Center for Transportation Research
The University of Texas at Austin

Project Summary Report 4197-S
Project 0-4197: Environmental Benefits of Intelligent Transportation Systems (ITS)
Authors: Tejas Mehta, Amulya Kottapalli, Hani S. Mahmassani, Chandra Bhat
January 2003

PROJECT SUMMARY REPORT

Intelligent Transportation Systems and the Environment

Introduction...

Air pollution results from two major sources: (1) stationary sources such as factories, industrial units, and power plants, and (2) mobile sources such as cars, trucks, and buses. The mobile sources, or the transportation sector, have been a major source of air pollution. The challenge now lies in improving the quality of the air we breathe without adversely affecting the mobility of the nation. Hence, it is important to explore transportation options that may result in potential air quality benefits. Intelligent Transportation Systems (ITS) constitute one such class of strategies that could have significant air quality benefits. Quantification of these benefits is therefore an important part of any ITS assessment effort and decision-making in the context of ITS deployment.

What We Did...

Initially, existing methods available in practice were reviewed to assess approaches and findings that may be immediately applicable in metropolitan areas to readily predict the impact of different ITS strategies, especially those that rely on provision of information to users. However, the assessment revealed that these impacts are highly specific to prevailing conditions in the particular network where they are applied. In other words, findings from previous studies are not readily transferable to other cities. Therefore a methodology is needed to perform specific case-by-case evaluations of the impact of particular ITS measures contemplated in a specific network.

This study set out to develop a framework to compare static and dynamic network modeling approaches in combination with modal emission models and EPA's MOBILE 5, to assess impacts of ITS strategies on mobile source emissions. A number of modeling tools and procedures are required to implement such a framework. In this study, DYNASMART-P, a network modeling and simulation tool was used for modeling traffic dynamics in the network. This tool was also used in this study for quasi-static modeling in order to provide a consistent platform for comparison. Modal emission models for light-duty vehicles based on emissions data from Oak Ridge National Laboratory (ORNL) are incorporated within the DYNASMART-P simulation framework. For heavy-duty vehicles, ONROAD models developed at Texas Southern University are used. In addition, EPA approved MOBILE 5 is also interfaced with DYNASMART-P for additional analysis.

This framework was then tested on a portion of the Fort Worth network and a portion of the Houston network. The potential of information-based ITS strategies like Variable Message Signs (VMS) and provision of in-vehicle information, is investigated for mitigating non-recurrent congestion resulting from an incident on a freeway corridor. The impact is studied by looking at the network wide as well as localized CO, HC and NOx emissions. VMS and in-vehicle information are selected as the target ITS strategies as they are among the easiest to deploy.

What We Found...

In general, ITS strategies do seem to have potential for reducing emissions levels. Table 1 provides the impacts of ITS strategies on a portion of the Fort Worth network surrounding the location of the incident. It is observed that the benefits of VMS are significant at the local level and not very substantial at the network level. In-vehicle information on the other hand, suggests mixed trends in benefits at the local and the network levels. This is expected because users with vehicle information are informed about the prevailing conditions well in advance and are thus diverted to alternate uncongested routes; the emissions on these routes may increase, offsetting the benefits around the location of the incident.

As market penetration and response rates for ITS technologies increase, the emissions start to decrease until a certain level, after which they start increasing again. The optimum level is found to be somewhere around 20-30%. A possible explanation for this is that as the market penetration increases, the diversion rates also increase and the alternate routes become more congested which may result in reduced emission benefits.

When heavy-duty vehicles are included in the analysis, it is seen that when the proportion of trucks is 2%, in-vehicle information remains an effective strategy at the local level, while VMS does not seem to have significant benefits. This may be because acceleration was not found to be a significant explanatory variable for the CO and HC emission models used for heavy-duty vehicles, and therefore smoothing of traffic flow as a result of VMS might not be adequately reflected. When the truck proportion is increased to 5%, there is a substantial increase in emissions at both local and network level and ITS strategies do not appear to be effective. However, it should be noted that the truck proportion of 2% is more realistic and 5% is on the higher side. Also, trucks are unlikely to form a high proportion of the vehicle fleet during peak hours when maximum congestion occurs.

Finally, the above observations and conclusions cannot be generalized to all the networks. The implementation of various ITS strategies needs to be performed specific to the network and the incident location. The complex nature of the pollutant emissions needs to be recognized while applying these strategies and any generalization may lead to overestimation of their benefits in some networks.

The Researchers Recommend...

Guidelines for Selecting Modeling Approach

Both network modeling and emission modeling approaches employed are crucial factors in evaluating the impacts of ITS strategies.

Table 1: Localized impacts of ITS strategies in Fort Worth network

Scenario	CO (kg/hr)	HC (kg/hr)	NOx (kg/hr)
Base Case	62.95	3.94	5.61
Incident (50% severity)	100.93 (60.33%)	6.44 (63.29%)	5.77 (2.76%)
In-Vehicle Info (30%)	61.56 (-39.01%)	3.98 (-38.18%)	5.60 (-2.84%)
VMS (30%)	84.00 (-16.77%)	5.44 (-15.58%)	5.67 (-1.73%)

* The use of modal emission models within a dynamic network modeling methodology generally results in estimates of impacts that are logically consistent with our expectations.

* Static network modeling approaches generally tend to underestimate CO and HC emissions while overestimating the NOx emission estimates. Therefore caution has to be exercised while using static modeling approaches.

* Modal emission modeling, being more receptive to vehicle operating modes, is theoretically superior to MOBILE 5/6 based approaches, but the modal emission model needs to be calibrated properly to ensure consistent results. Presently MOBILE 5/6 (EMFAC for California) are the only EPA approved approaches for performing emission inventory analysis.

* MOBILE based approaches are also more sensitive to the network modeling approach used and therefore network modeling approach becomes an important consideration when using MOBILE 5/6.

* When analyzing impacts of VMS on CO and HC emissions using dynamic network modeling results as an input to MOBILE 5, the aggregation interval is an important consideration. Using a finer temporal resolution is recommended as it results in emission estimates that are closer to level four estimates. As the averaging interval becomes coarser, the benefits of VMS are not adequately captured.

* When evaluating impacts of VMS and in-vehicle information, it is advisable to examine the results the affected (localized) sub-area, which usually results in more meaningful impact estimates than consideration of network-wide impacts.

* When evaluating impacts of in-vehicle information, static modeling approaches should be avoided, as these approaches fail to capture the impacts adequately.

Future Research...

This study took a first step towards presenting an integrated framework for assessing the impact of ITS strategies on mobile source emissions. A number of recommendations can be made for future research in this direction. First, comprehensive modal emission model should be developed based on emission testing data from a large sample of vehicles that is representative of the current vehicle fleet. Such a sample should also include heavy-duty and diesel vehicles. Procedures should also be developed to model emissions in the cold-start mode and not just in the hot transient mode. Other factors like ambient temperature, roadway grades, should also be included as explanatory variables in the modal emission model.

In terms of network modeling, the validity of uniform acceleration assumption should be tested and various other functional forms for acceleration should be explored. The network representation can also be enhanced to include detailed information like roadway grades and ambient temperature. The widespread use of Geographic Information Systems (GIS) can facilitate such a task.

In this study the ITS strategies were examined in isolation. Further studies may be conducted to analyze the impact of deploying these strategies simultaneously. Additionally, strategies for relieving congestion on arterials and frontage roads, such as signal coordination should also be analyzed in combination with the ITS strategies included in this study.

For More Details...

Research Supervisor: Hani S. Mahmassani, phone: (301) 405-0752
email: masmah@wam.umd.edu

TxDOT Project Director: Bill Knowles, P.E., phone: (512) 465-7648
email: wknowle@dot.state.tx.us

The research is documented in the following reports:

Report 4197-1, *Methodologies for Evaluating Environmental Benefits of Intelligent Transportation Systems,* December, 2001

Report 4197-2, *Immediately Applicable Methods for Evaluating Environmental Impacts of Intelligent Transportation Systems (ITS),* June, 2002

Report 4197-3, *Assessing the Environmental Benefits of Intelligent Transportation Systems Measures: Methodologies and Applications,* January, 2003

To obtain copies of a report: CTR Library, Center for Transportation Research,
(512) 232-3138, email: ctrlib@uts.cc.utexas.edu

TxDOT Implementation Status
December 2003

The research investigated the mobile source emission benefit of Intelligent Transportation Systems (ITS). The research has laid a foundation for further investigation into ITS air quality benefits while providing improved modeling tools. The research has provided new analysis techniques for enhancing air quality conformity determinations.

For more information, please contact Bill Knowles, P.E., Research and Technology Implementation Office, at (512) 465-7648 or email at wknowle@dot.state.tx.us.

Your Involvement Is Welcome!

Disclaimer

Center for Transportation Research
The University of Texas at Austin

The University of Texas at Austin
Center for Transportation Research Library
3208 Red River, Suite #115
Austin, TX 78705-2650