Guidelines on Integrating Environmental Impact Evaluation in Future ITS Deployment Studies

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1. Overview

The transportation sector, being a major source of air pollution, can play a very important role in improving air quality. The challenge lies in improving the quality of the air we breathe without adversely affecting the mobility of the nation.

In this context, it is important to explore transportation options that may result in potential air quality benefits. Intelligent Transportation Systems (ITS) technologies and operational concepts are increasingly being considered an integral element for improving transportation system operations. Recently, interest has also focused on investigating the emissions implications of various ITS interventions/deployments.

Network performance parameters and total emissions are, in principle, correlated. Poor traffic performance on a network with long queues and delays is typically associated with increased vehicle emissions. Conversely, a better traffic performance on a road network normally results in lower emissions. However, evaluation of air quality, in general, is a complex process. Evaluation of air quality benefits of ITS is further compounded by the fact that deployment of most ITS strategies has been relatively recent, and is largely still in its initial stages.

1.1 This Document

This document proposes general guidelines for integrating environmental impact evaluation in future ITS deployment studies. These guidelines are intended to assist parties undertaking future studies of ITS deployment plans to build environmental impact measures in their studies. The guidelines identify the kinds of analyses, operational indicators and proxies, and direct environmental measures (pre- and post-deployment) that would be recommended in the context of prototypical ITS deployments.

This “Guidelines Document” is to be seen as “work in progress” that needs to be updated as new approaches are developed to undertake environmental impact evaluation of ITS deployments, and as more experience is gained from evaluations in ongoing deployments.

1.2 ITS and Emissions

Advanced Traffic Management Systems (ATMS), Advanced Traveler Information Systems (ATIS), and Advanced Public Transportation Systems (APTS) represent ITS technologies that are under deployment. Deployment of ITS is likely to provide air quality benefits due to improved traffic flow and mitigation of congestion. To better understand expected air quality benefits of specific ITS deployments, the relation between ITS technologies and emission-producing activities needs to be clarified.

ATMS strategies can be broadly classified into strategies such as signal optimization and ramp metering, which are aimed at reducing recurrent congestion, and strategies like incident detection and rapid accident response, which are aimed at reducing non-recurrent congestion.

The traffic operational attributes/improvements that are most likely to be impacted by ITS technologies are the following:

Operating Speeds – ATMS, including incident management, are expected to result in improved traffic flow and reduced congestion, that are typically translated into improved operating speeds. For the most part, such improvements in operating speeds translate into reduced emissions in the urban road network. This point is discussed further later in this document.

Vehicle Kilometers Traveled - The primary impact of ITS technologies on vehicle kilometers traveled (VKT) is positive in nature, with better traveler information likely to result in drivers making informed trip decisions in terms of route selection. Nevertheless, the overall impact of information-related ITS technologies on vehicle kilometers traveled (VKT) can be mixed, since additional vehicle trips may be undertaken with improved capacity and travel speeds resulting from advanced traffic management.

Engine Idling - ATMS are likely to reduce delays at intersections. In addition, better information may reduce time spent in congested traffic conditions, thus reducing engine idling.

2. Prototypical ITS Deployments

In this “Guidelines Document”, specific ITS deployments were identified and are considered as prototypical for the purposes of illustrating approaches for integrating environmental impact evaluation in future ITS deployment studies.

The prototypical ITS deployments that were selected fall within the following three main User Services Bundles in the Canadian ITS Architecture:

Advanced Traffic Management

Incident management

Traveler Information

Pre-trip traveler information

Advanced Transit Systems

Transit signal priority

3. Relevant Operational Indicators

In evaluating emissions impacts of ITS deployments, there is need to identify specific transport operational improvements that are most indicative of such emissions impacts.

For each ITS deployment, the operational improvements that are most closely related to emissions implications need to identified. These are labeled as the "Relevant Operational Indicators" (ROI) and are relied on in further analysis.

Table 1 presents a summary of the Relevant Operational Indicators (ROI's) for the three prototypical ITS deployments identified earlier. The ROI's are based on the existing body of knowledge and reflect approaches typically used to estimate emissions implications of ITS.

The ROI's in Table 1 reflect the state-of-knowledge conclusion that environmental benefits assessment of ITS generally requires quantifying the vehicle activity parameters such as vehicle speeds, vehicle kilometers traveled (VKT), and/or vehicle hours traveled (VHT). Once these "operational indicators" are estimated for the before- and after-deployment cases, relative changes in emissions resulting from changes in these activity parameters may be estimated as well.

Next, and building on existing knowledge bases stemming from previous studies, the general relationships between operational improvements achieved through ITS strategies and the parameters that affect transport emissions (and air quality in general) are developed.

Table 1 – Relevant Operational Indicators for Prototypical ITS Deployments

ITS Deployment	**Anticipated Operational Impacts**	**Relevant Operational Indicator(s) (ROI)**[*]
Incident Management	• Reduction in incident duration • Reduction in secondary incidents • Reduction in delays	• Vehicle-kms of travel • Average operating speeds • Extent of idling delays[+]
Pre-Trip Traveler Information	• Reduction in Average Annual Daily Traffic (AADT)	• Vehicle-kms of travel
Transit Signal Priority	• Improvements in route travel times • Reduction in transit delays at intersections • Maintenance of service reliability	• Transit-vehicle-kms of travel[#] • Transit-vehicle idling delays[++]

(*) The ROI's should be estimated for a certain operating period (e.g. peak period) and for both before and after deployment

(+) Vehicle-minutes spent idling (in queue) due to intersection or incident delays;

(#) The after-deployment transit-vehicle-kms should reflect any reductions in transit vehicle requirements due to improved travel times

(++) Transit-vehicle-minutes spent idling due to intersection delays

3.1 ROI's for Prototypical ITS Deployments

Incident Management

Incident detection provides the responsible agency with the capacity to observe incident locations and subsequent congestion. This enables the agency to respond quickly, possibly based on pre-defined response plans, with likely reductions in incident duration. Further benefits are likely to accrue from subsequent reductions in secondary incidents resulting from the primary incident. The main relevant operational indicator (ROI) which is to be estimated/monitored is the extent of idling delays. Due to the expected reductions in incident duration and in secondary incidents based on the deployment of an incident management system (such as using video-based surveillance), a reduction in total incident-related idling delays would most likely be experienced. The change in this operational indicator should translate into reduced idling times and, subsequently, reduced idling pollutant emissions.

Due to re-routing and quicker incident clearance, an incident management program could also result in an improvement in operating speeds. The relevant operational indicators (ROI's) which are to be estimated/monitored include vehicle-kms of travel and average operating speeds. Changes in the traffic operating conditions could translate into modified vehicle-kms and improved operating speeds, with consequent changes in pollutant emissions.

Pre-Trip Traveler Information

The impact of information-related ITS technologies on trip-making can be mixed. While better information may result in drivers making informed trip decisions in terms of route selection, additional vehicle trips may be undertaken with improved capacity and travel speeds. Nevertheless, some studies have indicated that traveler information systems are likely to work in a way similar to demand management strategies, and this is expected to result in a reduction in Average Annual Daily Traffic (AADT). The main relevant operational indicator (ROI) which is to be estimated/monitored is the vehicle-kms of travel during the peak period, for instance, on roadway corridors covered by the pre-trip traveler information system. The change in this operational indicator, based on the deployment of pre-trip traveler information provision to the public, shall dictate the change in pollutant emissions.

Transit Signal Priority

Transit signal priority (TSP) is an operational strategy that facilitates the movement of transit vehicles through traffic-signal controlled intersections. Signal priority modifies the normal signal operation process to better accommodate transit vehicles. Implementing TSP is expected to result in reductions in transit travel times, transit delay, stops, and schedule unreliability[1]. The relevant operational indicators (ROI's) which are to be estimated/monitored include reduced transit vehicle idling delays at intersections, and,

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[1] Some studies have indicated that impacts to cross-street traffic and buses tend to be minor.

possibly, a reduction in fleet requirements[2] and transit vehicle-kms of travel. These changes in operational indicators should translate into reduced idling emissions; moreover, reductions in vehicle-kms for the transit fleet should translate into reduced pollutant emissions during travel.

3.2 General Relationships between ROI's and Emissions Implications

In general, total vehicular emissions on a roadway network (or any part thereof) result from moving vehicles and idling vehicles. These two components are typically computed as follows:

Mobile emissions = vehicle-kms of travel * mobile emission factor (gms/veh-km)

Idling emissions = vehicle-mins of queuing * idle emission factor (gms/veh-min)

It is to be noted that the (mobile) emission factor is a function of vehicular operating speed as well as fleet characteristics, while the idle emission factor is a function of fleet characteristics.

As such, the relation between relevant operational indicators (ROI's) above for the prototypical ITS deployments and emissions implications is summarized in Table 2 below.

A "direct relation" implies that a reduction in the ROI would imply in principle a similar, equivalent reduction in emissions. On the other hand, the emissions implication of a change in operating speed is not direct or clear-cut. Rather, emission factors for the main pollutants typically drop and then rise again with speed. While the absolute values of the emission factors depend on fleet characteristics (and other issues), Figure 1 presents typical variation in CO, HC, and NOx emission factors with speed.

Table 2 – General Relationships between ROI's and Emissions Implication

Relevant Operational Indicator (ROI)	Emissions Implication
Extent of idling delays (vehicle-mins of queuing)	Direct relation
Vehicle-kms of travel	Direct relation
Average operating speeds	Indirect relation – change in mobile emission factor

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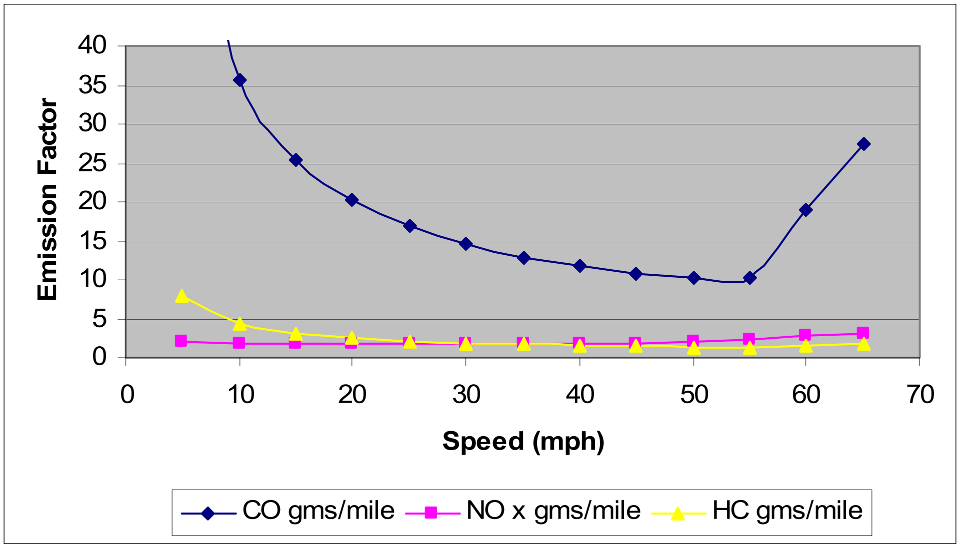
[2] Travel time reductions on certain routes may translate into lower fleet requirements.

Figure 1 – Typical Variation in Emission Factors with Operating Speed
Source***:*** *Estimating the Effects of Urban Transportation Alternatives*. Federal Highway Administration (FHWA), Dec. 1995.



4. Proposed Approaches

This "Guidelines Document" suggests alternative approaches for integrating environmental impact evaluation in future ITS deployment. The approaches reflect different levels of analysis sophistication that may be applied selectively, depending on the context and the technical capabilities of the agency undertaking the deployment exercise.

The concept of the ROI's is central to the Guidelines Document. The ROI's represent an attractive, simple concept that can be quickly grasped since it identifies specific tangible operational measures that are related to emissions impacts. These ROI's are considered as proxies for transport activities and operational measures that are indicative of emissions implications. In addition to the ROI's, three of the proposed approaches require the development of mobile and idle emission factors that can be used to estimate total emissions. Table 3 summarizes the approaches that are discussed in more detail below.

Table 3 – Proposed Approaches

Approach	Before/After ROI's	Emission Factors
1. Simplified/Sketch Planning	Estimated	Calculated
2. Simulation	Simulated	Calculated
3. Field - Level A	Measured in field	Calculated
4. Field - Level B	Measure emissions directly in field	

Development of Emission Factors

For estimating the levels of pollutants produced by traffic activities, *emission factor models* have been extensively used. Such models include the EPA's MOBILE series of models as well as the EMFAC model developed in California. Total emissions levels are typically computed based on link emission factors (function of link speed, in grams/vehicle-km) and vehicle-kilometers traveled per link. Alternatively, *modal emissions models* represent the relation between vehicle operating modes and emissions directly. For this purpose, emission-producing activities are modeled in detail.

Next, the EMFAC model developed by the California Air Resources Board (CARB) is described to illustrate the mechanics and inputs of prototypical emission factor models. Alternatively, MOBILE 5C/6C, the Canadian version of the U.S. EPA's MOBILE model, may be adopted to produce the required emission factors. A brief description of MOBILE 5C/6C is also presented below.

EMFAC (CARB 2002)

The EMFAC model generates emission factors in terms of grams of pollutant emitted per vehicle activity. Vehicle activity can be in terms of grams per mile or grams per hour, or grams per start, and depends on the emissions process. The emission factors depend on basic scenario data options for month or season. The model calculates a matrix of emission factors at specific values of temperature, relative humidity, and vehicle speed (idle and 1 mph to 65 mph) for each vehicle class/technology combination. The more important concepts/inputs needed in the EMFAC model are outlined below.

Vehicle fleet - "Vehicle fleet" refers to all the motor vehicles operating on roads. This fleet can be broken into 13 categories called classes (for example, class 1, passenger cars). These classes are based on the type of vehicle, but they also take weight class and fuel type (i.e. gas, diesel, or electric) into account. The number of vehicles in each class needs to be based on an analysis of motor vehicles registration data. The make-up of the vehicle fleet is dependent on the calendar year and geographic area.

Vehicle class - The EMFAC model can perform separate calculations for each of the thirteen classes of vehicles, by fuel usage and each technology group. Each vehicle class contains numerous technology groups, which represent common emissions characteristics such as emission standards, technologies, or in-use emissions.

Fuel - EMFAC estimates emissions from gasoline, diesel and electrically powered vehicles.

Technology group - The EMFAC model assumes that each vehicle class can be modeled by the individual behavior of unique technology groups. Each technology group represents vehicles from the same class but have distinct emission control technologies, have similar in-use deterioration rates, and respond the same to repair. A technology group can represent vehicles whose emissions standards are the same or those that have specific equipment installed on them (e.g., multi-port fuel injection, three-way catalyst, adaptive fuel controls, etc.) which makes them behave the same.

Model year - EMFAC contains emission factors and vehicle activity data for model years 1965 through 2040. Within each vehicle class, the model year is represented by a combination of technology groups.

Population - Vehicle population is typically determined through an analysis of vehicle registration data. These data are used in developing vehicle age matrices for specific base years for vehicle class, fuel type, geographic area, and vehicle ages 1 to 45 years.

MOBILE 5C/6C

MOBILE 5C/6C is a program adapted for use in Canada from the United States Environmental Protection Agency's MOBILE 5/6 Model. The program calculates emission factors for the purpose of developing national, provincial and regional emission inventories.

MOBILE 5C/6C produces estimated NOx, HC (VOC) and CO emission factors in grams per mile for on-road transportation sources from 1985 to 2020. These estimates are given by province for seven different classes of vehicles - light-duty vehicles, light-duty trucks and heavy-duty trucks (both gas and diesel); and motorcycles.

Average yearly emission factors account for the rate of emissions of new cars, the deterioration rate of vehicle stock (i.e. a rate in grams per mile which is a measure of the increase in emissions for each 10,000 miles of vehicle use), provincial driving habits and provincial climate and vehicle characteristics. The yearly average emission factor is a weighted average of four seasonal scenarios (winter, summer and two spring/fall scenarios) and two driving speeds (urban and highway).

Source: Environment Canada website http://www.ec.gc.ca

Approach 1 – Simplified/Sketch Planning

In this approach, ROI's may be estimated based on simplified/sketch planning techniques similar to SCRITS and IDAS. An overview of these two sketch planning tools for forecasting ITS impacts is provided below. The purpose of this overview is to provide examples of how such impacts are typically estimated.

SCRITS

SCRITS (SCReening for ITS) is a "spreadsheet analysis tool for estimating the user benefits of ITS, developed in response to the need for simplified estimates in the early stages of ITS related planning, in the context of either a focused ITS analysis, a corridor/sub-area transportation study, or a regional planning analysis."

As discussed above, environmental benefits assessment of ITS will generally require quantifying the vehicle activity parameters such as vehicle speeds, Vehicle Kilometers Traveled (VKT) or Vehicle Miles Traveled (VMT), Vehicle Hours Traveled (VHT). Once these parameters have been quantified, the emissions resulting from these activity parameters have to be estimated. SCRITS uses a series of look-up tables to perform the analysis of both the activity parameters and the emission estimation.

SCRITS estimates energy and environment benefits for only three ITS strategies, namely, Closed Circuit Television (CCTV), freeway traffic detection, and information and traffic signal systems. The first and third strategies are discussed next.

Closed Circuit Television (CCTV). The installation of CCTV results in the capability to visually observe the incident scene and the surrounding areas. Video-based traffic management using CCTV provides the responsible agencies with the capacity to observe the incident location and subsequent congestion. This enables the agencies to respond quickly, based on pre-conceived response plans, with likely reductions in incident duration. SCRITS analyzes the environmental benefits of using the following procedure:

The relevant parameters that the user is required to enter are:

1. Number of cameras installed
2. Percentage of CCTV coverage before improvement
3. Percentage of CCTV coverage after improvement
4. Estimated reduction in incident duration
5. Savings, in VMT, per weekday

To obtain the percentage of reduction in average incident duration, the change in the percentage coverage after improvement is multiplied by the reduction in incident duration. The incident related VHT is assumed to vary linearly with the incident duration, and so the percentage of savings in incident related VHT is presumed to be the percentage of change in incident duration. This gives the savings of incident related VHT after improvement. The freeway VMT after improvement can be calculated from the baseline VMT and the savings in freeway VMT.

The average weekday speeds before improvement are calculated by dividing the weekday freeway VMT by the sum of recurring and nonrecurring VHT. The average weekday speeds after improvement is calculated in a similar manner by calculating the values of the parameters after the improvement.

The emission factors for CO, NO_x, and HC in gms/mile as a function of average speeds are taken from the look-up tables. The emissions before and after improvement are found by multiplying these emission factors by the corresponding Vehicle Miles Traveled (VMT's), and the differences in these emissions are taken to be the benefits of Closed Circuit Television (CCTV).

Traffic Signalization Strategies. These strategies cover a broad range of traffic signalization improvements. In analyzing the environmental benefits of this strategy, SCRITS assumes that deploying this strategy will lead to an increase in the average system speed. The emissions factors for before and after improvement are taken from the look-up tables. The difference in these estimates are the benefits of the ITS deployment.

IDAS

The ITS Deployment Analysis System (IDAS) is software developed by the Federal Highway Administration that can be used in planning for Intelligent Transportation System (ITS) deployments. State, regional, and local planners can use IDAS to estimate the benefits and costs of ITS investments – which are either alternatives to or enhancements of traditional highway and transit infrastructure. IDAS can currently predict relative costs and benefits for more than 60 types of ITS investments.

The objective of the IDAS benefits module is to estimate impacts resulting from the deployment of ITS components. These impacts are quantified using various performance measures of travel time, travel time reliability, throughput, safety, emissions, energy consumption and noise. The benefits module uses the updated data set representing the ITS option and the unmodified data set representing the control alternative, to perform a series of analyses to generate the difference in performance between the two scenarios. The performance statistics are then passed on to the alternatives comparison module where values are attached to the changes in the various measures.

The IDAS benefits module is comprised of four individual submodules that provide estimates of impacts for different categories of performance measures. The benefits module consists of a travel time/throughput submodule, an environment submodule, a safety submodule, and a travel time reliability submodule. A brief overview of the environment submodule is provided below.

The environment submodule estimates changes in mobile source emissions, energy consumption, and noise impacts of ITS strategies. Using the performance statistics generated from the travel time/throughput submodule, the environment submodule estimates environmental performance measures by using a series of detailed look-up tables that consider emissions and energy consumption rates by specific network volume and traffic operating characteristics. The use of look-up tables provides the analyst with the ability to incorporate updated emissions and energy consumption rates as they become available. IDAS incorporates emissions and energy consumption rates from currently available sources, including Mobile 5 and California Air Resources Board EMFAC. The basic inputs and outputs of the module are provided in Figure 2 below.

Figure 2 - IDAS Environment Submodule

Inputs

User Inputs or Defaults

Mobile-5a emission rates by:
- Pollutant type (HC, CO, NOx)
- Speed range
- Vehicle type distribution

Fuel consumption rates by:
- Facility type
- Speed range
- Vehicle type
- Gas/diesel

California-EMFAC emission rates by:
- Pollutant type
- Speed range
- Analysis year
- Vehicle type distribution
- Temperature range

Other:
- Emission cost ($) by pollutant
- Energy cost ($) by fuel type
- Fuel type (%) by market sector

From Travel Time/Throughput Module

Trips/VMT by:
- Facility type/link
- Vehicle type/mode
- Speed range
- Time of day

Outputs

To Alternative Comparison Module and Cost Module

Emissions (kg) by:
- Pollutant type
- Vehicle type/mode
- Vehicle type/link

Energy consumption (gallons/liters) by:
- Fuel type
- Vehicle type/mode
- Facility type/link

Emission costs ($) by:
- Pollutant type
- Vehicle type/mode
- Facility type/link

Energy costs ($) by:
- Fuel type
- Vehicle type/mode
- Facility type/link

Source: IDAS User's Manual

Approach 2 – Simulation of ROI's

Different approaches have been proposed to evaluate implications of ITS deployments based on the underlying traffic simulation models.

Static models provide data on the spatial variation of average travel times, traffic volumes, and speeds in a roadway network. Such models typically focus on peak hour or peak period traffic conditions and are useful for developing emissions inventories in a certain area.

On the other hand, *dynamic traffic simulation-assignment models* can represent spatial and temporal variation of travel times, stopped times, speeds, queues, and travel distances over very short simulation intervals (e.g. 30 seconds). This type of output is more representative of the operational impacts of ITS interventions.

Washington et al. (1994) have described the current emission estimation practice in the following five steps:

Step 1. Quantifying emission-producing vehicle activities or ROI's (e.g. number of trips, VKT, idling delay, operating speeds) through a traffic simulation model;
Step 2. Providing data on vehicle, fuel, operating, and environmental characteristics to the emission factor model;
Step 3. Running the emission factor model to predict activity-specific emission rates for the given vehicle, fuel, operating, and environmental characteristics;
Step 4. Multiplying each activity estimate by its appropriate activity-specific emission rate; and,
Step 5. Summing the estimated emission for all the activities.

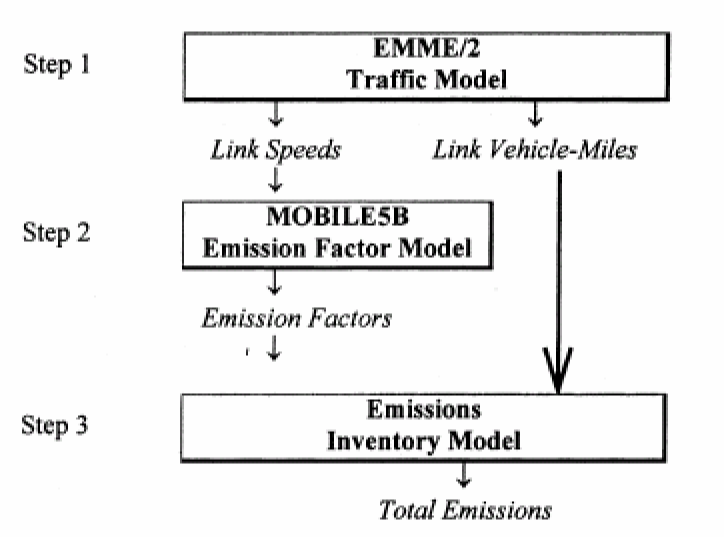
In this approach, ROI's (representing emission-producing vehicle activities) need be developed using either microscopic models like TRAF-NETSIM or CORSIM, or macroscopic models like FREFLO and TRANSYT-7F. Newer simulation models like INTEGRATION, DYNAMIT, and DYNASMART are better suited for simulating various ITS scenarios. Scenarios representing before/after ITS deployment conditions need to be considered.

Example – Simulation Using Static Traffic Model

A paper by Sbayti, El-Fadel, and Kaysi (2001) investigates the effect of three levels of roadway network aggregation, macro-scale (overall network basis), meso-scale (roadway functional class basis) and micro-scale (link-by-link basis) on emission inventories. A traffic model and an emission factor model were integrated to determine total emissions in the future Beirut Central District area for these three modeling approaches.

The modeling consists of three consecutive steps (Figure 3). EMME/2 (INRO Consultants Inc, 1998), a widely used static traffic model, is often interfaced with pollutant emissions/dispersion models to simulate the effect of changes in land use, traffic fleet characteristics, roadway network, and lane configurations on emission estimates. MOBILE5B, developed by the US Environmental Protection Agency, uses average speeds, vehicle fleet characteristics, ambient conditions, and trip duration distribution to estimate emission factors. Three levels of detail are used to estimate the total emissions, the macro-, meso and micro-scales. At the macro-scale, the average network speed was used to calculate an average emission factor for the whole network. Total emissions are estimated by multiplying total vehicle miles traveled (VMT) by the average emission factor. For the meso-scale approach, an average emission factor for every roadway functional class is determined. The contribution of each roadway functional class to pollutant emissions is then aggregated to yield total emissions. In the micro-scale method, link speeds are used to obtain emission factors for every link. Link VMT is multiplied by the corresponding link emission factors and summed over all links to obtain total emissions.

Figure 3 – Modeling Approach with Static Traffic Model



Example – Simulation Using Dynamic Traffic Model

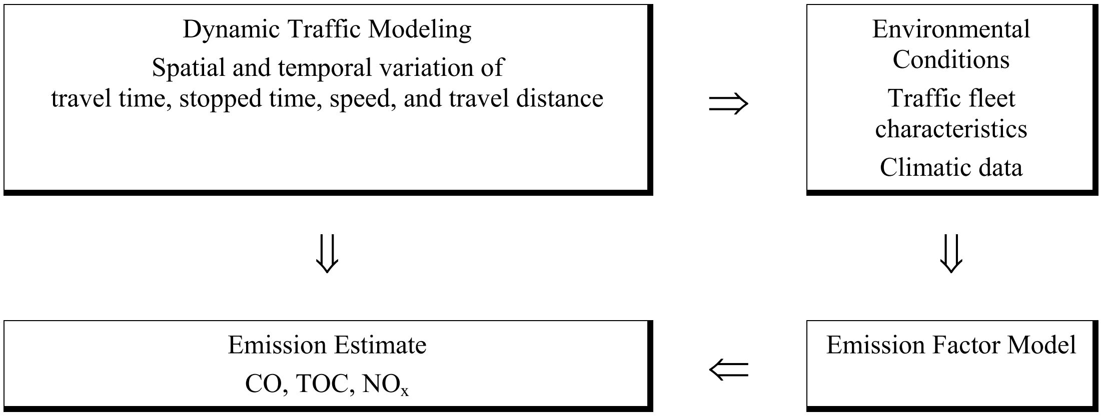
Kaysi, Chazbek, and El-Fadel (2004) developed a framework for assessing the potential of Intelligent Transportation Systems (ITS) in alleviating non-recurring traffic congestion and to estimate the resulting implications for vehicle-induced emissions in a congested city in a developing country.

A series of simulation scenarios were conducted using dynamic traffic simulation-assignment methodology, and resulting emissions were estimated using an emission factor model. DYNASMART and MVEI/EMFAC were the traffic and emission factor models used in this research (Figure 4). The scenarios were used to evaluate the impact of different

ITS deployment parameters - such as type of information provision (pre-trip, and in-vehicle) and driver compliance - on network performance and resulting emissions. Network performance measures such as travel and stop times were developed, and corresponding vehicle emissions are estimated using CO, NOx, and TOC as indicators for each scenario.

The experimental factors considered in defining simulation scenarios were information provision technique, market penetration/driver response, and incident duration which accounts for the time required for detection, response, and clearance. Three information provision techniques were simulated: 1) no information, 2) pre-trip information only (e.g. TV broadcasts), and 3) in-vehicle information (e.g. cell phone or Highway Advisory Radio). A certain percentage of drivers was then considered to comply with the route directives; different levels of driver response or compliance were considered.

Figure 4. Simulation sequence under dynamic traffic and emissions modeling



Approach 3 - Field Level A

This approach is very similar to Approach 2 except that quantification of the emission-producing vehicle activities or ROI's will be field-measured or obtained empirically under before/after ITS deployment conditions instead of being simulated using a traffic model.

Approach 4 – Field Level B

In this approach, emissions need to be measured directly in the field instead of computing them based on estimated, simulated, or measured ROI's and emission factors.

The following discussion presents a brief overview of the potential for and challenges of implementing air quality monitoring measures in the field to observe the impacts of ITS deployments. The conclusions from an NCHRP study on "Quantifying Air-Quality and Other Benefits and Costs of Transportation Control Measures" are presented since similar considerations are expected to apply in the case ITS deployments. Next, basic procedures related to field monitoring of potential air quality changes with ITS deployments are presented. Finally, some basic challenges involved in field monitoring are outlined.

Conclusions of NCHRP Study

Air quality monitoring to observe the impacts of ITS deployments is technically feasible for primary pollutants, such as CO, VOCs, and NOx (NCHRP 2001). Measurements of upwind concentrations can be subtracted from the downwind values as a means for characterizing the contribution of a roadway facility to ambient downwind concentrations. Experiments should be conducted both prior to and subsequent to deploying the ITS project. It is important to note, however, that observing ITS deployment effects is feasible only if they exceed a certain threshold value. For primary pollutants, this is on the order of 2 percent. Direct observation of ITS deployment effects on secondary pollutants is considerably more difficult.

Another point worthy of mention is that monitoring over a large geographic area to determine the effects of area wide ITS deployment programs is inherently more difficult than monitoring on a location- or facility-specific basis. The implication is that use of an air quality monitoring program to evaluate the impacts of a coordinated urban area program of ITS deployments is technically extremely difficult.

Finally, specialized ITS deployment air quality monitoring programs are costly. Preliminary estimates indicate that the cost of two 3-month monitoring programs (one before and the other after implementation) to examine the effects of ITS deployments on peak-hour CO levels downwind of a congested intersection (assuming an impact on emissions of about 10 percent) would be more than half a million dollars. If the effect on emissions is smaller (e.g., requiring two 1-year programs), then the cost would be even higher. Because of these high costs, it probably is not practical for local transportation or air quality agencies to undertake such specialized monitoring programs. This kind of research-grade monitoring, though, could be undertaken as part of a national research program (NCHRP 2001).

Field Monitoring: Basic Procedural Items and Challenges

For the purpose of measuring concentrations of primary pollutant including CO and NO_2, air samples are to be collected at critical locations (around the ITS deployment site) and analyzed for the presence of primary air pollutants. Air samples may need to be collected at normal and peak traffic conditions. Concentrations of primary pollutants may be measured using a manual air sampling analyzer. Certain protocols need to be applied. For instance, measurements may need to be 30-min average concentrations for CO and 10-min average concentrations for NO_2.

Primary pollutant levels and meteorological parameters need to be monitored at frequent averaging intervals (e.g. 10 seconds) before and during/after ITS deployment. Traffic data also needs to be collected (e.g. from sensors or detectors). Such high-resolution data should permit the transport facility contribution to local air quality to be separated from background components of local air quality, and enables correlations between pollutant flux and traffic flow to be made. For instance, traffic incidents (accidents/congestion) are expected to have a rapid impact on local air quality. During incidents, pollution flux is expected to increase significantly over pre-incident levels. Over-saturated traffic operating conditions would affect local air quality in a clear way, and, if avoided by ITS deployment, methods could significantly improve local air quality (Purdue University/Indiana Department of Transportation).

Field monitoring will need to be structured in a way to be able to capture such changes in air quality as a result of ITS deployment. Several challenges are expected to arise, nevertheless. For instance, studies have indicated that wind direction has an effect on the small-scale dispersion patterns of pollutants at chosen locations, and that it can influence the data captured by a monitor. It was found that a change in wind direction could result in an increase or decrease of monitored CO concentration of up to 80%, for a given level of traffic emissions and meteorological conditions. This and other local factors have to be studied carefully before designing and analyzing the results of field monitoring procedures.

5. References

Washington, S. and Guenselar, R., Sperling, D., “Emission Impacts of Intelligent Vehicle Highway Systems,” Transportation Planning and Air Quality II, 1994.

User’s Manual for SCRITS, SCReening Analysis for ITS. Science Applications International Corporation, January 1999.

IDAS-User’s Manual. Cambridge Systematics, available at: http://idas.camsys.com/documentation.htm

Quantifying Air-Quality and Other Benefits and Costs of Transportation Control Measures. NCHRP Report No: 462, 2001.

EMFAC 2002 User’s Guide. California Air Resources Board. Document and software available at http://www.arb.ca.gov/msei/on-road/latest_version.htm

H. Sbayti, M. El-Fadel, and I. Kaysi. “Effect of Roadway Aggregation Levels on Modeling of Traffic-Induced Emission Inventories in Beirut”, in *Transportation Research - Part D*, Vol. 7D, No.3, pp. 163-173 (2002).

I. Kaysi, C. Chazbek, and M. El-Fadel. “Traveler Information Provision for Incident Management: Implications for Vehicle Emissions”, Forthcoming in *The Journal of the Transportation Research Board*, Washington, D.C., 2004.