating both vehicle characteristics and local traffic conditions through modeling. If they can define the methodology, they are in a stronger position to develop criteria that favor their industry over its competitors and they can also be first to develop new vehicle and ITS technologies that will fare well in the evaluations. They are working hard to influence the Europeans and Americans to accept the modeling approach that they have been developing so that it can become an internationally recognized standard.

There is only limited public documentation of the Energy ITS Program, and it is sometimes not so easy to find. The bilingual color brochure introducing the program was once available online, but that no longer appears to be the case. A copy is attached as an

Appendix to this report. The researchers working on the program have begun to present some of their findings at international conferences such as the recent ITS World Congresses and the IEEE ITS conferences. These presentations have been focused primarily on the truck platooning development rather than the analyses to predict the impacts of the wider range of ITS systems.

The Energy ITS modeling and analysis activities have been divided into six primary themes, each of which has its own working group:

- (1) Definition of ITS Applications that Can Contribute to CO₂ Reductions
- (2) Traffic Simulation Modeling
- (3) Emissions Modeling
- (4) Probe Vehicle Monitoring Systems
- (5) Verification and Validation Methodology
- (6) International Traffic Data Warehouse

The Japanese have been eager to identify U.S. and European counterparts for more detailed interactions about these six theme areas. The Europeans have designated representatives in each of these areas through the mechanism of the ECOSTAND project, which was funded by the European Commission primarily to interact with Energy ITS (at a level of €735 K, including €128 K for travel and 71.5 labor months of effort).

3. Recommendations for U.S. Actions Related to the Six Themes in Energy ITS

Since the Energy ITS Program was initiated more than three years ago, and has less than two years remaining in its period of performance, there is some time urgency associated with the establishment of a U.S. approach for interacting with Japan's Energy ITS program and identifying representatives for more detailed consultations in each of its six theme areas. The University of California authors of this report have been filling those roles in an unofficial, stopgap, fashion for the past two years.

As previously mentioned, the Energy ITS Program has been divided into several major topic areas, all of which are addressed as "work packages" and are integrated as shown in Figure 1.

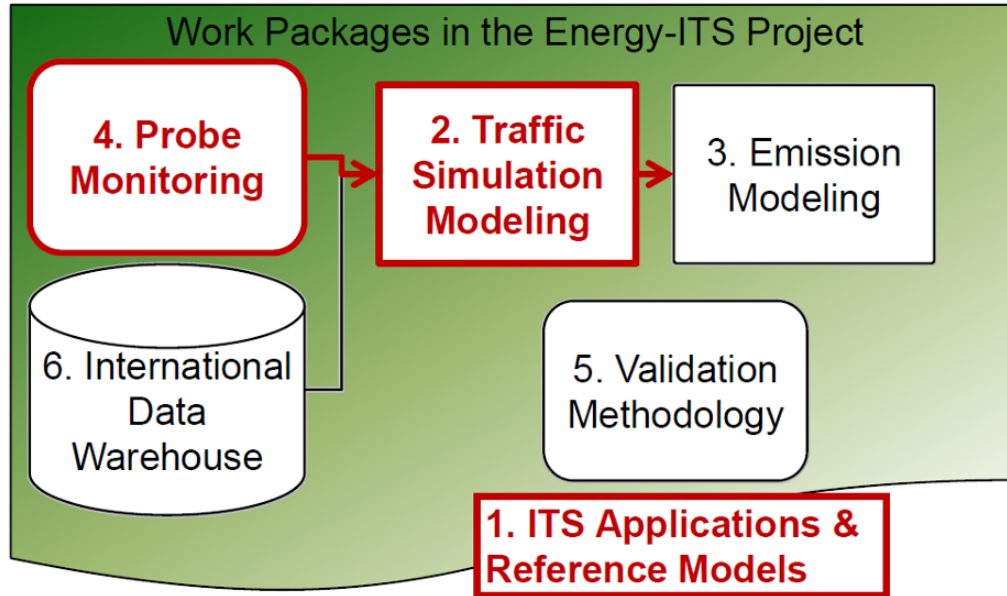


Figure 1: Work Packages of the Japanese Energy-ITS Program

A number of ITS applications have been identified as having major potential for reducing CO₂ emissions. These ITS applications are described in Section 3.1. In the context of these applications, there is a major effort to quantify and validate potential CO₂ reductions through a variety of tools, such as Probe Vehicle Monitoring (see Section 3.4), which feeds into a suite of Traffic Simulation Modeling tools, described in Section 3.2. These traffic simulation modeling tools are then “harmonized” with Emission Models (see Section 3.3) to predict the CO₂ reductions. The results are then addressed in the Verification and Validation Methodology, which is described in Section 3.5.

3.1 ITS applications that can contribute to CO₂ and pollutant emissions reductions

The ITS applications relevant to energy and emission reduction as discussed by the EU, Japan and the US are consistent in the following categories, as shown in Figure 2.

The applications categories include:

- *Applications that manage demand:* Applications under this category include real-time information that encourages travelers to make decisions based on the conditions of the transportation systems and to choose alternative travel times or modes including transit, bike or walk in addition to driving in order to avoid high emission travel options, and ITS enabled dynamic pricing in the form of road use, parking, and cordon charges.

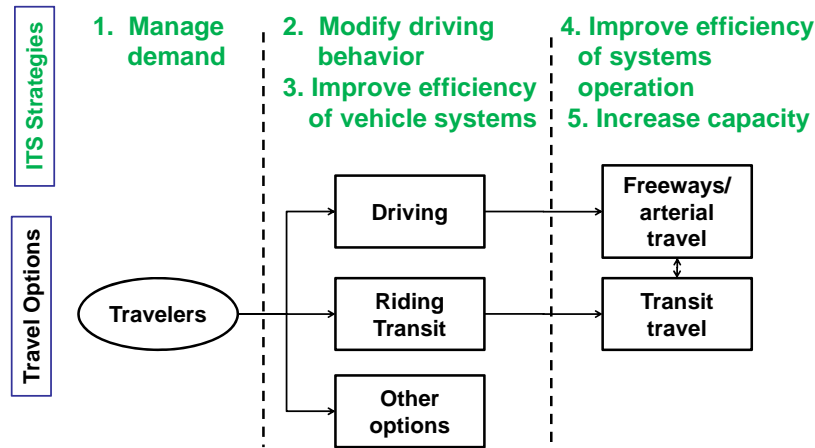


Figure 2: How ITS Applications Reduce Energy Use and Emissions

- *Applications for changing driver behaviors:* Applications under this category include eco driving with route selection based on real-time traffic condition information or energy efficiency and alerts about upcoming signal status through signal phase and time (SPAT) messages at intersections.
- *Applications for improving efficiency of vehicle systems:* Applications under this category include advanced vehicle control systems coupled with innovative power technologies, predictive engine control using geographic, traffic signal or traffic status information, integrated engine shutdown/restart system to reduce idling based on SPAT data, etc, to augment the driver's driving commands to make vehicles operate more efficiently.
- *ITS applications for improving system operational efficiency:* Applications under this category include what are typically considered as traditional ITS, which are designed for
 - Comprehensive performance measures for integrated transportation systems,
 - Improvements of highway operations: ramp metering, incident management, ETC, CMS traffic control optimization, etc.
 - Improvements to transit operations to offer more competitive modal choices: Transit Signal Priority, demand responsive transit, electronic fare collection, etc.
 - Safety enhancement technologies.

The applications for improvement of efficiency also include new ITS mobility services:

- Integrated Corridor Management to improve efficiency of all networks
- Connected Vehicles for mobility
- Vehicle Assist and Automation
- *ITS applications for increasing capacity:* Applications under this category include technologies for increasing the capacity of the existing infrastructure, such as CACC, Connected Vehicle-based safety applications and future Automated Highway Systems

3.2 Traffic Simulation Modeling

The major concern for both traffic simulation modeling and emissions modeling is that it be sensitive to changes that potential ITS applications may have on CO₂ reductions. For example, the models must be sensitive to changes in vehicle dynamics in Eco-Driving applications, where the accelerations and decelerations will be more moderate than what is typical seen in today's vehicle activity patterns. Other examples include being sensitive to traffic flow changes due to travel demand management and capacity reduction approaches.

As a result, the traffic simulation modeling approach in Energy ITS includes models at the different functional resolutions that are typically seen in the literature today:

- 1) *Microscopic traffic models*: There are a variety of microscopic models that address second-by-second trajectories of vehicles, mainly modeled at the intersection, corridor, or small city scale. There are a number of microscale traffic models that the Japanese research team is using, both commercial packages as well as their own models (VISSIM, NETSIM, microAvenue, etc.)
- 2) *Mesosopic traffic models*: The Energy ITS team recognizes that mesoscopic traffic modeling also needs to take place, primarily looking at link-level attributes of traffic. For example, they are concerned with kinematic waves that are analyzed in time-distance diagrams, looking for improvements in overall throughput and the smoothness of aggregate traffic trajectories. It appears that the research team is using their own mesoscale traffic modeling tools (e.g., AVENUE). This mesoscopic modeling takes place at the "town" or "city" spatial area.
- 3) *Macroscopic traffic models*: One of the ambitious goals of the Energy ITS research team is to perform transportation-related CO₂ analysis on larger regional scales, thereby requiring macroscopic traffic models. This type of modeling is very data intensive, and they are employing a variety of travel demand modeling tools such as DynaSmart and HEROINE.

With this defined set of traffic modeling levels, the Energy ITS team has identified how each ITS CO₂-reducing application fits in at the different levels. This is a reasonable approach when considering the difficulties in estimating emissions across a wide variety of applications.

One of the key elements that they rightly stress, is that there has to be "harmonization" or consistency between the different modeling levels. As a result, they call their approach a "hybrid traffic simulation" approach, where microscale modeling of an intersection may fit in to the next level of corridor modeling, which in turn may fit into the next level of city "sub-areas". They haven't provided a lot of details on how this harmonization is achieved, however they have cited an effort on "Japan Nationwide Traffic Simulation",

where most of the effort seems to be going into how to carry out computational parallelization using an area decomposition approach. This appears to be one of the pet projects of one of the team members from the iTransport Lab Company.

To date, full traffic simulation results have not yet been shown in the area, other than a few anecdotal examples made during their presentations.

3.3 Emissions Modeling

Very similar to the Traffic Simulation Modeling Component, the Japanese research team has recognized that it is also necessary to approach emissions modeling from a micro-, meso-, and macroscopic approach. This makes the integration or harmonization with the traffic models easier. At these different emissions modeling levels, they point out the key traffic parameters that matter the most from a CO₂ emissions point of view:

- 1) *Microscale*: for calculating fuel economy and CO₂ emissions, they are mainly concerned with second-by-second speed and acceleration profiles of every vehicle;
- 2) *Mesoscale*: for this level of emissions modeling, they calculate the product of the unit emissions amount and the duration/count of operating modes such as “stopping”, “acceleration”, “cruising” and “deceleration”. Using this approach, they can then see how the contribution of each of these modes changes with different ITS applications.
- 3) *Macroscale*: for this level of emissions modeling, they typically deal with the average travel speed of a trip. Therefore, in the macroscopic modeling framework, ITS applications are expected to change the average trip speeds of vehicles.

The Japanese research team has very explicitly matched together the different traffic simulation models with the various emissions modeling approaches. However, it is unclear in their research to date whether they have any consistency between the micro-, meso-, and macro-scale layers from an emissions modeling perspective. It appears that they are putting most of their efforts into the mesoscale modeling level.

For their microscale integration of traffic simulation models and emissions models, they simply take second-by-second vehicle velocity trajectories and directly apply a microscale emissions model. This typically works well if the emissions model is properly calibrated for different vehicle types and if the traffic simulation trajectory outputs are considered to be realistic (e.g., that they follow vehicle dynamics equations).

For their mesoscale integration, they rely on statistical models of emissions. This is potentially where many problems exist. Their mesoscale traffic simulation models produce representative vehicle trajectories that are called “stepwise speed function”.

They are a function of only set average speeds and specific durations for each of those average speeds. There is a potential danger in building a mesoscale emissions model this way, since it is not sensitive to the acceleration and deceleration patterns of a true vehicle trajectory. The response to this concern from the Japanese team is that they believe that statistically these acceleration/deceleration patterns will be represented by an average speed.

The Japanese research team has developed their own vehicle activity collection program to represent typical driving patterns in Japan. This seems like a very strange approach since there are already quite a lot of existing vehicle activity datasets that could be used for this purpose. Nevertheless, the actual second-by-second velocity patterns are changed into “stepwise speed functions”, greatly simplifying the resulting velocity profiles. Based on these stepwise speed functions, CO₂ emissions are calculated.

They have plans to do a variety of comparisons as part of their verification and validation process. They have also compared their method to the U.S. EPA’s MOVES model approach. They point out correctly that the MOVES model is sensitive to acceleration/decelerations as captured as a Vehicle Specific Power (VSP) factor, where the Japanese research team claim that the acceleration/deceleration effects are captured in their statistical method.

To date, we are somewhat skeptical of their approach, until they can show that they can accurately predict emissions this way.

Professor Matthew Barth of U.C. Riverside is interested and well-qualified to represent the U.S. in the continuing discussions with the Japanese and European counterparts regarding the emission models, which are closely related to much of his ongoing research.

3.4 Probe Vehicle Monitoring Systems

The Energy ITS approach to probe vehicle monitoring has been defined at a very macroscopic level, to collect data describing the transportation system’s operations at the regional level rather than more locally. This is consistent with the approach that they have taken to traffic and emissions modeling, but there are real questions about how effectively such a macroscopic approach can predict energy and CO₂ impacts of alternative ITS applications.

Japan would like to implement what they call a “social feedback cycle”, by which the public would voluntarily respond with behavioral changes based on feedback about CO₂ emissions. In other words, the CO₂ emissions would be estimated from the probe data and would be reported to the public every 15 minutes through the news media. If the results were bad (high emissions) people would be motivated to change their trip making behavior based on their own “eco consciousness.” This concept is based on a Japanese

vision of social cohesion and self-sacrifice for the good of society as a whole that probably does not translate well to other societies such as the U.S.

Japan already has seven private companies (mainly automotive OEMs) that are collecting probe data from their customers' in-vehicle information systems for purposes of providing enhanced traffic-responsive route guidance services. The Energy ITS concept is that the data from these service providers would be fused together and combined with data from infrastructure-based sensors in the highways and major arterials to produce a traffic index to describe aggregate conditions in each neighborhood (1 km square "mesh") as a whole, with the probes filling in the information about the smaller roads that are not instrumented. Each neighborhood's CO₂ emissions would be reported, with the intent of encouraging competition among neighborhoods to do better, although this concept does not appear to account for the major influence of through traffic on many neighborhoods, over which the neighborhood residents and workers would have virtually no control. The near-real-time updates of the data (every 15 minutes) are intended to encourage people to adjust their trip making behavior when local CO₂ emissions are high (defer, shorten or avoid trips or switch to less carbon-intensive modes).

The Japanese concept of the "social feedback cycle" to encourage societally beneficial behavior does not appear to have much applicability to the U.S. setting, but there should be opportunities to interact fruitfully with the Japanese researchers about the technical issues of probe data sampling, probe data fusion, and fusion of probe data with data from infrastructure-based detectors to develop better estimates of traffic conditions, all of which are important to a variety of ITS applications in the U.S.

Dr. Steven Shladover of PATH, who has participated in all the Energy ITS international meetings until now, is interested in continuing to interact with the Energy ITS team regarding the probe vehicle issues, which are closely related to some of his recent and current research projects involving use of probe vehicle data.

3.5 Verification and Validation Methodology

The Energy ITS research team understands the importance of model verification and validation before models can be trusted to produce useful predictions. This is particularly critical for situations in which models are developed on one continent but may be used to predict conditions on three continents, which could have significant differences in their transportation systems, driving behaviors and vehicle fleets. They would like to establish a common international framework for validating traffic simulation and CO₂ emission models, so that even if people in different countries choose to use different models they can provide each other with some assurance of model validity if they have followed the recommended methodology. They visualize creation of a validation manual, benchmark datasets to use for validation, and open disclosure of the results of model validation runs using the benchmark datasets.

The ideas behind this are not entirely new in Japan, but appear to be derived from experience that they have already had within the Japan Society of Traffic Engineers, which supported the adoption of a report of more than 50 pages on “Standard Verification Process for Traffic Flow Simulation Model” (1) more than ten years ago. This defines test cases and procedures to be used to evaluate several different types of traffic simulations for their ability to represent a variety of different traffic conditions.

The Energy ITS team recognizes that there are differing opinions among the countries about the merits of microscopic versus mesoscopic or macroscopic modeling approaches, and they would like to sidestep the associated controversies by reaching agreement on generic validation methodologies that could be applied regardless of which class of models was adopted. This means that the validation methodologies need to specify which intermediate or output variables are the most important ones to observe or measure, and then define the allowable tolerances for each one. They have already taken the initiative of offering a first benchmark dataset for researchers in other countries to apply to test their own models, and have encouraged the rest of the international community to come forward to exchange validation datasets. This dataset represents about one mile of arterial driving in Tokyo, with probe data collected during a four hour peak period using ten probe vehicles driving a round trip along the arterial at 3 minute intervals.

This topic of model verification and validation is a challenging one for all traffic flow theory and control researchers, and should be of interest to a broad community, not only those who are interested in energy and environment issues. Researchers who have interest and expertise with traffic simulation modeling and traffic data collection should be able to provide useful expertise in representing the U.S. in future international meetings with the Energy ITS team.

3.6 International Traffic Data Warehouse

The Japan Energy ITS research team correctly recognizes that the usefulness of the other components of research depends heavily on availability of real-world traffic data. For example, all of the simulation models require real-world traffic data for both calibration and validation purposes. Further, emission models highly depend on data collection from a subset of vehicles that are representative of the entire fleet. Perhaps most importantly, to properly assess the effects of ITS on traffic, real-world traffic data measurements are critical.

As a result, the Japan Energy ITS research team has developed an "International Traffic Data Warehouse" where a wide variety of traffic-related data can be stored and accessed by various researchers around the world. There are several goals that they are trying to achieve: 1) making this data warehouse easily accessible; 2) making the data searches and downloads fast and efficient; 3) utilizing a simple format that minimizes the amount of pre-processing required; 4) eliminating traffic data redundancy if at all possible; 5) providing a common source of traffic data that can be used to test models developed in

other regions of the world., and 6) collecting enough data to properly estimate effects of ITS applications under a range of network and traffic conditions.

The team has developed the architecture of the traffic data warehouse database and has since populated the warehouse with various datasets, primarily from Japan, but also including some provided by U.S. and European research groups. There are different types of data that are being collected that pertain to traffic:

- 1) Detector data: These typically correspond to spot measurements of traffic that can provide some estimate of traffic average speed, density, or flow; However other data exist in this category that may correspond to crash data or possibly weather data.
- 2) Video data: This consists of videos of various roadways where traffic can be readily seen. The goal here is to possibly extract vehicle trajectories from the video data sets.
- 3) Probe vehicle data: This type of data could consist of a wide variety of vehicle parameters that are delivered on a periodic basis while a vehicle is moving. Most common is vehicle speed and location information, provided at 1 Hz. Additional vehicle parameters can also be included, such as data from the vehicle's on-board databus or emissions data.
- 4) Simulation-based traffic information: It is unclear thus far if the team is also including data sets that have been generated from different traffic simulation runs. These simulated data can be useful for some applications (e.g., ITS effects that are variable depending on vehicle penetration rates in the fleet). However, there is the potential danger of over-using traffic simulation data in place of real-world data to reach conclusions about ITS benefits.

Overall, the database architecture and efforts behind it seem sound. There have been similar efforts at other locations (e.g., the U.S. National Renewable Energy Laboratory has created a large data base of vehicle activity data). At this point, the international warehouse database still needs a lot more data before it is truly useful for a wide set of researchers. It is very sparse at the moment, however when it is more complete, it can be used for a variety of purposes. The only other concern is that it is trying to capture a wide variety of data (e.g., detectors, video, simulation, probe) which makes it somewhat more complex than it perhaps needs to be.

Professor Matthew Barth of U.C. Riverside is interested and well-qualified to represent the U.S. in the continuing discussions with the Japanese and European counterparts regarding the traffic data warehouse.

4. Parallel Activities in Europe

Reduction of CO₂ emissions has within the past few years become the dominant motivator behind most of the new European research initiatives in ITS. This trend has been strengthened by the recent White Paper on European Transport Policy 2020 (2), which has very strong themes of reducing transportation's energy use and CO₂ emissions. Europe has set a goal for the entire transportation sector (including air) of reducing its

greenhouse gas (GHG) emissions relative to 1990 levels by 20% in 2030 and by 60% in 2050, even after accounting for growth in the population and economic activity. They plan to halve the use of conventionally fueled vehicles in urban areas by 2030 and eliminate them by 2050. At the same time, the policy White Paper states that “Curbing mobility is not an option” and “New mobility concepts cannot be imposed.” Considering these ambitious goals and constraints, ITS is bound to assume an important role.

There has already been a substantial level of effort invested in the CO₂ issue in Europe, with some projects already completed. The European environment is complicated to understand because of a wide range of project sponsors at different levels (regional, national and European), approaching the problem from different perspectives (economic competitiveness, transportation improvement, or environmental protection). There are three different Directorates General of the European Commission (analogous to U.S. cabinet level Departments) that sponsor ITS activities: DG Research, DG MOVE (transportation and energy policy) and DG INFSO (information society and media). DG INFSO has been the most visible in international ITS activities, and is the Directorate that signed the cooperative agreement with RITA for cooperation in ITS, but it is not the only sponsor of ITS research at the European level. The more basic scientific research projects regarding energy use in transport and the emission of CO₂ are sponsored by DG Research, while the policy and impact issues are sponsored by DG MOVE.

The Commission recently completed a project called TOSCA (Technology Options and Strategies towards Climate friendly trAnsport), seeking to determine how to reach the 2050 GHG reduction goal across the entire transportation sector (road, rail, air, marine) (3). This project considered a full range of dramatic actions on the technology, pricing and policy fronts, including alternative fuels and electrification, in combination with each other, and still found that the European goal would be extremely difficult to reach.

The most relevant European Commission activities involving the direct relationship between ITS and CO₂ are in DG INFSO, which as a whole is primarily motivated by improving Europe’s technological strength rather than improving its transportation system. They are currently sponsoring three major projects that are developing methods for using ITS to reduce CO₂ emissions, plus the smaller “coordinating action” project ECOSTAND for the express purpose of interacting with Japan and the U.S. They have also announced plans for significant new initiatives in their upcoming calls for proposals, leading to significant expansions beyond their current activities. The three major current projects are called eCoMove, In-Time and Freilot.

eCoMove (4) is the largest and most complex of the current DG INFSO projects on cooperative systems, and is considered to be the direct successor to the previous generation integrated projects CVIS and SAFESPOT. It is extremely significant that while the principal motivations for those antecedent projects were improving mobility and safety respectively, the motivation here is improving the environment. The eCoMove project, scheduled from April 2010 through March 2013, has a large consortium of partners from diverse sectors, including automotive OEMs and suppliers,

as well as research institutes. Their €2.5 million budget (about \$32.5 million) substantially exceeds the resources being invested in the U.S. on the analogous issues.

The eCoMove partners are aiming to develop and test several specific cooperative systems that are intended to save energy, using four test cars and two test trucks. The emphasis appears to be strongly vehicle oriented, rather than addressing public transit enhancements or other strategies to induce mode shift or trip reductions. The strategies include eco-driving strategies for influencing driver behavior, improving logistics efficiency and improving traffic control, aiming for a 20% energy saving if these strategies were to be fully implemented. They seek to balance traffic throughout the road network by providing route guidance to drivers and improve driving efficiency by using advanced driving assistance systems such as ACC and transmission shifting control to smooth out acceleration and braking maneuvers. They are also applying enhanced traffic control strategies for both arterials and freeways, to encourage green waves and reduce stop-and-go congestion patterns.

The second major DG-INFSO project of interest is In-Time (5), which is more multi-modal in its orientation, while also using real-time travel and traffic information to increase traffic efficiency. It is somewhat complementary to eCoMove in the sense that this project is trying to encourage mode shifts away from private personal vehicles by providing improved real-time information about alternatives. This three-year project began in April 2009, and is budgeted at €4.58 million (about \$6.6 million).

The third DG-INFSO project that is aiming at reducing CO₂ by use of ITS is Freilot (6), which is focused on improving the efficiency of urban goods movement. This project is funded at €4 million for the period from April 2009 – October 2011. It is applying a combination of strategies to reduce energy use in freight movement, combining eco-driving support to drivers with acceleration and speed limiters on trucks, enhanced traffic signal control and more efficient management of delivery spaces at freight destinations.

The next generation of European projects is already under development, based on the availability of a new funding allocation of €50 million this year to support proposals on low-carbon multi-modal freight and logistics and clean and efficient multi-modal mobility. Next year, there will be an additional €40 million allocated for two additional topic areas: Cooperative systems for low-carbon multi-modal mobility and European-Wide Service Platform for cooperative systems enabled services. In parallel with these ITS-focused projects, the “Green Car” initiative has provided €60 million in 2010 and 2011 to support projects on Information and Communication Technologies for the Fully Electric Vehicle, to help make electric vehicles more viable by providing their operators with better information to extend their range and more easily find recharging locations.

Taken together, and without even accounting for individual national programs, Europe appears to have invested more seriously in R&D on how to reduce transportation’s contributions to global climate change than any other region of the world. The decision makers there see this not only as an obligation to help avoid environmental catastrophe

but also as a commercial opportunity to position their industrial sector to take advantage of a rapidly growing international market for “Green” technologies.

5. Parallel Activities Elsewhere in Asia

Fast economic growth and increased mobility in Asian countries, including two of the largest emerging countries, China and India, have seen surges in emissions in recent years, largely contributed by massive increases of transportation emission. Traffic congestion has become one of the leading problems in these countries due to rapid expansion of highway networks and fast growing ownership of automobiles.

China has surpassed the United States to become the number one in CO₂ emissions. The Chinese government has recognized that China’s economic and social development is facing increasingly serious energy, resources and environmental constraints and has made a commitment that by 2020 the CO₂ emissions in China will be reduced by 40% to 45% per unit GDP from the 2005 level. Accordingly, policies have been developed to implement this goal. The State Council has incorporated the emission reduction goal in its 12th 5 year plan (2011-2015) including specifics about infrastructure development for highways, high speed rail, and urban travel. The State Planning and Reform Commission that is in charge of policies for developing ‘Energy and Emission Reduction Monitoring and Assessment Methods’. Together with the Ministry of Transportation (MOT), regulatory policies for reducing emissions and energy use have been released. MOT is also in the process of defining the characteristics and requirements of a ‘low carbon transport system’. New policies and guidance to the locals to address transportation related climate change issues are to be released soon.

Chinese central and local governments have taken steps to implement various policies. The most effective measures to date for reducing emissions are to retire high emission automobiles through regulatory means and to replace high emission older trucks, buses and cargo ships with new ones through subsidies. In metropolitan areas, public transportation systems, particularly subways and Bus Rapid Transit (BRT) systems, have been developed at an unprecedented pace. For example, in less than ten years, Beijing and Shanghai have each developed over 300 km of new subways. Other cities are following the Beijing and Shanghai examples. China is also rapidly constructing high speed rail networks across the country to not only make passenger travel between major cities fast, but also expanding rail freight capacity by making existing infrastructure available for freight transport. The funding devoted to these infrastructure developments, which directly or indirectly contribute to the reduction of energy use and emissions, is enormous. While instant results are seen (e.g., subways are packed with passengers immediately after they are open to public), the emissions remain high because the baseline pollution problem is tremendous and auto ownership is growing too rapidly, together with the fact that a large number of domestic produced vehicles do not meet high emission standard.

Research and development of new technologies, including ITS, have been mentioned in the new 5 year plan. The Ministry of Science and Technologies' (MOST) new technology program includes substantial research in transportation areas. Major research activities in the areas of electric vehicles, engine technologies and high speed rail have been identified and well funded. Specific to ITS, the current research and development directions focus on efficient information sharing and connectivity among different modes in order to improve the interoperability and efficiency of the multimodal transportation networks. While MOST is the primary agency funding research on ITS, most of the ITS technologies are mainstreamed by local governments. Various advanced traffic management and control devices and systems from international vendors are deployed nationwide. Traffic detection, probe vehicles and information are widely spread in major metropolitan regions. Although there are no research programs specifically focused on energy ITS issues similar to EU and Japanese programs discussed above, the deployment efforts have stated goals for, and would no doubt help to achieve, energy and emission reductions.

According to the U.S. Department of Energy's (DOE) Energy Information Administration (EIA), after China and the United States, among major polluters only India is expected to have significant growth of emissions over the next 20 years. India has also made a commitment for reducing its emissions per unit of GDP 20 to 25 percent below 2005 levels by 2020. There has been less information on India's specific plans and programs for emission reductions at this time.

6. Implications of International Activities for What AERIS Should be Doing

Europe and Japan have already been active for a number of years, and have already invested tens of millions of dollar equivalents, in projects aimed at applying ITS technologies to mitigate environmental problems in transportation. In both places, the motivations and support for the work have been diversified, providing multiple justifications for investment of resources:

- environmental improvement
- increased efficiency
- improved mobility
- saving money
- improving international economic competitiveness.

The importance of the final bullet item cannot be over-emphasized, because in both Europe and Japan the bulk of the funding has come from agencies that have this as their primary mission. This may also limit the opportunities for international collaboration on development of the specific applications, since they are perceived to have competitive implications.

Both Japan and Europe have invested the large majority of their applicable funding in the development and testing of new systems and services to reduce energy use in road

transportation, listed in Table 1, rather than in analysis or evaluation methods. These systems and services generally provide other benefits in parallel, such as saving time, reducing congestion, and saving money, so they are not single purpose energy saving systems. This means that they fit well into the broader ITS research agendas of their respective regions, and also have significant commercial potential as products.

Table 1 – International Applications Under Development for ITS to Improve the Environment

Sponsoring Project	ITS Energy-Saving Application
Energy ITS (Japan)	Automated truck platooning
eCoMove (Europe)	ecoSmartDriving – coaching drivers to drive efficiently
	eco-pre-TripPlanning – to choose efficient route
	on trip Green Routing – to update efficient route
	ecoDriverCoaching – for truck drivers
	ecoFleet Planning & Routing – for truck dispatchers
	ecoAdaptive Balancing & Control – for traffic signal control
	ecoMotorway Management – for highway traffic management
In-Time (Europe)	Pre-Trip Info – real-time multimodal information
	On-Trip Info - real-time multimodal information (smart phone)
	Eco-flow – traffic control optimization
Freilot (Europe)	Traffic management - Energy efficiency optimized intersection control
	Vehicle - Acceleration limiter and adaptive speed limiter
	Driver - Enhanced “green driving” support
	Fleet management - Real-time loading/delivery space booking

Not only the research resource commitment, but also the policy level commitment to using ITS to promote environmental goals, is currently significantly stronger in Europe and Japan than in the U.S. This poses a challenge for the formulation of the AERIS research program on ITS for the environment in the U.S. How can it most effectively coordinate and collaborate with its larger overseas counterparts, while delivering benefits in the U.S. that would not otherwise be gained? Does it have sufficient resources to develop several new applications that could be competitive with the well-funded overseas application developments?

The working group structure defined by Japan’s Energy ITS program already establishes a good framework for international interactions on an important set of issues, which can be addressed even with a modest level of investment. Development and evaluation of models to predict transportation and CO₂ emissions impacts is much less expensive than developing and testing new ITS systems. It is also vitally important for ensuring that ITS

systems and services are given the appropriate credit for their contributions to reducing CO₂ emissions. This issue was highlighted in the panel discussion comments by the representatives from all three regions at the Energy ITS workshop in Tokyo in October 2010. It will be much easier to get support for ITS deployments if there are well-established and authoritative methods for quantifying the amount of CO₂ that they are expected to save.

The technical challenges on the modeling and evaluation side are considerable, and failing to solve them could impede the deployment of ITS applications that are already developed. This is important because of the need to have authoritative methods for predicting the CO₂ impacts of the full range of ITS applications so that these can satisfy environmental review requirements and gain the support needed for deployment. The recent interactions with Japan's Energy ITS team have brought some of the technical challenges into focus, since the methods that are easiest to apply do not necessarily have the refinement needed to represent the changes that ITS deployments will produce. Some of the important technical questions that need to be resolved through new research include:

- What ITS/environmental modeling needs are not being met by existing tools?
- Which modeling approaches are needed to capture the environmental effects of which ITS services?
- How much difference does there need to be in the modeling approach for category pollutants versus CO₂/energy?
- Where should the boundaries be defined between traffic and emissions models, and macroscopic and microscopic modeling approaches? (Which traffic data need to be passed from traffic to emissions models?)
- How can the models be validated in the absence of large-scale deployments of the systems being modeled?

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Appendix A

Steve Shladover's paper for IEEE FISTS, Vienna, June 2011

Challenges to Evaluation of CO₂ Impacts of Intelligent Transportation Systems

Steven E. Shladover, *Member, IEEE*

Abstract—ITS systems can help reduce CO₂ emissions in three different ways, which need to be evaluated using different modeling paradigms. The ITS systems that reduce demand for vehicle travel should be analyzed using regional transportation planning models that explicitly represent modal choice and pricing sensitivity of travel choices. The ITS systems that improve vehicle operating efficiency should be evaluated using microscopic models of the effects on individual vehicles, and the results should be extrapolated to the system level based on travel statistics. ITS systems that improve infrastructure efficiency will generally require use of microscopic traffic simulation models, combined with new data representing how driver behavior is influenced by these systems in practice. Finally, concerns about latent and induced demand effects of transportation improvements need to be addressed with new research that reveals the real elasticities of travel demand.

I. INTRODUCTION

UNTIL recently, the goals of intelligent transportation system (ITS) deployments have generally been improving safety, relieving congestion, saving money and increasing driving comfort and convenience. Within the past few years, however, there has been a growing emphasis within international ITS programs in serving the goal of saving energy and thereby reducing CO₂ emissions. This change of emphasis has been most noticeable in Japan, with the advent of the very large Energy ITS Program [1]. The European Commission has followed suit with its EcoMove [2] program, and the U.S. in turn has begun work on the AERIS program [3].

Although it is easy to talk in sweeping generalities about the ability of ITS to save energy and reduce CO₂ emissions, it is not at all easy to make accurate predictions of the actual reductions that will be achieved by specific ITS deployments. Yet, such accurate predictions are seriously needed in support of ITS deployments because, like all new transportation projects, they are being scrutinized for CO₂ impacts as part of the environmental approval process. Furthermore, we should expect that CO₂ reductions will become increasingly important criteria for obtaining political support for new transportation initiatives as awareness of the global climate change challenge becomes more widespread.

Predicting the ability of ITS projects to reduce CO₂ emissions is challenging for several reasons. The first is that ITS itself is a broad collection of applications and strategies that have very different ways of influencing energy use and CO₂ emissions, and therefore cannot be modeled within a common framework or paradigm. As explained later in this paper, there are three distinctly different ways in which ITS can reduce transportation energy usage, and each of those needs to be analyzed differently. To complicate matters, the existing models and tools were not generally designed to reflect the phenomenology by which ITS saves energy, so these will need to be enhanced to provide the needed capabilities.

There is an additional ideological challenge that ITS applications must face, which is the “induced demand” argument that is commonly leveled against transportation projects that are designed to facilitate traffic flow. This issue, which will be addressed later in this paper, caused ITS to be rated relatively ineffective as a CO₂ mitigation strategy in the influential “Moving Cooler” study in the U.S. [4]. This study was refuted in a position paper published by ITS America [5], but the refutation was more qualitative than quantitative because of the shortage of authoritative data and models. Clearly, more work needs to be done by ITS researchers to develop these data and models.

II. HOW ITS CAN INFLUENCE CO₂ EMISSIONS

The potential for ITS to reduce CO₂ emissions has been recognized for a long time, going all the way back to the early days when it was still known as IVHS [6]. Different ITS applications and services can accomplish this by improving efficiency in different ways and therefore need to be analyzed differently.

A. Reducing Demand for Vehicle Travel

Some of the ITS applications can help reduce the overall demand for vehicle travel in several ways. ITS applications that improve the quality of public transportation services by providing better information to travelers, coordinating connections, increasing transit service speed and reliability, reducing delays experienced by transit riders and

making the transit ride smoother and more pleasant can encourage more travelers to change modes from personal automobile to transit. ITS technology can also be used to implement electronic road pricing, including congestion pricing based on real-time traffic conditions, discouraging drivers from making trips when congestion is heavy. Similarly, ITS can be used to implement variable pricing of parking in congested areas and provide real-time information about availability of parking spaces, discouraging drivers from driving to those destinations when parking is scarce.

The demand for vehicle travel can also be reduced by use of information from ITS, even when drivers do not cancel their trips. Navigation systems can provide more efficient routes than drivers are able to find themselves, and can avoid the mileage wasted when drivers get lost. When real-time ITS information shows that traffic congestion and parking availability are bad at specific locations and times, drivers can be encouraged to change routes and perhaps destinations as well, leading to less wasted vehicle mileage.

Although this discussion about reducing vehicle mileage has been focused on passenger car applications, the same kind of benefits can be achieved for trucks, where the economic incentives and benefits should be even greater.

B. Improving Vehicle Operational Efficiency

Another group of ITS applications improves the operational efficiency of vehicles, even if the distance that they drive is not changed. These applications influence more microscopic aspects of vehicle movements, either by advising the driver or by directly controlling the vehicle movements.

Drivers who accelerate and decelerate abruptly waste considerable energy themselves, but also impose inefficiency on the vehicles that follow them, whose drivers are forced into more abrupt maneuvers in order to avoid crashes. The acceleration and deceleration maneuvers can be smoothed out by vehicle speed control systems such as adaptive cruise control (ACC) and related systems designed for use in stop-and-go traffic.

Intelligent speed adaptation (ISA) can harmonize speed across vehicles in a highway section and discourage speeding, which wastes energy based on the excess aerodynamic drag at higher speeds.

Automated platooning of vehicles at very short gaps can reduce aerodynamic drag losses even without changing vehicle speeds. This has been demonstrated to be particularly effective for heavy trucks, which can save significant energy when electronically coupled together, since their drag coefficients when operated independently are quite high.

Vehicles in urban signalized traffic networks can receive advance information about imminent signal changes from the signal controller, enabling them to adjust their speeds to catch “green waves” and reduce the number of times they need to stop and idle at a red signal, and then re-accelerate to continue their trip. When the signals inform them about the amount of red time remaining, the vehicles can even switch their engines off to save idling fuel consumption, and then restart the engines immediately before the signal turns green.

C. Improving Infrastructure Operational Efficiency

The most complicated of the ITS applications to evaluate are the ones that improve the operational efficiency of the transportation infrastructure, both freeways and arterial networks. A wide range of ITS applications has been devised to increase effective capacity and reduce congestion levels. The effectiveness of these systems depends on complicated interactions among the vehicles, their drivers and the transportation management system. Their phenomenology is so diverse that predictions of their effectiveness have to be based on different analyses.

Freeway operational efficiency and capacity can be improved through strategies such as ramp metering and variable speed limits, which aim to prevent the traffic density from becoming so high that traffic flow breaks down, leading to stop-and-go inefficiencies and excess idling of stopped vehicles.

Arterial traffic signal control improvements can make better use of the capacity of signalized

intersections, minimizing the amount of green time wasted when no vehicles are present to use the green time, and minimizing the waiting time across the entire network. Arterials and freeways can be operated together as integrated corridors, optimizing the allocation of traffic to parallel links, especially when incidents restrict the capacity on one of the links. ITS information about incidents can be provided to drivers to enable them to re-route their trips around congested locations.

Since heavy vehicles (buses and trucks) use a lot more energy than light-duty vehicles and have much higher hourly operating costs, ITS strategies that give priority to these vehicles can have both economic and environmental benefits.

ITS technologies that improve the detection of and responses to incidents can reduce the durations of these incidents, restoring traffic flow to favorable conditions more quickly and reducing the inefficiencies associated with blocked lanes.

ITS includes a wide range of collision warning and avoidance systems, which are designed to reduce the frequency and severity of crashes. Reducing these crashes can reduce the non-recurrent congestion that they cause, which may account for as much as one-quarter of the congestion on urban freeways (and an even higher percentage on inter-urban highways).

The most advanced of the ITS applications, the automated highway system (AHS), provides the ultimate control of vehicle motions, integrating control of vehicles and of the traffic management system so that human error is removed and vehicle speed profiles can be smoothed out for maximum efficiency.

III. ASSESSING REDUCED DEMAND FOR VEHICLE TRAVEL

The ITS applications that reduce demand for vehicle travel need to be assessed using models that include explicit demand representations. These are normally the regional transportation planning models that are used to predict long-term changes in transportation needs based on economic, demographic and land-use changes. The models normally assume that all travelers have complete and accurate information about

each travel option (mode and route), which makes it hard to use them to compare scenarios with different availability of ITS-based information.

Changes in mode split between transit and automobiles are predicted by these models, using attributes of the trips by each mode such as travel time, wait time and out-of-pocket cost to the traveler. Differences produced by ITS systems and services generally need to be represented indirectly by adjusting the attributes that are already available in the model.

Pricing changes can generally be represented by adjusting the mode-specific costs in the planning models, but with the caveat that there is little practical experience in the U.S. with variable pricing. It is important to understand how travelers respond to prices that could change significantly during the course of a day, and how that response compares with their responses to long-term pricing differences. Once the relevant data have been collected from actual field experiences with these strategies, the resulting knowledge can be incorporated into the travel demand models.

The extent to which real-time information about traffic and parking conditions can cause travelers in the U.S. to shorten or abort their trips is generally unknown because of the absence of practical experience and data. These kinds of data are needed to determine the benefits that this type of information could provide.

IV. ASSESSING IMPROVEMENTS IN VEHICLE OPERATIONAL EFFICIENCY

In some sense, the vehicle operational efficiency improvements are the simplest to assess because they can be modeled at the vehicle level, with little influence from driver behavior or interactions with the traffic control infrastructure. The percentage improvements at the vehicle level can then be projected to the regional, state or national level based on the relevant statistics about the amount of travel under comparable conditions.

The relationship between driving speed and vehicle fuel consumption is already well documented [7], so the effects of ITS systems that limit speed, such as ISA or infrastructure-assisted

cooperative ACC, can be determined directly based on statistics about the baseline (current) distribution of highway speeds. The inefficiencies associated with congested stop-and-go highway driving are also well documented [7], so when the stabilizing effects of vehicle-vehicle cooperative ACC are well documented in test track experiments those results can be used directly to determine the savings.

The fuel saving potential of close-formation automated platooning of vehicles has also been well documented for trucks [8] – [9] and to a lesser extent for passenger cars as well [10]. Additional experiments addressing this issue are in progress at PATH and in Japan's Energy ITS Program, so there should soon be an ample body of data to show how much energy can be saved at the level of an individual vehicle or platoon. It is then straightforward to project these savings to the facility level or national level based on estimates of the number of vehicles that would be operating in close-formation platoons.

Improvements in vehicle operational efficiency in signalized arterial networks are more complicated to analyze, even if we start with the one-way flow of information from traffic signals to vehicles to enable the vehicles to drive more efficiently. The patterns of stopping and starting on signalized arterials are more complicated and diverse than highway shockwave patterns, and the ability of any individual vehicle to adjust its own speed to catch a green wave is constrained by the actions of the drivers of the surrounding vehicles, who may not be equipped to receive the same green wave information. In this case, the market penetration of equipped vehicles determines the ability of any individual vehicle to gain benefits. Traffic simulation has been used to make a preliminary estimate of the benefits that could be gained from one particular strategy [11], but much more research is needed to determine how the benefits will be affected by the specific eco-driving strategy, the traffic density, market penetration and signalization strategy. Fortunately, it should be possible to extrapolate the simulation results from a limited-scale example network to support regional and national predictions of impacts in comparable operating scenarios.

V. ASSESSING IMPROVEMENTS IN INFRASTRUCTURE OPERATIONAL EFFICIENCY

A. Freeway Management Systems

A variety of ITS strategies can improve the smoothness of freeway traffic flow and increase the effective capacity of the freeway. These congestion mitigation effects have the added benefit of reducing the amount of energy that vehicles need to consume to complete their trips.

The specific impacts that each ITS freeway management strategy will have can depend heavily on the local traffic patterns, peculiarities of roadway geometry, the way in which the strategy is implemented, strictness of police enforcement, and the driving styles of the local drivers. For example, although ramp metering has already been implemented in many locations it still requires significant fine-tuning whenever it is implemented at a new location. Variable speed limits for smoothing traffic flow is a much less mature concept, with significantly more uncertainties about its acceptability to the public and law enforcement community, and very little operational experience on which to base estimates of its effectiveness. Traffic models are still being developed and refined to predict its effectiveness.

Predicting the CO₂ savings that could be gained from implementation of a new freeway management system or strategy is still a research effort, requiring the development and calibration of state-of-the-art traffic flow simulations. The results from these simulation studies are going to be difficult to defend until there is more well-documented operational experience with these systems, supporting authoritative calibrations of the simulation models for their ability to predict traffic speed and density patterns at a sufficiently refined and microscopic level that they can produce useful inputs to the models that predict energy consumption and CO₂ production.

B. Arterial Traffic Control Systems

Signalized arterials have more complicated traffic conditions than freeways, and the current generation of traffic signal control strategies is based on use of pre-ITS traffic detection methods. Research is just beginning on identifying how to make use of the potentially richer traffic data that

could be provided through ITS, for example by using the vehicles as traffic data probes. Generalizing the results of this work will be challenging because of the great diversity of local road network geometries, traffic conditions, driving behaviors and traffic management strategies.

Traffic engineers have argued for decades about the relative merits of alternative traffic signal control strategies in terms of their ability to promote safety and mobility goals, even before the energy and environmental goals were made explicit. The addition of these new goals complicates the competition among strategies, and incorporation of the new measures of effectiveness to reflect these goals is likely to change the way signal control systems are optimized.

Although much traffic signal control strategy development is done at the macroscopic level, considering average delays or travel times through the network, this is not sufficient for assessing the energy consumption or CO₂ impacts of different alternatives. Since the processes that consume energy and produce CO₂ occur on shorter time scales and depend on detailed vehicle speed and acceleration profiles, it is going to be necessary to model and simulate the traffic signal control strategies at this more microscopic level.

C. Incident Management Strategies

ITS applications to incident management can provide incident response teams with faster and more accurate information about incidents so that they can respond more promptly and effectively, and can also alert travelers about the incident so that they can avoid getting caught in its congestion. The incident effects tend to be highly location specific and the impact of an incident on traffic depends strongly on the level of traffic at the time of the incident. These effects are hard to generalize to regional or national levels, beyond the very broad generalization about incidents being responsible for about half of the non-recurrent congestion, which is about half of total congestion.

Determining the effects that better incident management can have on CO₂ emissions is going to require finer-grain analysis than this. The first

part of the analysis requires better information than we currently have about the impacts that incidents are having on traffic, so that we can understand the quantitative relationship between the duration and extent of lane blockage (or visual distraction) and the upstream traffic volume as the inputs and the amount of extra traffic delay as the output. The second part of the analysis requires determining the relationship between improvements in incident information and the ability to shorten the duration of the incident. When these are combined, it becomes possible to model the potential savings in traffic delays, with concomitant savings in energy and CO₂ emissions.

D. Collision Warning and Avoidance Systems

Most of the research associated with collision warning and avoidance systems focuses on their safety benefits. These safety improvements can also help facilitate better traffic flow by eliminating crashes that produce non-recurrent congestion. As with the incident management strategies, two stages of analysis will be needed here – one to quantitatively determine the severity of the congestion problems that are currently being caused by crashes, and the second to determine how many of these crashes could have been avoided by use of collision warning and avoidance systems.

In most parts of the U.S., the estimates of congestion attributable to crashes are extremely coarse approximations, based on very little real data. There have been a few attempts to allocate non-recurrent congestion to specific causes such as crashes [12], but these require a great deal of work, beginning with access to detailed databases of traffic conditions and incident responder logs. Much more work will be needed to develop definitive data about this for a range of diverse environments around the U.S.

E. Automated Highway Systems

By fully automating the driving of vehicles, an automated highway system (AHS) can eliminate the human sources of variability in driving behavior and crashes. Vehicle speed profiles can be smoothed out, stop-and-go congestion and idling can be eliminated and aerodynamic drag can be reduced by driving the vehicles in close-

formation platoons, offering the potential for significant efficiency improvements.

AHS also offers the possibility to substantially increase the capacity of each highway lane, by a factor of as much as two or three [13]. While this can help greatly in avoiding congestion problems and smoothing traffic flow, it raises the prospect that this increase in capacity and ease of travel will induce more people to travel longer distances. That concern about stimulating additional travel demand has become an important political challenge that needs attention not only for AHS, but for all of ITS.

VI. INDUCED AND LATENT DEMAND

Transportation planners have long been concerned about the problem that new highway construction projects have rarely if ever produced the congestion reductions that were expected. Rather, the availability of the new highway capacity has stimulated additional travel, until the new infrastructure suffered as much congestion as there was before. There has been an unfortunate tendency to extrapolate from that experience to assume that ANY transportation system improvement that improves traffic flow or increases the effective capacity of the roadway system will suffer the same fate. This needs to be examined more carefully and critically. It is particularly important to draw a distinction between latent demand and induced demand.

Latent demand is a relatively short-term phenomenon that derives from the fact that people are often deterred from making trips that they would like to take because of the cost of those trips (out-of-pocket and/or time cost). If the cost of the trips is reduced, the deterrent to travel is diminished and more travel occurs. In this case, if the benefit to the traveler exceeds the cost, the trip is taken. It is reasonable to assume that if the ITS operational improvements to the transportation system reduce travel delays or costs, some travelers will travel more. The big unknown here is the demand elasticity – for each percentage reduction in travel cost, by what percentage will travel grow? Serious research is needed on this topic, to develop robust answers that represent the diversity of traveling conditions around the

country, based on real data for a variety of ITS applications. As long as the elasticity remains less than one, which it should be according to economic theory, the improvements in transportation efficiency will exceed the growth in travel, leading to a net saving.

Induced demand is a separate long-term phenomenon associated with the interaction between transportation and land use. When a new transportation facility or an expansion to an existing facility improves access to a location, that location becomes more attractive for commercial or residential development. If the transportation development is not coordinated with local land use planning and zoning, there is a risk of producing uncontrolled sprawl development, which is inefficient and has adverse long term implications for CO₂ emissions.

The locational changes associated with induced demand require substantial investments by real estate developers over the long term, which can only be justified based on large and definitive changes in accessibility. It is hard to imagine that these kinds of investments would be stimulated by ITS operational improvements, which are typically incremental in scale and have relatively subtle effects on the transportation system when taken individually. The one ITS application for which induced demand is a real concern is AHS because of its dramatic potential for capacity increase. Planning for AHS deployment will need to be done in close coordination with local land-use planning and zoning in order to proactively ensure that sprawl development is not stimulated.

VII. CONCLUDING REMARKS

Intelligent transportation systems contain such a wide variety of applications that they have to be evaluated using diverse approaches. No single modeling or prediction approach can be used to predict the contributions that ITS can make toward reducing transportation's production of CO₂.

Development of the underlying data and models needed to predict the ITS impacts on CO₂ appears to be one of the most critical research needs in support of efforts to enable ITS to reduce CO₂ emissions. This fundamental knowledge is needed in order to prioritize ITS deployments based on

their CO2 impacts and to gain broader support for ITS relative to more traditional transportation alternatives.

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Appendix B

Agendas and Minutes of International Workshops Organized by
Japan's Energy ITS Program

C.1 Tokyo, February 26-27, 2009

International Workshop on Energy ITS -Autonomous Driving

Date and time: February 26, 2009, 13:30-17:40
Venue: Tokyo International Exchange Center, Plaza HEISEI Conference Room 1
Sponsored by: JARI, ITS Japan

Program (tentative)

Moderator: Sadayuki Tsugawa (Meijo University)

13:30-13:40 Welcome Address
Terunobu Yamauchi (METI)
Juhani Jaaskelainen (EC DG INFSO)

13:40-15:40 Session 1 "Current Technologies and their Issues of Autonomous Driving"
15 minutes * 5 =75 minutes for presentation from panelists and 45 minutes for discussion
Panelists Keiji Aoki (JARI)
Niels J. Schouten (TNO)
Reiner Hoeger (Continental Automotive)
Umit Ozguner (The Ohio State University)
Steven Shladover (California PATH)

15:40-16:10 Break

16:10-17:40 Session 2 "Issues on Introduction and Deployment of Autonomous Driving"
15 minutes * 4 =60 minutes for presentation from panelists and 30 minutes for discussion
Panelists: Shoichi Washino (Tottori University of Environmental Studies)
Arnaud de La Fortelle (INRIA)
James Misener (California PATH)
Matthew J. Barth (University of California, Riverside)

17:40 Adjourn

18:00 Reception

***International Workshop on Energy ITS
Autonomous Driving***

Thursday 26th February, 2009

1:30 pm to 5:40 pm

Conference Room 1, Plaza Heisei, Tokyo International Exchange Center

Tokyo Academic Park, 2-79 Aomi, Koto-ku,

Tokyo Japan 135-8630

Attendees

Moderator

Dr. Sadayuki Tsugawa-Meijo University

EU

Mr. Juhani Jaaskelainen –European Commission, DG INFSO

Mr. Niels J. Schouten -TNO Science and Industry

Mr. Koichi Kawaguchi-TNO Automotive Japan

Dr. Reiner Hoeger-Continental Automotive GmbH

Dr. Arnaud de La Fortelle-INRIA

Mr. Thomas Benz-PTV

Mr. Jochen Feese-Daimler AG

Dr. Joerg Breuer-Daimler AG

Mr. Matthias Schulze-Daimler AG

America

Prof. Umit Ozguner-The Ohio State University

Mr. Steven Shladover-California PATH

Mr. James Misener-California PATH

Prof. Matthew J. Barth-University of California, Riverside

Japan

Mr. Terunobu Yamauchi-Ministry of Economy, Trade and Industry

Mr. Toshiyuki Nawata-Ministry of Economy, Trade and Industry

Mr. Shoichi Washino-Tottori University of Environmental Studies

Mr. Keiji Aoki-Japan Automobile Research Institute, ITS Center

Mr. Hiroyoshi Suzuki- Japan Automobile Research Institute, ITS Center

Mr. Kaoru Seki- Japan Automobile Research Institute, ITS Center

International Workshop on Energy ITS - Evaluation of CO2 emission from traffic flow
AGENDA

Date: 27th February 2009
Time: 13:00-17:00
Place: Tokyo International Exchange Center
Plaza HEISEI Conference Room 1

- | | |
|-------------------------------------------------------------------------------------------------|------------------------|
| [Session 1] | 13:00~15:00 |
| 1. Opening address (Mr. T. Yamauchi METI) | 13:00~13:05 |
| 2. Activities in Energy-ITS, a NEDO project, in Japan | 13:05~14:40 |
| (1) Outline of the project. (Prof. M. Kuwahara) | 13:05~13:10 |
| (2) Hybrid traffic simulation framework. (Dr. R. Horiguchi) | 10~15 min each |
| (3) Monitoring CO2 emission using probe data. (Dr. R. Horiguchi) | <i>I-Transport Lab</i> |
| (4) Modeling of CO2 emission model. (Mr. H. Hirai) | |
| (5) International Traffic Database. (Dr. M. Miska) | |
| (6) Validation scheme. (Prof. T. Oguchi) <i>-Tokyo Metro Univ. & IIS</i> | |
| (7) Inviting comments from EU and US. | 14:20~14:40 |
| 3. Presentation from US side (Mr. Matthew J. Barth) | 14:40~15:00 |
| [Coffee break] | 15:00~15:20 |
| [Session 2] | 15:20~17:00 |
| 4. Presentations from European side (Mr. Jean-Pierre Medevielle) | 15:20~15:50 |
| 5. Intensive discussion on the international collaboration scheme
(Chair: Prof. M. Kuwahara) | 15:50~17:00 |
| 6. Closing (Prof. M. Kuwahara) | |
| [Reception] | 18:00~ |

International Workshop on Energy ITS
Evaluation of CO2 emission from traffic flow
Friday 27th February, 2009
1 pm to 5 pm

Conference Room 1, Plaza Heisei, Tokyo International Exchange Center
Tokyo Academic Park, 2-79 Aomi, Koto-ku,
Tokyo Japan 135-8630

Attendees

Moderator

Prof. Masao Kuwahara-Tokyo University

EU

Mr. Juhani Jaaskelainen -Deputy Head of Unit, ICT for Transport EC

Prof. Jean-Pierre Medevielle-INRETS

Mr. Nour-Eddin EL Faouzi-INRETS

Mr. Frans op de Beek-TNO

Mr. Thomas Benz-PTV

America

Prof. Matthew J. Barth-University of California Riverside

Mr. Steven Shladover-California PATH

Mr. James Misener-California PATH

Japan

Mr. Terunobu Yamauchi-Ministry of Economy, Trade and Industry

Mr. Toshiyuki Nawata-Ministry of Economy, Trade and Industry

Mr. Ryota Horiguchi - i-Transport Lab. Co. Ltd

Mr. Hisatomo Hanabusa - i-Transport Lab. Co. Ltd

Dr. Marc Miska-Tokyo University

Mr. Hong Sungjoon-Tokyo University

Prof. Takashi Oguchi-Tokyo Metropolitan University

Mr. Hiroshi Warita-Metropolitan Expressway Co. Ltd

Mr. Hiroshi Hirai-Japan Automobile Research Institute

C.2 Stockholm, September 2009

Minutes, The 2nd International Workshop on Energy/ CO2 ITS

Date and Time: 25. Sep. 2009, 10:00-13:30

Venue: Meeting Room in Rica Talk Hotel beside the ITS World Congress #16 site
Stockholm, Sweden

Attendees:

From EUR;

Mr. J. Jaaskelainen, Ms. E. Boethius, Dr. E. Davila, Dr. T. Benz, Dr. S. Turksma,
Dr. R. Höger

From JPN;

Mr. T. Nawata, Mr. M. Yamagishi, Dr. M. Kuwahara, Dr. R. Horiguchi,
Mr. H. Hanabusa, Mr. H. Hirai, Dr. H. Oneyama, Dr. S. Tanaka, Dr. M. Miska,
Dr. S. Tsugawa, Mr. Mr. Y. Morita, Mr. K. Seki, Mr. Y. Suzuki, M. Yonezawa

From US;

Mr. J. Misener, Dr. S. Shladover

Discussion Results;

1. "Evaluation of CO2 Emissions from Traffic Flow" Session, 10:00-12:25

Adding to the below listed 10 research results' sharing, these points were agreed.

- Representatives of EU and JPN teams are Mr. Juhani Jaaskelainen of EC and Mr. Toshiyuki Nawata of METI. For the efficient communication among the collaborators, each team has to define a contact person shortly. For JPN side, Mr. Mitsuo. Yonezawa of JARI is the contact person.

- The six sub-topics listed below were re-confirmed and EU agreed to define the counter body and the responsible person for each of the sub-topics.

- The joint study team for each sub-topic will make a detailed research plan and exchanging progresses individually.

- All the relevant information should be disseminated also to US colleagues.

- The next workshop is to be held in Mar 2010. Venue should be Amsterdam or Tokyo
Shared 10 research results;

From JPN, the six sub-topics;

(1) ITS Applications by Dr. R. Horiguchi

(2) Traffic Simulation Modeling by Mr. H. Hanabusa

(3) Emission Modeling by Mr. H. Hirai

- (4) Probe Monitoring System by Dr. H. Oneyama
- (5) Validation Methodology by Dr. S. Tanaka
- (6) International Data Warehouse by Dr. M. Miska

From EUR;

- (1) ICT for Energy Efficiency by Dr. E. Davila
- (2) C2X by Dr. T. Benz
- (3) Energy efficient freight in controlled networks by Dr. S. Turksma

From US;

Green ITS Projects: A California Sample by Mr. J. Misener

2. "Automated Driving" Session, 12:30-13:30

- The below listed 3 research results were shared.

From JPN;

A Study on Inter-vehicle Communication for Truck Platooning by Mr. K. Seki

From EUR;

HAVEit: Driver Centric and Context-sensitive Automation to Enhance Safety and Improve Fuel Efficiency by Dr. R. Höger

From US;

Development and Evaluation of Selected Mobility Applications for VII
by Dr. S. Shladover

- Plans of experiments and demonstrations of automated trucks, and future workshops on automated driving were presented by Dr. S. Tsugawa. And, JPN, EU, and US agreed to have a workshop around ITS World Congress each year.

- EUR team made a proposal to JPN team to have a workshop in Mar 2010 along with "Evaluation of CO2 Emissions from Traffic Flow" workshop. Then, JPN team is to answer to accept it or not later, with clarifying the discussion points in Mar 2010.

C3. Amsterdam, March 2010

ITS on Energy Efficiency and CO2 Emission of Transport International Work-shop

RAI Convention Centre, Amsterdam
Room G107

DRAFT AGENDA

- Chair: *Mr W. Hoefs, EC and Prof. M. Kuwahara for METI*
- 09:30 Welcome and introduction of the participants
Mr W. Hoefs, EC and Prof. M. Kuwahara for METI
- 10.00 Status of the co-operation agreement including next steps and potential collaborative research
Mr W. Hoefs, Prof. M. Kuwahara
- 10:30 Introduction of each sub-topic's and the key points to be discussed
Mr W. Hoefs, EC and Prof. M. Kuwahara for METI
- Sub-topic 1, ITS Applications and Reference Models
 - Sub-topic 2, Traffic Simulation
 - Sub-topic 3, CO2 Emission Modelling
 - Sub-topic 4, Monitoring Using Probe Vehicles
 - Sub-topic 5, Validation Methodology
 - Sub-topic 6, International Traffic Database
- 12:30 *Lunch break*
- 13:15 Status of current actions in Europe on Energy Efficiency for Transport
Mr W. Hoefs and experts
- 13.45 Automated Driving: Status Update and Key Points Review
Mr W. Hoefs, EC, Prof. S. Tsugawa for METI, Mr Steven Shladover California PATH
- 14:30 Status of current actions in Japan on Energy Efficiency for Transport
Prof. S. Tsugawa for METI and experts
- 15:00 *Coffee Break*

- 15:15 Status of current actions and energy related projects in US on Energy Efficiency for Transport
Mr Steven Shladover
- 15:45 Conclusions, A.O.B, next meeting
- 16:00 End of the meeting

EC-METI Work-shop 23. Mar. 2010, Amsterdam

Participants from European Union

Mr. Wolfgang Hoefs, European Commission

Ms. Eva Boethius, European Commission

Mr. Wil Botman, FIA

Mrs. Siebe Turksma, Peek Traffic

Mr. Thomas Benz, PTV

Mr. Gino Franco, MIZAR

Mr. Jean-Charles Pandazis, ERTICO

Mr. Paul Kompfner, ERTICO

Mr. Nour-Eddin EL FAOUZI, INRETS

Mr. Frans op der Beek, TNO

Mr. Martijn de Kievit, TNO

Participants from Japan:

For “Evaluation of CO2 Emissions from Traffic Flow”

Prof. Masao Kuwahara, University of Tokyo

Mr. Marc Miska, University of Tokyo

Mr. Ryota Horiguchi, i-Transport Lab. Co., Ltd. (itl)

Mr. Hiroshi Hirai, Japan Automobile Research Institute (JARI)

Mr. Mitsuo Yonezawa, Japan Automobile Research Institute (JARI)

Mr. Seiji Hayashi, Japan Automobile Research Institute (JARI)

For “Automated Driving”

Prof. Sadayuki Tsugawa, Meijo University

Mr. Keiji Aoki, Japan Automobile Research Institute (JARI)

Mr. Hiroyoshi Suzuki, Japan Automobile Research Institute (JARI)

Mr. Shin Kato, Advanced Industrial Science & Technology (AIST)

Mr. Hidehiko Akatsuka, DENSO

Participants from the United States:

Mr. Jim Misener, California PATH

Mr. Steven Shladover, California PATH

Mr. Ryan D. Lamm, Southwest Research Institute

<Virtual> Ms. Marcia Pincus, the US DOT (ITS-JPO)

C4. Tokyo, October 22, 2010



11:00 - 11:05h

Opening

Dr. M. Kuwahara, University of Tokyo

11:05 - 12:00h

Statement of political goals from Europe, the United States and Japan

Dr. R. Bertini (USA), Mr. J. Jääskeläinen (EC), Mr. Tsujimoto (JPN)

12:00 - 12:45h

Keynote speech on Emission modeling

Dr. M. J. Barth, University of California Riverside

12:45 - 14:00

Lunch break

14:00 - 14:05h

Task force activities overview

Mr. M. Yonezawa, Japan Automobile Research Institute

14:05 - 15:35h

Task force results

1. ITS Applications (W.-B. Zhang, California PATH, USA)
2. Traffic Simulation Modeling (R. Horiguchi, i-Transport Lab, JPN)
3. Emission Modeling (H. Hirai, Japan Automobile Research Institute)
4. Probe Monitoring System (N.-E. El Faouzi, INRETS – ENTPE,

France)

5. Validation Methodology (S. Tanaka, University of Tokyo)

6. International Data Warehouse (M. Miska, University of Tokyo)

15:35 - 16:00h

Coffee break

16:00 - 17:00h

Key activity outlook from Europe and the United States
Mr. Beek (ECOSTAND), Ms. Pincus (AERIS), Mr. Cronin

(IntelliDrive)

17:00 - 17:45h

Panel discussion

Dr. Bertini, Dr. Shladover (USA), Mr. Jääskeläinen, Mr. Beek (EC), Dr.

Oguchi (JP)

17:45 - 18:00h

Closing

(Dr. M. Kuwahara)

C5. Busan, Korea, October 28, 2010

ITS on Energy Efficiency and CO2 Emission of Transport

International Work-shop

28th October 2010, from 10 am to 4 pm

Meeting Room in Seacloud Hotel, Busan

AGENDA

Chair: ***Prof. M. Kuwahara, University of Tokyo***

10:00 Welcome and introduction of the participants
Prof. M. Kuwahara, University of Tokyo

10:10 Reflections from Symposium
Mr. M. Yonezawa, JARI

10:20 Comments on Symposium and Workshop
Mr. T. Yamashita, METI
Mr. J. Jaaskelainen, EC
Dr. R. Bertini, US-DOT (RITA)

10:50 Introduction of each sub-topic's status and discussion of its key points
Chief researchers from each region (See the attached) and the other attendees

- Sub-topic 1: ITS Applications and Reference Models
- Sub-topic 2: Traffic Simulation
- Sub-topic 4: Monitoring Using Probe Vehicles

12:30 *Lunch break*

13:30 Introduction of each sub-topic's status and discussion of its key points
Chief researchers from each region (See the attached) and the other attendees

- Sub-topic 3: CO2 Emission Modelling
- Sub-topic 5: Validation Methodology
- Sub-topic 6: International Traffic Database

15:30 Summary of each sub-topic's discussion results and its next step
Dr. M. Miska, University of Tokyo

- 15:50 Confirmation of next workshop's date and venue
Mr. M. Yonezawa, JARI
- 15:55 Conclusions
Prof. M. Kuwahara, University of Tokyo
- 16:00 End of the meeting

4th Energy ITS Workshop, 28 October 2010, Seacloud Hotel, Bussan

Participants

Robert Bertini	<i>US DOT</i>	Marc Miska	<i>University of Tokyo</i>
Steven Shladover	<i>PATH</i>	Babak Mehran	<i>University of Tokyo</i>
Wei-Bin Zhang	<i>UC Berkeley/PATH</i>	Ryota Horiguchi	<i>ITL</i>
Jim Misener	<i>Booz Allen Hamilton</i>	Hisatomo Hanabusa	<i>ITL</i>
Thomas Benz	<i>PTV</i>	Mitsuo Yonezawa	<i>JARI</i>
Martijn De Kievit	<i>TNO</i>	Hirai Hiroshi	<i>JARI</i>
Masao Kuwahara	<i>University of Tokyo</i>	Seiji Hayashi	<i>JARI</i>
Takashi Oguchi	<i>University of Tokyo</i>	Shuichi Kanari	<i>JARI</i>
Shinji Tanaka	<i>University of Tokyo</i>	Tsuyoshi Yamashita	<i>METI</i>

Observers

Masanori Hayashi	<i>ITS Japan</i>	Koichi Sakai	<i>NILIM</i>
Nobukazu Kanesaki	<i>ITS Japan</i>		

Sub-Topic 1: ITS Applications and Reference Models

Ryota Horiguchi

1. The US will provide a list of ITS energy saving measures and share the findings with Japan and EU by the end of December 2010.
2. Comparing the list items, maximum of 2 or 3 high-priority common ITS applications are selected by the end of March 2011.
3. For the selected ITS applications, Japan drafts the preliminary version of the reference models and sends it to the US and EU for their comments. Revisions and feedbacks to the comments will be provided in the next workshop from Japan side.

Colleagues in charge:

JP	Ryota Horiguchi
EU	Martijn de Kievit, Thomas Bentz
US	Robert Bertini, Wei-Bin Zang

Sub-Topic 2: Traffic Simulation

Ryota Horiguchi

1. Japan is going to challenge combining different TS and EM models and clarify the technical issues by the end of March 2011 which complements the efforts made by the

US and EU.

2. Meanwhile the US and EU summarize the technical challenges and supporting discussions regarding their selected combination of TS and EM models by the next workshop.

Colleagues in charge:

JP Ryota Horiguchi
EU Martijn de Kievit, Thomas Bentz
US To be defined

Sub-Topic 3: CO₂ Emission Modeling

Hiroshi Hirai

1. The Meso-scale model which is under development is to be improved considering acceptable ranges for the confidence limits of the outputs.
2. Vehicle categories in the Japanese market are defined based on VMT (Vehicle Mile of Travel) and shared with the US and EU for their comments by the end of January 2011.
3. Considering the feedbacks, the vehicle category list is finalized and it will be presented in the next workshop.

Colleagues in charge:

JP Hiroshi Hirai
EU To be defined
US Matthew Barth

Sub-Topic 4: Probe Monitoring

Ryota Horiguchi

1. Probe data collection approaches in Japan, US and EU are to be summarized.
2. The landscapes regarding the traffic monitoring using various data sources (including probe data) in Japan, US and EU is to be created.

Colleagues in charge:

JP Ryota Horiguchi
EU Nur-Eddin El Faouzi
US Robert Bertini

Sub-Topic 5: Validation

Shinji Tanaka

1. It is agreed to make a common framework of the validation process which is applicable to different models to estimate traffic flow and CO₂ emission.
2. The Existing Standard Verification Manual prepared by JSTE (Japan Society of Traffic Engineers) in 2002 will be sent to the US and EU. Although this manual focuses only on the traffic model but it could be a base for the validation framework.
3. Validation items should depend on ITS applications. Draft matrix of ITS applications and validation items is to be shared between Japan, US and EU.
4. Japan will draft the preliminary validation process and distribute it to EU and US to get their feedbacks.
5. For the validation purpose, MOVES database which is maintained by Prof. Barth at UCR can be used. It is expected that some applicable data sets is provided by EU in the near future. Japan will also provide its own datasets.

Colleagues in charge:

JP Shinji Tanaka
EU Martijn de Kievit
US Wei-Bin Zhang

Sub-Topic 6: International Traffic Database

Marc Miska

1. Benchmark data are to be uploaded into database.
2. Feasibility of further expansions and sustainability of ITDb are to be evaluated.

Colleagues in charge:

JP Marc Miska and Babak Mehran

Other Tasks

1. US DOT will inform Japan and EU about the corresponding members for each of the six sub-topics.
2. EU will update the corresponding member list for each sub-topic.

Next Workshop

1 July 2011, Vienna

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