

Analyzing, Documenting, and Communicating The Impacts of Mobile Source Air Toxic Emissions in the NEPA Process

Requested by:

American Association of State Highway
and Transportation Officials (AASHTO)

Standing Committee on the Environment

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ABSTRACT

An increased awareness and concern for motor vehicle air toxic emissions has prompted state transportation agencies for the need to address air toxic emissions as part of their environmental review process. This study develops information and guidelines on available analytical models and techniques to assess mobile source air toxic (MSAT) impacts and how this information can be communicated in the environmental assessment. The study reviews and provides recommendations on available analytical modeling tools to use in MSAT assessments along with the identification of model strengths and weaknesses. A methodology has been developed which guides the transportation analyst in identifying the appropriate level of analysis using typically available information and potential level of exposure based on the size of the transportation project. Five potential levels of analysis are identified based on both technical and policy considerations so as to guide the transportation analyst in applying a consistent set of criteria for developing a MSAT assessment. Details are presented on how to conduct the MSAT assessment as well as on the amount of information which should be included at each level of analysis. Recommendations are provided on how best to communicate these findings as part of an environmental assessment document.

SUMMARY OF FINDINGS

The Clean Air Act Amendments of 1990 designated 188 air toxic pollutants as Hazardous Air Pollutants (HAPs) and required the U.S. Environmental Protection Agency (EPA) to undertake a number of studies and regulatory activities to reduce HAP emissions. Public concern about evaluating these toxic air pollutants in the National Environmental Policy Act (NEPA) process increased in the 1990s stemming from such studies as the National Air Toxics Assessment (NATA) program—a nationwide modeling and risk assessment study that estimated the cancer and non-cancer risk from air toxics for each census tract in the United States. NATA estimated that every county in the United States experiences an overall cancer risk of greater than 10^{-5} or 10 in 1 million (i.e., 10 cancer cases per million population over a lifetime of constant exposure) from all sources. The MATES II study, which estimated mobile source-related risks in the California South Coast region, assigned 90% of the total cancer risk to mobile sources with 70% of the total risk assigned to diesel particulate matter (DPM) from mobile sources.

The EPA 2001 Mobile Source Air Toxic (MSAT) Rule identified 21 hazardous air pollutants as MSATs. EPA identified six of the 21 pollutants as of greatest concern due to their high relative emissions and risk and because state agencies have indicated that these pollutants are major mobile source pollutants of concern. These six pollutants have become known as the “priority MSATs”¹ and are:

- Acetaldehyde
- Acrolein

¹ These priority MSATs are subject to change based on improved understanding of ambient levels and health effects. In particular the proposed new MSAT rule on the Control of Hazardous Air Pollutants from Mobile Sources (Federal Register, Vol. 71, No. 60, page 15813 and 15814, March 29, 2006) discusses the MSATs which pose the greatest risk at current levels based on updated information (includes naphthalene).

- Benzene
- 1,3-Butadiene
- Formaldehyde
- Diesel particulate matter plus diesel exhaust organic gases (DPM+DEOG)

A history of regulatory actions for non-mobile sources of air toxics has lead the public to ask that assessments be made for mobile source air toxics when part of a Federal action. NEPA process requires that major Federal actions that “significantly affect the quality of the human environment” undergo assessment of their environmental impact. With the recent availability of motor vehicle air toxic emission factors from MOBILE6.2, the feasibility of assessing air toxics as part of NEPA requires review and evaluation. If air toxic assessments are feasible, the NEPA process can then be used to disclose the potential impact, analyze alternatives and possibilities for mitigation, and inform the public about the impacts of air toxic emissions from a proposed project.

Based on the research findings five levels of analyses are suggested depending upon the size of the project, the project activity level, the level of concern, the proximity of the project to sensitive population groups, and available information. Each level of analysis requires additional user information and suggested levels of more detailed analysis are balanced with the size of the potential project impact.

Results

Identification of Emission and Dispersion Models

Modeling tools are widely available that are capable of predicting MSAT impacts from transportation projects. These tools have varying histories and applications in MSAT analyses. This study focused on identifying possible emission factor and air quality dispersion models

applicable to transportation projects that could be used in a NEPA setting. The emission factor models identified for detailed review included EMFAC2002, MOBILE6.2, and the U.S. EPA MOVES model currently in development (based on a review of the most current plans). Identified for each emission factor model was the applicable source category, input data requirements, the functionality of the model, types and applicability of output data, the MSAT species modeled, how the model estimates the MSAT emission factors, and known limitations or deficiencies with the priority MSAT species. While the use of these emission factor models are prescribed in federal policy and regulations the summary of information provides a convenient tool for the transportation analyst showing the emission factor models' applicability and capability specific to MSAT issues.

The air dispersion models that were reviewed include CALINE3, CALINE4, CAL3QHC(R), HYROAD, AERMOD, ISCST3, and CALPUFF. These models were selected based on their applicability and history in transportation-related settings. The types of transportation facilities to which these models may be applicable include roadways at ground level without intersections (e.g., freeway widening projects), roadways at ground level with intersections (e.g., traffic signal improvement), elevated freeways, parking lots, transit bus garages, rail lines with locomotive traffic, and intermodal freight terminals. Identified for each model are the meteorological requirements, site/geometry characterization, handling of the near field dispersion, availability of traffic simulation, how mobile source emissions are characterized, and removal process (chemical decay, wet/dry deposition), available model outputs, how MSAT may be treated and known limitations for transportation settings.

Information provided in these tables provides a starting point and basis for the transportation analyst to identify which modeling tool to potentially use in a MSAT assessment.

The summary presented for each model provides the analyst with a list of features that may be important to the transportation facility that is under review for MSAT assessment.

Assessment of Model Strengths and Weaknesses for Transportation Projects

To enable the transportation analyst to select the best modeling tools for MSAT assessment, emission factor and air dispersion models were assessed for their major strengths, weakness, limitations, and relative uncertainties for air toxic assessment for different types of transportation facilities. For each emission factor or air quality model, a matrix was developed listing strengths, weakness, limitations, and uncertainties associated with different types of transportation projects. For the emission factor models specific issues include: speed dependency by vehicle type, facility type, species, validation of the model, and underlying database; for air quality models specific issues include: meteorology, geometry, site characterization, dispersion parameters, traffic modeling capabilities, interaction between traffic and meteorology, decay for reactive pollutants, and emission linkages. No assessments were made for the MOVES model, as a draft air toxic version is not yet available. Similarly, the California EMFAC model does not currently contain an air toxic module and a future version of the model will only provide MSAT emissions on a county-by-county basis based on the California Air Resources Board speciation profiles.

This set of matrices provides the practitioner with specific information for use in assessing the ability, limitations and associated uncertainty for the emission factor and dispersion models focused on transportation-related MSAT issues for nearly all transportation situations evaluated under NEPA. The identified strengths and weaknesses add to the transportation analyst's understanding of how these tools can be used in transportation MSAT assessments. In particular, information on model weaknesses may help the transportation analyst understand why a given model may not be suitable for use in an MSAT assessment. When considering the relative strengths and

weaknesses of different models, the findings present a clearer picture of which modeling tools should be used in a given MSAT assessment. This information has been used in developing the recommendations on the modeling approaches for analyzing MSATs in the NEPA process.

Health Impacts of Mobile Source Air Toxics and Current Range in Concentration

To assist the transportation analyst in assessing the relative impact of the transportation project versus current conditions, an assessment was performed for each MSAT documenting the potential health impacts and range of concentrations occurring throughout the United States. Health effects of MSATs typically examined in risk assessments include carcinogenic and chronic non-carcinogenic effects. The study identified the carcinogenic potency for 12 of the MSATs, as well as the weight of evidence, type of evidence and the basis for the carcinogenicity finding. The Reference Concentrations (RfCs) is used to establish the safe non-cancer chronic exposure level. For most pollutants that have both carcinogenic and non-carcinogenic impacts, the 1 per million carcinogenic risk occurs at a lower concentration than the chronic RfC. An exception is formaldehyde.

The most current assessment of nationwide MSAT concentrations is available through EPA's National Air Toxic Assessment (NATA) national scale assessment. This assessment modeled 1999 outdoor air concentrations at census tract level resolution. For those MSATs not modeled as part of NATA, observed 2005 concentrations from the EPA's AirData Reports were used to develop estimates of background level concentrations. The distributions of observed concentrations are composed of varied numbers of samples, ranging from 29 to 388. In most cases the observed distributions are expected to be higher than the modeled distributions, as most modeled concentrations do not include background concentrations and observed concentrations were usually targeted at locations of expected high concentration.

The spatial patterns of observed and modeled concentrations suggest that most of the priority MSATs are of widespread² concern. In addition, naphthalene now appears to be of widespread concern (based on OEHHA's cancer potency value).

During environmental impact assessment of potential projects, estimation of background pollutant concentrations may be based on either pollutant measurements or air dispersion modeling. The optimal approach is local monitoring of the pollutants of interest. For MSATs the appropriate monitoring duration is at least one year, since monitoring of shorter duration can be biased due to seasonal patterns in ambient concentrations. Use of monitoring data from the EPA's AirData Reports is a cost-effective alternative to expensive local monitoring, if data are available at a nearby location. If no representative monitoring data are available, NATA model predictions can be used. NATA model predictions are available for every U.S. census tract for 1999, and are scheduled to be available for 2002 when a new round of modeling is completed in 2007³.

Suggested Procedures for Analyzing MSAT

Suggested procedures have been developed on how to select and apply the best available models and associated techniques for MSAT impact assessment in the NEPA process. The suggested approach uses both policy and technical considerations to determine the need and appropriateness for conducting a MSAT assessment. A set of policy and technical questions have been developed, and in conjunction with the responses to these questions should help guide the transportation analyst in determining an appropriate level of analysis under NEPA. The set of policy-related questions will help identify the appropriate level of analysis based on information

² For onroad and nonroad mobile sources, EPA estimates that approximately 110 million people live in areas of the U.S. where the combined upper-bound lifetime cancer risk from mobile source air toxics compounds exceeds 10 in a million. This risk is dominated by the emissions of benzene, acetaldehyde, and 1,3-butadiene

³ In addition, EPA intends to have available by mid-2007 NATA-like assessment tools that can be used to estimate *future year* background concentrations. It is also possible that some states may develop an estimate of future background concentrations and these could potentially be used in an analysis.

about the scope of the project, its likely impact to the community, and the general public's level of concern. Coupled with the policy-related questions are technical questions which identify the appropriate level of technical analysis based on health risk considerations. This combined set of questions will help to scope the transportation project for air toxic risk, with the policy questions identifying the appropriate level of analysis and the technical questions addressing the technical feasibility of the desired policy-level analysis.

The set of questions appears in Exhibit 1-1. The first level of analysis requires no review; subsequent levels require increasingly more data and analysis to demonstrate the projects potential MSAT impact. The first level of analysis identifies whether the project has either a categorical exclusion. At the second level, a qualitative analysis is recommended. This level of analysis is applicable when there is little chance for increased air toxic exposure or the uncertainty is so large that quantitative assessment is unlikely to convey any useful information to the reader of the NEPA document. It is anticipated that many of the most typical and smaller transportation projects will fall into this analysis category. The types of projects that will typically be found in this level of analysis are projects which improve operations or safety without substantially adding new capacity and therefore are anticipated to have very low potential impact. Examples include: freeway widening projects where increased capacity remains below the screening threshold level⁴ of 125,000 AADT; new interchanges where a new arterial segment is built to connect to an existing highway and the project's activity level remains below the 100,000 AADT threshold screening level; and a new interchange project developed to serve a new residential development where the project's activity level is below the screening threshold level of 40,000 AADT. These health-based screening thresholds were developed based on an

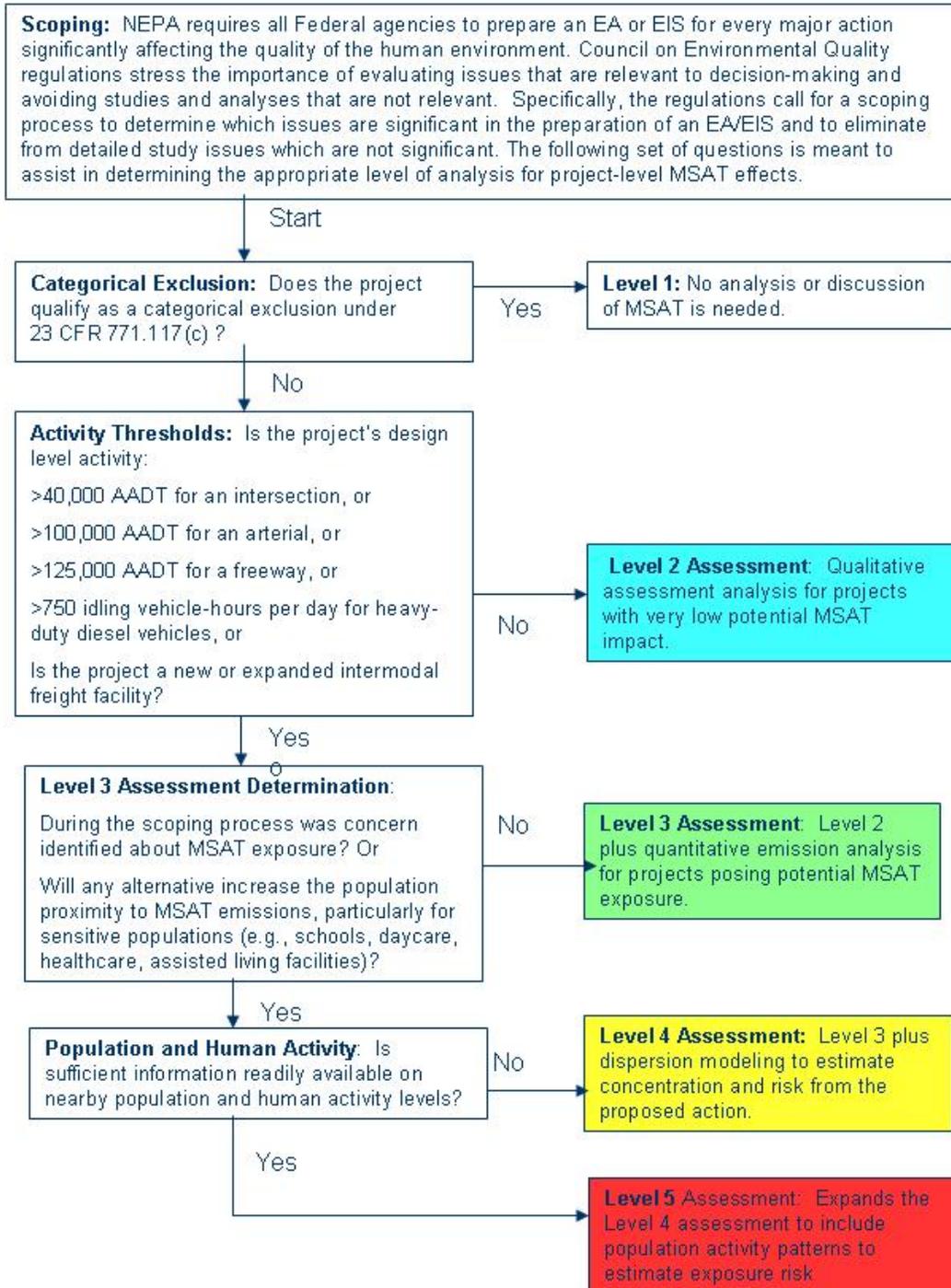
⁴ Appendix C contains detailed discussion for the basis of these threshold screening levels.

analysis of the key air toxic risk driver of benzene for three types of project settings based on a one in a million threshold risk level.

The third level of analysis develops a quantitative estimate of emissions for the proposed action and represents project settings which have a high potential for MSAT emissions to concentrate at high enough levels to be of potential concern. The fourth level of analysis expands upon the emission analysis by including dispersion modeling to estimate concentration and outdoor risk levels. The fifth level of analysis incorporates population activity patterns to estimate exposure risk.

Details are provided on the suggested steps needed in order to complete each level of analysis. Suggestions and tools are provided from which the analyst can develop model inputs or factors for use in the analysis. This includes suggested procedures to estimate changes in emissions based on projected speeds, fleet mix, and traffic volume as well as to account for changes in exposure distance if changed under the proposed action. Also, presented are suggested procedures that may be used to estimate background concentration and emission trends. For the more quantitative analyses (Levels 3-5), specific air quality and exposure models are suggested as well as discussion on the impacts from unavailable information on MSAT analysis and a summary on the credible scientific evidence to evaluate adverse impacts from MSATs.

Exhibit 1. Recommendation Flowchart (ICF International, NCHRP 25-25 Task 18)



Communication of MSAT Analysis Results and Health Impacts

The human health risk assessment literature discusses communication of analysis results through interpretation of health risk assessment (HRA) results, discussion of uncertainty in HRA, and overall presentation of the results. Considerable literature exists on how to communicate risk to the public; the primary points applicable to risk analyses of MSATs for transportation projects under NEPA include the following:

- Describe the project emission sources, the relevant MSATs, and the types of cancer and non-cancer health risks they pose.
- Define clearly the criteria for a significant impact of the project in the NEPA context.
- Explain and reference the information on toxicity, exposure, and dose-response that the transportation agency takes as given for purposes of the analysis.
- Identify and explain any health studies undertaken in the project area that are relevant to the MSAT analysis. Also, include reports outside the project area which are in areas of similar emission and exposure potential.
- Distinguish clearly among the types of health risks and their health metrics (e.g., unit risk factor, cancer risk, reference concentration level, hazard quotient, etc.) used in the analysis.
- For each impact metric, show a comparison of the results for each project alternative and the selected criterion of significance.
- Compare project impacts to other exposure information, such as regional or county-level MSAT emission inventories and measured MSAT concentrations as well as

- similar size scale facilities such as intermodal facilities, rail yards, bus terminals, travel plazas, parking facilities, and ports of varying size range and activity levels.
- Show MSAT results and comparisons in easy-to-understand graphical formats where possible.
 - Provide a discussion of uncertainty. The uncertainty discussion should support the agency's decision on what level of MSAT analysis to perform.
 - The discussion of uncertainties should include information on modeled ambient concentrations and exposure estimates. A discussion of uncertainties should also qualitatively describe the level of confidence attributed to toxicity information by environmental and health agencies.

Uncertainty in MSAT Analysis

The health risk assessment literature contains extensive coverage of the uncertainties involved in human health risk assessment. Some recent EISs have included discussions of uncertainties to comply with the CEQ regulations addressing incomplete and unavailable information. Based on the review of the uncertainty information and the current state of the science, the following conclusions may be drawn concerning the treatment of uncertainty in NEPA project analyses:

- Transportation projects vary widely in the need for and usefulness of MSAT analysis. Uncertainty is a substantive issue for smaller projects.
- Use of health risk assessment, with its attendant uncertainties, is warranted for some of the larger projects due to the larger risks posed.

- The primary purpose of NEPA is disclosure of information to facilitate selection among alternatives. This purpose includes disclosure of information to the public to support informed commenting on the analysis.
- The public demand for information in NEPA documents may exceed the level of analysis in which the agency has confidence for purposes of alternative selection and impact assessment. Thus, agencies may need to educate the public about uncertainties in the analysis to forestall comment that seeks to stop the project rather than guide the selection of alternatives under NEPA.
- The regulatory driver for discussion of uncertainty within the NEPA document is the CEQ regulations addressing incomplete and unavailable information (40 CFR 1502.22).
- A large uncertainty range in MSAT results does not automatically invalidate their use in comparing alternatives. Relative (not absolute) differences among alternatives, when calculated by consistent methodology, are generally valid for purposes of ranking alternatives.
- Many MSAT analyses show a decline in emissions over time regardless of the project, and the difference between future alternatives is typically much less than the overall secular reduction. However, this does not relieve the study from characterizing differences among the project alternatives, even in the presence of uncertainty.

Conclusions

This study enables transportation agencies to effectively develop an approach to evaluate and communicate the impacts of toxic air pollutants emitted from surface transportation sources. The study provides a suggested approach for the transportation analyst to follow in the following areas:

- MSAT impacts for transportation projects and programs under the National Environmental Policy Act;
- Suggested procedures in applying air quality and emission factor models and other technical methods in the analysis of MSAT assessments;
- A health based MSAT screening procedure for the level of detail needed in the analysis that balances the level of detail, analytic rigor, and resource requirements with the likely magnitude and significance of project impacts;
- How to communicate MSAT project level impacts in the NEPA documents that is consistent with the limitations and uncertainties with current modeling tools and in the absence of National Ambient Air Quality Standards (NAAQS)

In addition, the study provides to the transportation community as a whole an approach which:

- Promotes consistency among MSAT evaluation methods so that the relative impacts of roadway projects and programs can be compared and;
- Assure that the quality of MSAT analysis for NEPA documents is sufficient to meet statutory and regulatory requirements, to support agency decision-making, and to adequately inform the public about the air toxic impacts of projects in the NEPA context.

CHAPTER 1. Introduction

This document is designed to assist transportation agencies in evaluating the impacts of toxic air pollutants emitted from surface transportation sources. These pollutants are known as mobile source air toxics or MSATs. NCHRP's purposes in issuing this best state of practice are to:

- Provide technical guidance to analysts who are responsible for evaluating MSAT impacts of transportation projects and programs under the National Environmental Policy Act (NEPA, 42 U.S.C. 4321 et seq.);
- Determine best practices in applying models and other technical methods in the analysis of MSATs;
- Recommend project screening procedures that will result in levels of detail, analytic rigor, and resource requirements that are commensurate with the likely magnitude and significance of project impacts;
- Promote consistency among MSAT evaluation methods so that the relative impacts of roadway projects and programs can be compared; and
- Assure that the quality of MSAT analysis for NEPA documents is sufficient to meet statutory and regulatory requirements, to support agency decision-making, and to adequately inform the public about the air quality impacts of projects in the NEPA context. These goals are codified in the NEPA implementing regulations of the Council on Environmental Quality (CEQ, 1978) and the U.S. Department of Transportation (US DOT, 1979).

The information presented here is intended for air quality analysts, project managers, and technical reviewers within transportation agencies and their contractors. It is assumed that the

reader is familiar with the basic regulatory frameworks for the NEPA process and air quality assessment. It is also assumed that the reader has some familiarity with air quality impact analysis methods for transportation projects. The details of procedures established in other guidance issued by air quality regulatory agencies are not repeated here, but references are provided to guidelines that the reader may wish to review.

The Need for MSAT Analysis

The Clean Air Act Amendments of 1990 designated 188 air toxic pollutants as Hazardous Air Pollutants (HAPs) and required the U.S. Environmental Protection Agency (EPA) to undertake a number of study and regulatory activities to reduce HAP emissions. Public concern about evaluating these toxic air pollutants in the NEPA process increased in the 1990s, partly due to several pivotal agency studies (Houk and Claggett 2006). Chief among these studies and rules were the EPA National Air Toxics Assessment (EPA 2000), the California South Coast Air Quality Management District MATES II study (SCAQMD 2000), and the EPA “MSAT Rule” (EPA 2001). The National Air Toxics Assessment (NATA) was a nationwide modeling and risk assessment exercise that estimated the cancer and non-cancer risk from air toxics for each county in the U.S. NATA estimated that every county in the U.S. experiences an overall cancer risk of greater than 10^{-5} or 10 in 1 million (i.e., 10 cancer cases per million population over a lifetime) from all sources. The MATES II study, which estimated mobile source-related risks in the South Coast region, assigned 90% of the total cancer risk to mobile sources with 70% of the total risk assigned to diesel particulate matter (DPM) from mobile sources.

The EPA 2001 MSAT Rule identified 21 hazardous air pollutants as mobile source air toxics. Table 1 lists the 21 MSATs identified by EPA. EPA decided to focus short-term work on six of the 21 pollutants as the MSATs of greatest concern due to their high relative emissions and

toxicity (EPA 1999a, as cited in MSAT Rule) and because state agencies have indicated that these pollutants are major mobile source pollutants of concern (EPA MSAT Rule, Preamble).

These six pollutants have become known as the “priority MSATs” and are listed below:

- Acetaldehyde
- Acrolein
- Benzene
- 1,3-Butadiene
- Formaldehyde
- Diesel particulate matter plus diesel exhaust organic gases (DPM+DEOG)

**Table 1. Agency Lists of HAPs Associated with Mobile Sources
(ICF International, NCHRP 25-25 Task 18)**

	CAA Hazardous Air Pollutant	US EPA: 2001 MSAT Rule	FHWA: Priority MSAT	FAA: Aircraft-Related*
1	Acenaphthene†			†
2	Acenaphthylene†			†
3	Acetaldehyde	•	•	•
4	Acrolein	•	•	•
5	Anthracene†			†
6	Arsenic Compounds	•		
7	Benzene	•	•	•
8	Benzo(a)anthracene†			†
9	Benzo(a)pyrene†			†
10	Benzo(b)fluoranthene†			†
11	Benzo(ghi)perylene†			†
12	Benzo(k)fluoranthene†			†
13	1,3-Butadiene	•	•	•
14	Chromium Compounds	•		
15	Chrysene†			†
16	Dibenz(a,h)anthracene†			†
17	Diesel Exhaust/ DPM+DEOG††	•	•	
18	Dioxins/Furans	•		
19	Ethylbenzene	•		•
20	Fluoranthene†			†
21	Fluorene†			†
22	Formaldehyde	•	•	•
23	n-Hexane	•		•
24	Indeno(1,2,3-cd)pyrene†			†
25	Lead Compounds	•		•
26	Manganese Compounds	•		
27	Mercury Compounds	•		
28	Methyl Tertiary Butyl Ether	•		
29	Naphthalene	•		•
30	Nickel Compounds	•		
31	Phenanthrene†			†
32	Polycyclic Organic Matter (POM)	•		•
33	Propionaldehyde			•
34	Pyrene†			†
35	Styrene	•		•
36	Toluene	•		•
37	2,2,4-Trimethylpentane			•
38	Xylene	•		•

* Includes commercial aircraft, general aviation (GA) aircraft, and ground service equipment (GSE).

† As polycyclic organic matter (POM) or polycyclic aromatic hydrocarbons (PAH) given as a group of 7-PAH or 16-PAH. These compounds may also be components of the pollutant Diesel Exhaust/ DPM+DEOG listed separately in table.

†† Includes particle-bound POM and PAH compounds that are also listed separately in this table.

Sources: EPA 2001, FHWA 2006, FAA 2003.

As concern about MSATs has mounted, the Federal Highway Administration (FHWA) and state departments of transportation have increasingly received requests for MSAT analysis in agency-funded environmental impact statements (EISs). The issue of air toxics has been raised with several major highway projects around the country, resulting in lengthy deliberations and in some cases, litigation (FHWA 2004, FHWA 2006).

At the same time, the Federal Aviation Administration (FAA) has also received increasing requests for MSAT analysis in its EISs for airport projects. Airport projects typically involve MSAT emissions from multiple source classes including aircraft, on-road vehicles, and off-road sources such as aircraft ground service equipment and construction equipment. Experience in the early 2000s with MSAT analysis for major EISs at large airports such as Los Angeles International, Chicago O'Hare (FAA, 2005a), and Philadelphia International led to FAA's issuance of interim MSAT guidance (FAA 2005b). California agencies have long required MSAT analysis as well as health risk assessment in Environmental Impact Reports (EIRs), which are the California state-level counterpart to NEPA EISs.

MSATs in NEPA Studies for Transportation Projects

Most projects focus on priority MSATs as they represent the bulk of total health risk. All of the priority MSATs can cause respiratory health effects, and all except acrolein are EPA-designated probable or known carcinogens. Benzene, a known carcinogen, and DPM are viewed as especially harmful. The MATES II study identifies DPM as the primary cancer risk factor out of all MSATs.

Proximity to transportation facilities, typically roadways, has been established as a primary factor leading to community exposure and potentially increased risk. Numerous studies in recent years have found adverse health impacts that seem to be linked to proximity to a

roadway, including increased incidence of asthma and cancer. (Houk and Claggett 2006; for one summary of studies, see John Hopkins Workshop, 2004). According to FHWA, “many of the findings are from studies that do not measure exposures and have relatively low numbers of subjects. The possibility exists that there is a correlation between road proximity and health risk, but that finding is not conclusive.” (FHWA *ca.* 2004). However, the public health community perspective is best reflected in the summary document from the John Hopkins Workshop (2004) which documents “In conclusion, a substantial and growing body of evidence from epidemiologic studies indicates that residence in close proximity to roadways with high traffic density is associated with increased risk of a broad spectrum of health outcomes in adults and children. The scientific evidence is stronger for the health outcomes of mortality, lung function, and lung cancer in adults, and for respiratory symptoms including asthma/wheezing and lung function in children. The interpretation of study results for asthma medication or health care use, cancer in children, and atopy are less consistent.”

More recent studies support a finding of increased risk from exposure in proximity to transportation facilities. For example, two recent studies, Gauderman *et al.* (2005) and McConnell *et al.* (2006), both observed a statistically significant association of increasing childhood asthma rates with decreasing distance to freeways in several California towns⁵. The weight of the current evidence indicates that it is reasonable to use proximity to a transportation project facility as a screening tool in NEPA evaluations of MSATs.

In NEPA air quality studies of criteria pollutants, the threshold for “significant” impacts is commonly taken to be an ambient concentration standard. Section 109 of the CAA states that National Ambient Air Quality Standards (NAAQS) are to be set at levels that, “allowing an

⁵ Both of these studies used routinely available emissions and air quality modeling tools for conducting their analyses, indicative of acceptance of these tools within the scientific and public health research community.

adequate margin of safety, are requisite to protect the public health.” In contrast to criteria pollutants, no NAAQS have been established for HAPs or for MSATs in particular (lead is designated as both a criteria pollutant and a HAP). Until the 1990s, ambient measurements of HAPs were rare, and concentrations of HAPs commonly found in the ambient air were not thought to present a significant health risk.

However, increased measurement and further study of HAPs and associated health risks have shown that for some locations and activity levels, HAPs may pose a health risk. However, unlike criteria pollutants, HAPs in general are not ubiquitous (although exceptions exist e.g., benzene and PAH) and do not have a “bright line” or threshold value for cancer where no effects are observed. For these reasons, as well as the relatively high level of remaining uncertainty associated with many of the HAPs’ health effects, no NAAQS have been established for the HAPs.

Absent NAAQS for HAPs, a number of states have established guideline levels for ambient HAP concentrations. The guidelines are usually based on occupational limits set by the U.S. Occupational Safety and Health Administration (OSHA), the National Institute for Occupational Safety and Health (NIOSH), and similar bodies, because health impact data for non-workplace populations exposed to ambient HAP levels typically have not been available. To derive ambient guideline levels, state agencies typically reduce the OSHA/NIOSH limits according to assumed ratios of exposure time for occupational versus ambient settings, and by additional factors of safety (typically an order of magnitude) to account for sensitive non-workplace populations. These guideline levels vary widely among states and do not carry the legal force of a standard. Some states apply their ambient HAP guidelines only to stationary emission sources and exempt all mobile sources. Some NEPA analyses of mobile sources have attempted to apply state guidelines, whether officially applicable or not. The usefulness of such

applications has been limited by the high level of uncertainty in workplace-derived guideline levels and the scarcity of data on ambient background concentrations of HAPs.

Typically, the scientific basis of the state guideline is not sufficiently robust to support a determination that a concentration that exceeds the guideline level would actually represent a significant impact in the context of NEPA. The large uncertainties in the scientific understanding of health effects of HAPs as well as in the methodologies for estimating HAP emissions and concentrations continue to prevent the establishment of NAAQS or single-number standards for MSATs under NEPA. Instead, quantification of health impacts relies on health risk assessment which is subject to large uncertainties of its own.

Many NEPA analyses have estimated emissions but not the resulting concentrations or health risk. An emissions inventory analysis provides information on total emissions levels that can be used to satisfy the NEPA purpose of comparing project alternatives. This approach depends on the assumption that potential impacts of the alternatives are adequately represented by the aggregate emissions. The uncertainties involved in estimating emissions alone are considerably less than those involved in estimating risk. By only estimating emissions, the typical NEPA analysis will use resources to improve the emission inventory to support better relative aggregate comparison of the project alternatives for NEPA decision making, but at the cost of not estimating the absolute risk magnitude comparison.

HAPs other than MSATs are normally not evaluated separately in NEPA analyses of surface transportation projects. MSATs as a class, and priority MSATs in particular, should be good surrogates for all relevant HAPs because most are species of volatile organic compounds (VOC) or particulate matter (PM). The speciation distributions of VOC emissions are generally similar for broad classes of transportation sources. The speciation of PM emissions differs markedly between

gasoline and diesel sources, but less so within these source classes. In most cases, if emissions of priority MSATs are insignificant, then emissions of other transportation HAPs will also be insignificant and need not be analyzed in detail. Nevertheless, the analyst should be alert for emission sources for which priority MSATs may not be good surrogates for other HAPs. In these cases priority MSAT emissions, which are mostly associated with on-road diesel sources, may not be accurate indicators of other HAP emissions⁶. Common examples of mobile sources with characteristics different from diesels include all-gasoline fueled fleets, alternative fueled or hybrid-electric vehicles, and aircraft and equipment having gas turbine engines (most non-aircraft gas turbines in transportation use are in military vehicles). Transportation projects may also include stationary sources, such as maintenance facilities, that may emit HAPs other than MSATs.

Agency Approaches to HAP/MSAT Analysis

Agencies with air quality responsibilities have taken a number of approaches to HAP analysis. Though the agency methods usually do not differentiate between MSATs and other HAPs, the principles are valid for any pollutant. These approaches can be distinguished by whether they employ the principles of human health risk assessment (HRA). Appendix A provides details on the characteristics of each agency's approach that are relevant for developing MSAT analysis methods for NEPA studies. While this information is not a complete compendium of agency HAP approaches, the materials reviewed were chosen for their completeness, originality or exemplary status, and potential applicability to the development of MSAT analysis approaches.

A clear difference in philosophy and purpose exists between those agencies that require HRA and those that do not. Agencies that require HRA are those that are charged to be

⁶ Note this only applies to diesel PM and that other VOC-based HAPs (e.g., benzene) do not track diesel sources.

protective of air quality and health. Many, but not all, of the state and regional agencies that require HRA have jurisdiction in California where the HRA mandate has a long-established history. For an example of a non-California authority, see the Minnesota Pollution Control Agency guidance (MPCA 2004) which requires HRA for some stationary sources and certain projects under Minnesota's NEPA-like Environmental Review Program. These agencies' guidelines include consideration of the uncertainties in HRA but place priority on public disclosure and mitigation of potential risks. In the NEPA/CEQA context these agencies are rarely project sponsors and their agency mission does not include promotion, funding, or construction of transportation projects. All of the HRA methodologies examined are similar in approach and in the algorithms used, but differ in the specific modeling assumptions, the exposure and toxicity values, and impact/risk criteria that the analyst is required to use.

The agencies examined above whose MSAT guidance does not generally require HRA take a much more cautionary approach toward conducting HRA's due to uncertainties in the analysis. FHWA concepts that projects should be screened by type, activity level, and receptor location are well-established and are valid if the thresholds are set at appropriate values. The FAA guidance is particularly cautionary toward uncertainties, in part because the current state-of-the-science does not yet allow accurate estimates of ultrafine particle emissions (most PM emissions from gas turbines are of less than 0.1 micron aerodynamic diameter). Recent studies directed at improving this understanding include the APEX and UNA-UNA studies (Wey, 2006). Both FHWA and FAA note that their guidelines are subject to updating as the science of MSAT analysis improves.

Health Risk Assessment Concepts and Their Application to Transportation Agencies

Many human health risk assessments have used the four-step HRA process to describe potential impacts and risks associated with a site that has potentially hazardous materials, or with

a stationary facility subject to New Source Review permitting. An MSAT method might apply this process as the California air quality agencies and others have. However, transportation agencies cannot be expected to carry out all the steps; some of the steps call for expertise in health science or demographics, rather than transportation expertise. A mapping of the four steps to transportation agency capabilities is shown in Table 2 below.

**Table 2. Health Risk Assessment Process and Transportation Agencies
(ICF International, NCHRP 25-25 Task 18)**

Health Risk Assessment Step	Typical Technical Activities	Level of Uncertainty	Within purview of transportation agencies?
1. Data Collection	Determine sources and pollutants emitted	Lowest	Yes
2. Exposure Assessment	Source Activity/ Emissions Inventory	Medium	Yes
	Dispersion Modeling/ Ambient Concentrations	Medium	Yes
	Receptor/Population Characteristics	Variable	Maybe
3. Toxicity (Dose-Response) Assessment	Health effects research for target receptor/population	High	No
4. Risk Characterization	Quantitative individual risk calculation	High	Yes, if steps 2 and 3 information exists

Use of this Study Relative to the FHWA Policy Document

This document should be viewed as a report which provides suggestions to state DOTs on when and how to select and apply currently available techniques for analyzing and predicting the impacts of MSATs in the NEPA process based on current best practices. This document summarizes how to document and communicate the potential MSAT impacts. On the other hand, the FHWA interim guidance document (FHWA, 2006) is a FHWA policy document which describes procedures and advises FHWA Division offices on when to analyze MSAT in the NEPA process for highways.

Toxicity Information for Priority MSAT Analysis

Table 3 indicates that transportation agencies clearly cannot carry out Step 3, Toxicity Assessment, by themselves. Rather, they will need to rely on health science agencies to do so. However, transportation agencies can apply in their own methodologies the health-based toxicity data provided by health science agencies. The toxicity data would include several metrics of toxicity and impact. All metrics must be considered in order to encompass all possible impacts. These metrics are described below. Health risk assessments have commonly used the same basic equations to calculate these metrics. Some variations have been used, including adjustment factors, to account for special circumstances. For metrics of impact, a quantitative criterion level must also be used to evaluate whether an adverse impact has been estimated.

It is helpful to consider these metrics and criteria along two dimensions as shown in Table 3: cancer versus non-cancer, and acute versus chronic. Acute refers to health impacts of short-term exposure, typically 24 hours or less. Chronic refers to longer-term exposures, typically one year to a lifetime. Exposure for periods greater than 24 hours is sometimes subdivided in the literature into additional subcategories such as sub-chronic. For purposes of this guidance, chronic refers to all exposure that is not acute; i.e., 24 hours to lifetime. Table 3 summarizes the toxicity metrics and the impact criteria used in a typical HRA for NEPA projects.

**Table 3. Summary Matrix of Health Effects Metrics
(ICF International, NCHRP 25-25 Task 18)**

Health Outcome		Time Scale	Acute	Chronic
		Cancer	Toxicity Metric	
Impact Metric/ Criterion			Not Applicable	Cancer risk (probability) or excess lifetime cancer risk (probability).
Non-Cancer	Toxicity Metric		EPA acute chronic reference concentration or risk-specific dose, CA acute reference exposure level	EPA chronic reference concentration or risk-specific dose, CA chronic reference exposure level
	Impact Metric/ Criterion		Acute Hazard Quotient (HQ) and Hazard Index (sum of HQs)	Chronic Hazard Quotient (probability) and Hazard Index (fractional index, sum of HQs)

Cancer Risk. To measure risks from developing cancer, many risk assessments have used the metric Cancer Risk (CR), or Excess Lifetime Cancer Risk (ELCR). This metric represents the probability that an individual will develop cancer in his or her lifetime as a result of exposure to the substance in question. EPA generally considers risks (CR or ELCR) of less than 10^{-6} (one in a million) to be acceptable and acts to reduce cancer risks greater than 10^{-4} (1 in 10,000). Considered as criteria for project impacts, these risk levels would roughly bracket the existing risk levels from background air pollution. Even in remote areas of the U.S., EPA has estimated that risks from background levels of air pollution are in the range of 1×10^{-5} (Guinnup 2003 as cited in FHWA ca. 2004). The MATES II study estimated the average carcinogenic risk in the South Coast Air Basin from all sources at about 1.4×10^{-3} or 1,400 per million people (SCAQMD 2000a). The definition of the degree of project impact at which risk becomes excessive—the impact criterion—is a social and policy decision that would be addressed by each local community.

The calculation of CR/ELCR is dependent on a Unit Risk Factor (URF) as an input parameter, defined as the probability that a person will get cancer from exposure to the source over 70 years, per 1 microgram/cubic meter ($\mu\text{g}/\text{m}^3$) concentration of the pollutant of interest.

URFs are determined in Step 3 of the risk assessment process. As noted above, transportation agencies are clearly dependent on health science agencies for this step. In a NEPA project MSAT analysis, the URFs normally are taken as a given and the CR/ELCR is derived as the ratio of a modeled concentration (in $\mu\text{g}/\text{m}^3$) to the URF.

Non-Cancer Risk. To measure non-cancer risks, many risk assessments have used the metrics Hazard Quotient (HQ) and Hazard Index (HI). HQs are fractional indices that can be derived for various pathways or target human health/organ systems. An HQ is the ratio of an exposure concentration for a given compound to the RfC for that compound. The sum of HQs for several compounds is an HI. An HQ or HI less than one indicates that no adverse health effects are expected, while an HQ or HI in excess of one indicates that adverse effects are possible. HQ and HI estimates cannot be interpreted as a probability of adverse health effects.

The calculation of HQ and HI is dependent on a Reference Concentration (RfC) or California Reference Exposure Level (REL) as an input parameter for toxicity. EPA characterizes an RfC/REL as “an estimate (with uncertainty spanning perhaps an order of magnitude) of a daily inhalation exposure of the human population (including sensitive subgroups) that is likely to be without an appreciable risk of deleterious effects during a lifetime.” (EPA 2006b.) The same concept may also be expressed as a Risk-Specific Dose (RSD) which is an estimate of exposure like the RfC/REL but with the value set to reflect a specific risk level such as 10^{-5} . As with URFs, the RfCs/RELs are determined in Step 3 of the risk assessment process. For MSATs, the inhalations RfCs/RELs are expressed as ambient concentrations. In a NEPA project MSAT analysis, the RfCs/RELs normally are a given and each HQ is derived as the ratio of a modeled concentration (in $\mu\text{g}/\text{m}^3$) to the RfC/REL.

Table 4 lists the current U.S. values of the toxicity metrics for the priority MSATs.

Table 4. Values of Hazard and Risk Metrics for Inhalation for the Priority MSATs (ICF International, NCHRP 25-25 Task 18)

Priority MSAT	Cancer Risk		Noncancer Effects (Hazard)		
	Chronic (Lifetime)		Acute	Chronic	
	US EPA IRIS (URF*)	California OEHHA/ARB (URF*)	California OEHHA/ARB (REL**)	US EPA IRIS (RfC**)	California OEHHA/ARB (REL**)
Acetaldehyde	2.2×10^{-6}	2.7×10^{-6}	Not estimated	9	9.0
Acrolein	Not assessed in program	Not estimated	0.19	0.02	0.06
Benzene	7.8×10^{-6}	2.9×10^{-5}	1,300	30	60.
1,3-butadiene	3×10^{-5}	1.7×10^{-4}	Not estimated	2	20.
Diesel Exhaust/ DPM+DEOG	Assessed; value not estimated	3.0×10^{-4}	Not estimated	5	5.0
Formaldehyde	1.3×10^{-5}	6.0×10^{-6}	94.	Not assessed	3.0

* Unit Risk Factor (URF): Probability of cancer per person per 70-year exposure, per $1 \mu\text{g}/\text{m}^3$ concentration.

** Reference Concentration (RfC) or Reference Exposure Level (REL): Continuous lifetime concentration ($\mu\text{g}/\text{m}^3$) at which no adverse health impacts are observed.

Sources: CARB 2006a, EPA 2006b.

Table 4 shows that while some values exist for the priority MSATs, some values are missing or are inconsistent across jurisdictions. This missing and inconsistent information points to the need for continued scientific research and indicates the limitations of such MSAT health impact analysis with the current state of scientific knowledge.

Exposure Information for Priority MSAT Analysis

For those MSAT analyses that derive quantitative estimates of risk, the basis for the exposure calculation is ambient concentrations output from modeling. Various metrics of exposure can be selected according to policy choice, characteristics of the source and the study area. In modeling terms this determines the selection of the receptor locations to be selected as output for the dispersion modeling results.

A single location of maximum modeled concentration, sometimes referred to as the Point of Maximum Impact (PMI), is often chosen. When combined with conservative (tending to

overstate impact) assumptions of population type and exposure duration (e.g., lifetime exposure of sensitive groups), a worst-case risk estimate is created that can be used as part of a screening process. If all metrics calculated from this worst case fall within acceptable levels of risk, then adverse impacts may be assumed not to occur.

Projects that are large or located in close proximity to receptors may fail such a screening test, and must analyze the interaction between concentrations by receptor location and the variations in degree of exposure by location in order to produce a more realistic risk estimate.

Metrics that might be selected in this case include the following:

- Known locations of sensitive populations—facilities or population centroid locations where the impact of exposure might be relatively great (i.e., high response per dose in a given population).
- Population weighted ambient concentrations
- Reasonable Maximal Exposure (RME)—hypothetical maximum exposure expected from the project.
- Maximum Exposed Individual Resident (MEIR) and Maximum Exposed Individual Worker (MEIW)—hypothetical individual who might receive maximum exposure.

An analysis might need to use any or all of these metrics depending on the characteristics of the project and the study area. All of these metrics are most useful when the project impact can be characterized adequately by the conditions at one or a small set of worst-case locations.

However, if a project is estimated to have impacts that exceed criteria or threshold levels over a wide area, then a risk estimate covering the entire affected population is needed. Population risk estimates are often needed in evaluating project alternatives that have maximum impacts which are

of similar magnitude, but that differ in the number or extent of receptors affected. A typical NEPA example would be alternative alignments for a highway segment within a single community. To compare alternatives meaningfully, modeled concentrations for the set of receptors throughout the study area are processed along with the exposure assumptions for the area represented by each receptor. The aggregated result of the analysis is a type of population risk estimate, and is typically represented graphically using shading or contours overlaid on a base map.

Exposure estimates and similar data can be displayed using graphic techniques that express both the values and the accompanying uncertainties. A number of techniques have been developed for this purpose (Eaton *et al.* 2003, Howard and MacEachren 1996). Examples include:

- Gradients of shading, hue, or color saturation,
- Contours drawn with visual cues such as thick or dashed lines and in/out arrows,
- Representation of areas as “clouds” rather than with defined boundaries,
- Use of paired views in which one shows the data and the other shows the reliability and uncertainty.

This technique is common in NEPA analysis for other disciplines, notably noise. In community noise analysis of transportation projects, overall noise levels may be represented by contours and incremental changes in noise levels due to the project may be represented by a map overlain by a grid with an indicator of change shown in each grid cell.

Research Approach

The research plan for this study consisted of four major tasks:

- **Task 1—Identification of Emission and Dispersion Models** This task identified currently available analytic tools applicable to predicting MSAT impacts for

transportation projects. This included both emission factor models and air quality dispersion models that would likely be used in a NEPA setting. For each of the emission factor models it was identified which MSAT species the model had been developed for, how the models can be extended/applied for the other MSAT species, and known limitations or deficiencies with the “priority” MSATs. Similarly, the air quality models were identified as to their applicability for use in transportation projects, their meteorological requirements, and their site/geometry characterization, their handling of the near field dispersion, traffic simulation, how mobile source emissions are characterized, and their removal process. This identification allows users to better understand the tools and resources available for characterizing MSAT impacts for the wide variety of transportation projects.

- **Task 2—Assessment of Models Strength and Weakness for Transportation**

Projects—This task assessed the major strengths, weakness, limitations and relative uncertainties of the emission factor and air quality dispersion models for air toxic assessment for different types of transportation facilities. Matrices were developed listing transportation projects and emission factor or air quality models identifying their associated strengths, weakness, limitations, and uncertainties. Issues assessed for the emission factor models include: speed dependency by vehicle type, facility type, species, validation of the model, and underlying database; for air quality models issues addressed include: meteorology, geometry, site characterization, (e.g., building near the source), dispersion parameters, traffic modeling capabilities, interaction between traffic and meteorology, decay for reactive pollutants and emission linkages. The set of matrices provide practitioners with specific information for use in

assessing the ability, limitations and associated uncertainty for the emission factor and dispersion models focused on transportation issues. Additionally, a discussion of the air toxic impact and associated health impact for each MSAT was developed relative to the current range of MSAT concentrations found in urban and rural areas for use in transportation specific projects. This information will enable practitioners to communicate the impact of a transportation project relative to existing conditions.

- **Task 3—Recommended Procedures for Analyzing MSATs in NEPA—**

Recommendations are developed on how to select and apply the best available models and associated techniques for MSAT impact assessment in the NEPA process. The approach to the selection process used both technical and policy considerations as to the need and appropriateness for conducting a mobile source air toxic assessment. A set of questions are developed to guide the transportation analyst on the appropriate level of analysis under NEPA. Up to five levels of analysis are considered depending upon the transportation project under consideration. The policy-related questions help to identify the appropriate level of analysis based on the scope of the project, its likely impact to the community, and the general public's level of concern. Technical questions identify the feasibility of conducting the analysis given the scope of the project and information available. The findings from this task provide a consistent approach for practitioners to make MSAT analyses of transportation projects. Additionally, the approach provides the practitioner with a justification and basis for the level of MSAT analysis conducted under the NEPA process.

- **Task 4—Recommendations in Communicating and Documenting MSAT Health Impacts in NEPA—**Guidance is developed for each level of analysis on the

information needed to document potential MSAT impacts. Incorporated into the level of analysis is the uncertainty based on the analytical technique recommended and associated health effects. Some recommendations for inclusion in the guidance are: an objective description of the current state of health science, acknowledgement of the on-going research, and current local MSAT concentrations as well as trends in MSAT emissions. As part of this effort a review was performed on the current approaches used by transportation agencies to communicate MSAT health impacts and incorporate the approaches which have proven effective into the guidance. The recommendations will allow transportation practitioners to provide clear and effective communication on MSAT issues to both the technical and public audience. The guidance establishes a clear and consistent methodology for practitioners to effectively communicate MSAT findings for transportation projects, including increases in MSAT risk exposure and their associated health impacts.

CHAPTER 2. Findings

In this Chapter we present the findings of the research based on the proposed research scope as presented in the Work Plan (ICF Consulting, 2005). The findings focus on six key areas of investigation:

- Identification of modeling tools in support of MSAT analysis
- Assessment of modeling tools' strengths and weaknesses
- Health Impacts of Mobile Source Air Toxics and Current Range in Concentration
- Recommendations on the best approach for analyzing MSATs
- Communication of MSAT analysis results and health impacts
- Uncertainty in MSAT analysis.

Both the findings and their meaning in terms of use, policies, and recommended procedures are discussed in this section. Supporting details are presented in the Appendix as appropriate.

Identification of Currently Available Modeling Tools in Support of MSAT Analysis

Modeling tools are widely available to predict MSAT impacts from transportation projects. These tools have varying histories and applications in MSAT analyses. This effort focused on identifying possible emission factor and air quality dispersion models applicable to transportation projects that would likely be used in a NEPA setting.

The emission factor models identified for detailed review include EMFAC2002, MOBILE6.2, and the U.S. EPA MOVES model currently in development (based on a review of the

most current plans).⁷ For each emission factor model we identify the applicable source category, input data requirements, the functionality of the model, types and applicability of output data, the MSAT species modeled, how the model estimates the MSAT emission factors, and known limitations or deficiencies with the priority MSAT species. Table 5 through Table 7 show the findings from the examination of the emission factor models and evaluations available for these three models.

While the use of these emission factor models are prescribed in federal policy and regulations the summary presented here provides a convenient summary to the transportation analyst showing the emission factor models' applicability and capability specific to MSAT issues. The tables show some of the known limitations of the emission factor models associated with specific MSATs.

⁷ Other models are available (e.g., Microfac, MEASURE, CMEM, TRANSIMS) (Singh and Sloan, 2005) ,but these are emission factor models that require extensive supporting information to develop emissions and are not specifically endorsed by EPA or CARB and use of these other models would require a lengthy approval process for their use and application.

Table 5. Mobile 6.2—Application for MSATs—Functionality and Limitations (ICF International, NCHRP 25-25 Task 18)

Model	MOBILE6.2 ¹																						
Agency	US EPA OTAQ																						
Availability	www.epa.gov/otaq/m6.htm																						
Source Categories	Onroad mobile sources for 1955-2050 calendar years																						
Input Requirements	Calendar year, minimum and maximum temperature, and fuel volatility																						
Optional Inputs	<p>Vehicle registration/distributions, speeds and speed distributions, VMT, diesel sales fractions by vehicle type.</p> <p>Alternative-fueled vehicle fractions.</p> <p>Ambient conditions: temperature, humidity, solar load, altitude.</p> <p>Time parameters: season, month (January or July), and time of day.</p> <p>Fuel parameters: Reid Vapor Pressure of gasoline and oxygenated fuel, diesel fuel sulfur content.</p> <p>Control programs: Stage II, Inspection and Maintenance, anti tampering programs.</p> <p>Tier standards and alternative fuels included:</p> <p>Fuel % aromatics, % olefins, % benzene, E200 (% of vapor a gasoline produces at 200 F), E300, oxygenate type and fractional volume, sulfur content of diesel.</p> <p>Engine starts per day, soak times, vehicle speed distributions.</p> <p>Hydrocarbon species and particle size cutoff.</p> <p>Alternative pollutant emission ratios, parameters.</p>																						
Outputs	<p>Gram per mile emission rates for all pollutants: heavy-duty diesel has idle PM emission rate option in grams per hour;</p> <p>Other idle emission rates estimated from 2.5 mph average speed bin</p>																						
MSAT Pollutants	<p>The following MSATs are explicitly modeled in MOBILE6.2:</p> <table border="1"> <thead> <tr> <th>Name</th> <th>Code</th> </tr> </thead> <tbody> <tr> <td>Benzene</td> <td>BENZ</td> </tr> <tr> <td>Methyl Tertiary Butyl Ether</td> <td>MTBE</td> </tr> <tr> <td>1,3-Butadiene</td> <td>BUTA</td> </tr> <tr> <td>Formaldehyde</td> <td>FORM</td> </tr> <tr> <td>Acetaldehyde</td> <td>ACET</td> </tr> <tr> <td>Acrolein</td> <td>ACRO</td> </tr> <tr> <td>Organic Carbon Portion of Diesel Exhaust PM</td> <td>OCARBON</td> </tr> <tr> <td>Elemental Carbon Portion of Diesel Exhaust PM</td> <td>ECARBON</td> </tr> <tr> <td>Total Carbon Portion of Gasoline Exhaust PM</td> <td>GASPM</td> </tr> <tr> <td>Lead Portion of Exhaust Particulate</td> <td>Lead</td> </tr> </tbody> </table>	Name	Code	Benzene	BENZ	Methyl Tertiary Butyl Ether	MTBE	1,3-Butadiene	BUTA	Formaldehyde	FORM	Acetaldehyde	ACET	Acrolein	ACRO	Organic Carbon Portion of Diesel Exhaust PM	OCARBON	Elemental Carbon Portion of Diesel Exhaust PM	ECARBON	Total Carbon Portion of Gasoline Exhaust PM	GASPM	Lead Portion of Exhaust Particulate	Lead
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**Table 5. Mobile 6.2—Application for MSATs—Functionality and Limitations
(ICF International, NCHRP 25-25 Task 18) (continued)**

Functionality	
MSATs	<p>VOC, CO, NOx based on test results over drive cycles Toxics calculated as fractions of VOC or PM based on technology groups, driving cycles, normal and high emitters, and gasoline fuel properties</p> <p>Based on large number of tests for variety of fuels Accounts for impacts of emissions control technology, normal vs. high emitters, fuel properties</p> <p>Six priority MSAT emissions explicitly modeled using the same algorithms as the MOBTOX² emission model All gas phase MSAT dependent upon vehicle speed, temperature, RVP and fuel sulfur</p>
Priority	
1) Acetaldehyde	<p>Explicitly modeled in MOBILE6.2 Also function of fuel ethanol</p>
2) Acrolein	<p>Explicitly modeled in MOBILE6.2 Not modeled in MOBTOX. Calculated as 0.06-0.45% of TOG based on vehicle type/technology.⁸ Based on limited data from older vehicle technology</p>
3) Benzene	<p>Explicitly modeled in MOBILE6.2 Also function of fuel benzene, aromatic content Component of both exhaust and evaporative emissions. 1996 NATA comparison showed 90% of annual average site concentrations agree within a factor of 2.³</p>
4) 1,3-Butadiene	<p>Explicitly modeled in MOBILE6.2 Also function of fuel olefins and how well the catalyst is functioning.</p>
5) Exhaust PM	<p>Results independent of speed for both gasoline and diesel fueled vehicles Estimates for light- and heavy-duty vehicles Does NOT include effects of high load/acceleration, malfunctioning vehicles (smokers), deterioration, ambient temperature, oxygenated fuel, extended idle Little information on gasoline PM emissions or high-emitters Model generally valid within approximately a factor of 2 for diesel PM.³</p>
6) Formaldehyde	<p>Explicitly modeled in MOBILE6.2 Also strong function of fuel MTBE for gasoline vehicles</p>

**Table 5. Mobile 6.2—Application for MSATs—Functionality and Limitations
(ICF International, NCHRP 25-25 Task 18) (continued)**

Other	<p>MTBE also explicitly modeled for exhaust and evaporative emissions; only in gasoline vehicles</p> <p>Other MSATs estimated through "ADDITIONAL HAPS" command, but requires user-provided external datafiles specifying: ratios of MSAT to VOC (e.g., gaseous HAPs), ratios of MSAT to PM (e.g., PAHs), or basic emission rates plus deterioration factors (e.g., metals) by fuel types.⁴</p> <p>Default (csv) data files for several fuels available in MOBILE6.2 zip archive.⁷</p> <p>Either the ratio or emissions factor method may be used to predict emissions of:</p> <ul style="list-style-type: none"> Dioxin/Furans Nickel Compounds Arsenic Compounds Manganese Compounds Chromium Compounds Mercury Compounds Xylene Styrene n-Hexane Naphthalene Toluene Ethyl benzene Polycyclic Organic Material (POM - 16 separate compounds)
Known Limitations	<p>PM based on PART-5 model. Does not include effects of high-load conditions, malfunctioning vehicles (smokers), vehicle deterioration, temperature, speed, or fuel oxygenate.</p> <p>Toxic to VOC ratios for heavy-duty vehicles are based on limited data from older technology vehicles and may require revision.^{3,5}</p> <p>Toxic to VOC ratios assumed to be constant in all modes of vehicle operation.⁶</p> <p>Improvement also needed for:³</p> <ul style="list-style-type: none"> MSAT emissions from HDVs Toxic fractions from different diesel formulations Sensitive to vehicle speeds, registration distribution, VMT fractions by vehicle classes, temperature, and RVP and other fuel properties. Particularly pronounced for regional emission inventories.⁹ Low temperature cold starts Gasoline PM emissions

Table 5. Mobile 6.2—Application for MSATs—Functionality and Limitations (ICF International, NCHRP 25-25 Task 18) (continued)

References	
1	<p><u>User's Guide to MOBILE6.1 and MOBILE6.2, Mobile Source Emission Factor Model</u> U.S. EPA, August 2003. Available at http://www.epa.gov/otaq/models/mobile6/420r03010.pdf</p>
2	<p>MOBTOX was a modified version of MOBILES to simulate MSAT emissions. Its algorithms were peer reviewed and documented, but its use was very difficult. It has been supplanted by MOBILE6.2 (Ref 1,3)</p>
3	<p>Richard Cook, <u>U.S.EPA Highway Vehicle Emission Models and Data for Estimating Air Toxics</u>, Air Toxics Workshop, Transportation Research Board Annual Meeting, January 9, 2005.</p>
4	<p><u>Upgrading MOBILE to include Air Toxic Emission Factors Proposed MOBILE6.2 Project Description</u>, EPA, May 15, 2001. Available at http://www.epa.gov/otaq/models/mobile6/m62scop.pdf</p>
5	<p><u>Estimation of Motor Vehicle Toxic Emissions and Exposure in Selected Urban Areas</u>, NESCAUM, October, 1999 Available at http://www.nescaum.org/committees/aqph/MSPeerReview/ExSumm.html</p>
6	<p>Rich Cook, <u>Developing Air Toxic Emission Inventories for Mobile Sources</u>, Air Toxics Risk Assessment Modeling Tools Symposium, Region 5, July 15-17, 2003</p>
7	<p>ZIP-file archive of MOBILE6.2, including external datafiles (csv) for producing emissions of additional HAPs available at http://www.epa.gov/otaq/models/mobile6/mobile62.zip</p>
8	<p>Rich Cook and Edward L. Glover, <u>Technical Description of the Toxics Module for MOBILE6.2 and Guidance on Its Use for Emission Inventory Preparation</u>, U.S. EPA OTAQ, EPA420-R-02-029, November 2002</p>
9	<p>Cook et al., <u>Preparing Highway Emissions Inventories for Urban Scale Modeling: A Case Study in Philadelphia</u>, submitted for publication, 2005.</p>

Table 6. EMFAC 2002—Application for MSATs—Functionality and Limitations (ICF International, NCHRP 25-25 Task 18)

Model	EMFAC2002 (v2.20) ¹
Agency	California Air Resources Board
Availability	http://www.arb.ca.gov/msei/on-road/latest_version.htm
Source Categories	Emissions from the California on-road fleet from 1970–2040 by county, basin, air district, or statewide
Input Requirements	Geographic area, calendar year, month or season, title, model years included, inspection and maintenance (I/M) programs, emission mode, and output options.
Optional Inputs	Specific output options dependent on the report type requested.
Outputs	Total emissions, grams per activity emission rates, or basic emission rates (BER; for each vehicle class and model year) of pollutants.
MSAT Pollutants	Particulate Matter (PM) and lead are the only explicitly modeled MSATs in EMFAC2002 Hydrocarbons (HC) may be expressed as TOG, ROG, THC, or CH ₄ . MSATs may then be computed externally as a fraction of PM or appropriate HC based on technology groups and fuel properties.
Functionality	Calculates emission rates of HC, CO, NOx, PM, lead, SO ₂ and CO ₂ for 45 model years for each vehicle class by calendar year, twenty four hourly periods, month of the year, and air district, air basin, county, or subcounty in California. ² Operates in three modes: <i>Burden</i> (tons/day) appropriate for regional inventories, <i>Emfac</i> (grams/activity) for areawide average emissions, and <i>Calimfac</i> (grams/mile) for detailed basic emission rates.
MSATs	Only PM and lead calculated directly.
Known Limitations	"Future refinements to EMFAC will include the incorporation of toxic air contaminants, greenhouse gases and a direct interface to travel demand models and geographic information systems" ² , however, most MSATs must now be calculated externally. ARB plans to internalize calculations on speciation of MSAT based on emission inventories of PM and TOG in EMFAC. This could include as many as 55 species determined as fractions of total PM and 720 species based on TOG. ³ However, the level of detail is only sufficient for inventory calculations, not emissions factors segregated by vehicle class or operating mode and, therefore, not appropriate for hotspot assessment. ⁴ Also, the emissions factors are based on data for the California fleet, and therefore differ from those used for MOBILE or MOVES.
References	<ol style="list-style-type: none"> 1 Emfac2001 (version 2.08) / Emfac2002 (version 2.20) User's Guide, CARB. Available at http://www.arb.ca.gov/msei/on-road/downloads/docs/users_guide.zip 2 Overview of the EMFAC Emissions Inventory Model, California Air Resources Board's Emissions Inventory Series, Vol. 1, Issue 6 Available at http://www.arb.ca.gov/msei/on-road/briefs/emfac7.pdf, 2003. 3 ARB speciation profiles and size fractions are discussed at http://www.arb.ca.gov/ei/speciate/speciate.htm 4 Personal communication: Larry Hunsaker, CARB, 4/3/2006

**Table 7. MOVES—Application for MSATs—Functionality and Limitations
(ICF International, NCHRP 25-25 Task 18)**

Optional Inputs	Not yet known.
Outputs	Core model outputs will be emission factors and total emissions. Will provide emission estimates at three scales: macroscale (county), mesoscale (link/travel analysis zone), microscale (roadway up to corridor)
MSAT Pollutants	Will be based on updated data for MSATs currently being collected.
Functionality	Will simulate all criteria pollutants in MOBILE and NONROAD, air toxics as currently explicitly modeled in MOBILE6.2, and greenhouse gases (N2O, CO2 and CH4). Will provide life cycle (well to pump) analysis incorporating Argonne's GREET model. Uses "binning" approach to aggregate any driving pattern into seconds in (speed, engine/vehicle specific power) bins and pairs with emission rates. The "binning" for physical and operational characteristics such as engine size, model year and speed will use the Physical Emission Rate Estimator (PERE) to predict fuel economy associated with each "bin".
MSATs	Based on analysis of influences on toxic fractions - fuel composition, hot/cold starts, vehicle types and technologies, driving cycles/modal distributions, and other factors shown to influence toxic fractions (e.g., ambient temperature) Emission will be based on operating mode subdivided into bins of speed and vehicle specific power and are likely to be chained off of calculated hydrocarbon and particulate matter emissions as done for MOBILE. ³ Mass emission rates may be indexed to the mass fuel consumed through the use of PERE if enough supporting information is available.
Known Limitations	Not yet known.
References	<ol style="list-style-type: none"> 1 Megan Beardsley, MOVES Update, CRC On-road Emissions Workshop, March 29, 2004. Available at http://www.epa.gov/otaq/models/ngm/may04/crc0304u.pdf 2 Koupal, et al., EPA's Plan for MOVES: A Comprehensive Mobile Source Emissions Model Available at www.4cleanair.org/MOVES.pdf 3 Megan Beardsley, personal communication (March, 2006).

The air dispersion models that were considered for detailed review include CALINE3, CALINE4, CAL3QHC(R), HYROAD, AERMOD, ISCST3 and CALPUFF. These models were selected based on their applicability in transportation-related settings. The types of transportation facilities to which these models may be applicable include: roadways at ground level without intersections (e.g., freeway widening projects), roadways at ground level with intersections (e.g., traffic signal improvement), elevated freeways, parking lots, transit bus garages, rail lines with locomotive traffic, and intermodal freight terminals (e.g., locomotive to truck transfer, ship to truck, etc.). For each model we identified the meteorological requirements, the site/geometry characterization, the handling of the near field dispersion, the availability of traffic simulation, how mobile source emissions are characterized, and removal process (chemical decay, wet/dry deposition), available model outputs, how MSAT may be treated and known limitations for transportation settings. Table 8 through Table 14 show the findings from the examination of the air quality models.

At the present time the choice of the most appropriate modeling tool is not prescribed by policy and the information provided in these tables provides a starting point and basis for the transportation analyst to identify which modeling tool to use in a MSAT assessment. The summary presented for each model provides the analyst with a list of features that may be important to the transportation facility that is under review for MSAT assessment. The tables also show some of the known limitations of the air quality models associated with specific MSATs. This information—when combined with the assessment of the strengths and weaknesses of the models as discussed in the next section—will provide the necessary information for transportation analysts to determine the best modeling choice for use in an MSAT assessment.

**Table 8. CALINE3—Application for MSATs—Capabilities and Limitations
(ICF International, NCHRP 25-25 Task 18)**

Model	The Calpuff Modeling System ¹
Agency	Earth Tech, Inc.
Availability	Developed and maintained by Earth Tech, but available from the EPA as a "preferred or recommended model" primarily for long-range transport http://www.epa.gov/scram001/dispersion_prefrec.htm#calpuff
Design/Applicable Use	A non-steady-state, multi-layer, multi-species gaussian puff dispersion model. Simulates temporal and spatially varying meteorology for pollution transport, transformation and removal. Includes algorithms for subgrid scale effects. Includes algorithms for wet scavenging and dry deposition, and chemical transformation. Applicable for a limited number of point, area, volume sources. Capabilities for complex terrain and/or meteorology and long-range transport (MESOPUFF replacement) Range from tens of meters to hundreds of kilometers.
Meteorological Requirements	Requires same minimum data as ISC3, but can also use multiple stations. Met preprocessor including diagnostic regional wind field generator and boundary layer calculations for both land and over water (CALMET). Can also operate with single station winds.
Site/Geometry Characterization	Can simulate complex terrain, over water transport, coastal interaction, and building downwash (Huber-Snyder; Schulman-Scire). Area source algorithm uses slug formalism rather than polygons. Also simulates volume sources.
Dispersion Characteristics	Includes downwash, plume rise, wet/dry removal, and puff splitting/elongation. Fumigation and wind shear effects are included. Uses surface roughness, Monin-Obukhov length scale for turbulence, solar radiation in dispersion parameterization from CALMET. Includes several options for gaussian dispersion coefficients: turbulence measurements, similarity theory from estimate of surface heat and momentum flux, or Pasquill-Gifford dispersion coefficients.
Traffic Simulation	None included.
Emissions Characterization	Specified by area (mass/area-s) or volume (mass/s). User specified initial sigma-z for area and initial sigma-y and sigma-z for volume sources. Need to externally determine emissions from emission factor model. No linkages to mobile source emission factors.
Species Included	Generally not specific. However, does include some chemistry for sulfur and nitrogen compounds.
Removal Processes	Wet/dry removal simulated using a full resistance model for dry deposition and empirical scavenging coefficients for the wet removal Has capabilities for user-specified diurnal cycles of transformation rates for all species modeled.
Outputs	Three general output file types are produced: a list file with output overview, a restart file, and unformatted files of species concentrations and deposition amounts, and information for visibility calculations. The concentration files can be read into the post processing routine, CALPOST, to generate concentrations at receptors for given averaging periods. Similar capability for deposition.
MSAT Pollutants	Any inert MSATs may be obtained by specifying appropriate emission, deposition, and decay rates.
Other Known Limitations for Transportation Projects	Application in the Portland Air Toxic Study showed that for the best understood mobile source air toxic emission (benzene) that modeled concentrations were generally within a factor of two of the observed concentration and in several cases within the range of uncertainty of the observed concentration ² . Also, the study identified that estimates of area source benzene were overestimated.
References	<ol style="list-style-type: none"> 1 A User's Guide to the Calpuff Dispersion Model, Earth Tech, Inc., 196 Baker Ave., Concord, MA, 01742, January, 2000. 2 Relationship between motor vehicle emissions of hazardous pollutants, roadway proximity, and ambient concentrations in Portland, OR Cohen, J., Cook, R., Bailey, C., Carr, E., Environmental Modeling and Software 20 (2005) 7-12.

**Table 9. CALINE4—Application for MSATs—Capabilities and Limitations
(ICF International, NCHRP 25-25 Task 18)**

Model	The California Line Source Model, version 4 (CALINE4) ¹
Agency	California Department of Transportation (Caltrans)
Availability	Available from Caltrans at: http://www.dot.ca.gov/hq/env/air/calinesw.htm
Design/Applicable Use	Caline4 (aka CL4) is essentially Caline3 with additional parameters for enhanced characterization. Designed for roadway air emissions under free flow conditions with line sources for near-field, steady-state, short-term modeling. Applicable range is few meters to 500 m from roadway.
Meteorological Requirements	Wind speed and direction, standard deviation of wind direction, stability class, and mixing height as for Caline3. CL4 uses standard deviation of wind direction (sigma-theta) to characterize dispersion. Applies uniform meteorological conditions over the domain.
Site/Geometry Characterization	Improves Caline3 by adding additional capabilities for intersection, street canyon, and parking facility simulation capabilities. Also allows declaration of acceleration/deceleration times, but this formulation is considered outdated for current vehicle technology.
Dispersion Characteristics	Improves over Caline3 by adjusting initial sigma-z by residence time over roadway; initial sigma-z increased by mixing zone residence time; sigma-z based on initial sigma-z and value of sigma-z at a distance traveled by each line segment over the mixing zone based on Smith ² power curves using Pasquill stability class with adjustment for vehicle heat flux based on traffic volume. Sigma-y parameterized based on observed sigma theta and Draxler ³ Lagrangian diffusion time.
Traffic Simulation	Improves Caline3 by adjusting for residence time idle and vehicle heat flux effects on vertical dispersion. Additional methods included for bluff or street canyons and parking lots.
Emissions Characterization	As in Caline3, emissions are determined from links with specified volume, gram per mile emission factor, and road width. Improves Caline3 by adding an intersection module which includes vehicle idle. However, this intersection modal emission calculation is considered outdated and no longer appropriate for today's fleet.
Species Included	CO, other inert gases, PM, and option for NO2 with deterioration.
Removal Processes	Deposition determined by specifying single deposition and settling velocity as done in Caline3. NO2 option uses "Discrete Parcel Method" first-order reaction with sunlight and ozone and requires NO2 photolysis rate constant.
Outputs	Model predicted concentrations for hourly intervals for each receptor for each traffic or intersection link, emissions, and meteorological condition specified.
MSAT Pollutants	Only PM treated directly. Other inert MSATs may be treated via inert gas calculations.
Other Known Limitations for Transportation Projects	Model formulation does not allow wind speeds less than 0.5 m/s. Model approximations restrict surface roughness to between 3 and 400 cm. Source heights limited between +/- 10m and sigma-theta between 5 and 60°. Model does not perform well if terrain is sufficiently rugged to cause spatial variability in the wind field. Mixing zone widths expected to be at least 10m and link lengths less than 10 km but at least as large as the mixing zone width. Tendency for freeway scenarios is more often overpredict (> factor of 2, 12-15%) than underpredict (< factor of 2, 1-7%). Tendency for freeway scenario to overpredict when winds are light (1-2 m/s)
References	<ol style="list-style-type: none"> 1 <u>CALINE4 - A Dispersion Model for Predicting Air Pollutant Levels Near Roadways</u>, Paul E. Benson, Office of Transportation Laboratory, California Department of Transportation Available at http://www.dot.ca.gov/hq/env/air/calinemn.htm 2 Smith, F.B. A Scheme for Estimating the Vertical Dispersion of a Plume From a Source Near Ground Level, Air Pollution Modeling, No. 14, CCMS/NATO, 1972. 3 Draxler, R.R. Determination of Atmospheric Diffusion Parameters, <i>Atmospheric Environment</i>, Vol. 10, No. 2, pp 99-105, 1976.

**Table 10. HYROAD—Application for MSATs—Capabilities and Limitations
(ICF International, NCHRP 25-25 Task 18)**

Model	The Hybrid Roadway Intersection Model (HYROAD) ¹
Agency	ICF Consulting and KLD Associates, under sponsorship of FHWA and NCHRP.
Availability	Publicly available from the EPA as an "alternative model" http://www.epa.gov/scram001/dispersion_alt.htm#hyroad
Design/Applicable Use	An integrative model that simulates traffic (a microscale transportation model which simulates individual vehicle movement), emissions (composite emission factors and distribution of emissions based on the traffic simulation), and dispersion. Applicable range is up to 500 m from roadway and hourly concentrations of CO, PM, or other inert pollutants, including MSATs. Dispersion is simulated with a Lagrangian puff and gridded, non-uniform wind and stability field derived from traffic module outputs. Designed for roadway intersections with up to 5 approach and departure legs for short-term high concentration episodes.
Meteorological Requirements	Wind speed, direction, sigma-theta, stability class, mixing height, temperature Determines a set of meteorological fields (wind speeds and turbulent mixing) conditions over the domain influenced for each signal phase.
Site/Geometry Characterization	Detailed site-specific geometry, including turn bays and through lanes, turn movements, signal cycle timing, width of median, width of lanes, lane restrictions (e.g., HOV), pedestrian traffic crossing for all approach and departure links.
Dispersion Characteristics	Lagrangian puff approach based on CALPUFF. Puffs are transported and dispersed according to local, non-uniform wind fields influenced by vehicle-induced flows and wakes under varying signal phase conditions. ² Enhanced vertical dispersion over roadways. Initial sigma-y is mean lane width. Initial sigma-z is 1.5 m.
Traffic Simulation	Includes microscopic traffic simulation model (TRAF-NETSIM) as basis for generating traffic information. TRAF-NETSIM logic determines individual vehicle movements according to car-following logic based on neighboring vehicles, traffic control devices, and driver behavior each second. Relies on user supplied traffic volume, fleet mix, and turning motions.
Emissions Characterization	Base emission factors from MOBILE5 or MOBILE6 are included as inputs, but are used in a regression analysis to calculate composite emission factors based on current conditions at each time period. Vehicle speed and acceleration distributions tracked by signal phase and roadway segment, then used in emissions calculations to calculate a weighted average emission rate for the appropriate speed correction factor by driving cycles; emissions are distributed around intersection based on fuel consumption. Spatial and temporal distribution of emissions is based on vehicle operation predictions rather than uniformly distributed. Spatial allocation at discrete 10-m block lengths; developed to integrate with modal emissions modal (accel, cruise, idle)
Species Included	Model set for CO only. Inert species only. Code may be modified or results post processed to treat other species.
Removal Processes	Deposition and settling based on parameterization by Ermak ³ with single, specified velocity for each. No reactive decay treatment.
Outputs	Output file from traffic simulation module includes all traffic parameters (turning movements, queue length, speeds, volumes, delay, etc.) at each node in the traffic simulations. Output file from dispersion simulation provides concentrations at each receptor for each time period in dispersion simulation.
MSAT Pollutants	No MSATs treated directly. PM and other inert MSATs may be obtained by making minor changes in the code or post processing.
Other Known Limitations for Transportation Projects	Minimum wind speed is 0.3 m/s. HYROAD model evaluation comparison with CAL3QHC demonstrated better performance over CAL3QHC for three intensively monitored intersections; as well as for a set of SLAMS "hot-spot" monitoring sites ⁴ Requires more input information than CAL3QHC - primarily intersection geometry Limited to intersection settings
References	<ol style="list-style-type: none"> 1 <u>USER'S GUIDE TO HYROAD -- THE HYBRID ROADWAY INTERSECTION MODEL</u>, Systems Applications International, Inc. and KLD Associates, Inc. SYSAPP-02-073d, July 2002. 2 Eskridge, R.E., and Catalano J.A., <u>ROADWAY -- A Numerical Model for Predicting Air Pollutants Near Highway's -- User's Guide</u>, EPA/600/8-87/010, Atmospheric Sciences Research Laboratory, USEPA/ORD, Research Triangle Park, NC, March 1987. 3 Ermak D.L. An analytical model for air pollutant transport and deposition from a point source. <i>Atm. Env.</i>, Vol. 11. pp. 231-237, 1977. 4 HYROAD Model Formulation, prepared by ICF Consulting, SYSAPP-02/047d, July 2002.

**Table 11. CAL3QHC(R)—Application for MSATs—Capabilities and Limitations
(ICF International, NCHRP 25-25 Task 18)**

Model	CAL3QHC and CAL3QHCR ¹
Agency	US EPA
Availability	Publicly available from the EPA as an "other preferred or recommended model" http://www.epa.gov/scram001/dispersion_prefrec.htm#cal3qhc
Design/Applicable Use	CAL3QHC and CAL3QHC-R combine the Caline3 dispersion model with a traffic queuing algorithm to estimate running and idling emissions at intersections. R-version differs by allowing up to 1-year of meteorology. Applicable range is three meters to 150 m from roadway.
Meteorological Requirements	Same as Caline3. Applies uniform conditions over the domain.
Site/Geometry Characterization	Same as Caline3, but requires intersection specifications for queue links. Can simulate up to 120 roadway links/segments.
Dispersion Characteristics	Same as Caline3. Also includes the ISCST2 calm processing routine (CALMPRO).
Traffic Simulation	Improves Caline3 by adding traffic queuing algorithm that calculates queue length, delay, volume/capacity; R-version allows a year of traffic/signalization data, volume variation by hour/day of week.
Emissions Characterization	Generally same as Caline3, but improves estimation by including characterization of idling emissions while vehicles are queued.
Species Included	Same as CALINE3, but also Includes capability of PM.
Removal Processes	Same as Caline3.
Outputs	Model predicted concentrations for hourly intervals for each receptor for each meteorological condition. Model will report 1-hour and 8-hour average CO as well as 24-hour or annual average PM concentration Long version output also lists each link contribution to the maximum concentration.
MSAT Pollutants	In addition to CO the model includes the capability for the analysis of particulate matter (PM).
Other Known Limitations for Transportation Projects	Traffic operational characteristics (delay and capacity) based on 1985 Highway Capacity Manual. Selected by EPA as recommended guideline model for estimating CO concentrations near intersections based on model comparison study using the then available New York City Route 9A data and MOBILE4.1 model ² Intersections with unbalanced flow volumes (traffic volume dominate in one direction) leads to excessive queue length estimate and historical over prediction of CO; MOBILE6 has reduced idle emission >50% relative to M4.1 which leads to improved model performance Model does not simulate situations with wind speeds less than 1 m/s
References	<ol style="list-style-type: none"> 1 User's Guide to CAL3QHC Version 2.0: A Modeling Methodology for Predicting Pollutant Concentrations Near Roadway Intersections USEPA Office of Air Quality Planning and Standards, RTP, NC 27711, EPA-454/R-92-006 (Revised), September, 1995. 2 DiCristofaro, D., Strimailis, D. Mentzer, R, Evaluation of CO Intersection Modeling Techniques Using a New York City Database", Sigma Research Corporation, EPA Contract No. 68D90067, Work Assignment 3-2 (1992), 156 pp.

**Table 12. ISCST3—Application for MSATs—Capabilities and Limitations
(ICF International, NCHRP 25-25 Task 18)**

Model	The Industrial Source Complex (Short-Term) Model, version 3 ¹
Agency	US EPA
Availability	Publicly available from the EPA as an "alternative model" http://www.epa.gov/scram001/dispersion_alt.htm#isc3
Design/Applicable Use	Short-term, steady-state Gaussian plume model to assess concentrations resulting from a wide variety of emission sources. Can account for: settling and dry deposition of particles; downwash; point, area, and volume sources; plume rise; separation of point sources; and terrain. Can use the Emissions Modeling System for Hazardous Pollutants (EMS-HAP) to process an emission inventory for input. Is also coupled with the Building Profile Input Program (BPIP) and the Building Profile Input Program for PRIME (BPIPPRM) to calculate building heights and projected building widths for structures. As of December, 2005, AERMOD has supplanted ISC as EPA's preferred model. Effective operating range from tens of meters up to 50 km
Meteorological Requirements	Wind speed, direction, stability, and mixing height. Also, precipitation for wet deposition. Calm processing routine may be employed to avoid low wind speed values and resulting unrealistically high concentrations.
Site/Geometry Characterization	Specifications for area and volume source and combinations for line source modeling. Area sources may be rotated. Requires surface roughness. May include building wake effect characterization.
Dispersion Characteristics	Gaussian plume diffusion. Uses a numerical integration approach for area sources. Initial sigma-y and sigma-z can be specified based on source sizes.
Traffic Simulation	None explicitly included.
Emissions Characterization	Specified by point (mass/s), area (mass/area-s), or volume (mass/s). Include a plume rise calculation for point sources. Need to externally determine emissions from emission factor model. Not directly linked to mobile source emission factor model.
Species Included	Not specific. Any species may be included.
Removal Processes	Employs dry and wet deposition options for both gas and particle emissions under the TOXICS option. Simple exponential decay included with user specified half-life.
Outputs	A variety of output files may be produced for a various averaging periods for both air concentrations and deposition amounts. Generally, output files produce resultant pollutant concentrations at specified receptors from individual or groups of sources. Various types of averaging may be done and various values (e.g., 1st, 2nd highest peak concentration) selected. Various formats are available in different output files, including: maximum or threshold exceedance; sequential results for post processing, including for various averaging times; high value summaries, generally for plotting packages; and (unformatted) files of threshold exceedances for inclusion in the TOXST model.
MSAT Pollutants	No species are treated explicitly. Any MSATs may be obtained by specifying appropriate emission, deposition, and decay rates. and if used gas specific information on reactivity, solubility, ratio of gas to liquid phase concentration (Henry's law constant)
Other Known Limitations for Transportation Projects	Requires specification of either urban or rural location. Minimum wind speed of 1.0 m/s. No enhanced traffic induced dispersion or turbulent mixing. Found to underpredict near field concentrations at a truck stop setting due to dated discrete parameterization scheme of Pasquill-Gifford. Also evaluated for long-term average performance at a truck stop. ² Requires user to develop external link between Mobile emission factor model and expected mass per unit time emission rate
References	<p>1 <u>USER'S GUIDE FOR THE INDUSTRIAL SOURCE COMPLEX (ISC3) DISPERSION MODELS</u>. US EPA, Office of Air Quality Planning and Standards, Emissions, Monitoring, and Analysis Division, Research Triangle Park, North Carolina 27711, September 1995</p> <p>2 Modeling Hotspot Transportation-Related Air Quality Impacts using AERMOD and HYROAD, W. Seth Hartley and E. Carr of ICF Consulting and C. Bailey, National Vehicle and Fuel Emission Laboratory, Office of Transportation and Air Quality, EPA, Ann Arbor, MI presented at Guideline on Air Quality Models: Applications and FLAG Developments -- An AWMA Specialty Conference, Denver, CO April 26-28, 2006</p>

**Table 13. AERMOD—Application for MSATs—Capabilities and Limitations
(ICF International, NCHRP 25-25 Task 18)**

Model	The AMS/EPA Regulatory Model (AERMOD) ¹
Agency	US EPA
Availability	Publicly available from the EPA as a "preferred or recommended model" http://www.epa.gov/scram001/dispersion_prefrec.htm#aermod
Design/Applicable Use	Gaussian plume with updated PBL turbulence parameterization A next generation model designed as the ISCST3 successor; still formulated as a steady-state Gaussian plume model Range from tens of meters up to 50 km
Meteorological Requirements	Meteorological data required to run the dispersion model is prepared with the AERMET ² preprocessor. Generally, the same meteorological data is required as for ISC, although the boundary layer parameterization in the model is different: a continuous Monin-Obukhov length parameterization replaces the older discrete stability class scheme in ISC. Minimum meteorological requirements are hourly surface observations of wind speed and direction, ambient temperature, opaque or total sky cover, and the morning upper air sounding (1200 GMT). Station pressure is also recommended, but not required. Calm processing routine may be employed to avoid low wind speed values, but is not necessary. If not used then instrument threshold minimum wind speed is required.
Site/Geometry Characterization	Generally same as ISCST3 (with PRIME). Also uses local Bowen ratio (sensible/latent heat) and albedo. Uses local upwind surface roughness to determine dispersion. Area sources may be modeled as polygons or circles.
Dispersion Characteristics	ISC structure with improved parameterizations for: terrain interaction and building downwash (PRIME), urban dispersion, CBL Gaussian in horizontal with a bi-Gaussian probability density function in the vertical, plume splitting into elevated stable layer and re-enter to the boundary layer, and plume meander, surface characteristics may be changed by direction and month, use of the latest understanding of boundary layer parameterization, uses continuous growth functions for dispersion based on turbulence based on measure or boundary layer theory, includes a mechanical mixed layer near ground
Traffic Simulation	None included.
Emissions Characterization	Generally similar to ISC3. Specified by point (mass/s), area (mass/area-s), or volume (mass/s). AERMOD differs in treatment of volume sources only in initial plume size by adding the square of the initial plume size to the square of the ambient plume size. Need to externally determine emissions. No linkages to mobile source emission factors.
Species Included	Not specific. Any species may be included.
Removal Processes	Has current dry and wet deposition algorithms based on Argonne National Lab ³ and peer review ⁴ Simple exponential decay included with user specified half-life.
Outputs	A variety of output files may be produced for a variety of purposes and include an array of results. Generally, output files produce resultant pollutant concentrations at specified receptors from individual or groups of sources, although error and restart files are also produced. Various types of averaging may be done and various values (e.g., 1st, 2nd highest peak concentration) selected. Various formats are available in different output files, including: maximum or threshold exceedance; sequential results for post processing, including for various averaging times; high value summaries, generally for plotting packages; and (unformatted) files of threshold exceedances.
MSAT Pollutants	No species are treated explicitly. Any inert MSATs may be obtained by specifying appropriate emission, deposition, and decay rates.
Other Known Limitations for Transportation Projects	Model evaluation studies to date have focused primarily on elevated source of emissions, with the notable exception of the Prairie Grass Database which showed the model to underpredict the short-term peak; long-term average performance not known. No enhanced traffic induced dispersion or turbulent mixing.
References	<ol style="list-style-type: none"> 1 <u>USER'S GUIDE FOR THE AMS/EPA REGULATORY MODEL - AERMOD (REVISED DRAFT)</u>, US EPA, Office of Air Quality Planning and Standards, Emissions, Monitoring, and Analysis Division, Research Triangle Park, North Carolina 27711, November 1998. 2 <u>USER'S GUIDE FOR THE AERMOD METEOROLOGICAL PREPROCESSOR (AERMET) (REVISED DRAFT)</u>, US EPA, Office of Air Quality Planning and Standards, Research Triangle Park, North Carolina 27711, November 1998. 3 Wesely, M. L., P. V. Doskey, and J.D. Shannon, <u>Deposition Parameterizations for the Industrial Source Complex (ISC3) Model</u>. Draft ANL Report, ANL/ER/TM-nn, DOE/xx-nnnn, Argonne National Laboratory, Argonne, Illinois 60439, 2001. 4 Walcek, C., G. Stensland, L. Zhang, H. Huang, J. Hales, C. Sweet, W. Massman, A. Williams, J. Dicke, <u>Scientific Peer-Review of the Report "Deposition Parameterization for the Industrial Source Complex (ISC3) Model."</u>, The KEVRIC Company, Durham, NC, 2001.

**Table 14. CALPUFF—Application for MSATs—Capabilities and Limitations
(ICF International, NCHRP 25-25 Task 18)**

Model	The Calpuff Modeling System ¹
Agency	Earth Tech, Inc.
Availability	Developed and maintained by Earth Tech, but available from the EPA as a "preferred or recommended model" primarily for long-range transport http://www.epa.gov/scram001/dispersion_prefrec.htm#calpuff
Design/Applicable Use	A non-steady-state, multi-layer, multi-species gaussian puff dispersion model. Simulates temporal and spatially varying meteorology for pollution transport, transformation and removal. Includes algorithms for subgrid scale effects. Includes algorithms for wet scavenging and dry deposition, and chemical transformation. Applicable for a limited number of point, area, volume sources. Capabilities for complex terrain and/or meteorology and long-range transport (MESOPUFF replacement) Range from tens of meters to hundreds of kilometers.
Meteorological Requirements	Requires same minimum data as ISC3, but can also use multiple stations. Met preprocessor including diagnostic regional wind field generator and boundary layer calculations for both land and over water (CALMET). Can also operate with single station winds.
Site/Geometry Characterization	Can simulate complex terrain, over water transport, coastal interaction, and building downwash (Huber-Snyder; Schulman-Scire). Area source algorithm uses slug formalism rather than polygons. Also simulates volume sources.
Dispersion Characteristics	Includes downwash, plume rise, wet/dry removal, and puff splitting/elongation. Fumigation and wind shear effects are included. Uses surface roughness, Monin-Obukhov length scale for turbulence, solar radiation in dispersion parameterization from CALMET. Includes several options for gaussian dispersion coefficients: turbulence measurements, similarity theory from estimate of surface heat and momentum flux, or Pasquill-Gifford dispersion coefficients.
Traffic Simulation	None included.
Emissions Characterization	Specified by area (mass/area-s) or volume (mass/s). User specified initial sigma-z for area and initial sigma-y and sigma-z for volume sources. Need to externally determine emissions from emission factor model. No linkages to mobile source emission factors.
Species Included	Generally not specific. However, does include some chemistry for sulfur and nitrogen compounds.
Removal Processes	Wet/dry removal simulated using a full resistance model for dry deposition and empirical scavenging coefficients for the wet removal Has capabilities for user-specified diurnal cycles of transformation rates for all species modeled.
Outputs	Three general output file types are produced: a list file with output overview, a restart file, and unformatted files of species concentrations and deposition amounts, and information for visibility calculations. The concentration files can be read into the post processing routine, CALPOST, to generate concentrations at receptors for given averaging periods. Similar capability for deposition.
MSAT Pollutants	Any inert MSATs may be obtained by specifying appropriate emission, deposition, and decay rates.
Other Known Limitations for Transportation Projects	Application in the Portland Air Toxic Study showed that for the best understood mobile source air toxic emission (benzene) that modeled concentrations were generally within a factor of two of the observed concentration and in several cases within the range of uncertainty of the observed concentration ² . Also, the study identified that estimates of area source benzene were overestimated.
References	<ol style="list-style-type: none"> 1 A User's Guide to the Calpuff Dispersion Model, Earth Tech, Inc., 196 Baker Ave., Concord, MA, 01742, January, 2000. 2 Relationship between motor vehicle emissions of hazardous pollutants, roadway proximity, and ambient concentrations in Portland, OR Cohen, J., Cook, R., Bailey, C., Carr, E., Environmental Modeling and Software 20 (2005) 7-12.

For both the emission factor and air quality models, the model summaries allow users to better understand the tools and resources available for characterizing MSAT impacts for the wide variety of transportation projects which state DOTs may be called upon to assess or provide review comment. The results from this task provide a convenient summary of available models and techniques which the transportation analyst can use in MSAT impact assessment for a wide variety of transportation projects.

Assessment of Model Strengths and Weaknesses for Transportation Projects

To enable the transportation analyst to select the best modeling tools for MSAT assessment, emission factor and air dispersion models were assessed for their major strengths, weakness, limitations, and relative uncertainties for air toxic assessment for different types of transportation facilities. For each emission factor or air quality model, a matrix was developed listing strengths, weakness, limitations, and uncertainties associated with different types of transportation projects. For the emission factor models specific issues include: speed dependency by vehicle type, facility type, species, validation of the model, and underlying database; for air quality models specific issues include: meteorology, geometry, site characterization, dispersion parameters, traffic modeling capabilities, interaction between traffic and meteorology, decay for reactive pollutants, and emission linkages. No assessments were made for the MOVES model, as a draft air toxic version is not yet available. Similarly, the California EMFAC model does not currently contain an air toxic module and a future version of the model will only provide MSAT emissions on a county-by-county basis based on the California Air Resources Board speciation profiles (<http://www.arb.ca.gov/ei/speciate/speciate.htm>).

Table 15 shows the findings from the examination and evaluation of the MOBILE6.2 emission factor model. Appendix B contains a list of recent studies evaluating the performance of emission factor and air quality dispersion models focused on transportation air quality issues.

Table 15. Emission Factor Models—MOBILE6.2: Relative Strength and Weaknesses (S/W) for Analysis of Air toxics from Transportation Projects (ICF International, NCHRP 25-25 Task 18)

	A	B	C	D	E
1	Emission Factor Models: MOBILE6.2 Relative Strength and Weaknesses (S/W) for Analysis of Air Toxics from Transportation Projects				
2	Facility Type	Speed Dependency by Vehicle Type	Species	Validation of Model and Underlying Database	
3	Arterial	<p>S: Emissions characterized and verified by expected speed distribution.</p> <p>W: Requires anticipated values of speed and fleet distributions at facility, as well as fuel properties. Does not change DPM emission rate with speed.</p>	<p>S: Emissions will increase with VMT for all species. Includes accounting for high-emitting gas phase vehicles and fuel properties. Gas-phase toxics are based on up-to-date in-use and certification data and accounts for aggressive driving behavior and air conditioning use.</p> <p>W: Heavy-duty gasoline and diesel vehicles emissions are based on limited (≤ 5) dataset of older technology vehicles. Model does not include effects of malfunctioning vehicles or high load conditions for DPM.¹</p>	<p>S: Gaseous MSAT missions based on VOC emissions from tens of thousands of tests over driving cycles and more than 50 technical reports. For example, benzene emission factor from Van Nuys Tunnel study for 1995 and MOBILE6.2 agreed to within 20%. Many of the reports have received external scientific peer review.¹</p> <p>W: Other than 6 MSATs explicitly modeled, requires user-defined emission rates or scale factors to VOC or PM. MOBILE6 PM emission rates known to have limitations. Model does not account for HDV fuel properties on toxic emissions. HDV toxic emissions database limited to those used in MOTOX5B. 2</p>	
4	Freeway	<p>S: Emissions characterized and verified by expected speed distribution.</p> <p>W: Requires anticipated values of speed and fleet distributions at facility, as well as fuel properties. Based on limited high speed driving test cycles.</p>	<p>S: Emissions will increase with VMT for all species. Includes accounting for high-emitting gas phase vehicles and fuel properties. Gas-phase toxics are based on up-to-date in-use and certification data and accounts for aggressive driving behavior and air conditioning use.</p> <p>W: Heavy-duty gasoline and diesel vehicles emissions are based on limited (≤ 5) dataset of older technology vehicles. Model does not include effects of malfunctioning vehicles or steep grade conditions for DPM.¹</p>	<p>S: Gaseous MSAT missions based on VOC emissions, validated in tens of thousands of tests over driving cycles and more than 50 technical studies. Many of the reports have received external scientific peer review.¹</p> <p>W: Other than 6 MSATs explicitly modeled, requires user-defined emission rates or scale factors to VOC or PM. MOBILE6 PM emission rates known to have limitations. Tunnel studies, which have no transient operation, have shown reasonably good agreement (factor of 2) (HEI Research Report No. 107 - Emissions from Diesel and Gasoline Engines Measured in Highway Tunnels and Gertler, A. and Sagebiel, J., What Have Tunnel Studies Told Us About Mobile Source Air Toxic Emissions?, Presented at CRC Air Toxics Modeling Workshop, Woodlands, TX, February 26-27, 2002. MOBILE6.2 and measured DPM data. MOBILE6.2 does not account for HDV fuel properties on toxic emissions. HDV toxic emissions database limited to those used in MOTOX5B. 2</p>	
6	Interchange/Ramps	<p>S: Emissions characterized and verified by expected speed distribution. For LDGV aggressive driving adjustments are included for gas-phase air toxics. Adjustments based on analysis of FTP and UC driving cycles.</p> <p>W: Requires anticipated values of speed and fleet distributions at facility, as well as fuel properties. Does not include any adjustments for acceleration effects for HDV. Does not change DPM emission rate with speed.</p>	<p>S: Emissions will increase with VMT for all species. Includes accounting for aggressive driving for benzene, 1,3 butadiene and formaldehyde. Based on 12 vehicles measured by CARB. Gas-phase toxics are based on up-to-date in-use and certification data and air conditioning use.</p> <p>W: Heavy-duty gasoline and diesel vehicles emissions are based on limited (≤ 5) dataset of older technology vehicles. Model does not include effects of malfunctioning vehicles or acceleration for DPM.¹</p>	<p>S: Gaseous MSAT emissions based on VOC emissions, validated in tens of thousands of tests over driving cycles for speed effects. For LDGV algorithms adjusted for aggressive driving for running and start emissions for all speeds and roadway types.</p> <p>W: Other than 6 MSATs explicitly modeled, requires user-defined emission rates or scale factors to VOC or PM. Acceleration effects for LDGV based on limited dataset. Does not account for any HDV acceleration effects. Model does not account for HDV fuel properties on toxic emissions. HDV toxic emissions database limited to those used in MOTOX5B. 2</p>	
8	Intersection	<p>S: Emissions characterized and verified by expected speed distribution. For LDGV aggressive driving adjustments are included for gas-phase air toxics. Adjustments based on analysis of FTP and UC driving cycles.</p> <p>W: Requires anticipated values of speed and fleet distributions at facility, as well as fuel properties. Does not include any adjustments for acceleration effects for HDV. Does not change DPM emission rate with speed.</p>	<p>S: Emissions will increase with VMT for all species. Includes accounting for aggressive driving for benzene, 1,3 butadiene and formaldehyde. Based on 12 vehicles measured by CARB. Gas-phase toxics are based on up-to-date in-use and certification data and air conditioning use. Idle emission rates for DPM are explicitly modeled.</p> <p>W: Heavy-duty gasoline and diesel vehicles emissions are based on limited (≤ 5) dataset of older technology vehicles. Model does not include effects of malfunctioning vehicles or acceleration for DPM.¹</p>	<p>S: Gaseous MSAT emissions based on VOC emissions, validated in tens of thousands of tests over driving cycles for speed effects. For LDGV algorithms adjusted for aggressive driving for running and start emissions for all speeds and roadway types. Also validated in a Connecticut field study evaluating MOBILE6.2 emission ratios against benzene/toluene ratios at seven sampling locations.³</p> <p>W: Other than 6 MSATs explicitly modeled, requires user-defined emission rates or scale factors to VOC or PM. Acceleration effects for LDGV based on limited dataset. Does not account for any HDV acceleration effects. Model does not account for HDV fuel properties on toxic emissions. HDV toxic emissions database limited to those used in MOTOX5B. 2</p>	
10	Parking Area/Travel Center/Intermodal Facility	<p>S: Emissions characterized and verified by expected speed distribution.</p> <p>W: Requires anticipated values of speed and fleet distributions at facility, as well as fuel properties. Does not change DPM emission rate with speed. Idle emission rates are only explicitly reported for DPM.</p>	<p>S: Emissions will increase with VMT for all species. For benzene, includes evaporative emissions for both hot soak and resting. Idle emissions for DPM explicitly modeled.</p> <p>W: Heavy-duty gasoline and diesel vehicles emissions are based on limited (≤ 5) dataset of older technology vehicles. Model does not include effects of malfunctioning vehicles or high load conditions for DPM.¹</p>	<p>S: Gaseous MSAT emissions based on VOC emissions, validated in tens of thousands of tests over driving cycles and more than 50 technical reports.¹</p> <p>W: Other than 6 MSATs explicitly modeled, requires user-defined emission rates or scale factors to VOC or PM. Benzene evaporative emissions based on proprietary vapor equilibrium model developed by GM. Mobile6 PM emission rates known to have limitations. Model does not account for HDV fuel properties on toxic emissions. HDV toxic emissions database limited to those used in MOTOX5B. 2</p>	
12					
13					
14	¹ U. S. EPA Highway Vehicle Emission Models and Data for Estimating Air Toxics, Richard Cook, USEPA OTAQ, Air Toxics Workshop.				
15	² Transportation Research Board Annual Meeting, January 9, 2005.				
16	³ Available at: http://www.tbarquality.com/miscdocs/w2005H9%20Onroad%20TRB2005ks2.pdf				
17	² The specific studies which comprise the data set for the MOTOX5B algorithms are described in Appendix D of the 1999 document, "Analysis of the Impacts of Control Programs on Motor Vehicle Toxics Emissions and Exposure in Urban Areas and Nationwide" (EPA-420/R-99-029).				
18	³ Nadim, F.; Iranmahboob, J.; Holmen, B.; Hoag, G.E.; Perkins, C.; Dahmani, A.M. (2003) Application of computer models to assess the effects of emission-reduction programs for a sustainable urban air quality management. Conference paper at "Application of Technology in Urban Development." Iranian Academic Association.				
21	¹⁹ http://www.epa.gov/OMS/regs/toxics/tox_archive.htm#1				
22	²⁰ Application of Technology in Urban Development, Dec 2003, Iran.				

Table 16 through Table 22 show the findings from the examination and evaluation of the CALINE3, CALINE4, CAL3QHC(R), HYROAD, AERMOD, ISCST3 and CALPUFF models. This set of tables provides the practitioner with specific information for use in assessing the ability, limitations and associated uncertainty for the emission factor and dispersion models focused on transportation-related MSAT issues. For each model and each type of transportation project the following parameters and their implications were evaluated in evaluating the models strengths and weaknesses:

Meteorology – site specific wind speed and direction, traffic induced vehicle wake effects, variation in wind direction, capable of modeling a full year

Geometry – capable of specify line source as link, multiple link capabilities and consideration of median, facilitate user with spatial information layout

Site Characteristics – consider grade differences, characterizes obstacles, or structures

Dispersion Parameters – adjustments to ambient dispersion due to vehicle movement, heat exhaust, consideration on horizontal and vertical dispersion effects

Traffic Modeling Capabilities – include a microscopic traffic simulation model or an approximation

Interaction between Traffic and Meteorology – number of vehicles considered as impact on near road flow field,

Reactive Decay – assess near field changes of reactive pollutants

Emission Linkages - capability for linking emission factor model with dispersion model for simulating project emissions to include traffic volume, speeds, link variations, spatial and temporal variation, modal considerations

Table 16. Air Quality Models—CALINE3: Relative Strength and Weaknesses (S/W) for Analysis of Air toxics from Transportation Projects (ICF International, NCHRP 25-25 Task 18)

Transportation Project	Meteorology	Geometry	Site Characterization	Dispersion Parameters	Traffic Modeling Capabilities	Interaction between Traffic and Met	Reactive Decay	Emission Linkages
Roadway Widening	S: Includes site specific meteorological data; W: Does not include wind generation induced from traffic	S: Can include additional lane(s) as well as median width change	S: Includes options for specifying at-grade, depressed, and bridge; W: Does not consider obstacles or structures outside lanes	S: includes enhanced roadway dispersion effects based on residence time W: Does not consider change in near field flow direction due to vehicle movement activity; adjustment for vehicle heat flux effects on vertical dispersion	W: User specified volume for each link only	W: none - roadway dispersion not dependent upon number of vehicles; heat flux not dependent upon number of vehicles	W: None	W: No capability to vary emissions as a function of transient vehicle operations within the link
HOV Lane Addition	S: Includes site specific meteorological data; W: Does not include wind generation induced from traffic	S: can include additional lane as well as median with change; W: Does not recognize lane restriction	S: Includes options for specifying at-grade, depressed, and bridge; W: Does not consider obstacles or structures outside lanes	S: includes enhanced roadway dispersion effects based on residence time W: Does not consider change in near field flow direction due to vehicle movement activity; adjustment for vehicle heat flux effects on vertical dispersion	W: User specified volume for each link - does not recognize lane restriction	W: none - roadway dispersion not dependent upon number of vehicles; heat flux not dependent upon number of vehicles	W: None	S: HOV lane modeled as separate link; W: No capability to vary emissions as a function of transient vehicle operations within the link
Roadway Intersection	S: Includes site specific meteorological data; W: Does not include wind generation induced from traffic	W: No specific capability for modeling intersections	S: Includes options for specifying at-grade, depressed, and bridge; W: Does not consider obstacles or structures outside intersection	S: includes enhanced roadway dispersion effects based on residence time W: Does not consider change in near field flow direction due to vehicle movement activity; adjustment for vehicle heat flux effects on vertical dispersion	S: Can specify multiple links to separate idle activity from running emissions W: specification of varying links must be done outside of model	W: none - roadway dispersion not dependent upon number of vehicles; heat flux not dependent upon number of vehicles	W: None	S: User-specified emission factor for each links; W: No capability to vary emissions as a function of transient vehicle operations within the link; no separate idle emission link
Interchange/ Ramp	S: Includes site specific meteorological data; W: Does not include wind generation induced from traffic; uniform flow field	S: Can include curved alignments through multiple link as well as bridge type sections;	S: Includes options for specifying at-grade, depressed, and bridge; W: Does not consider obstacles or structures outside ramp.	S: includes roadway dispersion effects based on residence time over roadway W: Does not consider change in near field flow direction due to vehicle movement activity or exhaust heat flux effects	W: User specified volume for each link only	W: roadway dispersion not dependent upon number of vehicles	W: None	W: Only user-specified emission factor for each link. W: No capability to vary emissions as a function of transient vehicle operations within the link
Parking Area/ Travel Center/ Intermodal Facility	S: Includes site specific meteorological data;	W: No parking link type specification; would need to specify multiple links to characterize area	W: Does not consider obstacles or structures outside of area	W: modeling of activity on link will automatically be adjust for induced mechanical turbulence based on road width residence time; does not consider change in near field flow field due to exhaust heat flux	W: User specified volume for each link; user must explicitly translate volume based on transient time at facility	None	W: None	W: No capability to vary emissions as a function of transient vehicle operations within the link

Table 17. Air Quality Models—CAL3QHC: Relative Strength and Weaknesses (S/W) for Analysis of Air toxics from Transportation Projects (ICF International, NCHRP 25-25 Task 18)

Meteorology	Geometry	Site Characterization	Dispersion Parameters	Traffic Modeling Capabilities	Interaction between Traffic and Met	Reactive Decay	Emission Linkages
<p>S:Includes site specific meteorological data; "R" version of model may model a full year</p> <p>W: Does not include wind generation induced from traffic</p>	<p>S: Can include additional lane(s) as well as median width change</p>	<p>S:Includes options for specifying at-grade, depressed, and bridge;</p> <p>W: Does not consider obstacles or structures outside lanes</p>	<p>S: includes enhanced roadway dispersion effects based on residence time</p> <p>W: Does not consider change in near field flow direction due to vehicle movement activity; adjustment for vehicle heat flux effects on vertical dispersion</p>	<p>W:User specified volume for each link only</p>	<p>W: none - roadway dispersion not dependent upon number of vehicles; heat flux not dependent upon number of vehicles</p>	<p>W: None</p>	<p>W: User-specified emission factor for each link; No capability to vary emissions along link</p>
<p>S:Includes site specific meteorological data; "R" version of model may model a full year</p> <p>W: Does not include wind generation induced from traffic</p>	<p>S: can include additional lane as well as median width change; W: Does not recognize lane restriction</p>	<p>S:Includes options for specifying at-grade, depressed, and bridge;</p> <p>W: Does not consider obstacles or structures outside lanes</p>	<p>S: includes enhanced roadway dispersion effects based on residence time</p> <p>W: Does not consider change in near field flow direction due to vehicle movement activity; adjustment for vehicle heat flux effects on vertical dispersion</p>	<p>W: User specified volume for each link - does not recognize lane restriction</p>	<p>W: none - roadway dispersion not dependent upon number of vehicles; heat flux not dependent upon number of vehicles</p>	<p>W: None</p>	<p>S: HOV lane modeled as separate link; W: User-specified emission factor for each link; No capability to vary emissions along link</p>
<p>S:Includes site specific meteorological data; "R" version of model may model a full year</p> <p>W: Does not include wind generation induced from traffic</p>	<p>S: Includes capabilities full capability for modeling intersections</p>	<p>S:Includes options for specifying at-grade, depressed, and bridge;</p> <p>W: Does not consider obstacles or structures outside intersection</p>	<p>S: includes enhanced roadway dispersion effects based on residence time</p> <p>W: Does not consider change in near field flow direction due to vehicle movement activity; adjustment for vehicle heat flux effects on vertical dispersion</p>	<p>S: Estimate vehicle queue based on 1985 Highway Capacity Model and Deterministic Queuing Theory; user may specific signal cycle length, saturation flow rate, signal type and arrival rate W: Queue lengths maybe overestimated in overcapacity conditions leading to overestimates of concentration</p>	<p>W: none - roadway dispersion not dependent upon number of vehicles; heat flux not dependent upon number of vehicles</p>	<p>W: None</p>	<p>S: User-specified emission factor for each separate queue and running links; W: No capability to vary emissions along link</p>
<p>S:Includes site specific meteorological data; "R" version of model may model a full year</p> <p>W: Does not include wind generation induced from traffic; uniform flow field</p>	<p>S: Can include curved alignments through multiple link as well as bridge type sections;</p>	<p>S:Includes options for specifying at-grade, depressed, and bridge;</p> <p>W: Does not consider obstacles or structures outside ramp.</p>	<p>S: includes roadway dispersion effects based on residence time over roadway W: Does not consider change in near field flow direction due to vehicle movement activity or exhaust heat flux effects</p>	<p>W:User specified volume for each link only</p>	<p>W: roadway dispersion not dependent upon number of vehicles</p>	<p>W: None</p>	<p>W: Only user-specified emission factor for each link. W: No capability to vary emissions along link</p>
<p>S:Includes site specific meteorological data; "R" version of model may model a full year</p>	<p>W: No parking link type specification; would need to specify multiple links to characterize area</p>	<p>S:Includes options for specifying at-grade, depressed, and bridge;</p> <p>W: Does not consider obstacles or structures outside of area</p>	<p>S: modeling of activity as a queue link will prevent model adjustment for horizontal dispersion from vehicle movement activity</p>	<p>W: User specified volume for each link; user must explicitly translate volume based on transient time at facility</p>	<p>None</p>	<p>W: None</p>	<p>W: Only user-specified emission factor for each link.</p>

¹ CAL3QHC is based on the same meteorological algorithms as used in CALINE3, but includes a traffic model queuing algorithm

Table 18. Air Quality Models—CALINE4: Relative Strength and Weaknesses (S/W) for Analysis of Air toxics from Transportation Projects (ICF International, NCHRP 25-25 Task 18)

Transportation Project	Meteorology	Geometry	Site Characterization	Dispersion Parameters	Traffic Modeling Capabilities	Interaction between Traffic and Met	Reactive Decay	Emission Linkages
Roadway Widening	S: Includes sigma-theta (std deviation in wind direction); physically accounts for wind direction variation; W: Does not include wind generation induced from traffic	S: Can include additional lane(s) as well as median width change	S: Includes options for specifying at-grade, depressed, and bridge; W: Does not consider obstacles or structures outside lanes	S: includes enhanced roadway dispersion effects based on residence time:adjustment for vehicle heat flux effects on vertical dispersion W: Does not consider change in near field flow direction due to vehicle movement activity	W: User specified volume for each link only	S: heat flux dependent upon number of vehicles; W: roadway dispersion not dependent upon number of vehicles	W: only applicable for NO to NO2 conversion	W: User-specified based on emission factor model with modal factor based on Colorado DOH model. W: No longer appropriate for use with the MOBILE6 or EMFAC emission factor models.
HOV Lane Addition	S: Includes sigma-theta (std deviation in wind direction); physically accounts for wind direction variation; W: Does not include wind generation induced from traffic	S: can include additional lane as well as median with change; W: Does not recognize lane restriction	S: Includes options for specifying at-grade, depressed, and bridge; W: Does not consider obstacles or structures outside lanes	S: includes enhanced roadway dispersion effects based on residence time:adjustment for vehicle heat flux effects on vertical dispersion W: Does not consider change in near field flow direction due to vehicle movement activity	W: User specified volume for each link - does not recognize lane restriction	S: heat flux dependent upon number of vehicles; W: roadway dispersion not dependent upon number of vehicles	W: only applicable for NO to NO2 conversion	W: User-specified based on emission factor model with modal factor based on Colorado DOH model. No longer appropriate for use with the MOBILE6 or EMFAC emission factor models.
Roadway Intersection	S: Includes sigma-theta (std deviation in wind direction); physically accounts for wind direction variation; W: Does not include wind generation induced from traffic	S: Includes capabilities for intersections; W: requires user to specify accel/decel time, average number of vehicles handled per cycle per lane and average number of vehicles delayed per cycle per lane	S: Includes options for specifying at-grade, depressed, and bridge; W: Does not consider obstacles or structures outside intersection	S: includes enhanced roadway dispersion effects based on residence time:adjustment for vehicle heat flux effects on vertical dispersion W: Does not consider change in near field flow direction due to vehicle movement activity	W: User required specification of volumes by link both departure and approach; no direct link to a microscopic traffic simulation model	S: heat flux dependent upon number of vehicles; W: roadway dispersion not dependent upon number of vehicles	W: only applicable for NO to NO2 conversion	W: Emission profile developed from user specifying accel/decel time, average number of vehicles handled per cycle per lane and average number of vehicles delayed per cycle per lane. Information not readily available.
Interchange/Ramp	S: Includes sigma-theta (std deviation in wind direction); physically accounts for wind direction variation; W: Does not include wind generation induced from traffic	S: Can include curved alignments through multiple link as well as bridge type sections.	S: Includes options for specifying at-grade, depressed, and bridge; W: Does not consider obstacles or structures outside ramp.	S: includes enhanced roadway dispersion effects based on residence time: adjustment for vehicle heat flux effects on vertical dispersion W: Does not consider change in near field flow direction due to vehicle movement activity	W: User specified volume for each link only	S: heat flux dependent upon number of vehicles; W: roadway dispersion not dependent upon number of vehicles	W: only applicable for NO to NO2 conversion	S: User-specified based on emission factor model with modal factor based on Colorado DOH model explicit for accel/decel. W: No longer appropriate for use with the MOBILE6 or EMFAC emission factor models.
Parking Area/Travel Center/Intermodal Facility	S: Includes sigma-theta (std deviation in wind direction); physically accounts for wind direction variation;	S: Includes capabilities for parking lot link type; W: requires user to specify transient emission factor (this would include weighted adjustment for cold-starts and hot starts)	S: Includes options for specifying at-grade, depressed, and bridge; W: Does not consider obstacles or structures outside of area	S: adjustments made for vehicle heat flux effects on vertical dispersion based on number of vehicles	W: User specified volume for each link; user must explicitly determine travel time/speed	S: heat flux dependent upon number of vehicles;	W: only applicable for NO to NO2 conversion	S: User-specified transient emission factor based on modal factor from Colorado DOH model. W: No longer appropriate for use with the MOBILE6 or EMFAC emission factor models. Emissions are uniformly distributed over area.

Table 19. Air Quality Models—HYROAD: Relative Strength and Weaknesses (S/W) for Analysis of Air toxics from Transportation Projects (ICF International, NCHRP 25-25 Task 18)

Transportation Project	Meteorology	Geometry	Site Characterization	Dispersion Parameters	Traffic Modeling Capabilities	Interaction between Traffic and Met	Reactive Decay	Emission Linkages
Roadway Widening	S: Includes site specific meteorological data with sigma theta (std deviation in wind direction); physically accounts for wind direction variation.	S: Detailed site-specific geometry; includes width of median, width of lanes	S: Does allow specification of local surface roughness W: Does not consider obstacles or structures outside intersection; does not include options for specifying at-grade, depressed and bridge.	S: vehicle-induced flows and wakes; as well as enhanced vertical dispersion over roadway; modeled as multiple-puff release; puff growth is gaussian, but flow field is non-uniform; initial sigma-y is lane width. W: not specifically designed to model lane addition of widening; emission release point the same for light and heavy duty vehicles	S: user specified traffic volume for each link; microscopic traffic simulation model used to generate other traffic information; tracks vehicle speed and acceleration distributions by 10-meter roadway segment; individual vehicles moved once a second to account for traffic conditions; vehicle movements determined according to car-following logic based on neighboring vehicles, and driver behavior.	S: roadway induced buoyancy dependent upon number of vehicles from exhaust heat flux; vehicle speed and acceleration distributions by 10-meter roadway segment for use in induced flows and turbulence - creates non-uniform flow field	W: None	S: Emission factor from MOBILE6 as inputs, but speed distributions from the traffic module are used in a regression analysis for each time period to calculate composite emission factors whose underlying speed distribution best fits current conditions. Spatial and temporal distribution of emissions based on vehicle operation rather than uniformly distributed. W: not current linked to modal emissions model, but does have functional future capability; not specifically designed for lane addition or widening
HOV Lane Addition	S: Includes site specific meteorological data with sigma theta (std deviation in wind direction); physically accounts for wind direction variation.	S: Detailed site-specific geometry; includes width of median, width of lanes, lane restrictions	S: Does allow specification of local surface roughness W: Does not consider obstacles or structures outside intersection; does not include options for specifying at-grade, depressed and bridge.	S: vehicle-induced flows and wakes; as well as enhanced vertical dispersion over roadway; modeled as multiple-puff release; puff growth is gaussian, but flow field is non-uniform; initial sigma-y is lane width. W: not specifically designed to model only HOV lane addition; emission release point the same for light and heavy duty vehicles	S: user specified traffic volume for each link; microscopic traffic simulation model used to generate other traffic information; tracks vehicle speed and acceleration distributions by 10-meter roadway segment; individual vehicles moved once a second to account for traffic conditions; vehicle movements determined according to car-following logic based on neighboring vehicles, and driver behavior.	S: roadway induced buoyancy dependent upon number of vehicles from exhaust heat flux; vehicle speed and acceleration distributions by 10-meter roadway segment for use in induced flows and turbulence - creates non-uniform flow field	W: None	S: Emission factor from MOBILE6 as inputs, but speed distributions from the traffic module are used in a regression analysis for each time period to calculate composite emission factors whose underlying speed distribution best fits current conditions. Spatial and temporal distribution of emissions based on vehicle operation rather than uniformly distributed. W: not current linked to modal emissions model, but does have functional future capability; not specifically designed for HOV lane addition

Table 19. Air Quality Models—HYROAD: Relative Strength and Weaknesses (S/W) for Analysis of Air toxics from Transportation Projects (ICF International, NCHRP 25-25 Task 18) (continued)

Transportation Project	Meteorology	Geometry	Site Characterization	Dispersion Parameters	Traffic Modeling Capabilities	Interaction between Traffic and Met	Reactive Decay	Emission Linkages
Roadway Intersection	S: Includes site specific meteorological data with sigma theta (std deviation in wind direction); physically accounts for wind direction variation.	S: Detailed site-specific geometry; turn bays, through lanes for approach and departure links, width of median, width of lanes, turn movements, signal cycle timing; W: Handles only a maximum of five approach and departure legs	S: Does allow specification of local surface roughness W: Does not consider obstacles or structures outside intersection; does not include options for specifying at-grade, depressed and bridge.	S: vehicle-induced flows and wakes; as well as enhanced vertical dispersion over roadway; modeled as multiple-puff released under varying signal phase conditions; puff growth is gaussian, but flow field is non-uniform; initial sigma-y is lane width. W: emission release point the same for light and heavy duty vehicles	S: user specified traffic volume for each link; microscopic traffic simulation model used to generate other traffic information; tracks vehicle speed and acceleration distributions by signal phase and 10-meter roadway segment; individual vehicles moved once a second to account for traffic conditions; vehicle movements determined according to car-following logic based on neighboring vehicles, traffic control devices, and driver behavior; pedestrian traffic crossing.	S: roadway induced buoyancy dependent upon number of vehicles from exhaust heat flux; vehicle speed and acceleration distributions by signal phase and 10-meter roadway segment for use in induced flows and turbulence - creates non-uniform flow field	W: None	S: Emission factor from MOBILE6 as inputs, but speed distributions from the traffic module are used in a regression analysis for each time period to calculate composite emission factors whose underlying speed distribution best fits current conditions. Spatial and temporal distribution of emissions based on vehicle operation rather than uniformly distributed. W: not current linked to modal emissions model, but does have functional future capability
Interchange/Ramp	S: Includes site specific meteorological data with sigma theta (std deviation in wind direction); physically accounts for wind direction variation.	S: Detailed site-specific geometry; width of median, width of lanes; W: Does not have link specific for ramps	S: Does allow specification of local surface roughness W: Does not consider obstacles or structures outside ramp; does not include options for specifying at-grade, depressed and bridge.	S: vehicle-induced flows and wakes; as well as enhanced vertical dispersion over roadway; modeled as multiple puff released; puff growth is gaussian, but flow field is non-uniform W: emission release point the same for light and heavy duty vehicles	S: user specified traffic volume for each link; microscopic traffic simulation model used to generate other traffic information; tracks vehicle speed and acceleration, distributions by 10-meter roadway segment; individual vehicles moved once a second to account for traffic conditions; vehicle movements determined according to car-following logic based on neighboring vehicles, traffic control devices, and driver behavior. W: No ramp metering capability	S: roadway induced buoyancy dependent upon number of vehicles from exhaust heat flux; vehicle speed and acceleration distributions per 10-meter roadway segment for use in induced flows and turbulence.	W: None	S: Emission factor from MOBILE6 as inputs, but speed distributions from the traffic module are used in a regression analysis for each time period to calculate composite emission factors whose underlying speed distribution best fits current conditions. Spatial and temporal distribution of emissions based on vehicle operation rather than uniformly distributed. W: not current linked to modal emissions model, but does have functional future capability

Table 19. Air Quality Models—HYROAD: Relative Strength and Weaknesses (S/W) for Analysis of Air toxics from Transportation Projects (ICF International, NCHRP 25-25 Task 18) (continued)

Transportation Project	Meteorology	Geometry	Site Characterization	Dispersion Parameters	Traffic Modeling Capabilities	Interaction between Traffic and Met	Reactive Decay	Emission Linkages
Parking Area/ Travel Center/ Intermodal Facility	S: Includes site specific meteorological data with sigma theta (std deviation in wind direction); physically accounts for wind direction variation.	W: No parking link type specification	S: Does allow specification of local surface roughness. W: Does not consider obstacles or structures outside of area	S: vehicle-induced flows and wakes; as well as enhanced vertical dispersion over road segments; modeled as multiple puff released; puff growth is gaussian. W: emission release point the same for light and heavy duty vehicles	S: user specified traffic volume for each link; W: microscopic traffic simulation model used to generate other traffic information -- not developed for the modeling of parking or intermodal facilities	S: induced buoyancy dependent upon number of vehicles from exhaust heat; vehicle speed and acceleration distributions per 10-meter segment for use in induced flows. W: not configured for application to parking/intermodal facility	W: None	W: Not configured to work directly with intermodal facility/parking/travel center; emissions linked to on-road traffic module

Table 20. Air Quality Models—AERMOD: Relative Strength and Weaknesses (S/W) for Analysis of Air toxics from Transportation Projects (ICF International, NCHRP 25-25 Task 18)

Transportation Project	Meteorology	Geometry	Site Characterization	Dispersion Parameters	Traffic Modeling Capabilities	Interaction between Traffic and Met	Reactive Decay	Emission Linkages
Roadway Widening	S: Needs site specific meteorological data - wind speed, direction, temperature and cloud cover; W: Does not include wind generation induced from traffic; requires morning temperature sounding	S: Can model a combination of area and volume source as line sources	S: May include nearby building or obstacle wake effect characterization; includes state of the science building wake algorithm (PRIME); surface roughness and ground reflectivity may vary for up to 12 wind directions W: Does not include options for depressed source	S: Gaussian plume diffusion with numerical integration approach for area sources more accurate than finite-line area source algorithm; can use irregularly shaped (circles or polygon) area sources W: Does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	W: No traffic modeling capabilities	W: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for associated heat flux	S: Has simple exponential decay via user specified half-life W: Has no chemical reactivity	W: Need to externally determine emissions from emission factor model for each area or volume source
HOV Lane Addition	S: Needs site specific meteorological data - wind speed, direction, temperature and cloud cover; W: Does not include wind generation induced from traffic; requires morning temperature sounding	S: Can model a combination of area and volume source as line sources W: Does not consider lane restrictions	S: May include nearby building or obstacle wake effect characterization; includes state of the science building wake algorithm (PRIME); surface roughness and ground reflectivity may vary for up to 12 wind directions W: Does not include options for specifying depressed source	S: Gaussian plume diffusion with numerical integration approach for area sources more accurate than finite-line area source algorithm; can use irregularly shaped (circles or polygon) area sources W: Does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	W: No traffic modeling capabilities	W: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for associated heat flux	S: Has simple exponential decay via user specified half-life W: Has no chemical reactivity	W: Need to externally determine emissions from emission factor model for each area or volume source
Roadway Intersection	S: Needs site specific meteorological data - wind speed, direction, temperature and cloud cover; W: Does not include wind generation induced from traffic; requires morning temperature sounding	S: Can model a combination of area and volume source as line sources W: Does not consider intersection layout	S: May include nearby building or obstacle wake effect characterization; includes state of the science building wake algorithm (PRIME); surface roughness and ground reflectivity may vary for up to 12 wind directions W: Does not include options for specifying depressed source	S: Gaussian plume diffusion with numerical integration approach for area sources more accurate than finite-line area source algorithm W: Does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	W: No traffic or intersection queuing capabilities	W: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for associated heat flux	S: Has simple exponential decay via user specified half-life W: Has no chemical reactivity	W: Need to externally determine emissions from emission factor model for each area or volume source
Interchange/Ramp	S: Needs site specific meteorological data - wind speed, direction, temperature and cloud cover; W: Does not include wind generation induced from traffic; requires morning temperature sounding	S: Can model a combination of area and volume source as line sources W: No specific features for ramps	S: May include nearby building or obstacle wake effect characterization; includes state of the science building wake algorithm (PRIME); surface roughness and ground reflectivity may vary for up to 12 wind directions W: Does not include options for specifying depressed source	S: Gaussian plume diffusion with numerical integration approach for area sources more accurate than finite-line area source algorithm; can use irregularly shaped (circles or polygon) area sources W: Does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	W: No traffic modeling capabilities	W: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for their associated heat flux	S: Has simple exponential decay via user specified half-life W: Has no chemical reactivity	W: Need to externally determine emissions from emission factor model for each area or volume source
Parking Area/Travel Center/Intermodal Facility	S: Needs site specific meteorological data - wind speed, direction, temperature and cloud cover; W: Requires morning temperature sounding	S: Can model as area and volume source with aspect ratio of up to 10:1	S: May include nearby building or obstacle wake effect characterization; includes state of the science building wake algorithm (PRIME); surface roughness and ground reflectivity may vary for up to 12 wind directions; W: Does not contain option for specifying parking facility	S: Gaussian plume diffusion with numerical integration approach for area sources more accurate than finite-line area source algorithm; can use irregularly shaped (circles or polygon) area sources W: No adjustment for vehicle heat flux effects on vertical dispersion	S: User can specify idle and transient at separate locations based on vehicle activity levels	W: No adjustment for the number of vehicles and their activity and for their associated heat flux	S: Has simple exponential decay via user specified half-life W: Has no chemical reactivity	S: Can specify emissions for each volume and area source based on activity levels and vehicle type W: Need to externally determine emissions from

Table 21. Air Quality Models—ISCST3: Relative Strength and Weaknesses (S/W) for Analysis of Air toxics from Transportation Projects (ICF International, NCHRP 25-25 Task 18)

Transportation Project	Meteorology	Geometry	Site Characterization	Dispersion Parameters	Traffic Modeling Capabilities	Interaction between Traffic and Met	Reactive Decay	Emission Linkages
Roadway Widening	S: Includes site specific meteorological data; W: Does not include wind generation induced from traffic	S: Can model a combination of area and volume source as line sources	S: May include nearby building or obstacle wake effect characterization; W: Does not include options for specifying at-grade, depressed, and bridge;	S: gaussian plume diffusion with numerical integration approach for area sources more accurate than finite-line area source algorithm W: does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	W: No traffic modeling capabilities	W: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for associated heat flux	S: has simple exponential decay via user specified half-life W: has no chemical reactivity	W: need to externally determine emissions from emission factor model for each area or volume source
HOV Lane Addition	S: Includes site specific meteorological data; W: Does not include wind generation induced from traffic	S: Can model a combination of area and volume source as line sources W: Does not consider lane restrictions	S: May include nearby building or obstacle wake effect characterization; W: Does not include options for specifying at-grade, depressed, and bridge;	S: gaussian plume diffusion with numerical integration approach for area sources more accurate than finite-line area source algorithm W: does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	W: No traffic modeling capabilities	W: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for associated heat flux	S: has simple exponential decay via user specified half-life W: has no chemical reactivity	W: need to externally determine emissions from emission factor model for each area or volume source
Roadway Intersection	S: Includes site specific meteorological data; W: Does not include wind generation induced from traffic	S: Can model a combination of area and volume source as line sources W: Does not consider intersection layout	S: May include nearby building or obstacle wake effect characterization; W: Does not include options for specifying at-grade, depressed, and bridge;	S: gaussian plume diffusion with numerical integration approach for area sources more accurate than finite-line area source algorithm W: does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	W: No traffic intersection queuing capabilities	W: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for associated heat flux	S: has simple exponential decay via user specified half-life W: has no chemical reactivity	W: need to externally determine emissions from emission factor model for each area or volume source
Interchange/Ramp	S: Includes site specific meteorological data; W: Does not include wind generation induced from traffic	S: Can model a combination of area and volume source as line sources W: No specific features for ramps	S: May include nearby building or obstacle wake effect characterization; W: Does not include options for specifying at-grade, depressed, and bridge;	S: gaussian plume diffusion with numerical integration approach for area sources more accurate than finite-line area source algorithm W: does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	W: No traffic modeling capabilities	W: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for associated heat flux	S: has simple exponential decay via user specified half-life W: has no chemical reactivity	W: need to externally determine emissions from emission factor model for each area or volume source
Parking Area/Travel Center/Intermodal Facility	S: Includes site specific meteorological data;	S: Can model as area and volume source with aspect ratio of up to 10:1 W: No specific features for parking lots	S: May include nearby building or obstacle wake effect characterization; W: Does not contain option for specifying parking facility	S: gaussian plume diffusion with numerical integration approach for area sources more accurate than finite-line area source algorithm W: no adjustment for vehicle heat flux effects on vertical dispersion	S: User can specify idle and transient at separate locations based on vehicle activity levels	W: No adjustment for the number of vehicles and their activity and associated heat flux	S: has simple exponential decay via user specified half-life W: has no chemical reactivity	S: Can specify emissions for each volume and area source based on activity levels and vehicle type W: need to externally determine emissions from emission factor model for each area or volume source

Table 22. Air Quality Models—CALPUFF: Relative Strength and Weaknesses (S/W) for Analysis of Air toxics from Transportation Projects (ICF International, NCHRP 25-25 Task 18)

Transportation Project	Meteorology	Geometry	Site Characterization	Dispersion Parameters	Traffic Modeling Capabilities	Interaction between Traffic and Met	Reactive Decay	Emission Linkages
Roadway Widening	S: Needs site specific meteorological data - wind speed, direction, temperature, stability class, mixing height; W: Does not include wind generation induced from traffic	S: Can model a combination of area and volume source W: Line source algorithm not appropriate for mobile source	S: May include nearby building or obstacle wake effect characterization; surface roughness and albedo may vary if using gridded field option; W: Does not include options for specifying at-grade, depressed, and bridge	S: Gaussian puff diffusion with numerical integration approach for area sources; elongated puff-near field for more accurate simulation; dispersion coefficient may be based on similarity theory; W: Does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	W: No traffic modeling capabilities	W: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for associated heat flux	S: Has chemical transformation for Sox and Nox emissions; or user specified diurnal cycle	W: Need to externally determine emissions from emission factor model for each area or volume source
HOV Lane Addition	S: Needs site specific meteorological data - wind speed, direction, temperature, stability class, mixing height; W: Does not include wind generation induced from traffic	S: Can model a combination of area and volume sources W: Does not consider lane restrictions; line source algorithm not appropriate for mobile source	S: May include nearby building or obstacle wake effect characterization; surface roughness and albedo may vary if using gridded field option; W: Does not include options for specifying at-grade, depressed, and bridge	S: Gaussian puff diffusion with numerical integration approach for area sources; elongated puff-near field for more accurate simulation; dispersion coefficient may be based on similarity theory; W: Does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	W: No traffic modeling capabilities	W: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for associated heat flux	S: Has chemical transformation for Sox and Nox emissions; or user specified diurnal cycle	W: Need to externally determine emissions from emission factor model for each area or volume source
Roadway Intersection	S: Needs site specific meteorological data - wind speed, direction, temperature, stability class, mixing height; W: Does not include wind generation induced from traffic	S: Can model a combination of area and volume sources W: Does not consider intersection layout	S: May include nearby building or obstacle wake effect characterization; surface roughness and albedo may vary if using gridded field option; W: Does not include options for specifying at-grade, depressed, and bridge	S: Gaussian puff diffusion with numerical integration approach for area sources; elongated puff-near field for more accurate simulation; dispersion coefficient may be based on similarity theory; W: Does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	W: No traffic or intersection queuing capabilities	W: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for associated heat flux	S: Has chemical transformation for Sox and Nox emissions; or user specified diurnal cycle	W: Need to externally determine emissions from emission factor model for each area or volume source
Interchange/Ramp	S: Needs site specific meteorological data - wind speed, direction, temperature, stability class, mixing height; W: Does not include wind generation induced from traffic	S: Can model a combination of area and volume source W: No specific features for ramps; line source algorithm not appropriate for mobile source	S: May include nearby building or obstacle wake effect characterization; surface roughness and albedo may vary if using gridded field option; W: Does not include options for specifying at-grade, depressed, and bridge	S: Gaussian puff diffusion with numerical integration approach for area sources; elongated puff-near field for more accurate simulation; dispersion coefficient may be based on similarity theory; W: Does not include enhanced roadway dispersion effects based on residence time, no adjustment for vehicle heat flux effects on vertical dispersion; does not consider change in near field flow direction due to vehicle movement activity	W: No traffic modeling capabilities	W: No interaction between met and traffic; no adjustment for roadway dispersion or number of vehicles for associated heat flux	S: Has chemical transformation for Sox and Nox emissions; or user specified diurnal cycle	W: Need to externally determine emissions from emission factor model for each area or volume source; no modal emission factor
Parking Area/Travel Center/Interpositional Facility	S: Needs site specific meteorological data - wind speed, direction, temperature, stability class, mixing height;	S: Can model as area and volume source with aspect ratio of up to 10:1 W: No specific features for parking lots	S: May include nearby building or obstacle wake effect characterization; surface roughness and albedo may vary if using gridded field option; W: Does not include options for specifying at-grade, depressed, and bridge	S: Gaussian puff diffusion with numerical integration approach for area sources; elongated puff-near field for more accurate simulation; dispersion coefficient may be based on similarity theory; W: No adjustment for vehicle heat flux effects on vertical dispersion	S: User can specify idle and transient at separate locations based on vehicle activity levels	W: No adjustment for the number of vehicles and their activity for the associated heat flux	S: Has chemical transformation for Sox and Nox emissions; or user specified diurnal cycle	S: Can specify emissions for each volume and area source based on activity levels and vehicle type W: Need to externally determine emissions from emission factor model for each area or volume source; no modal emission factor

The information presented here builds upon the information provided in our identification of analytical tools available for air toxic assessment. These tables provide specific information on model strengths and weaknesses for nearly all transportation situations evaluated under NEPA. The identified strengths and weaknesses add to the transportation analyst’s understanding of how these tools can be used in transportation MSAT assessments. In particular, information on model weaknesses may help the transportation analyst understand why a given model may not be suitable for use in an MSAT assessment. When considering the relative strengths and weaknesses of different models, the findings present a clearer picture of which modeling tools should be used in a given MSAT assessment. This information has been used in the section entitled, *Five Levels of Analyses for Air Toxic Assessment under NEPA*, to provide recommendations on the best modeling approaches for analyzing MSATs in the NEPA process. These findings are summarized here in the table below and presented again later in the report in Table 27.

Table 23. Best Available Air Quality Modeling Tools for use in Analyzing MSATs under NEPA (ICF International, NCHRP 25-25 Task 18)

Facility/Project Type	Primary Air Quality Model	Secondary Air Quality Model	Comments
Roadway Widening	CALINE4	CALINE3	
HOV Lane Addition	CALINE4	CALINE3	
Roadway Intersection	CAL3QHC(R)	HYROAD	With the release of the MOVES model HYROAD may be the preferred choice as the model can be directly linked to the modal emission factors.
Interchange/Ramp	CALINE4	CALINE3	Carefully consideration should be given to the emission factors under grade or acceleration environment.
Freight Terminal/ Intermodal Transfer Parking/ Travel Center/	AERMOD	ISC3	If facility is located where unusual meteorological conditions (fumigation, stagnation) occur then CALPUFF is the preferred model.

Health Impacts of Mobile Source Air Toxics and Current Range in Concentration

To assist the transportation analyst in assessing the relative impact of the transportation project versus current conditions, an assessment was performed for each MSAT documenting the potential health impacts and range of concentrations occurring throughout the U.S.

Health effects of MSATs may be divided into two categories: carcinogenic and chronic non-carcinogenic. Table 24 presents estimates of carcinogenic potency for 12 of the MSATs⁸, as well as the weight of evidence and type of evidence. The carcinogenic potency estimates are taken preferentially from the EPA's Integrated Risk Information System (IRIS). If no estimate is available from IRIS, the next minimum risk level is obtained from the U.S. Department of Health and Human Services' Agency for Toxic Substances and Disease Registry (ATSDR). After that, the California Office of Environmental Health and Hazard Assessment (OEHHA) toxicity values are used. Finally, some toxicity values are taken from those developed by the EPA's Office of Air Quality Planning and Standards (OAQPS) for the National Air Toxics Assessment (NATA). Brief summaries of the weight of evidence and the basis for the carcinogenicity finding are also included in Table 25 from both IRIS and the International Agency for Research on Cancer (IARC).

⁸ There is inadequate evidence in humans for the carcinogenicity of acrolein.

Table 24. Carcinogenic potency of MSATs (ICF International, NCHRP 25-25 Task 18)

Pollutant	Unit Risk Factor (URF) and 1 per million risk concentration	Classification and Evidence
Acetaldehyde	IRIS: $2.2\text{e-}6 (\mu\text{g}/\text{m}^3)^{-1}$ $0.45 \mu\text{g}/\text{m}^3$	<u>IRIS</u> : B2 (Probable human carcinogen based on sufficient evidence of carcinogenicity in animals ⁹) <u>IARC</u> : 2B (Possible human carcinogen based on sufficient evidence in animals and inadequate evidence in humans)
Arsenic	IRIS: $4.3\text{e-}3(\mu\text{g}/\text{m}^3)^{-1}$ $2.3\text{e-}4 \mu\text{g}/\text{m}^3$	<u>IRIS</u> : A (Known human carcinogen, based on sufficient evidence from human data ¹⁰) <u>IARC</u> : 1 (causally associated with cancer in humans)
Benzene	IRIS: $2.2\text{e-}6 \text{ to } 7.8\text{e-}6 (\mu\text{g}/\text{m}^3)^{-1}$ $0.13 \text{ to } 0.45 \mu\text{g}/\text{m}^3$	<u>IRIS</u> : A (Known human carcinogen for all routes of exposure based upon convincing human evidence ¹¹ as well as supporting evidence from animal studies) <u>IARC</u> : 1 (causally associated with cancer in humans)
1,3-Butadiene	IRIS: $3\text{e-}5 (\mu\text{g}/\text{m}^3)^{-1}$ $0.033 \mu\text{g}/\text{m}^3$	<u>IRIS</u> : A (Known human carcinogen based on sufficient evidence of carcinogenicity in animals ¹²) <u>IARC</u> : 2A (Probable human carcinogen)
Chromium, hexavalent	IRIS: $1.2\text{e-}2 (\mu\text{g}/\text{m}^3)^{-1}$ $8.3\text{e-}5 \mu\text{g}/\text{m}^3$	<u>IRIS</u> : A (Known human carcinogen by the inhalation route, based on studies of occupational exposure ¹³) <u>IARC</u> : 1 (causally associated with cancer in humans)

⁹ Based on increased incidence of nasal tumors in male and female rats and laryngeal tumors in male and female hamsters after inhalation exposure.

¹⁰ Increased lung cancer mortality was observed in multiple human populations exposed primarily through inhalation. Also, increased mortality from multiple internal organ cancers (liver, kidney, lung, and bladder).

¹¹ Leukemia

¹² Supported by the total weight of evidence provided by the following: (1) sufficient evidence from epidemiologic studies of the majority of U.S. workers occupationally exposed, i.e. increased lymphohematopoietic cancers and a dose-response relationship for leukemias in polymer workers, (2) sufficient evidence in laboratory animal studies^{i.e.} tumors at multiple sites in mice and rats by inhalation, and (3) numerous studies consistently demonstrating that 1,3-butadiene is metabolized into genotoxic metabolites by experimental animals and humans

¹³ Lung cancer

Pollutant	Unit Risk Factor (URF) and 1 per million risk concentration	Classification and Evidence
Diesel particles	OEHHA: $3e-4 (\mu\text{g}/\text{m}^3)^{-1}$ $0.0033 \mu\text{g}/\text{m}^3$	<p><u>IRIS</u>: likely to be carcinogenic to humans by inhalation supported by the following: (1) strong but less than sufficient evidence for a causal association between diesel exhaust exposure and increased lung cancer risk among workers in varied occupations where exposure to diesel exhaust occurs; (2) extensive supporting data including the demonstrated mutagenic and/or chromosomal effects of diesel exhaust and its organic constituents, and knowledge of the known mutagenic and/or carcinogenic activity of a number of individual organic compounds that adhere to the particles and are present in the diesel exhaust gases</p> <p><u>CARB</u>: Calculations using the two studies of Garshick <i>et al.</i> (1987a, 1988) and the reanalyses of the individual data of the Garshick <i>et al.</i> (1988) cohort study provide a number of estimates of unit risk. The relative risks reported in these studies were related to estimates of the actual exposures to estimate potential cancer risks. Because of uncertainties in the actual workplace exposures, OEHHA developed a variety of exposure scenarios to bracket the possible exposures of interest.</p>
Formaldehyde	IRIS: $1.3E-5 (\mu\text{g}/\text{m}^3)^{-1}$ $0.08 \mu\text{g}/\text{m}^3$	<p><u>IRIS</u>: B1 (probable human carcinogen based on adequate evidence for carcinogenicity in animals¹⁴ and limited evidence in humans¹⁵)</p> <p><u>IARC</u>: 2A (Probable human carcinogen)</p>

¹⁴ An increased incidence of nasal squamous cell carcinomas was observed in long-term inhalation studies in rats and in mice. The classification is supported by in vitro genotoxicity data and formaldehyde's structural relationships to other carcinogenic aldehydes such as acetaldehyde.

¹⁵ Nine studies were reviewed that showed statistically significant associations between site-specific respiratory neoplasms and exposure to formaldehyde or formaldehyde-containing products.

Pollutant	Unit Risk Factor (URF) and 1 per million risk concentration	Classification and Evidence
Lead compounds	OEHHA: $1.2 \times 10^{-5} (\mu\text{g}/\text{m}^3)^{-1}$ $0.0833 \mu\text{g}/\text{m}^3$	<u>IRIS</u> : B2 (probable human carcinogen, based on sufficient evidence of carcinogenicity in animals ¹⁶) <u>IARC</u> : 2B (Possibly carcinogenic to humans)
Methyl-tert-butyl ether (MTBE)	OEHHA: $2.6 \times 10^{-7} (\mu\text{g}/\text{m}^3)^{-1}$ $3.85 \mu\text{g}/\text{m}^3$	<u>IARC</u> : 3 (Not classifiable for human carcinogenicity)
Naphthalene	OEHHA: $3.4 \times 10^{-5} (\mu\text{g}/\text{m}^3)^{-1}$ $0.029 \mu\text{g}/\text{m}^3$	<u>IRIS</u> : C (Possible human carcinogen by inhalation, based on suggestive animal evidence ¹⁷) <u>IARC</u> : 2B (Possibly carcinogenic to humans)
Nickel compounds	USEPA OAQPS: $1.6 \times 10^{-4} (\mu\text{g}/\text{m}^3)^{-1}$ $0.00625 \mu\text{g}/\text{m}^3$ (Conservatively assumes that 65% of emitted nickel is insoluble, and that all insoluble nickel is crystalline)	<u>USEPA</u> : A (Known human carcinogen, based on (1) increased risks of lung and nasal cancer in humans exposed to nickel refinery dust, most of which was believed to have been nickel subsulfide; (2) increased tumor incidences in animals by several routes of administration in several animal species and strains; and (3) positive results in genotoxicity assays form the basis for this classification) <u>IARC</u> : 2B (possibly carcinogenic to humans)
Polycyclic organic matter (POM)	USEPA OAQPS: $5.5 \times 10^{-5} (\mu\text{g}/\text{m}^3)^{-1}$ $0.018 \mu\text{g}/\text{m}^3$ (Total POM assumed to have a carcinogenic potency equal to 5% of that for pure benzo[a]pyrene, CARB: 1.1×10^{-3})	<u>USEPA</u> : benzo[a]pyrene B2 (Probable human carcinogen based on sufficient evidence of carcinogenicity in animals) <u>IARC</u> : benzo[a]pyrene 2A (probable human carcinogen based on sufficient evidence for carcinogenicity in animals ¹⁸ and limited evidence in humans ¹⁹)

¹⁶ Ten rat bioassays and one mouse assay have shown statistically significant increases in renal tumors with dietary and subcutaneous exposure to several soluble lead salts

¹⁷ Observations of benign respiratory tumors and one carcinoma in female mice only exposed to naphthalene by inhalation

¹⁸ Several types of malignant tumors have been induced in rodents by benzo[a]pyrene.

Table 25 presents the Reference Concentrations (RfCs) for chronic exposure and the target systems. For pollutants that have both carcinogenic and non-carcinogenic impacts, the 1 per million carcinogenic risk occurs at a lower concentration than the non-carcinogenic chronic RfC.

**Table 25. Non-carcinogenic health effects of MSATs
(ICF International, NCHRP 25-25 Task 18)**

Pollutant	Chronic Reference Concentration ($\mu\text{g}/\text{m}^3$)	Target Systems
Acetaldehyde	9	Respiratory
Acrolein	0.02	Respiratory
Arsenic compounds	0.03 (OEHHA)	Developmental
Benzene	30	Immunological
1,3-Butadiene	2	Reproductive
Chromium, hexavalent	0.1	Respiratory
Diesel particles	5	Respiratory
Ethylbenzene	1000	Developmental
Formaldehyde	9.8 (ASTDR)	Respiratory
n-Hexane	200	Neurological, respiratory
Lead compounds	1.5 (USEPA OAQPS)	Developmental
Manganese compounds	0.05	Neurological
Mercury compounds	0.09 (OEHHA)	Neurological
Methyl-tert-butyl ether (MTBE)	3000	Liver, kidney, ocular
Naphthalene	3	Respiratory
Nickel compounds	0.065 (OEHHA)	Respiratory, immunological
Styrene	1000	Neurological
Toluene	400	Respiratory, neurological
Xylene	100	Neurological

Current Range in Concentrations

The most current assessment of nationwide MSAT concentrations is available through EPA's National Air Toxic Assessment (NATA) national scale assessment (<http://www.epa.gov/ttn/atw/nata1999/tables.html>). This assessment modeled 1999 outdoor air concentrations at county level resolution. For those MSATs not modeled as part of NATA, observed 2005 concentrations from the EPA's AirData Reports

¹⁹ Epidemiological evidence for human cancer from exposure to benzo[a]pyrene is found in studies of roofers, tar distillers, patent-fuel workers, and creosote-exposed brickmakers.

(<http://www.epa.gov/air/data/geosel.html>) were used to develop estimates of background level concentrations²⁰. Figure 1 through Figure 38 present distributions of observed (2005) and modeled (1999) outdoor concentrations. Toxicity levels are also included in the figures (1 per million, 1 per 100,000 risk) for those pollutants with carcinogenic risk to provide perspective on the concentrations. For those pollutants with only non-cancer endpoints the RfC is provided. This information may be used in an analysis to identify current background level concentrations for a particular location.

The distributions of observed concentrations are composed of varied numbers of samples, ranging from 29 to 388. No observations were identified for diesel particles (diesel particles are difficult to distinguish from particles emitted by several other sources, and therefore cannot be directly characterized with current monitoring technology) or polycyclic organic matter (POM), both of which are complex mixtures of several compounds. Source receptor or apportionment studies²¹ have identified annual average diesel PM concentrations ranging from 0.4 to 5.0 $\mu\text{g}/\text{m}^3$, depending upon the locations and source apportionment model (Frazer, et al., 2003; Kim et al., 2003; Kim and Hopke, 2004; Lewis et al., 2003; Manchester-Neesvig and Schauer, 2003; Maykut et al., 2003; Zheng et al., 2002). In the case of particle-bound arsenic, lead, manganese, and nickel, the observations are stratified by particle size: i.e., total suspended particles (TSP), particles with aerodynamic diameters of 10 microns or less (PM_{10}), or particles with aerodynamic diameters of 2.5 microns or less ($\text{PM}_{2.5}$).

²⁰ Note: One year of air monitoring data may be subject to significant meteorological variability.

²¹ Receptor models are mathematical procedures for identifying and quantifying the sources of ambient air pollutants at a site (receptor), primarily on the basis of the concentrations of source-tracing chemical species measured at the receptor and generally without need of emissions inventories and meteorological data, the simpler approach (chemical mass balance) requires detailed information on the emission source chemical profiles of potential contributing sources and the corresponding chemical data from measurements made at a single ambient air sample. The more complex approach requires (multivariate approach) chemical measurements from hundreds of ambient air samples which are mathematically manipulated simultaneously, but without the need for the emission source chemical profiles; instead, they are generated from the ambient data themselves.

The 1999 modeled distributions are presented for all 66,300 U.S. Census tracts (labeled “total”), as well as for “urban” and “rural” stratifications (53,716 and 12,584 tracts, respectively). For several pollutants, the NATA study compared their model predictions to observed concentration at the same location and time period (i.e., acetaldehyde, benzene, formaldehyde, lead, manganese, and nickel). For those pollutants the figures below include the annual average model-to-monitor ratio found in the NATA study. In addition, the observed and modeled distributions for each pollutant are presented on the same page for comparison on an aggregate level. When comparing these distributions, the following points should be kept in mind:

- The observed values were measured in 2005 while the modeled values are estimates produced in 1999.
- The observed values represent distribution of the annual averages across multiple sites, parallel to the NATA results.
- The observed values in some cases come from small data sets, and in any case are neither geographically exhaustive (in contrast to the predictions) nor a probability sample. Rather, they are more likely to represent locations where high or moderate concentrations are expected.
- The modeled values for the particle-bound pollutants do not include re-entrained road dust or soil dust. Neglecting this contribution to concentrations would tend to lead to under-prediction.
- The modeled values for most of the pollutants (acrolein, arsenic, chromium VI, ethylbenzene, *n*-hexane, lead, manganese, MTBE, naphthalene, nickel, POM, styrene, and toluene) do not include background concentration estimates, which would reflect

natural sources or sources located farther than 50 km from the tract. Neglecting this contribution to concentrations would tend to lead to under-prediction.

Thus, even if the modeled values were perfectly accurate estimates, the observed and modeled distributions would not necessarily be expected to match exactly. In most cases the observed distributions are expected to be higher than the modeled distributions, although the modeled distributions might include some extreme values not covered by the smaller set of observed samples.

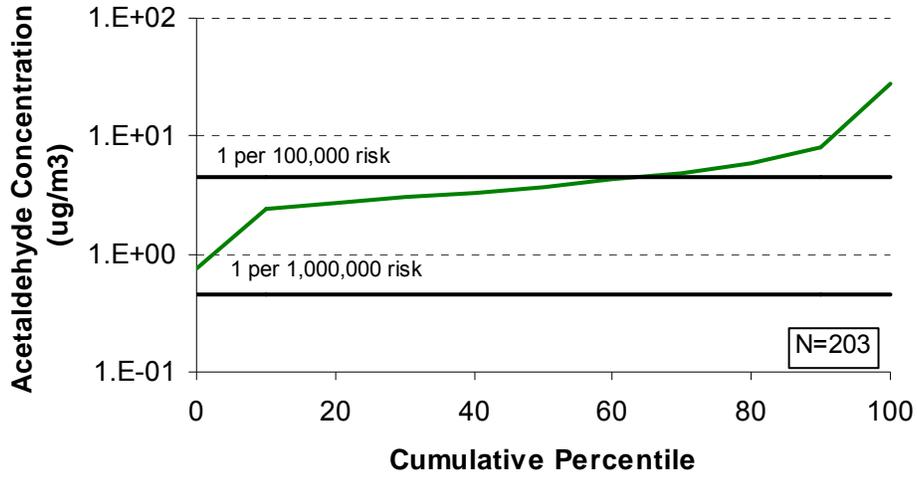
Another issue in the comparison of observed and modeled particle-bound pollutants is the question of what size fraction of observed concentrations is the proper basis of comparison. To the extent that emissions are combustion-related, they are probably composed primarily of PM₁₀ and/or PM_{2.5}. Note that the model-to-monitor comparisons from the NATA study were based primarily on observed TSP.

Acetaldehyde

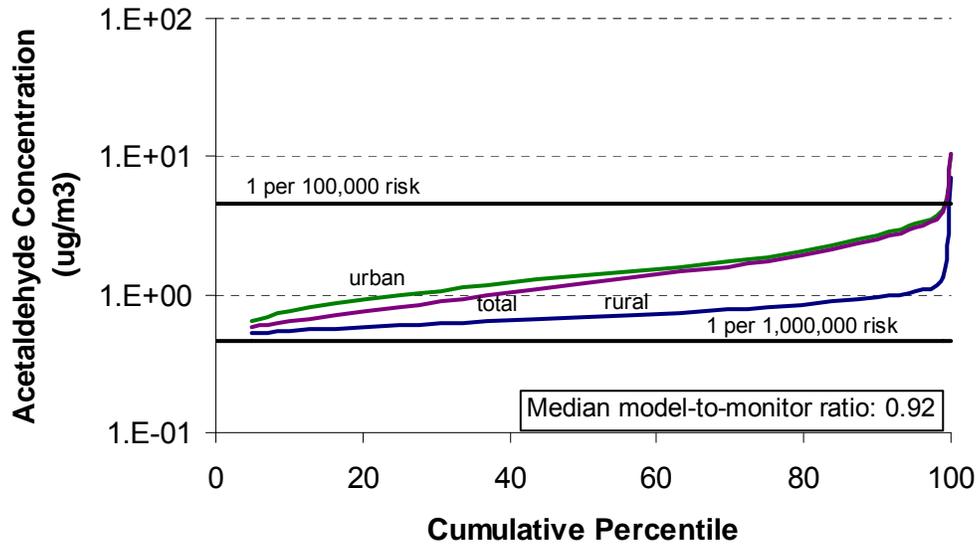
Figure 1 and Figure 2 present the observed and modeled concentration distributions of acetaldehyde, respectively. The modeled values include a component of acetaldehyde formed in the atmosphere from other pollutants (i.e., secondary formation), as well as an estimate of the background concentration. As noted in Figure 2, the NATA performance evaluation indicated that the modeled concentrations agreed well with the observed values in the same locations.

Both distributions exceed the 1 per 1,000,000 cancer risk level throughout. The distribution of modeled concentrations shows that relatively few locations have concentrations that exceed the 1 per 100,000 risk level: 212 Census tracts or 0.3%.

**Figure 1. Observed Annual Average Concentrations of Acetaldehyde (AirData, 2005)
(ICF International, NCHRP 25-25 Task 18)**



**Figure 2. 1999 NATA Annual Average Concentration Estimates of Acetaldehyde
(ICF International, NCHRP 25-25 Task 18)**



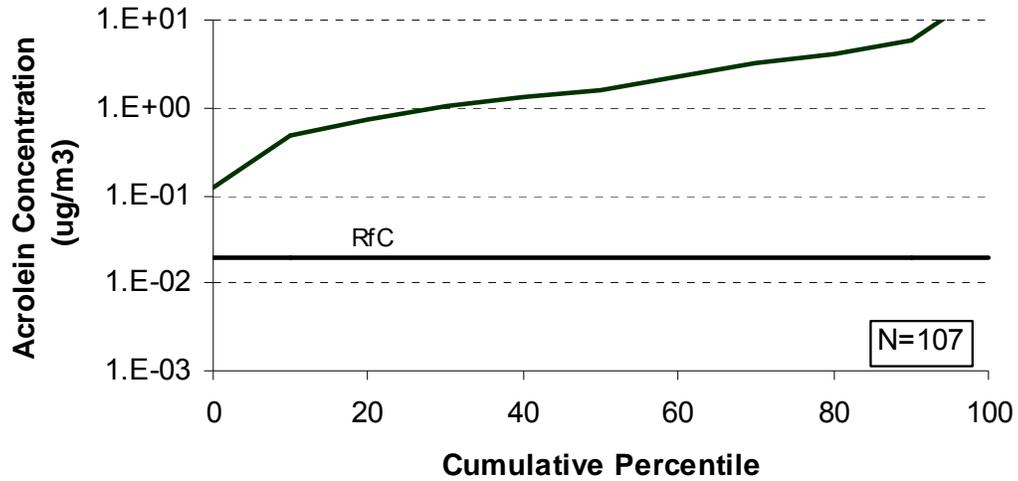
Acrolein

Figure 3 and Figure 4 present the observed²² and modeled concentration distributions of acrolein, respectively. As noted above, the modeled values do not include an estimate of the background concentration.

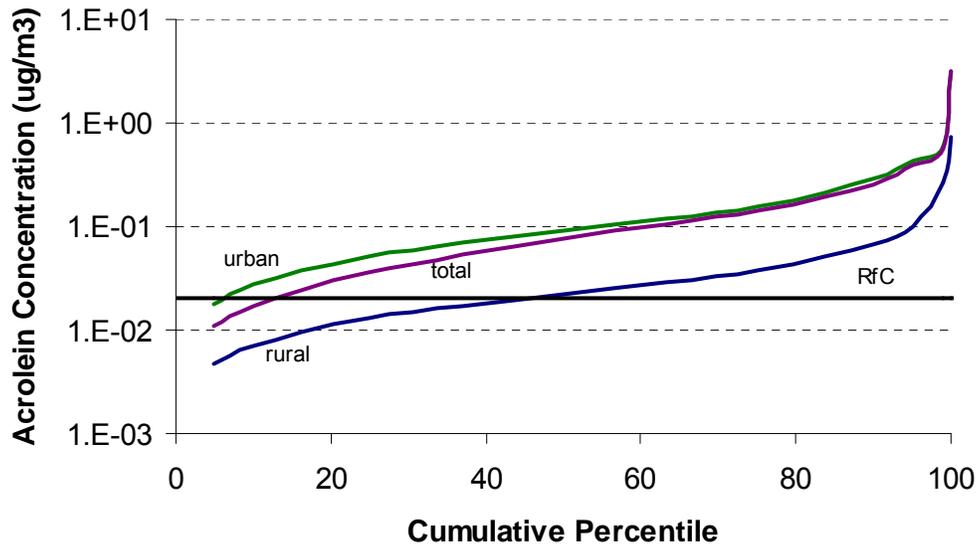
The observed concentration distribution exceeds the RfC (0.02 µg/m³) throughout. The modeled concentration distributions exceed the RfC for about 95% of urban tracts and about half of rural tracts.

²² Note: The method used to measure acrolein is undergoing reevaluation it's likely that many of the sites used dinitrophenylhydrazine (DNPH)-coated cartridges. If so, they are likely an underestimate.

**Figure 3. Observed Annual Average Concentrations of Acrolein (AirData, 2005)
(ICF International, NCHRP 25-25 Task 18)**



**Figure 4. 1999 NATA Annual Average Concentration Estimates of Acrolein
(ICF International, NCHRP 25-25 Task 18)**



Arsenic

Figure 5 and Figure 6 present the observed and modeled concentration distributions of arsenic, respectively. The observed concentrations are stratified by particle size. As noted above, the modeled values do not include an estimate of the contribution from background concentrations or an estimate of the contribution from re-entrained road dust.

All the observed distributions exceed 1 per million cancer risk throughout. About 75% of the TSP observations, 20% of the PM10 observations, and 10% of the PM2.5 observations exceed the 1 per 100,000 cancer risk concentration. About 25% of the TSP observations exceed the 1 per 10,000 cancer risk concentration.

More than 20% of the modeled urban concentrations and almost 5% of the modeled rural concentrations exceed the 1 per 1,000,000 cancer risk concentration. About 1% of the modeled urban concentrations and 41 of the modeled rural concentrations exceed the 1 per 100,000 cancer risk concentration. Twenty-six modeled urban concentrations exceed the 1 per 10,000 cancer risk level.

Figure 5. Observed Annual Average Concentrations of Arsenic Compounds (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

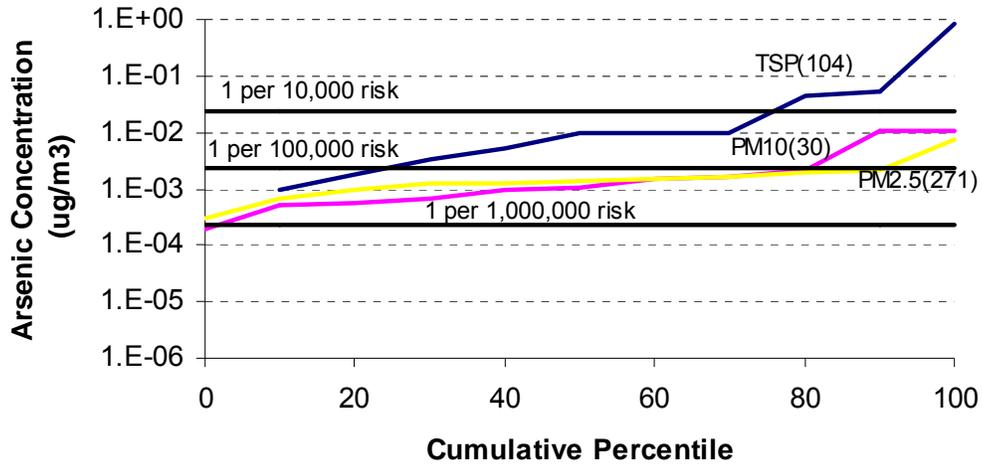
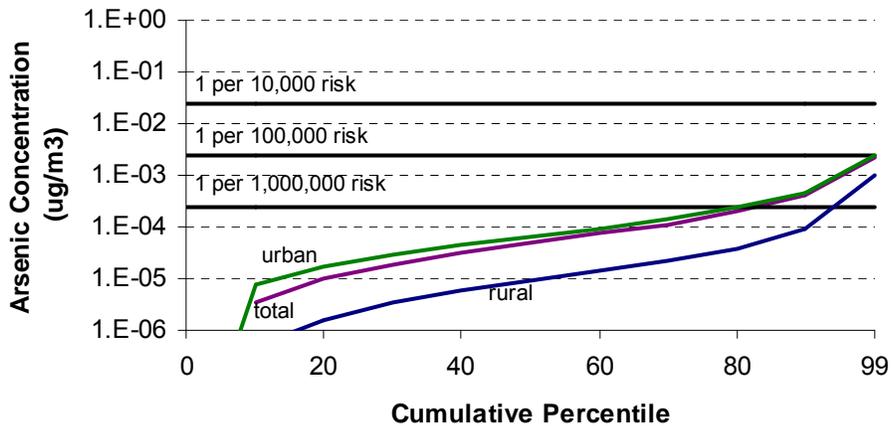


Figure 6. 1999 NATA Annual Average Concentration Estimates of Arsenic Compounds (ICF International, NCHRP 25-25 Task 18)

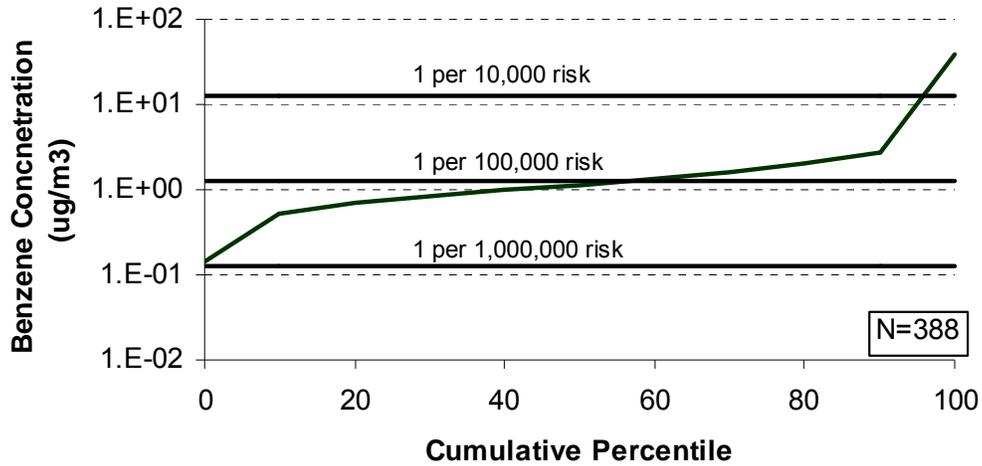


Benzene

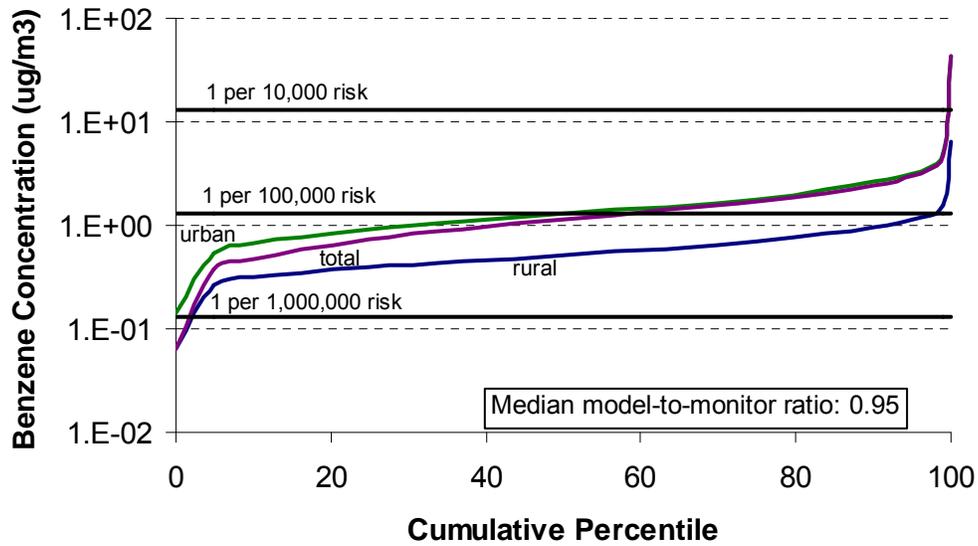
Figure 7 and Figure 8 present the observed and modeled concentration distributions of benzene, respectively. The modeled values include an estimate of the background concentration. As noted in Figure 8, the NATA performance evaluation indicated that the modeled concentrations agreed well with the observed values in the same locations.

Both distributions exceed the 1 per 1,000,000 cancer risk level throughout. The upper segment (approximately 40%) of the observed distribution exceeds the 1 per 100,000 cancer risk level. About 55% of urban tracts but only about 3% of the rural tracts modeled were found to exceed the 1 per 100,000 cancer risk level.

**Figure 7. Observed Annual Average Concentrations of Benzene (AirData, 2005)
(ICF International, NCHRP 25-25 Task 18)**



**Figure 8. 1999 NATA Annual Average Concentration Estimates of Benzene
(ICF International, NCHRP 25-25 Task 18)**



1,3-Butadiene

Figure 9 and Figure 10 present the observed and modeled concentration distributions of 1,3-butadiene, respectively. The modeled values include an estimate of the background concentration.

The observed distribution shows exceedances of the 1 per 1,000,000 cancer risk level almost throughout, and exceedances of the 1 per 100,000 cancer risk level for approximately 15% of samples. The distribution of NATA predictions shows exceedances of the 1 per 1,000,000 cancer risk level for more than 90% of urban tracts and more than 20% of rural tracts, and exceedances of the 1 per 100,000 cancer risk level for about 10% of urban tracts and 51 rural tracts.

Figure 9. Observed Annual Average Concentrations of 1,3-Butadiene (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

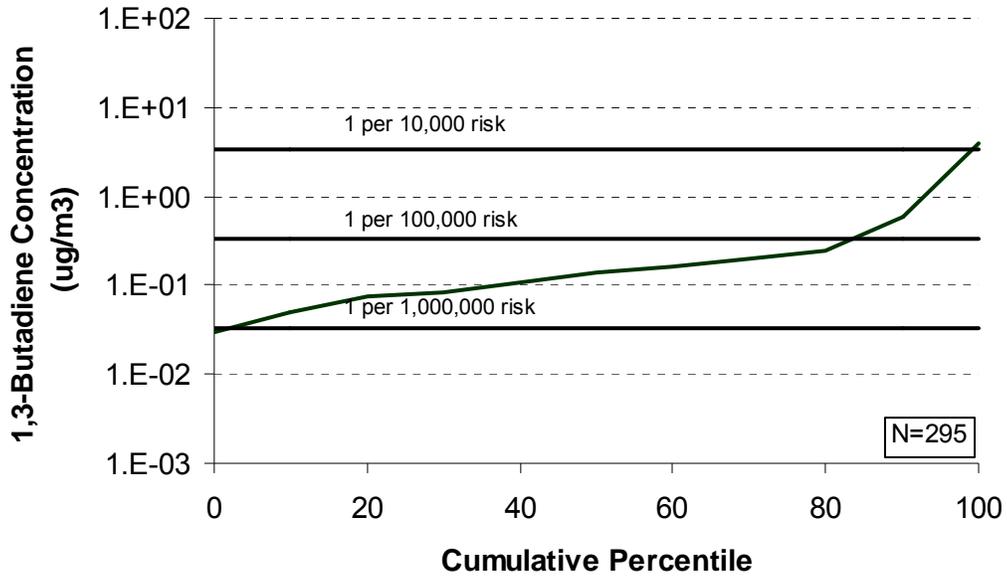
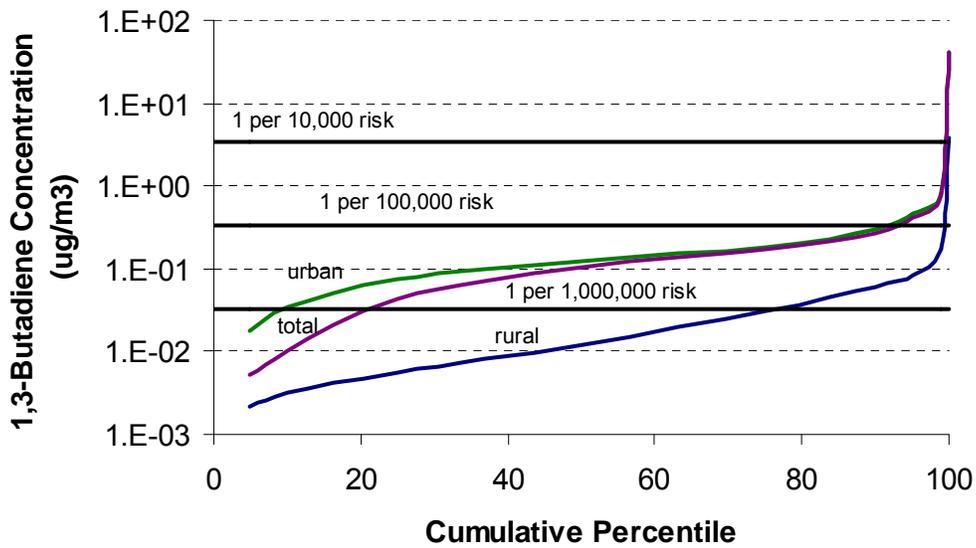


Figure 10. 1999 NATA Annual Average Concentration Estimates of 1,3-Butadiene (ICF International, NCHRP 25-25 Task 18)



Chromium, Hexavalent

Figure 11 and Figure 12 present the observed and modeled concentration distributions of hexavalent chromium, respectively. As noted above, the predictions do not include an estimate of background concentration contributions or an estimate of the contribution from re-entrained road dust. The observed distribution shows exceedances of the 1 per 1,000,000 cancer risk level for approximately 28% of the samples, and exceedances of the 1 per 100,000 cancer risk level for approximately 25% of samples. The distribution of NATA predictions shows exceedances of the 1 per 1,000,000 cancer risk level for more than 55% of urban tracts and about 17% of rural tracts, and exceedances of the 1 per 100,000 cancer risk level for more than 7% of urban tracts and almost 3% of rural tracts. The extreme upper end of the distribution includes 220 urban and 43 rural exceedances of the 1 per 1,000 cancer risk level.

Figure 11. Observed Annual Average Concentrations of Hexavalent Chromium (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

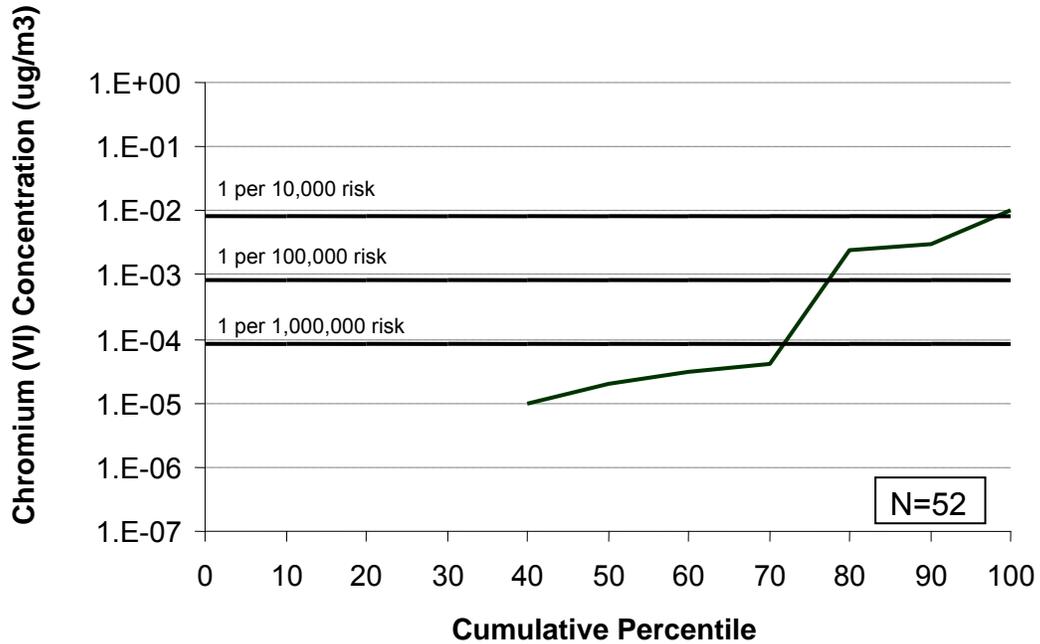
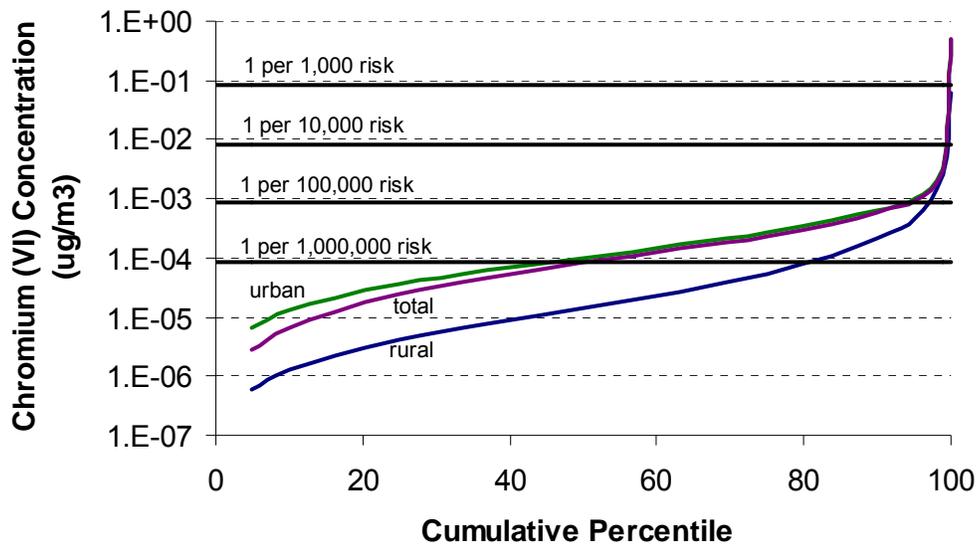


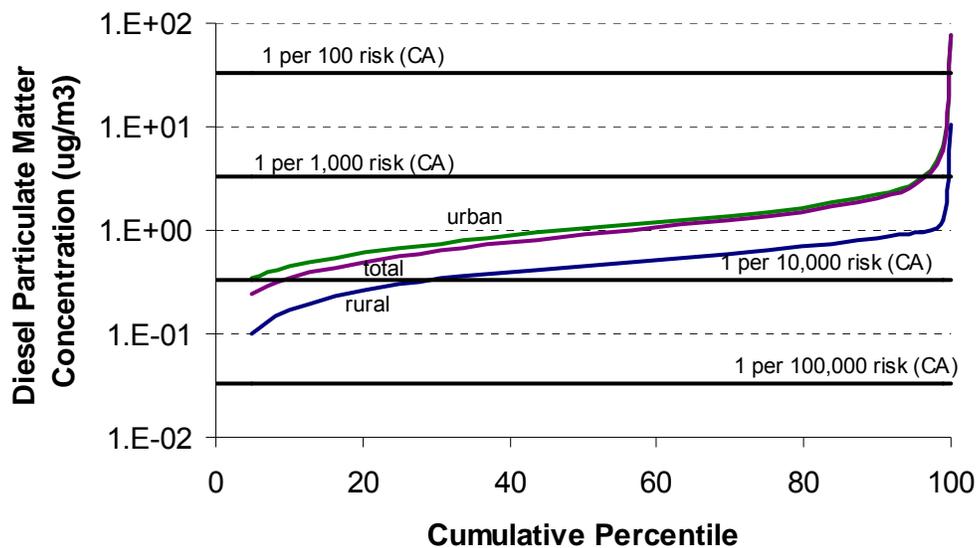
Figure 12. 1999 NATA Annual Average Concentration Estimates of Hexavalent Chromium (ICF International, NCHRP 25-25 Task 18)



Diesel Particles

Figure 13 presents the modeled concentration distribution of diesel particles for 1999. As noted above, no observed concentrations are available. The modeled values include background concentration contribution estimates from long-range transport, but do not include re-entrained road dust. The distribution shows that almost all tracts exceed the 1 per 100,000 cancer risk value based on California’s OEHHA risk value (EPA does not currently have a risk value). About 95% of modeled urban concentrations and about 67% of modeled rural concentrations exceed the 1 per 10,000 cancer risk level. About 5% of modeled urban concentrations and 10 modeled rural concentrations exceed the 1 per 1,000 cancer risk level. Eight modeled urban concentrations exceed the 1 per 100 cancer risk level.

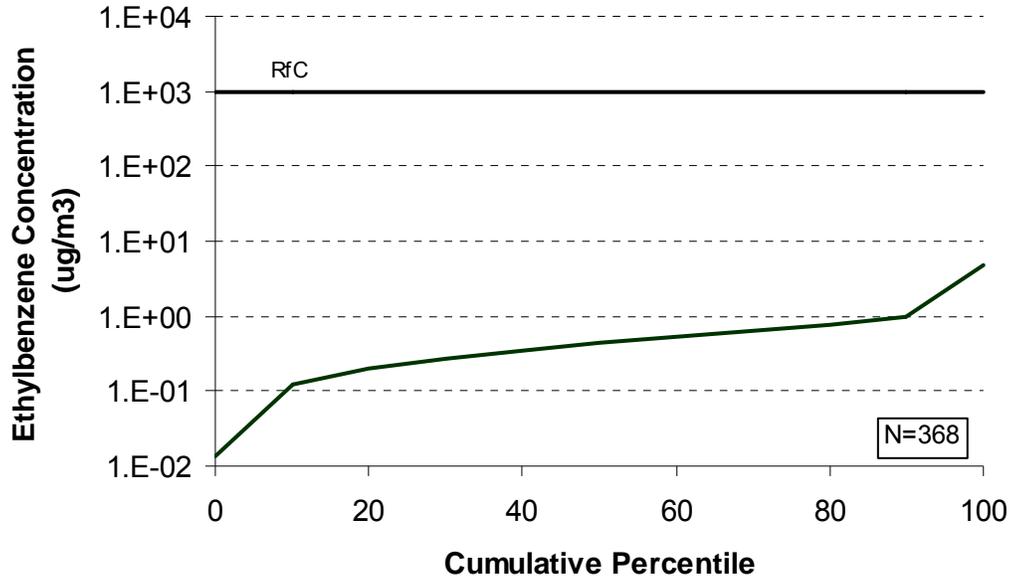
Figure 13: 1999 NATA annual average concentration estimates of Diesel Particulate Matter (ICF International, NCHRP 25-25 Task 18)



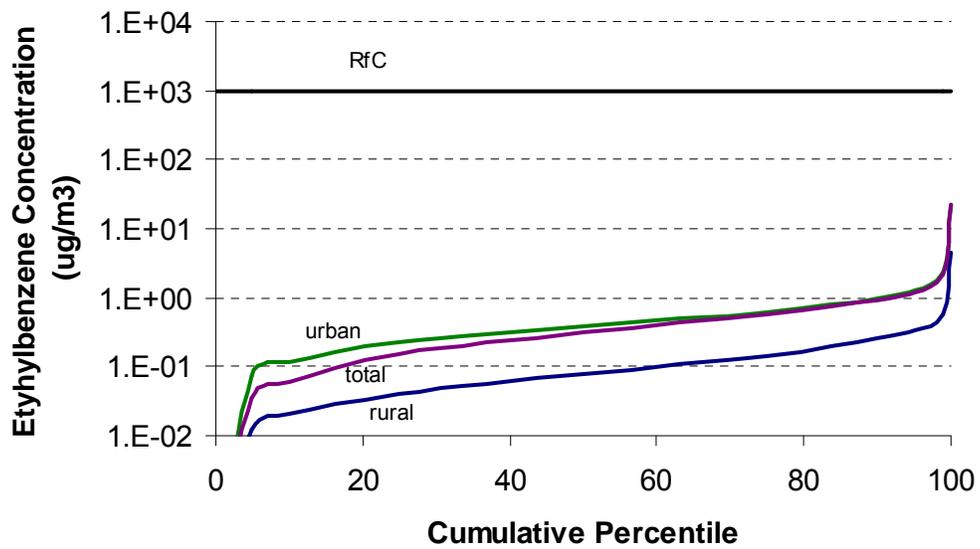
Ethylbenzene

Figure 14 and Figure 15 present the observed and modeled concentration distributions of ethylbenzene, respectively. As noted above, the modeled concentrations do not include an estimate of background concentrations. All measured and modeled concentrations are well below the RfC.

**Figure 14. Observed Annual Average Concentrations of Ethylbenzene (AirData, 2005)
(ICF International, NCHRP 25-25 Task 18)**



**Figure 15. 1999 NATA Annual Average Concentration Estimates of Ethylbenzene
(ICF International, NCHRP 25-25 Task 18)**



Formaldehyde

Figure 16 and Figure 17 present the observed and modeled concentration distributions of formaldehyde, respectively. The modeled values include a component of formaldehyde formed in the atmosphere from other pollutants (i.e., secondary formation), as well as an estimate of the background concentration from natural sources and long-range transport. As noted in Figure 17, the NATA performance evaluation indicated that the modeled concentrations were generally somewhat lower than the observed values in the same locations. The underestimate may be due to missing emission sources, underestimates of secondary components, or underestimates of background concentrations.

The observed distribution shows exceedances of the RfC for about 10% of samples. (As noted above the RfC is lower than the 1 per million cancer risk concentration.) The distribution of predictions shows that relatively few locations have concentrations that exceed the reference concentrations: 54 census tracts or 0.08%.

Figure 16. Observed Annual Average Concentrations of Formaldehyde (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

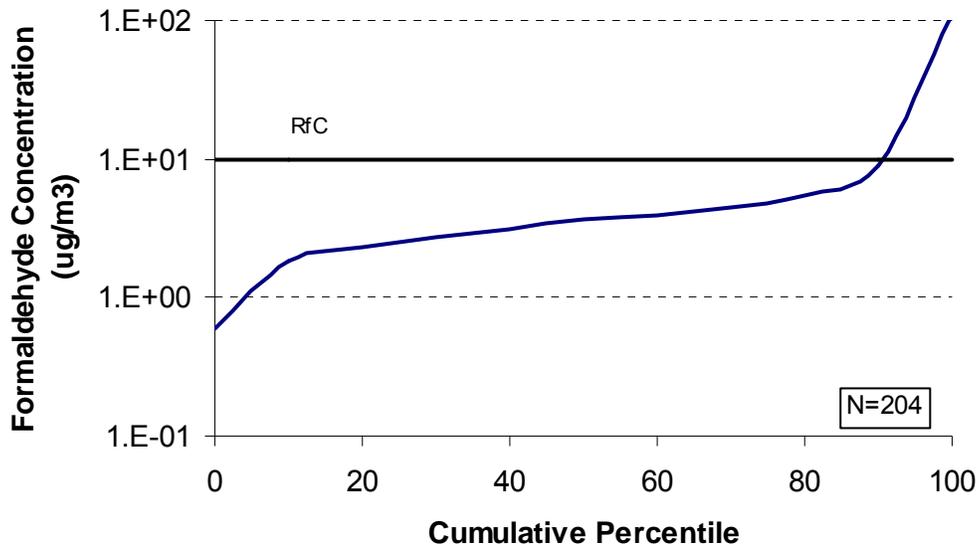
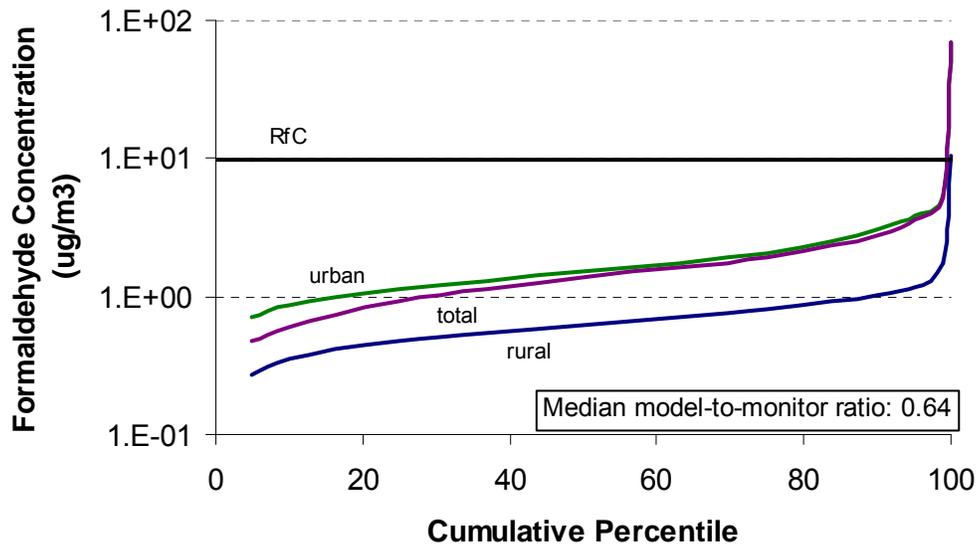


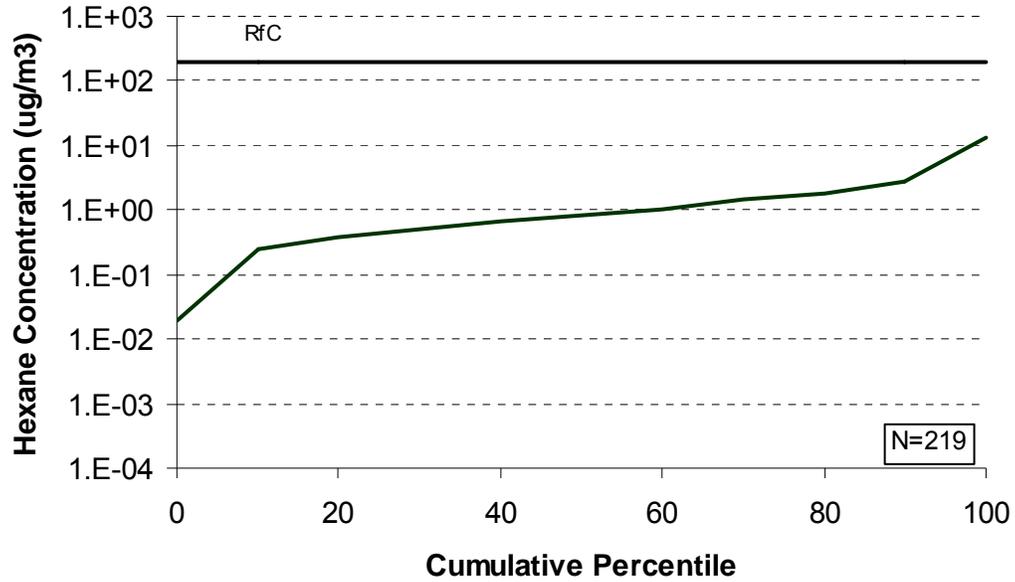
Figure 17. 1999 NATA Annual Average Concentration Estimates of Formaldehyde (ICF International, NCHRP 25-25 Task 18)



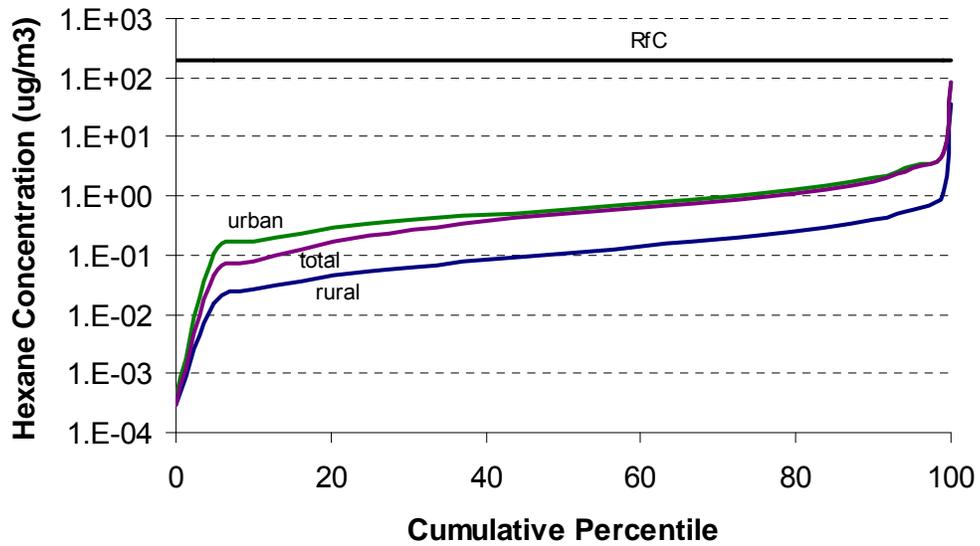
n-Hexane

Figure 18 and Figure 19 present the observed and modeled concentration distributions of n-Hexane, respectively. As noted above, the modeled concentrations do not include an estimate of background concentrations. All measured and modeled concentrations are well below the RfC.

**Figure 18. Observed Annual Average Concentrations of n-Hexane (AirData, 2005)
(ICF International, NCHRP 25-25 Task 18)**



**Figure 19. 1999 NATA Annual Average Concentration Estimates of n-Hexane
(ICF International, NCHRP 25-25 Task 18)**



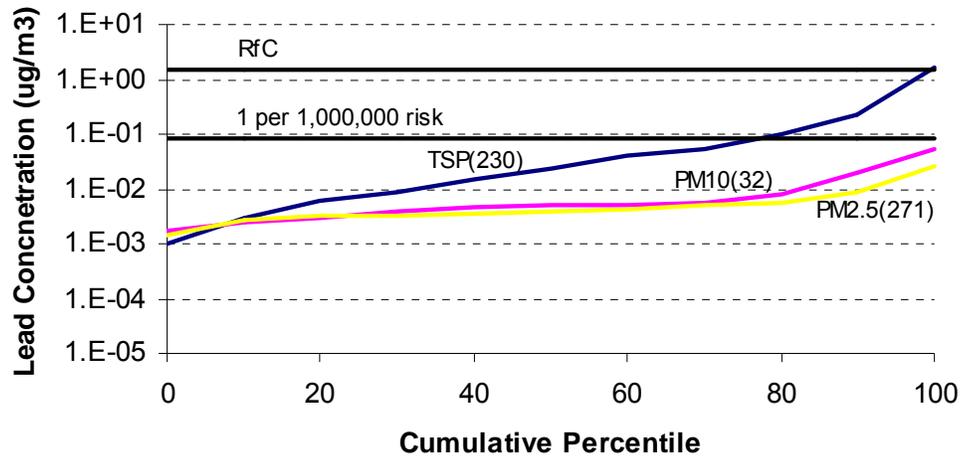
Lead

Figure 20 and Figure 21 present the observed and modeled concentration distributions of lead, respectively. The observed concentrations are stratified by particle size. As noted above, the modeled values do not include an estimate of the contribution from background concentrations or an estimate of the contribution from re-entrained road dust.

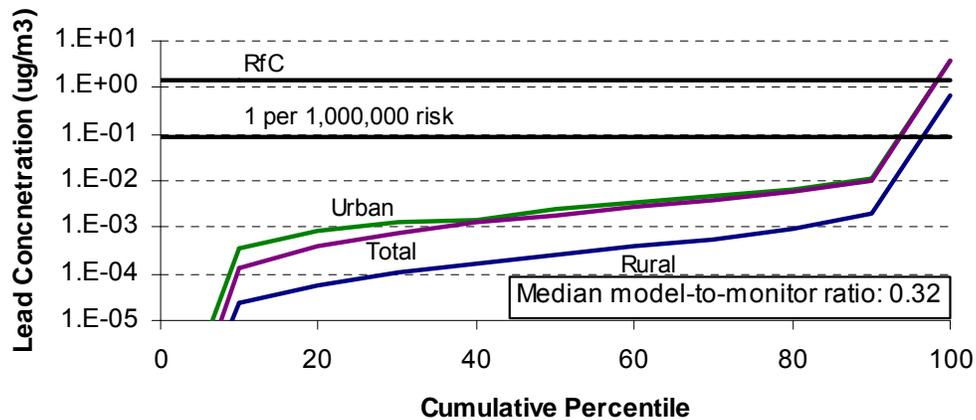
The observed distributions of PM10-bound and PM2.5-bound lead are below the 1 per million cancer risk and RfC throughout. But about 25% of the TSP-bound lead observations exceed the 1 per million cancer risk. Two of the observations of TSP-bound lead (less than 1%) exceed the RfC. These two observations, as well as several others in the upper portion of the observed distribution, were made in the vicinity of the single remaining U.S. primary lead smelter.

About 10% of the modeled urban concentrations and about 5% of the modeled rural concentrations exceed the 1 per 1,000,000 cancer risk concentration. Only two urban tracts are modeled to have lead concentrations exceeding the RfC.

**Figure 20. Observed Annual Average Concentrations of Lead Compounds (AirData, 2005)
(ICF International, NCHRP 25-25 Task 18)**



**Figure 21. 1999 NATA Annual Average Concentration Estimates of Lead Compounds
(ICF International, NCHRP 25-25 Task 18)**



Manganese

Figure 22 and Figure 23 present the observed and modeled concentration distributions of manganese, respectively. The observed concentrations are stratified by particle size. As noted above, the modeled values do not include an estimate of the contribution from background concentrations or an estimate of the contribution from re-entrained road dust. As noted in Figure 23, the NATA performance evaluation indicated that the modeled concentrations were generally somewhat lower than the observed values in the same locations. This underestimate may be due the omission of background concentrations and re-entrained road dust contributions, other missing emission sources, and/or comparison of predictions to observed concentrations of a different size fraction.

About 25% of the TSP-bound manganese observations exceed the RfC, but only one observed PM10-bound manganese concentration (about 3%) and only one observed PM2.5-bound manganese concentration (less than 1%) exceed the RfC.

Figure 22. Observed Annual Average Concentrations of Manganese Compounds (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

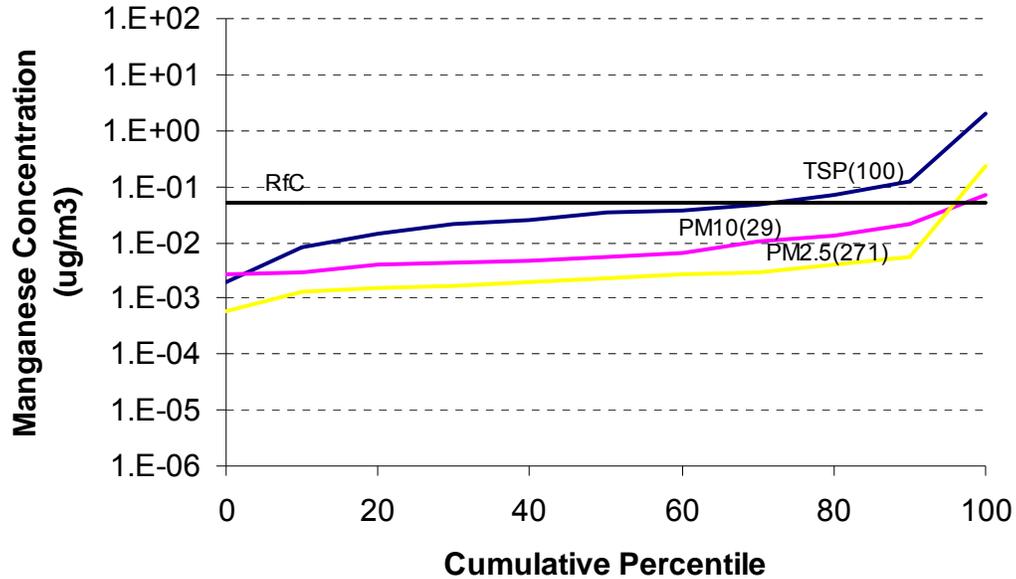
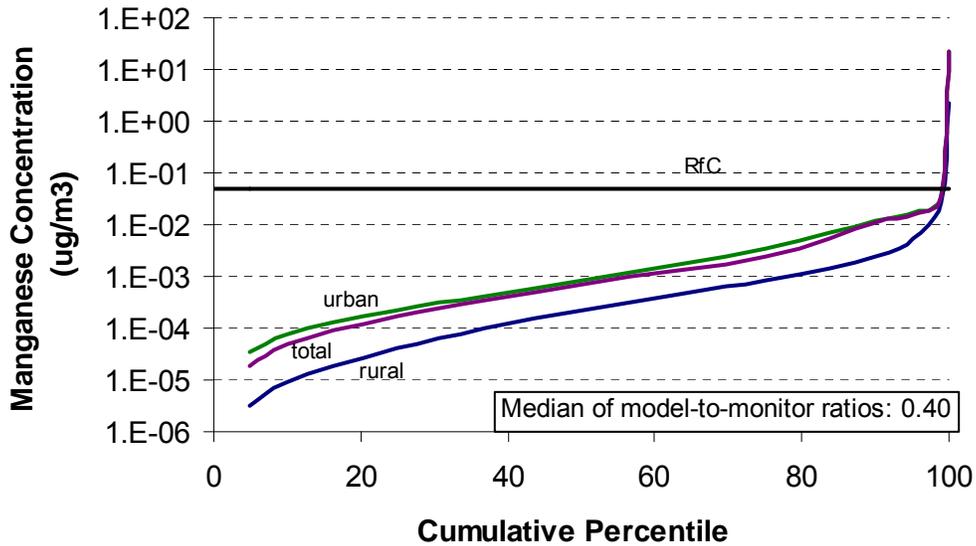


Figure 23. 1999 NATA Annual Average Concentration Estimates of Manganese Compounds (ICF International, NCHRP 25-25 Task 18)



Mercury

Figure 24 and Figure 25 present the observed and modeled concentration distributions of mercury, respectively. The observed concentrations are all PM_{2.5}-bound (few TSP-bound or PM₁₀-bound observations were identified.) with most, if not all measurements, made based on x-ray fluorescence (XRF). The modeled values include an estimated background concentration contribution, but not a contribution from re-entrained road dust.

The observed concentration distribution is below the RfC throughout, and only one modeled concentration exceeds the RfC. Note that for about 75% of the modeled concentrations more than 90% of the concentration estimate comes from the background concentration assumption.

Figure 24. Observed Annual Average Concentrations of Mercury Compounds (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

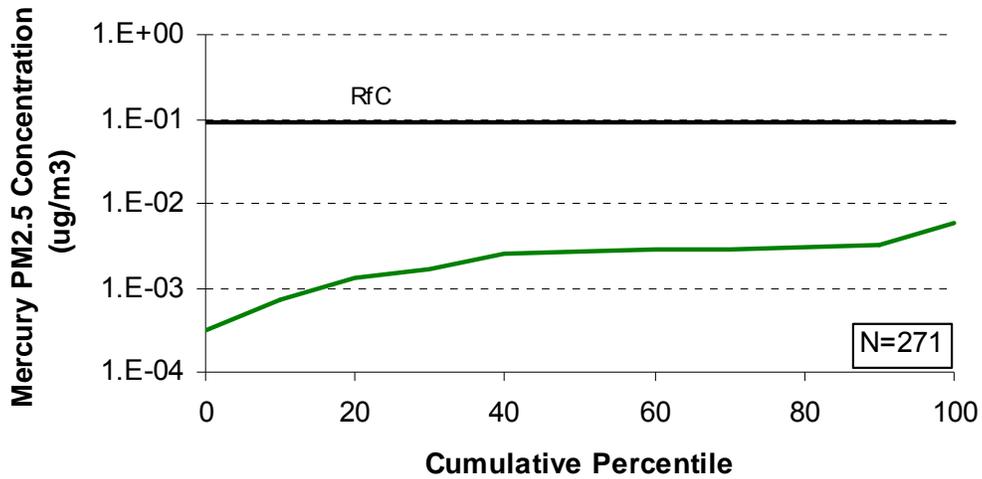
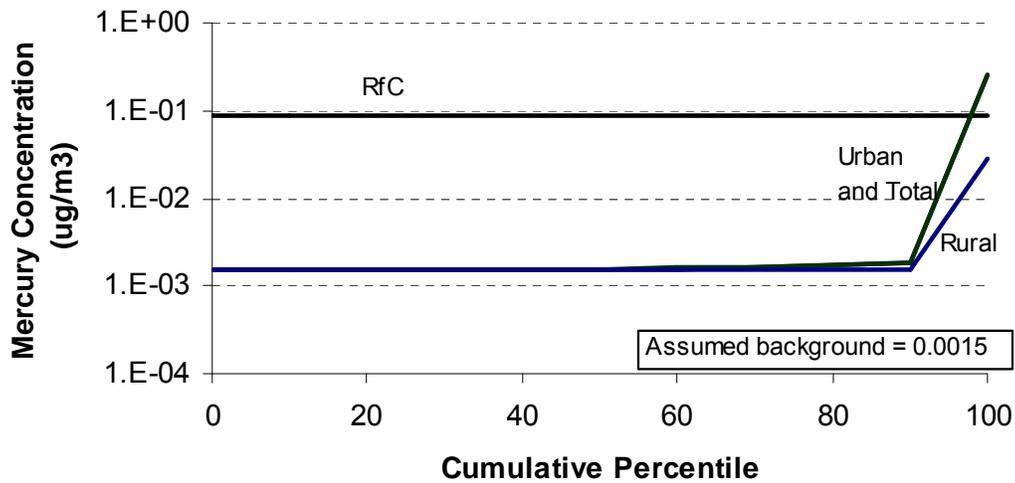


Figure 25. 1999 NATA Annual Average Concentration Estimates of Mercury Compounds (ICF International, NCHRP 25-25 Task 18)



Methyl-Tert-Butyl Ether (MTBE)

Figure 26 and Figure 27 present the observed and modeled concentration distributions of MTBE, respectively. The modeled concentrations do not include an estimated background concentration contribution.

Approximately 3% of the observed concentrations exceed the 1 per million cancer risk level. About 6% of the urban modeled concentrations, but only two rural modeled concentrations exceed the 1 per million cancer risk level.

Figure 26. Observed Annual Average Concentrations of Methyl-Tert-Butyl Ether (MTBE) (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

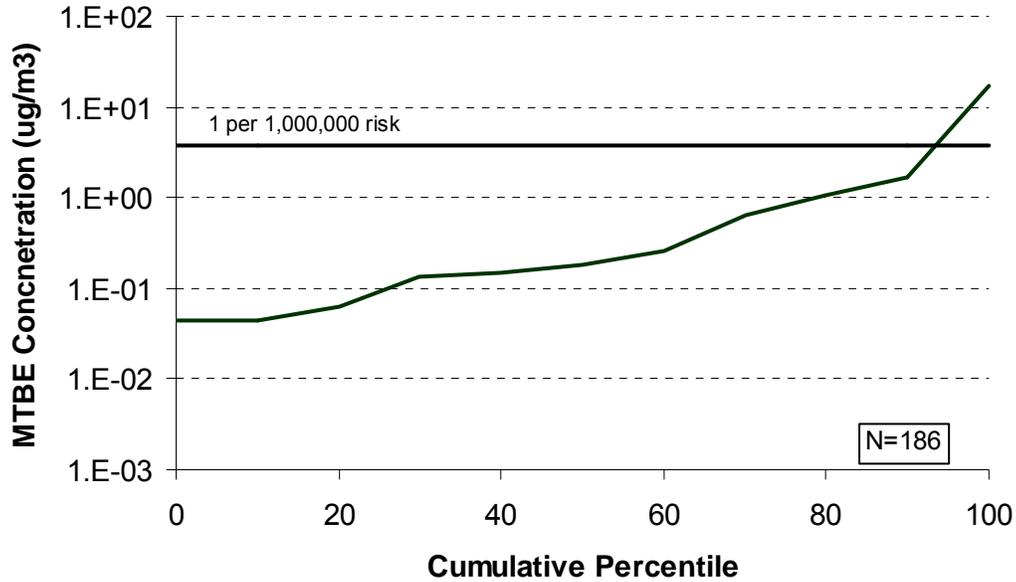
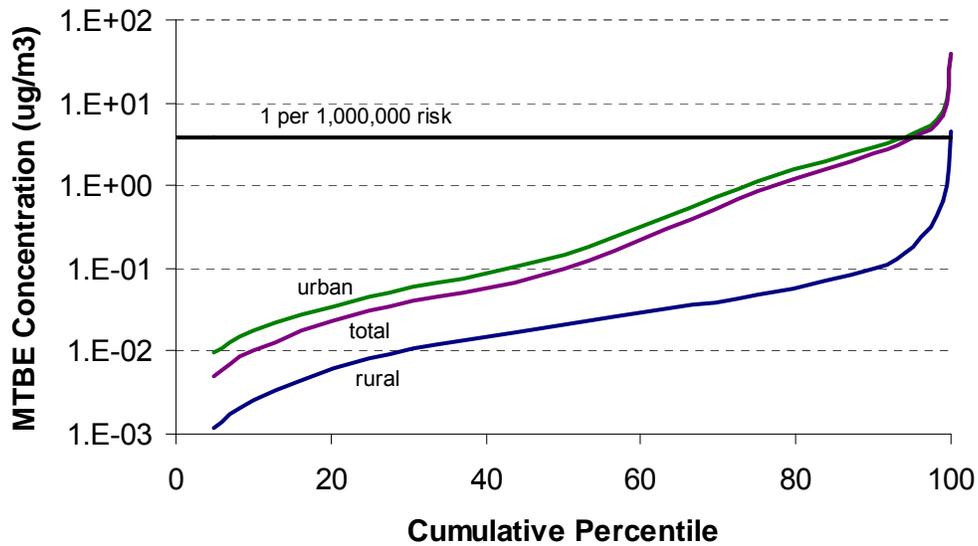


Figure 27. 1999 NATA Annual Average Concentration Estimates of Methyl-Tert-Butyl Ether (MTBE) (ICF International, NCHRP 25-25 Task 18)



Naphthalene

Figure 28 and Figure 29 present the observed and modeled concentration distributions of naphthalene, respectively. As noted above, the naphthalene predictions do not include an estimate of the contribution from background concentrations.

More than 85% of the observed naphthalene concentrations exceed the 1 per million cancer risk level, and more than 55% exceed 1 per 100,000 cancer risk level.

More than 75% of modeled urban concentrations and about 12% of modeled rural concentrations exceed the 1 per million cancer risk level. Almost 4% of modeled urban concentrations, but less than 1% of modeled rural concentrations (20 tracts), exceed the 1 per 100,000 cancer risk level.

Figure 28. Observed Annual Average Concentrations of Naphthalene (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

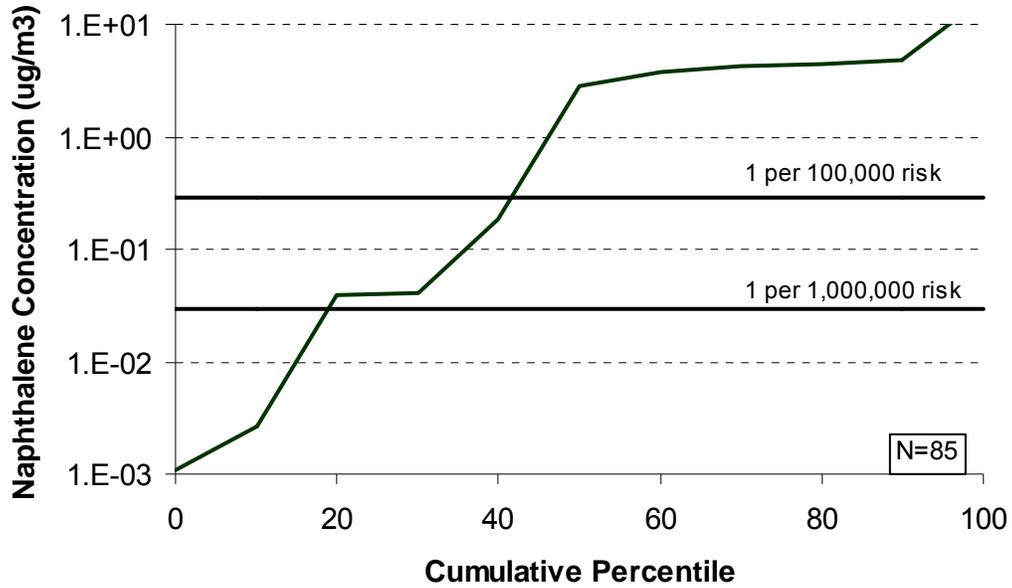
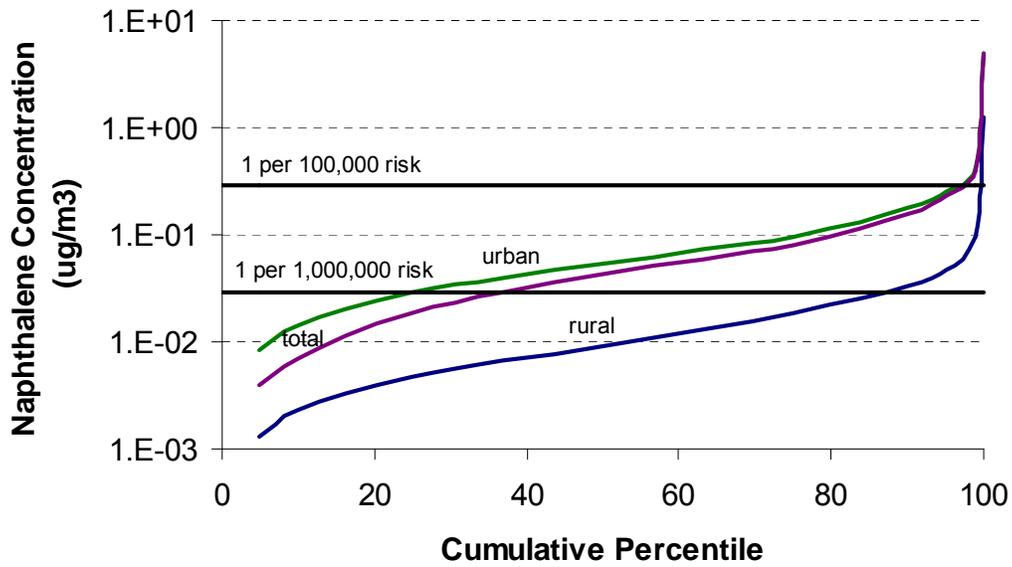


Figure 29. 1999 NATA Annual Average Concentration Estimates of Naphthalene (ICF International, NCHRP 25-25 Task 18)



Nickel

Figure 30 and Figure 31 present the observed and modeled concentration distributions of nickel, respectively. The observed concentrations are stratified by particle size. As noted above, the modeled values do not include an estimate of the contribution from background concentrations or an estimate of the contribution from re-entrained road dust. As noted in Figure 31, the NATA performance evaluation indicated that the modeled concentrations were generally somewhat lower than the observed values in the same locations. This underestimate may be due to the omission of background concentrations and re-entrained road dust contributions, other missing emission sources, and/or comparison of predictions to observed concentrations of a different size fraction.

About 38% of the observed TSP-bound nickel concentrations exceed the 1 per million cancer risk concentration, and about 8% exceed the 1 per 100,000 cancer risk level. About 3% of the observed PM10-bound and about 3% of observed PM2.5-bound nickel concentrations exceed the 1 per million cancer risk.

More than 6% of modeled urban concentrations and about 1.5% of modeled rural concentrations exceed the 1 per million cancer risk level. Less than 1% of modeled urban concentrations (239 tracts) and only seven modeled rural concentrations exceed the 1 per 100,000 cancer risk level.

Figure 30. Observed Annual Average Concentrations of Nickel Compounds (AirData, 2005) (ICF International, NCHRP 25-25 Task 18)

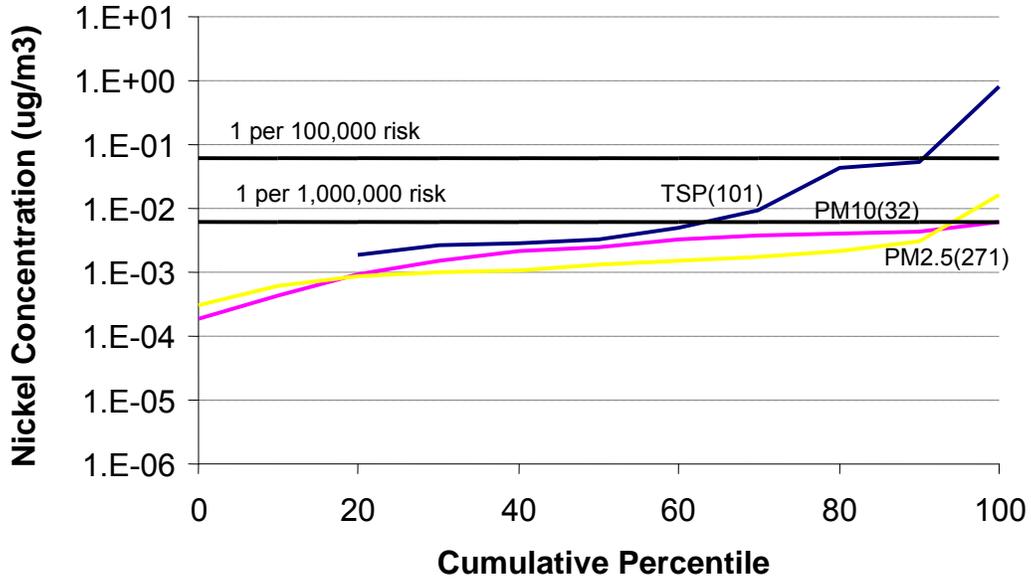
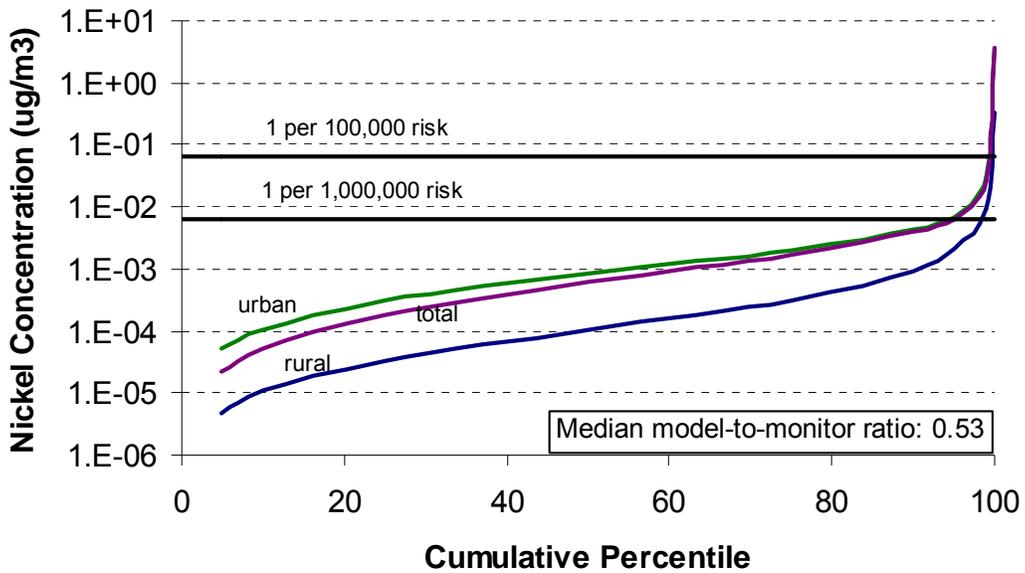


Figure 31. 1999 NATA Annual Average Concentration Estimates of Nickel Compounds (ICF International, NCHRP 25-25 Task 18)

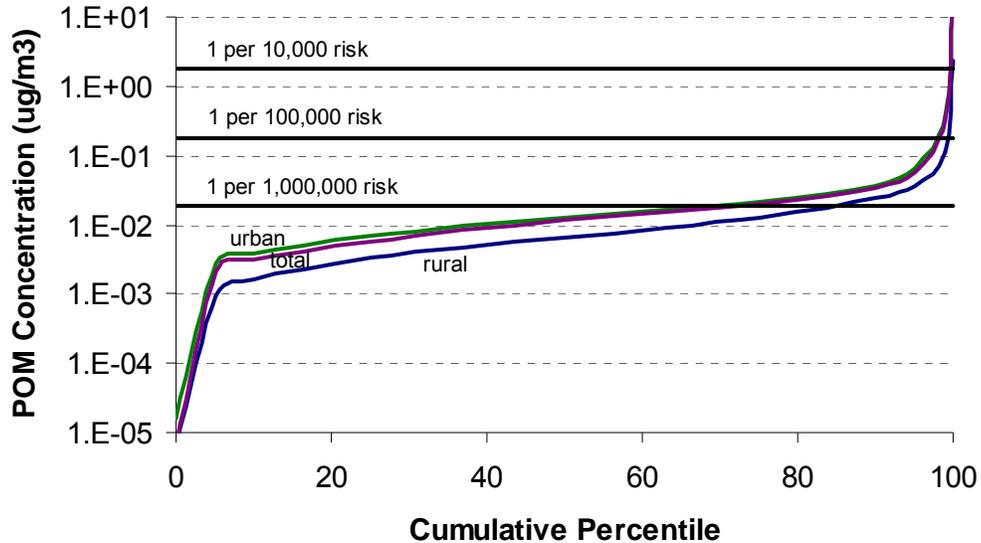


Polycyclic Organic Matter (POM)

Figure 32 presents the modeled concentration distributions of POM in 1999. As noted above, no observed concentrations were identified. The modeled values do not include an estimate of background concentration contributions.

More than 30% of modeled urban concentrations and more than 14% of modeled rural concentrations exceed the 1 per million cancer risk level. About 2% of modeled urban concentrations and 60 modeled rural concentrations exceed the 1 per 100,000 cancer risk level. Only 14 modeled urban concentrations and four modeled rural concentrations exceed the 1 per 10,000 cancer risk levels.

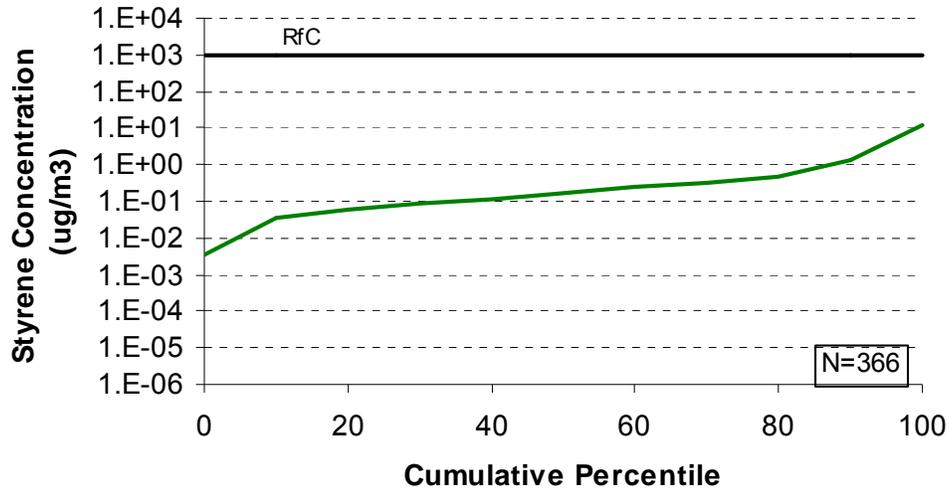
Figure 32. 1999 NATA Annual Average Concentration Estimates of Polycyclic Organic Compounds (POM) (ICF International, NCHRP 25-25 Task 18)



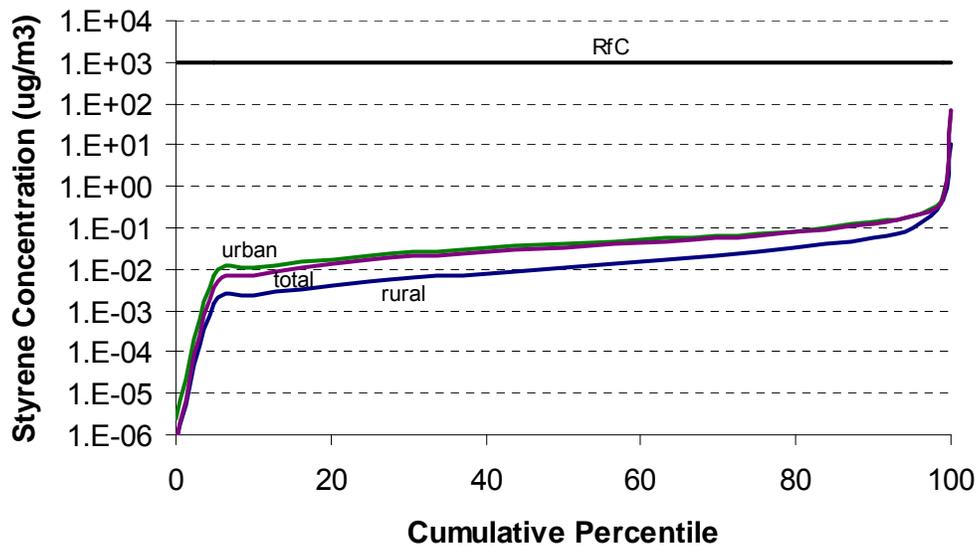
Styrene

Figure 33 and Figure 34 present the observed and modeled concentration distributions of styrene, respectively. As noted above, the modeled values do not include an estimate of the contribution from background concentrations. All measured and modeled concentrations are well below the RfC.

**Figure 33. Observed Annual Average Concentrations of Styrene (AirData, 2005)
(ICF International, NCHRP 25-25 Task 18)**



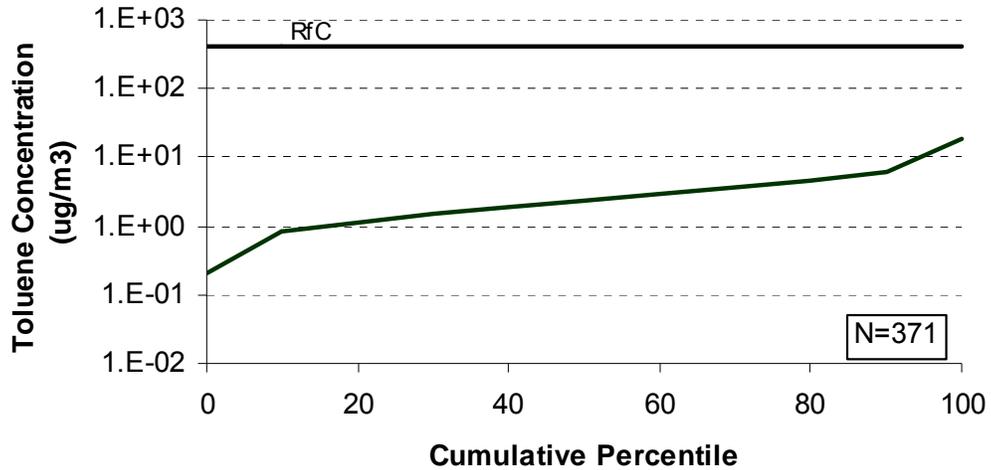
**Figure 34. 1999 NATA Annual Average Concentration Estimates of Styrene
(ICF International, NCHRP 25-25 Task 18)**



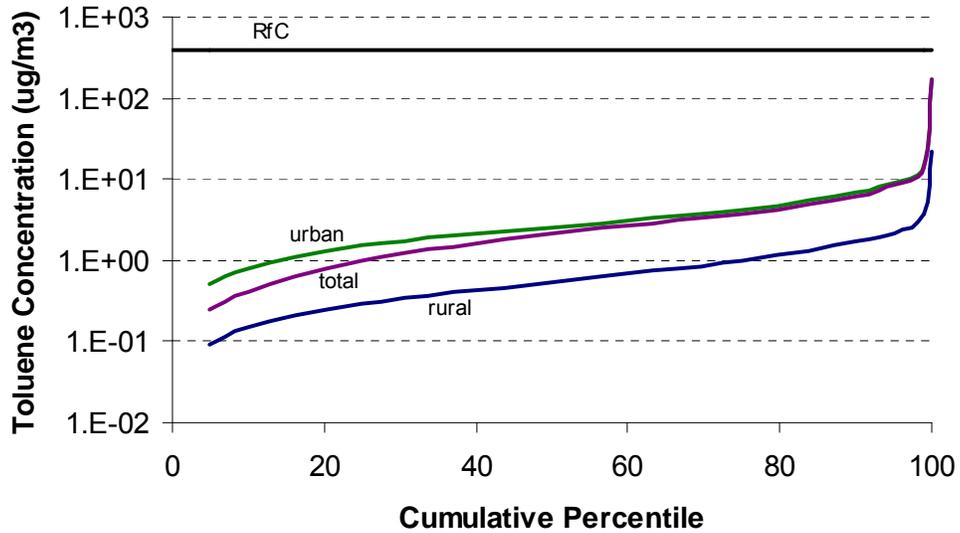
Toluene

Figure 35 and Figure 36 present the observed and modeled concentration distributions of toluene, respectively. As noted above, the modeled values do not include an estimate of the contribution from background concentrations. All measured and modeled concentrations are well below the RfC.

**Figure 35. Observed Annual Average Concentrations of Toluene (AirData, 2005)
(ICF International, NCHRP 25-25 Task 18)**



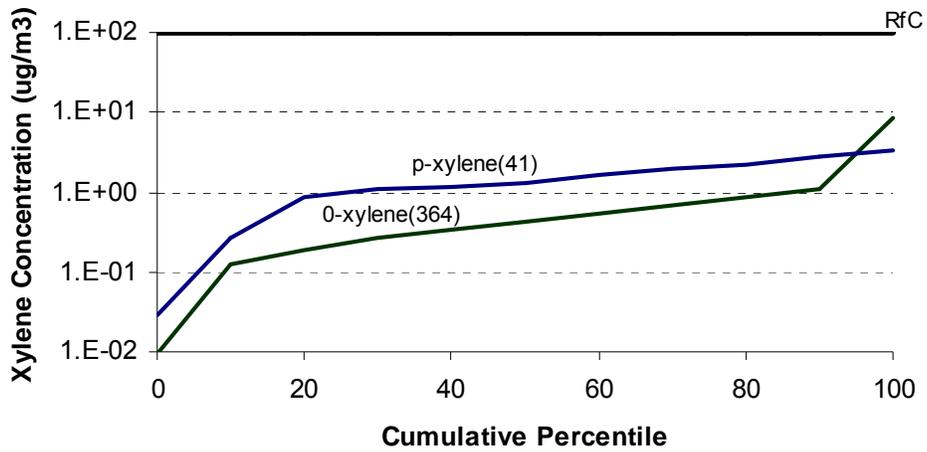
**Figure 36. 1999 NATA Annual Average Concentration Estimates of Toluene
(ICF International, NCHRP 25-25 Task 18)**



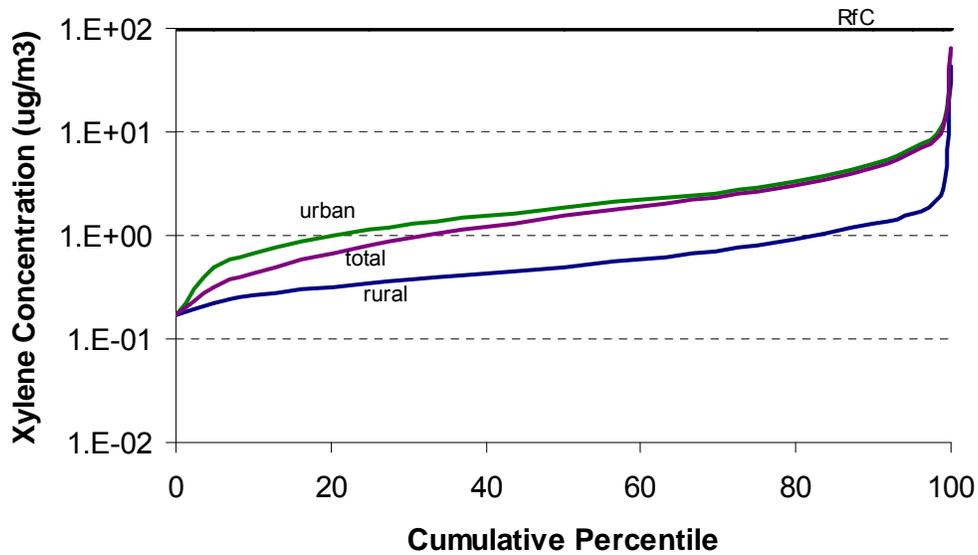
Xylene

Figure 37 and Figure 38 present the observed and modeled concentration distributions of xylene, respectively. The modeled values include an estimate of the contribution from background concentrations. All measured and modeled concentrations are well below the RfC.

**Figure 37. Observed Annual Average Concentrations of Xylene (AirData, 2005)
(ICF International, NCHRP 25-25 Task 18)**



**Figure 38. 1999 NATA Annual Average Concentration Estimates of Xylene
(ICF International, NCHRP 25-25 Task 18)**



Summary

The spatial patterns of observed and modeled concentrations suggest that the following pollutants are of widespread concern with respect to potential health impacts.

- Acetaldehyde
- Acrolein
- Arsenic
- Benzene
- 1,3-Butadiene
- Diesel particles
- Naphthalene

The findings suggest that the following pollutants are of concern in some areas with respect to potential health impacts.

- Chromium, hexavalent
- Formaldehyde
- Lead
- Manganese
- Methyl-tert-butyl ether (MTBE)
- Nickel
- Polycyclic Organic Matter (POM)

Estimating Background Pollutant Concentrations for Environmental Assessment

During environmental impact assessment of potential projects, estimation of background pollutant concentrations may be based on either pollutant measurements or air dispersion modeling.

The optimal approach is local monitoring of the pollutants of interest. For MSATs the appropriate monitoring duration is at least one year, since monitoring of shorter duration can be biased due to seasonal patterns in ambient concentrations.

Use of monitoring data from the EPA's AirData Reports is a cost-effective alternative to expensive local monitoring, if data are available at a nearby location. Each monitor has a designated scale of representation as follows:

- Microscale, representative of several to 100 m
- Middle scale, representative of 100 to 500 m
- Neighborhood scale, representative of 0.5 to 4 km
- Urban scale, representative of 4 to 50 km

If no representative monitoring data are available, NATA model predictions can be used. As noted above, NATA model predictions are available for every U.S. Census tract for 1999, and are scheduled to be available for 2002 when a new round of modeling is completed in 2007²³.

Recommended Procedures for Analyzing MSAT

Recommendations have been developed on how to select and apply the best available models and associated techniques for MSAT impact assessment in the NEPA process. The approach uses both policy and technical considerations to determine the need and

²³ EPA intends to have available by mid-2007 NATA-like assessment tools that can be used to estimate future year background concentrations. It is also possible that some states may develop an estimate of future background concentrations and these could potentially be used in an analysis.

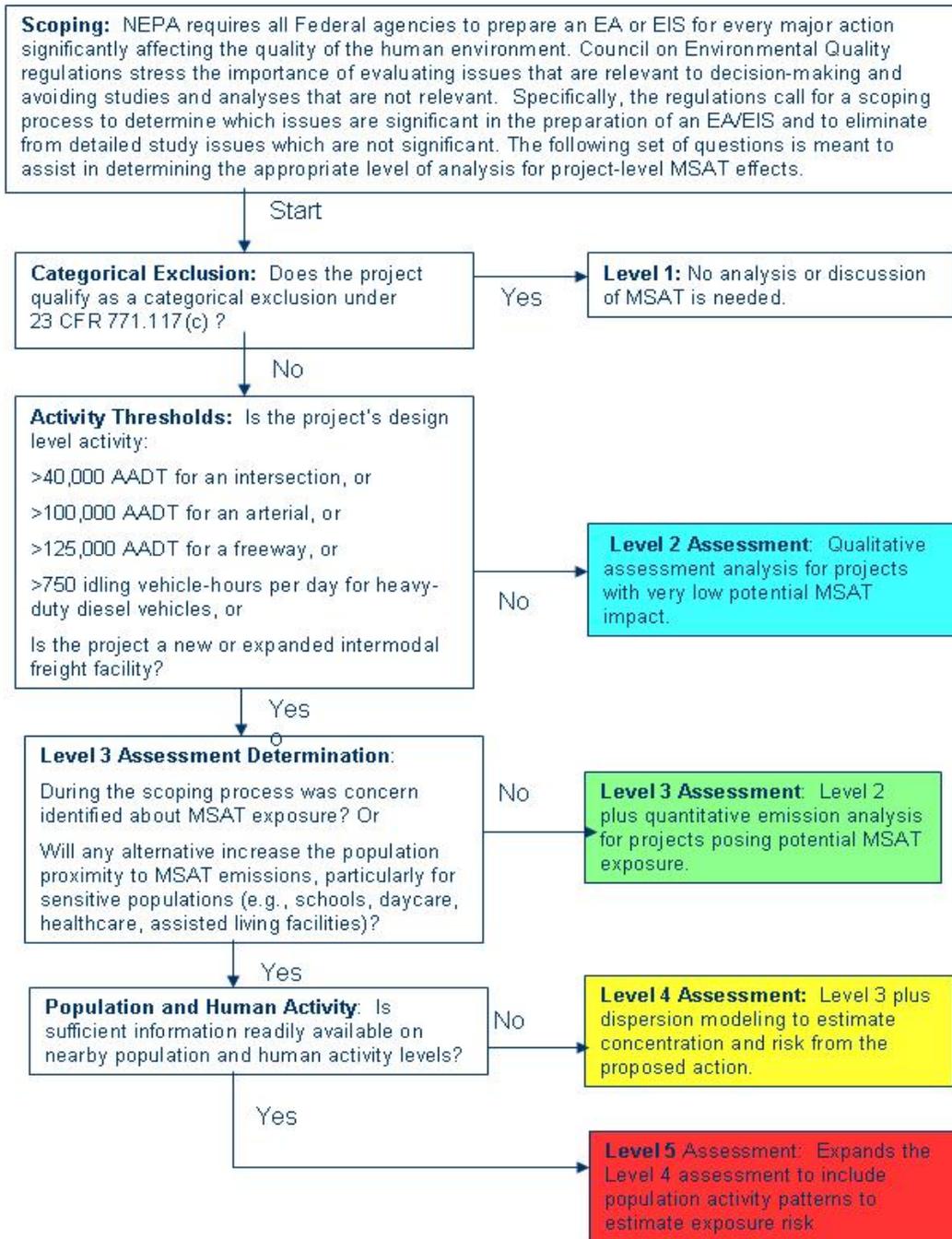
appropriateness for conducting a MSAT assessment. A set of policy and technical questions have been developed, and responses to these questions should guide the transportation analyst in determining the appropriate level of analysis under NEPA.

The set of policy-related questions help identify the appropriate level of analysis based on information about the scope of the project, its likely impact to the community, and the general public's level of concern. Coupled with the policy-related questions are technical questions which identify the appropriate level of technical analysis based on health risk considerations. This combined set of questions fully scope the transportation project, with the policy questions identifying the appropriate level of analysis and the technical questions addressing the technical feasibility of the desired policy-level analysis. Based on these considerations five analysis levels were identified with each level of analysis balancing the need for an increased level of analysis due to the projects potential for risk with the increased level of effort to conduct the analysis.

The full set of questions appears in Figure 39. The first level of analysis requires no review; subsequent levels require increasingly more data and analysis to demonstrate the projects potential MSAT impact. The first level of analysis identifies whether the project has either a categorical exclusion under 23 CFR 771.117(c). At the second level, a qualitative analysis is recommended. This level of analysis is applicable when there is little chance for increased air toxic exposure or the uncertainty is so large that quantitative assessment is unlikely to convey any useful information to the reader of the NEPA document. The third level of analysis develops a quantitative estimate of emissions for the proposed action. The fourth level of analysis expands upon the emission analysis by including dispersion modeling to estimate concentration and risk toxicity. The fifth level of analysis incorporates population activity patterns to estimate exposure risk.

A detailed discussion is presented for each level of analysis in the following section.

Figure 39. Recommendation Flowchart (ICF International, NCHRP 25-25 Task 18)



Five Levels of Analyses for Air Toxic Assessment under NEPA

Level 1—Air Toxic Risk Assessment

To reach this level of assessment the proposed project must be categorically excluded under 23 CFR 771.117(c), in which case no analysis or discussion of MSATs is needed. However, supporting documentation should show that the project qualifies as a categorical exclusion and/or exemption. In addition, the project should document the basis for the determination that no meaningful air-related impacts occur as a result of the project based on a brief description of the factors considered to support this conclusion.

Level 2—Qualitative Air Toxic Assessment

It is anticipated that many of the more typical transportation projects will fall into this analysis category. The types of projects that will typically be found in this level of analysis are projects which improve operations without substantially adding new capacity and therefore are anticipated to have very low potential impact. Examples include: freeway widening projects where increased volume remains below the screening threshold level of 125,000 AADT in the design year; new interchanges where a new arterial segment is built to connect to an existing highway and the project's traffic volume remains below the 100,000 AADT design year threshold screening level; and a new interchange project developed to serve a new residential development where the project's traffic volume is below the screening threshold level of 40,000 AADT in the design year. Appendix C provides a detailed discussion on the development of these health risk-based screening thresholds from analysis of the key risk drivers.

EPA has identified some 21 hazardous air pollutants as mobile source air toxics (66 CFR 17235). Based on EPA's 1996 NATA National Scale Assessment (<http://www.epa.gov/ttn/atw/>

nata/natsaov.html) a set of six MSAT's were identified as mobile source air toxics of greatest concern and have been referred to as the priority MSATs. The six MSATs originally identified are:

- Benzene
- Diesel PM and organic gases
- 1,3 butadiene
- Acrolein
- Formaldehyde
- Acetaldehyde

The analysis at this level and all other levels will focus the assessment on these same six MSATs.

The *primary steps* for this analysis are described as follows:

- 1) Qualitatively describe how the project will affect traffic volume, speed, and vehicle mix for each proposed alternative. These three parameters have effects on total MSAT emissions. Use information based on latest emission factor model and studies. See the discussion on Level 2 Recommended Tools for current best available approach. For each of the priority MSATs, discuss how these three parameters are affected by the project action and alternatives.
- 2) Describe how the project alternatives may alter current and projected traffic patterns in the vicinity of the project. The project may lead to traffic increases in some locations and decreases in other locations. Traffic pattern changes may also impact exposure distance, especially to sensitive receptors.
- 3) Summarize and tally the expected changes for each of the four parameters (traffic volume, speed, vehicle mix, traffic pattern) for each project alternative. Based on the number of changes, compare the various alternatives to inform decision makers which of the alternatives has the least likely impact. Note that while the changes for

each parameter are not necessarily equal in terms of their change to MSAT emissions for each project alternative, this comparison will convey useful information on the likely direction of change (no change/increase/decrease), particularly at the local level.

- 4) Obtain background concentrations for the location or model predictions from the most recent NATA (see discussion under Level 2 Recommended Tools section) for the particular county where the project is located, unless local site-specific data are available. The NATA data may be expressed as a range of concentrations using information on the project setting as a discriminating value. This information will provide an assessment of the likely current situation at the location of the project. See discussion on the MSAT Emission Trends in the Level 2 Recommend Tools Section.
- 5) Summarize the current state or regional emission trends for MSATs, if available; otherwise summarize the current national emissions trends for MSATs as discuss applicability to the project. This discussion should compare state, regional, or national trends for MSATs relative to the project's proposed completion date within the near term (5 years), mid-term (10-15 years) and project life (25-30 years). The discussion should identify that the national overall trend is downward through 2015, even with increasing VMT due to fuel regulations and engine technologies regulations, but that the proposed action or alternative may slow the downward trend (depending upon the project-specific change in VMT, fleet mix, and speed). See discussion on MSAT Emission Trends in the Level 2 Recommend Tools Section.

- 6) **Conclusion:** Discuss the likely range in current background concentrations and estimate future background²⁴ concentrations for the project setting using the information gathered in Step 4 and 5 above. Statements can then be made that because of the conservative assumptions and screening analysis done under the NCHRP 25-25, Task 18 study, this type of project has low potential to result in a toxic hotspot. Also, because the study is not foreseen to have any potential adverse impacts, no discussion is needed on the current science of air toxic assessment.

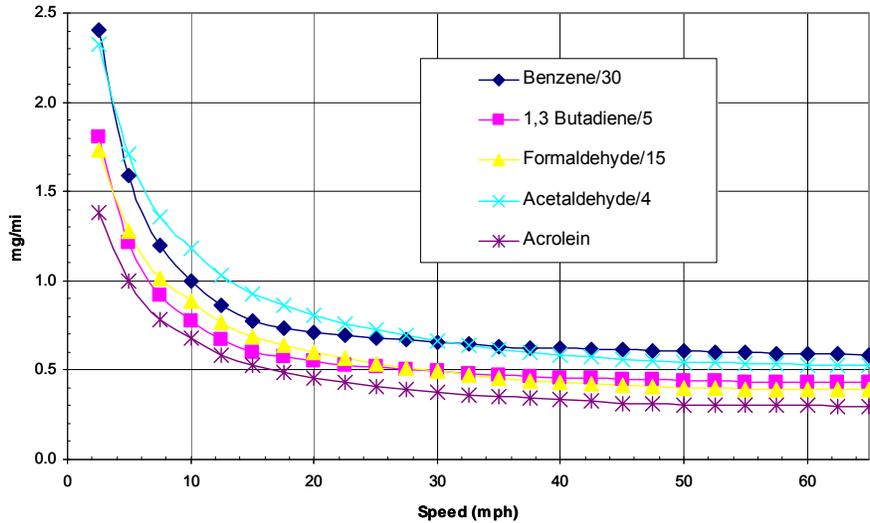
Level 2 Recommended Tools

- **Methods for Estimating Emission Direction for Key Parameters.** For the speed and fleet mix parameters, the latest available emission factor model should be used to show how priority MSAT emissions change with these parameters. This information will then form the basis for discussion of the change in MSATs resulting from the proposed action.
 - **Speed.** Currently, the best available tool for estimating emission factors for MSATs is from EPA's MOBILE6.2 model. The information available is suitable for estimating the likely change in direction as result of the proposed action. In an analysis done by FHWA (Tang et al., 2003), priority MSAT emission rates were determined as a function of speeds for freeways (Figure 40) and arterials (Figure 41). If the proposed action changes the speed on the facility then the figure(s) below can be used to estimate the relative change in MSAT emissions.²⁵

²⁴ EPA intends to have available by mid-2007 NATA-like assessment tools that can be used to estimate future year background concentrations. It is also possible that some states may develop an estimate of future background concentrations and these could potentially be used in an analysis.

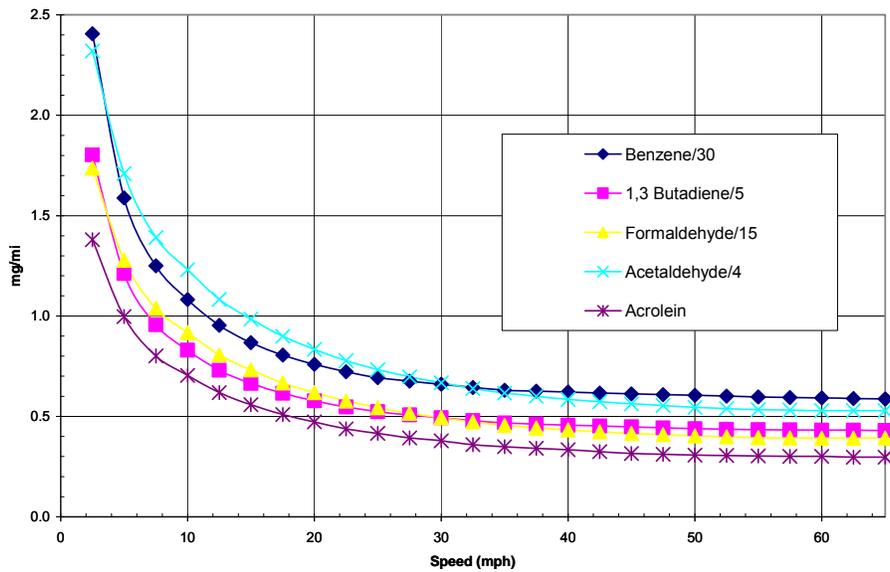
²⁵ Appendix D contains the specific values output by MOBILE6.2 as used in Figures 40-44 these can be used to better quantify the relative change from a proposed action.

**Figure 40. Freeway Facility Speed Effects on MSATs
(ICF International, NCHRP 25-25 Task 18)**



Note: Based on application of MOBILE6.2 with national default in calendar year 2010. Diesel PM not shown as reported as constant with speed. Fuel RVP set to 8.5 pounds per square inch (psi). Min/Max temperatures of 88.0 °F and 100.0 °F and benzene fuel content of 1.5%. To display MSATs on same graph the true emission factor has been scaled, the true emission factor is equal to the value in the graph multiplied by the denominator. For example, the true benzene emission rate at 10 mph is (1.0*30) = 30 mg/mi.

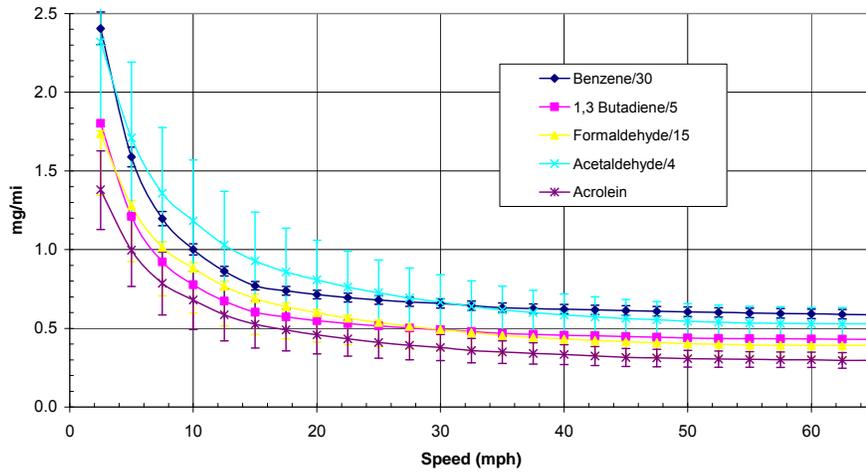
**Figure 41. Arterial Facility Speed Effects on MSATs
(ICF International, NCHRP 25-25 Task 18)**



Note: Based on application of MOBILE6.2 with national default in calendar year 2010. Diesel PM not shown as reported as constant with speed. Fuel RVP was set at 8.5 pounds per square inch (psi). Min/Max temperatures of 88.0 degrees Fahrenheit and 100.0 degrees Fahrenheit and benzene fuel content of 1.5%. To display MSATs on same graph the true emission factor has been scaled, the true emission factor is equal to the value in the graph multiplied by the denominator. For example, the true benzene emission rate at 52.5 mph is (0.6*30) = 18 mg/mi.

- **Fleet mix.** Similar to speed effects, the best available tool for estimating changes in fleet mix on MSAT emissions is to apply EPA's MOBILE6.2 emission factor model. The information available is suitable for estimating the likely direction of the change in MSAT emissions as result of the proposed action. As was done for speed effects, the priority MSAT emission rates were modeled as a function of speeds for freeways (Figure 42) and arterials (Figure 43) along with an upper and lower bound for the heavy-duty diesel vehicles fractions of 2 and 15 percent. Changes in fleet mix have the potential to impact MSAT emissions. If the proposed action changes the HDDV fraction for the facility then the figure(s) below can be used to estimate the relative change in the MSAT emissions.

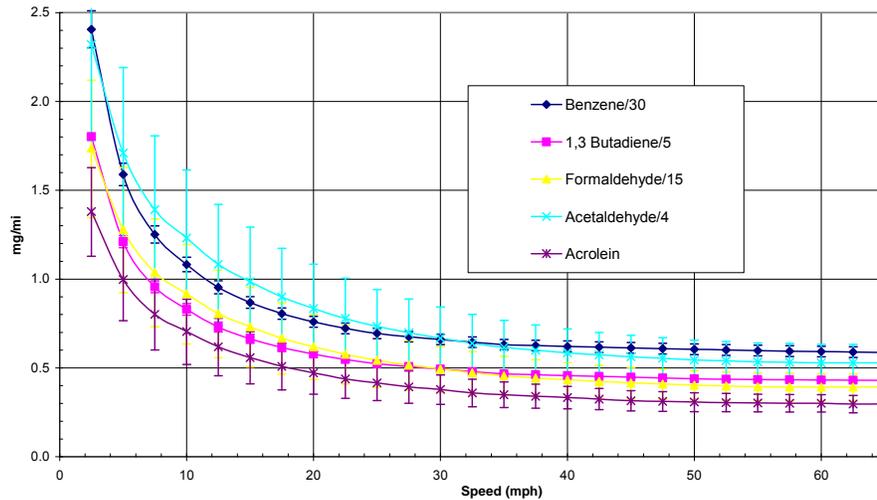
Figure 42. Freeway Facility Speed and Fleet Mix Effects on MSAT Emission Factors (ICF International, NCHRP 25-25 Task 18)



Note: Error bars show change relative to default fleet (8.5% HDDV) for 2% HDDV and 15% HDDV. Benzene is highest with 2% HDDV. All other MSATs are higher with greater HDDV percentage except butadiene which is higher with 15% HDDV at low speeds and then crosses at 47.5 mph to have higher concentrations with lower (2%) HDDV at higher speeds. To display MSATs on same graph the true emission factor has been scaled, the true emission factor is equal to the value in the graph multiplied by the denominator. For example, the true benzene emission rate at 10 mph is $(1.0 \cdot 30) = 30$ mg/mi.

Figure 43. Arterial Facility Speed and Fleet Mix Effects on MSAT Emission Factors (ICF International, NCHRP 25-25 Task 18)

(Ranges Based on 2% and 15% HDDV Fleet Mix)

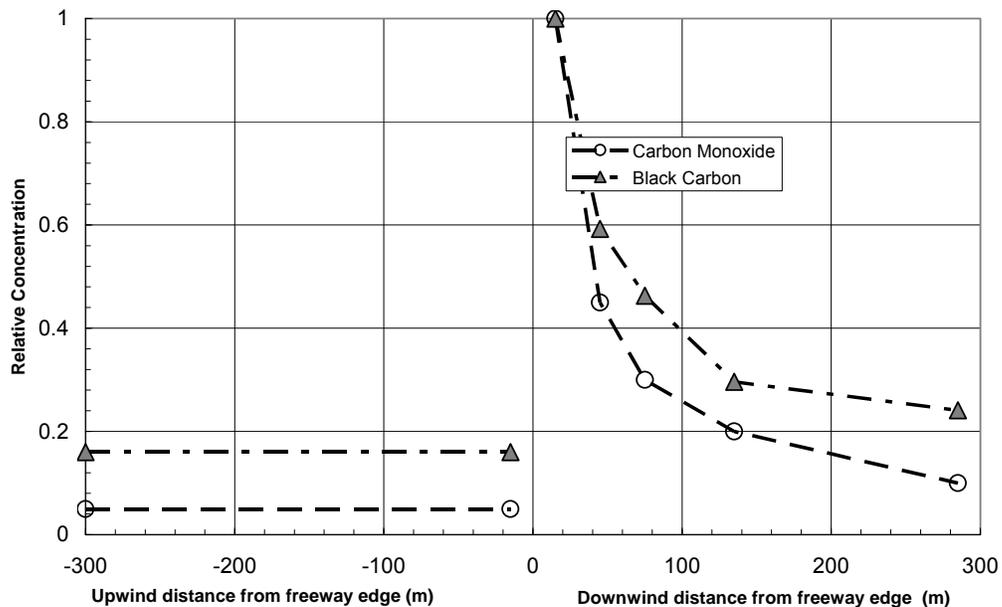


Note: Error bars show change relative to default fleet (8.5% HDDV) for 2% HDDV and 15% HDDV. Benzene is highest with 2% HDDV. All other MSATs are higher with greater HDDV percentage except butadiene which is higher with 15% HDDV at low speeds and then crosses at 47.5 mph to have higher concentrations with lower (2%) HDDV at higher speeds. To display MSATs on same graph the true emission factor has been scaled, the true emission factor is equal to the value in the graph multiplied by the denominator. For example, the true benzene emission rate at 52.5 mph is $(0.6 \cdot 30) = 18$ mg/mi.

The other parameters can be characterized as follows:

- Traffic volume.** As a first order estimate, emissions of MSAT vary linearly with volume; i.e., doubling the traffic volume will double the emissions, assuming no limitation imposed by capacity.
- Distance curve.** If the proposed action changes the relative distance between the roadway and the location of exposed individuals (exposure distance) then Figure 44 can be used as a conservative estimate of the potential increase or decrease in MSAT exposure. The figure shows the relative change in pollutant concentration as a function of downwind distance. The black carbon measurement can be used as a close approximation for diesel PM and the carbon monoxide as a surrogate for the other gas-phase priority MSATs.

Figure 44. Relative Carbon Monoxide and Black Carbon Concentrations vs. Downwind Distance (ICF International, NCHRP 25-25 Task 18)



Notes: Based on measurements collected during the daytime (May-July 2001) adjacent to the 30-m wide I-405 freeway by Zhu, Hinds, Kim and Sioutas (2002). Traffic density ranged from 140 to 250 vehicles per minute. Wind direction were consistently perpendicular to the freeway at 1-2 m/s. Less than 5% of vehicles were heavy-duty diesel trucks.

- **Background Concentrations.** An estimate should be made of the background MSAT concentration at the proposed location of the transportation project. This estimate will provide a reviewer with useful information on the likely air toxic concentration in the vicinity of the proposed project. Because it is cost prohibitive to conduct air toxic monitoring at all locations in the U.S.²⁶, EPA has assessed the current conditions at the census tract level through air quality modeling. This assessment is known as the National Air Toxic Assessment—National Scale Assessment (NATA-NSA). The most current [results of its national-scale assessment](#) were released in February 2006 based on a 1999 emissions inventory. The assessment identifies the concentration for each priority MSAT (as well as many other MSATs) as a distribution with values reported at the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentiles for each county in the U.S. The transportation analyst can then select the appropriate percentile to use for the estimated mobile background concentration based on a local understanding of the county-level emission densities. For locations where this information is not known or unavailable, a GIS spatial analysis of census tract block group population density can be used as a surrogate for estimating the emission density distribution within the county to determine the appropriate percentile ranking.
- **Mobile Source Air Toxics Emissions Trends.** EPA is the lead federal agency for administering the Clean Air Act and has certain responsibilities regarding the health effects of MSATs. EPA issued a Final Rule on Controlling Emissions of Hazardous Air Pollutants from Mobile Sources, 66 FR 17229 (March 29, 2001). This rule was issued under the authority in Section 202 of the Clean Air Act. In this rule, EPA

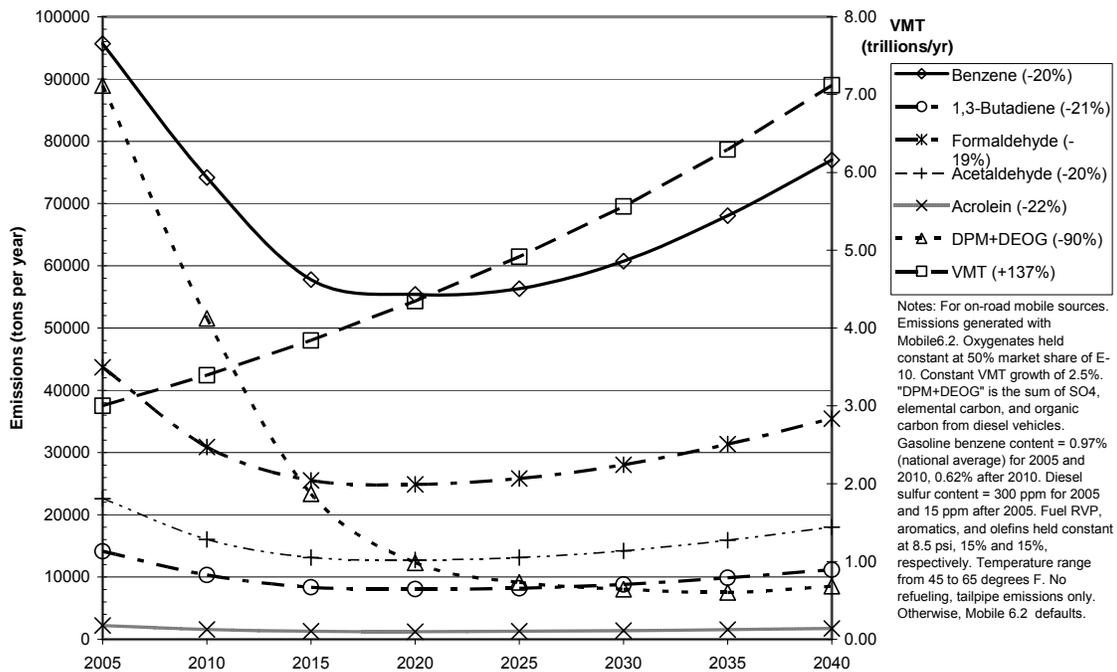
²⁶ In some circumstances it may be possible to use ambient monitoring data for background concentration. This data can be obtained from AirData website (<http://www.epa.gov/air/data/index.html>)

examined the impacts of existing and newly promulgated mobile source control programs, including its reformulated gasoline (RFG) program, its national low emission vehicle (NLEV) standards, its Tier 2 motor vehicle emissions standards and gasoline sulfur control requirements, and its proposed heavy duty engine and vehicle standards, and on-highway sulfur control requirements for diesel fuel. The rule established toxics emissions performance standards for gasoline refiners and committed to additional rulemaking to evaluate the need for and feasibility of additional controls. On February 9, 2007, EPA issued new rules to reduce hazardous air pollutants from mobile sources. The new standards would significantly lower emissions of benzene and other air toxics by: (1) lowering benzene content in gasoline; (2) reducing exhaust emissions from passenger vehicles operated at cold temperatures (under 75 degrees F); and (3) reducing emissions that evaporate from, and permeate through, portable gasoline containers (note that this last proposed measure does not directly affect on-road emissions of MSATs).

Based on these regulations, in the near-term (between 2005 and 2010—see Figure 45) there are projected reductions in on-highway emissions of acrolein, benzene, formaldehyde, 1,3-butadiene, and acetaldehyde of 22 percent to 30 percent, and on-highway reductions of diesel PM emissions of 42 percent, even with a 13 percent increase in VMT. The highest emissions reduction projections occur in the mid-term (between 2005 and 2020), where projected on-highway emissions reductions of acrolein, benzene, formaldehyde, 1,3-butadiene, and acetaldehyde are 40 percent to 42 percent, and projected reductions for on-highway diesel PM emissions are 74 percent, even with a 28 percent increase in VMT. However, the long-term emissions

reduction projections show smaller decreases for the gas-only air toxics as the increase in VMT overtakes the regulatory reductions. Between 2005 and 2040 on-highway emissions of acrolein, benzene, formaldehyde, 1,3-butadiene, and acetaldehyde are projected to decrease between 19 percent to 22 percent, but on-highway diesel PM emissions are projected to fall by 90 percent, even with a 138 percent increase in VMT as shown in Figure 45.

Figure 45. U.S. Annual Vehicle Miles Traveled (VMT) vs. Mobile Source Air Toxics (MSAT) Emissions (2005–2040)
(ICF International, NCHRP 25-25 Task 18)



Level 3—Quantitative Emissions Assessment

This type of analysis will use the available information on the proposed action and alternatives in conjunction with the best available emission factors to quantitatively estimate the impact for MSAT emissions. The projects that fall into this category have shown a high potential for MSAT emissions to concentrate at high enough levels to be of potential concern. The type of projects that would fall into this category would include major intermodal freight facilities and highway projects which add or create new capacity above the 125,000 AADT for interstates, 100,000 AADT for arterials, or 40,000 AADT for intersections.

The analysis should focus on the priority MSAT emissions, as these are the most likely principal contributors to any significant increase in health risk. The analysis of the proposed action and its alternatives will provide decision makers with information that discriminates between project alternatives as well as information on the relative impact of the action in comparison with existing air toxic concentrations.

The *primary steps* for this analysis are described as follows:

- 1) Quantitatively assess the change in transportation-related parameters which result from the proposed action and alternatives. These include how the project and the alternatives will affect traffic volume, speed, and vehicle fleet mix. Of these parameters, speed and vehicle fleet mix can be used in the most currently available emission factor model to provide reliable estimate of changes in MSAT emissions between alternatives. See the discussion on the Level 3 Recommended Tools for further information on application of this approach. For each of the priority MSATs, discuss how these three parameters are affected by the project action and alternatives.

- 2) Assess how the project may alter current traffic patterns in the vicinity of the project. Traffic may increase in some locations and decrease in other locations. Traffic pattern changes may also impact exposure distance, especially to sensitive receptors.
- 3) For each alternative, quantitatively summarize the expected change in MSAT emissions. This will provide decision makers with the ability to compare the relative differences in emissions impacts between the various alternatives.
- 4) Obtain background concentrations for the location or model predictions from the most recent NATA for the particular county where the project is located. This data may be expressed as a range of concentrations using information on the project setting as a discriminating value. This information will provide an assessment of the likely current situation at the location of the project. See discussion on the MSAT Emission Trends in Level 3 Recommend Tools Section.
- 5) Summarize the current national emission trends for MSATs. This discussion should compare national trends for MSAT emissions relative to the project's proposed completion date with the near term (5 years), mid-term (10-15 years) and project life (25-30 year). The discussion should identify that the trend is downward through 2015, even with increasing VMT due to fuel regulations and engine technologies regulations, but that the proposed action of alternative will likely slow the downward trend (depending upon project specific change in VMT, fleet mix, speed). See discussion on the MSAT Emission Trends (2005-2040) in Level 3 Recommend Tools section.

- 6) **Conclusion:** Discuss the likely range in current background concentrations and estimate future background²⁷ concentrations for the project setting from the information gathered in Step 4 and 5 above. Identify the air toxic emissions associated with the project relative to the no action and various action alternatives. Because this project has a high potential to result in a local toxic hotspot, the analysis should include a discussion on the limitations of currently available tools for assessing the health impacts from MSAT emission changes. This is a requirement under Council of Environmental Quality (CEQ), which implements NEPA regulations (40 CFR 1502.22(b)). See discussion on the *Unavailable Information for Project Specific MSAT Impact Analysis* in the Level 3 Recommended Tools Section.

Level 3 Recommended Tools

- **Methods for Estimating Emissions for Key Parameters.** For the speed and fleet mix parameters, the latest available emission factor model should be used to show how emissions of priority MSATs change with these parameters. This information will then form the basis for discussion of the change in MSATs with respect to the proposed action.
 - **Speed.** Currently, the best available tool for estimating emission factors for MSATs is EPA’s MOBILE6.2 emission factor model. While the model has limitations in estimating emissions for a particular vehicle for a particular speed, it can provide a reliable approach for comparing emissions under proposed project alternatives. In most cases the decision maker will want information on how

²⁷ EPA intends to have available by mid-2007 NATA-like assessment tools that can be used to estimate future year background concentrations. It is also possible that some states may develop an estimate of future background concentrations and these could potentially be used in an analysis.

projected emissions vary between the proposed action and alternatives. In providing this estimate, average speed information from the proposed action provides suitable information for comparing project alternatives. EPA anticipates releasing a new mobile emission factor model called **MO**tor **V**ehicle **E**mission **S**imulator (MOVES) in 2007 suitable for estimating modal emissions at the project level specific to varying locations within the project. Until the release of MOVES, the assessment should be made through the use of average speeds for each proposed project alternative.

- **Fleet mix.** Here again, the best tool currently available for estimating emission factor changes as a result of fleet mix changes is EPA's MOBILE6.2 emission factor model. While the basis of the model is somewhat limited to older technologies, most of the MSAT emission changes are associated with VOC emissions, and the model has incorporated more recent engine emission reduction technology making it suitable for assessing project alternatives. Until MOVES becomes available the assessment should be made using the appropriate fleet mix as an input for MOBILE6.2 for each project alternative.
- **Background Concentrations.** An estimate should be made of the background MSAT concentrations at the proposed location of the transportation project. This will provide a reviewer useful information on the likely air toxic concentration in the vicinity of the proposed project. If available, local near-site monitoring data should be used to estimate background concentrations²⁸. However, because it is cost prohibitive to conduct air toxic monitoring at all locations in the U.S., EPA has assessed the current

²⁸ In some circumstances it may be possible to use ambient monitoring data for background concentration. This data can be obtained from AirData website (<http://www.epa.gov/air/data/index.html>)

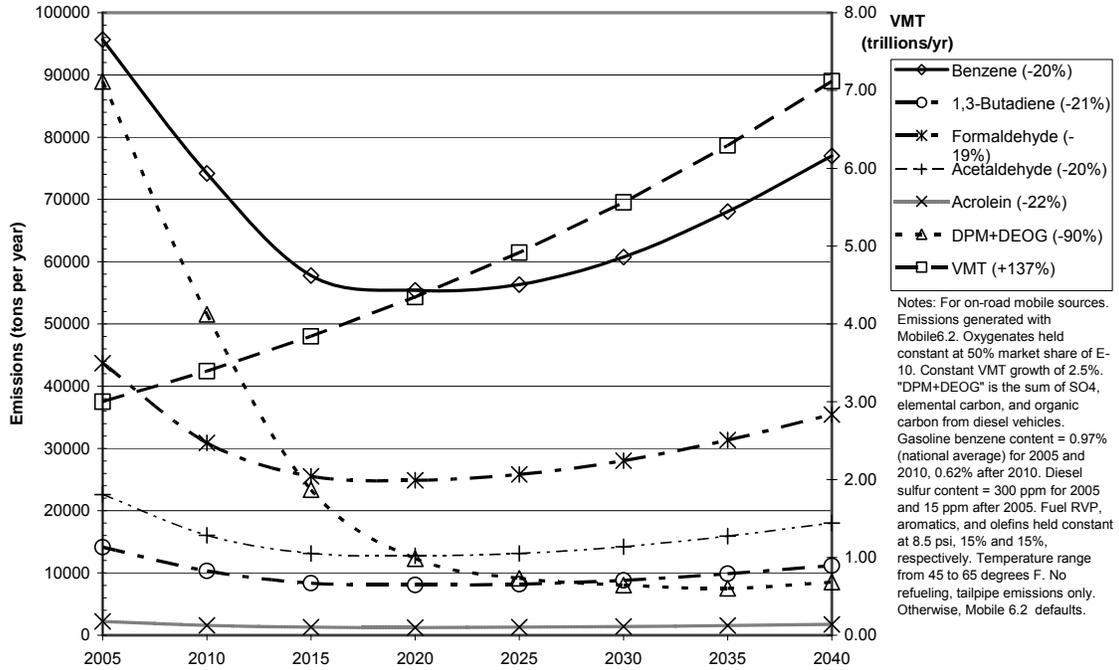
conditions at the census tract level through air quality modeling. This assessment is known as the National Air Toxic Assessment—National Scale Assessment (NATA-NSA). The most current [results of its national-scale assessment](#) were released in February 2006 based on a 1999 emission inventory. The assessment identifies the concentration for each priority MSAT (as well as many other MSATs) as a distribution with values reported at the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentile for each county in the U.S. The transportation analyst can then select the appropriate percentile to use for the estimated background concentration based on a local understanding of the county-level emission densities. For locations where this information is not known or unavailable, a GIS spatial analysis of census tract block group population density can be used as a surrogate for estimating the emission density distribution within the county to determine the appropriate percentile ranking.

- **Mobile Source Air Toxics Emissions Trends.** EPA is the lead federal agency for administering the Clean Air Act and has certain responsibilities regarding the health effects of MSATs. EPA issued a Final Rule on Controlling Emissions of Hazardous Air Pollutants from Mobile Sources, 66 FR 17229 (March 29, 2001). This rule was issued under the authority in Section 202 of the Clean Air Act. In this rule, EPA examined the impacts of existing and newly promulgated mobile source control programs, including its reformulated gasoline (RFG) program, its national low emission vehicle (NLEV) standards, its Tier 2 motor vehicle emissions standards and gasoline sulfur control requirements, and its proposed heavy duty engine and vehicle standards and on-highway sulfur control requirements for diesel fuel. The rule established toxics emissions performance standards for gasoline refiners and

committed to additional rulemaking to evaluate the need for and feasibility of additional controls. In February 7, 2007, EPA issued new rules to reduce hazardous air pollutants from mobile sources. The new standards would significantly lower emissions of benzene and other air toxics by: (1) lowering benzene content in gasoline; (2) reducing exhaust emissions from passenger vehicles operated at cold temperatures (under 75 degrees F); and (3) reducing emissions that evaporate from, and permeate through, portable gasoline containers (gas cans, note that this last measure does not directly affect on-road emission of MSATs).

Based on these regulations, in the near-term (between 2005 and 2010) there are projected reductions in on-highway emissions of acrolein, benzene, formaldehyde, 1,3-butadiene, and acetaldehyde of 22 percent to 30 percent (see Figure 46), and on-highway reductions of diesel PM emissions of 42 percent, even with a 13 percent increase in VMT. The highest emissions reduction projections occur in the mid-term (between 2005 and 2020), where projected on-highway emissions reductions of acrolein, benzene, formaldehyde, 1,3-butadiene, and acetaldehyde are 40 percent to 42 percent, and projected reductions for on-highway diesel PM emissions are 74 percent, even with a 28 percent increase in VMT. However, the long-term emissions reduction projections show smaller decreases for the gas-only air toxics as the increase in VMT overtakes the regulatory reductions. Between 2005 and 2040 on-highway emissions of acrolein, benzene, formaldehyde, 1,3-butadiene, and acetaldehyde are projected to decrease between 19 percent to 22 percent, but on-highway diesel PM emissions are projected to fall by 90 percent, even with a 138 percent increase in VMT as shown in Figure 46.

Figure 46. U.S. Annual Vehicle Miles Traveled (VMT) vs. Mobile Source Air Toxics (MSAT) Emissions (2005-2040)
 (ICF International, NCHRP 25-25 Task 18)



Unavailable Information for Project-Specific MSAT Impact Analysis. Available technical tools have limitations in their ability to assess project-specific health impacts from the emissions changes associated with project alternatives. Due to these limitations, the following discussion should be included in accordance with CEQ regulations (40 CFR 1502.22(b)) regarding incomplete or unavailable information.

- **Information That is Incomplete.** At this level of assessment, evaluating the environmental and health impacts from MSATs on a proposed highway project involves emissions modeling in order to compare emissions between different alternatives. This assessment entails specific issues of concern regarding limitations with emission factor estimation methodology.
- **Emissions.** The current EPA tool used to estimate MSAT emissions from motor vehicles, MOBILE6.2, is not sensitive to vehicle speed for a specific location, but is considered to give reliable estimates using average speed over a trip, and hence is more appropriate for estimating emissions on a regional basis. This means that MOBILE6.2 has more limited capabilities to estimate emission factors for a specific operating condition for a specific facility type. Because of this limitation, MOBILE6.2 is less certain in estimating emission effects for a local assessment than for a region wide or corridor study. For diesel particulate matter, MOBILE6.2 emission factors do not change with vehicle speed, although the other MSAT emission rates do vary with speed as expected. Also, the basis for the emissions rates used in MOBILE6.2 for both diesel particulate matter and MSATs are based on a limited number of vehicle test engines built in the early 1990s. These issues are being addressed in the EPA's new emission factor model, MOVES. However in the interim,

these limitations do not prevent an emission analysis from being conducted as the model still produces a reasonable understanding of how a project will affect MSAT emissions, particularly for the larger scale projects which are considered under this level of analysis. MOBILE6.2's limitations reduce the certainty regarding MSAT emissions projections, but remain an adequate tool for projecting emissions trends and for conducting comparative emission analyses between project alternatives.

Summary of Existing Scientific Evidence Relevant to Evaluating the Adverse Impacts of MSATs. Research on the health impacts of MSATs has been ongoing for over twenty years. For different MSATs, there are a variety of studies showing either statistically associated adverse health outcomes through epidemiological studies and/or animal studies (typically rats) which demonstrate adverse health outcomes. Research on long-duration low exposure studies is on-going. Further, model-based and empirical studies have confirmed that spatial detail is important in characterizing the air toxic impacts of transportation sources (Zhang et al., 2005; McConnell, et al., 2006).

The EPA, as well as state agencies, has assessed the risks associated with emissions of priority MSATs. The EPA's Integrated Risk Information System (IRIS) is a database of human health effects that may result from exposure to various substances found in the environment. The IRIS database is located at <http://www.epa.gov/iris>. The toxicity information for the priority MSATs is identified in the IRIS database and summarized for cancer-causing potential based on a "weight of evidence characterization for carcinogenicity." The following bullets present a summary of the agency's most current evaluations of the potential cancer-related hazards for the five chemicals and the diesel particulate matter mixture. The IRIS web site should be reviewed during preparation of the NEPA document to see if updates have been made to this information.

- **Benzene** is characterized as a *known human carcinogen* based upon convincing human evidence as well as supporting evidence from animal studies. This is EPA's strongest statement on scientific evidence to support carcinogenic risk association. Both epidemiologic studies and case studies provide clear evidence of a causal association between exposure to benzene and leukemia as well as blood disorders, anemia and Hodgkin's lymphoma. These human data are supported by animal studies. The animal data add to the argument that exposure to benzene increases the risk of cancer in multiple species at multiple organ sites (blood cells, oral and nasal, liver, stomach, lung, ovary, and mammary gland). Recent evidence supports the viewpoint that there are likely multiple mechanistic pathways leading to cancer. A range of 2.2×10^{-6} to 7.8×10^{-6} is the estimated increase in the lifetime cancer risk of an individual who is exposed for a lifetime to $1 \mu\text{g}/\text{m}^3$ benzene in air.
- **1, 3-butadiene** is characterized as *carcinogenic to humans* by inhalation. The characterization is supported by the total weight of evidence provided by: (1) sufficient evidence from epidemiologic studies of the majority of U.S. workers occupationally exposed to 1,3-butadiene; (2) sufficient evidence in laboratory animal studies showing that 1,3-butadiene causes tumors at multiple sites in mice and rats by inhalation; and (3) numerous studies consistently demonstrating that 1, 3-butadiene is metabolized by experimental animals and humans. The inhalation cancer risk of 3×10^{-5} is the increase in the lifetime cancer risk of an individual who is exposed for a lifetime to $1 \mu\text{g}/\text{m}^3$ 1,3 butadiene in air.

- The potential carcinogenicity of **acrolein** cannot be determined because the existing data are inadequate for an assessment of human carcinogenic potential for either the oral or inhalation route of exposure.
- **Formaldehyde** is a *probable human carcinogen*, based on limited evidence in humans, and sufficient evidence in animals. Human data include nine studies that show statistically significant associations between site-specific abnormal growth of tissue in the respiratory system and exposure to formaldehyde or formaldehyde-containing products. Animal studies have shown an increased incidence of nasal cell carcinomas in long-term inhalation studies in rats and in mice. The inhalation cancer risk of 1.3×10^{-5} is the increase in the lifetime cancer risk of an individual who is exposed for a lifetime to $1 \mu\text{g}/\text{m}^3$ formaldehyde in air.
- **Acetaldehyde** is a *probable human carcinogen* based on increased incidence of nasal tumors in male and female rats and laryngeal tumors in male and female hamsters after inhalation exposure. Inadequate evidence is available from human epidemiological studies. The inhalation cancer risk of 2.2×10^{-6} is the increase in the lifetime cancer risk of an individual who is exposed for a lifetime to $1 \mu\text{g}/\text{m}^3$ acetaldehyde in air.
- **Diesel exhaust (DE)** is *likely to be human carcinogenic* though inhalation from environmental exposures. The characterization is supported by the total weight of evidence provided by: (1) strong but less than sufficient evidence for a causal association between DE exposure and increased lung cancer risk among workers in varied occupations where exposure to DE occurs; (2) extensive supporting data demonstrating mutagenic and/or chromosomal effects of DE and its organic constituents; and (3)

evidence of carcinogenicity of DPM and the associated organic compounds in rats and mice by other routes of exposure (dermal, tracheal, and just beneath the skin). Diesel exhaust is the combination of diesel particulate matter and diesel exhaust organic gases. No quantitative inhalation cancer risk value has been established by EPA at this time, as available data are considered too uncertain for a confident quantitative dose-response analysis and subsequent derivation of cancer unit risk for DE.

The priority MSATs also have chronic non-cancer health issues. Again, information is available from IRIS which describes the agency's most current understanding of health impacts from chronic exposures. To characterize the health impacts health researchers have developed the inhalation Reference Concentration (RfC) which is based on the assumption that thresholds exist for certain toxic effects such as cellular necrosis. The inhalation RfC considers toxic effects for both the respiratory system and for effects peripheral to the respiratory system. It is generally expressed as a concentration. The RfC is an estimate, with uncertainty (both plus and minus) typically spanning an order of magnitude, of the daily inhalation exposure of the human population, including sensitive subgroups, that is likely to be without an appreciable risk of a negative effect during a lifetime of exposure. The following bullets present a summary of EPA's most current evaluations of the potential chronic (non-cancer) hazards associated with the five chemicals and the diesel particulate matter mixture. (The IRIS web site should be reviewed during preparation of the NEPA document to see if updates have been made to this information.)

- **Benzene.** The inhalation RfC considers toxic effects for both the respiratory system and for effects peripheral to the respiratory system. Benzene was found to decrease lymphocyte blood count. The overall confidence in this RfC assessment is medium with an RfC of 30 $\mu\text{g}/\text{m}^3$.

- **1,3-butadiene.** The most critical effect from chronic inhalation exposure was ovarian atrophy in female mice and testicular atrophy in male mice. The overall confidence in the assessment is medium with an RfC of $2.0 \mu\text{g}/\text{m}^3$.
- **Acrolein.** Exposure has found to impair lung function as well as entail nasal effects. The overall confidence in this RfC assessment is medium with an RfC of $2 \times 10^{-2} \mu\text{g}/\text{m}^3$.
- **Formaldehyde.** Insufficient data upon which to develop an RfC.
- **Acetaldehyde.** The most critical effect from chronic inhalation exposure was degeneration of olfactory tissue. The overall confidence in the assessment is low with an RfC of $9.0 \mu\text{g}/\text{m}^3$.
- **Diesel exhaust (DE).** Has chronic respiratory effects and is the principal non-cancer hazard to humans from DE exposure. Prolonged exposures may also impair pulmonary function and could produce symptoms, such as cough, phlegm, and chronic bronchitis. Respiratory effects are considered the "critical effect" for the derivation of a chronic RfC for DE. The overall confidence level in the RfC is considered medium in a range of low to high confidence with an RfC of $5.0 \mu\text{g}/\text{m}^3$.

There have been other studies that address MSAT health impacts in proximity to roadways. The Health Effects Institute, a non-profit organization funded approximately equally by EPA and the worldwide motor vehicle industry, is conducting research on improving the understanding of: diesel exhaust and associated impact on carcinogenicity and non cancer endpoints; atmospheric transformation of diesel emissions; occupational exposures to aldehydes, 1,3 butadiene, multiple air toxics as well as studies on traffic-related exposures at toxic hotspots; respiratory impairment; and significance of toxic secondary emissions. In addition HEI is embarking on a study of the

emissions from the latest diesel engine technology designed to meet EPA's 2007 exhaust PM emission standards for heavy duty diesel trucks. After peer review and publication these studies will be available to EPA and will be used as needed to update or revise the agency's best understanding of the possible adverse human health impacts. This should be viewed as a continuing effort to better understand the association between exposure and health effects.

California's Office of Environmental Health Hazard Assessment (OEHHA) has made cancer risk assessments following procedures generally similar to those used by EPA. The approach uses both animal and human data, when available, as part of the dose-response assessment. The approaches have been peer reviewed by advisory committee of scientists from outside California's State government (the California Air Resources Board's Scientific Review Panel) using a formalized process. Table 26 provides a comparison between MSAT cancer risk values developed by OEHHA and by EPA in IRIS. Some of the differences are due to California's use of more recent studies which the state has reviewed and used in their assessment, superseding EPA information. This is the case for both 1,3-butadiene and formaldehyde. California is working to harmonize the findings as part of the recommendations made by California's Risk Assessment Advisory Committee (RAAC) regarding harmonization within Cal/EPA and with U.S. EPA.

**Table 26. Comparison of Priority Mobile Source Air Toxic Cancer Unit Risk Values—
California Based Toxic Air Containment Program
and Corresponding US EPA IRIS Cancer (ICF International, NCHRP 25-25 Task 18)**

Unit Risk Values *				
Chemical	California Hot Spots	Unit Risk	IRIS Unit Risk	HS/IRIS Ratio
		($\mu\text{g}/\text{m}^3$) ⁻¹	($\mu\text{g}/\text{m}^3$) ⁻¹	
Acetaldehyde	TAC	2.7 E-6	2.2 E-6	1.2
Acrolein		N/A	N/A	N/A
Benzene	TAC	2.9 E-5	7.8 E-6	3.7
1,3-Butadiene	TAC	1.7 E-4	3.0 E-5	5.7
Diesel Exhaust	TAC	3.0 E-4	N/A	N/A
Formaldehyde	TAC	6.0 E-6	1.3 E-5	0.5

N/A—Not available; insufficient information upon which to base a risk value

TAC—California Toxic Air Contaminant Program

** Upper end unit risk values if range is given, as of 1 June 2006*

In addition to cancer risks, California has also developed reference concentration levels (RfC) following procedures documented in California's Air Toxics Hot Spots Program Risk Assessment Guidelines, Part III: *The Determination of Chronic Reference Exposure Levels for Airborne Toxicants*, which presents a method for deriving inhalation exposure levels to protect the public from a lifetime of exposure to hazardous airborne substances. The guidelines incorporate many of the EPA's procedural recommendations. The values for the priority MSATs are given in Table 27 below. The concentration for diesel PM is the same as the value listed in EPA's IRIS and the value for acrolein is three times higher. With the exception of acrolein, for which no unit risk values is available, these concentrations are much higher than a value triggering a one in a million cancer risk.

Table 27. Comparison of Priority Mobile Source Air Toxic Chronic Reference Concentration Levels with California Reference Concentration Levels (ICF International, NCHRP 25-25 Task 18)

Chemical	Reference Concentration Level*			
	California RfC	IRIS RfC		CA/IRIS Ratio
		(µg/m ³)	(µg/m ³)	
Acetaldehyde	TAC	9.0	9.0	1.0
Acrolein	TAC	0.06	0.02	3.0
Benzene	TAC	60	30	2.0
1,3-Butadiene	TAC	20	2	10.0
Diesel Exhaust	TAC	5.0	5.0	1.0
Formaldehyde	TAC	3.0	N/A	N/A

TAC—California Toxic Air Contaminant Program

N/A—Not available; insufficient information upon which to discern a reference concentration level

Some recent studies have reported that proximity to roadways is related to adverse health outcomes—particularly respiratory problems (John Hopkins School of Public Health, 2004). Many of these studies have been published in peer reviewed journal articles and have shown a strong association between elevated MSAT concentrations and roadway proximity and, in a number of cases, with adverse health outcomes—particularly for sensitive subpopulations. While these studies are retrospective, they are suggestive of the linkages between MSAT emissions and the motor vehicle activity projected for this level of analysis and indicate that adverse health impacts may be possible.

While no one study is definitive, these studies in aggregate are suggestive that reasonable scientific evidence is available that indicates an adverse impact may occur as a result of MSAT emissions, particularly at locations in close proximity to concentrated motor vehicle activity. Based on the current understanding and potential for adverse effects, it appears that a prudent course of action is to provide an estimate of the potential emission changes under a proposed action given the existing evidence to support the possibility of an adverse health outcome.

Relevance of Incomplete Information to Evaluating Reasonably Foreseeable Significant Adverse Impacts on the Human Environment and Evaluation of Impacts Based Upon Research Methods Generally Accepted in the Scientific Community. Because of the limitations in currently available emission models as discussed earlier, a quantitative assessment of the effects of air toxic emissions is not recommended at this time for relatively small projects. Tools are available that allow reasonable emissions change estimates to compare alternatives under larger projects. The amount of MSAT emissions from each of the project alternatives can be predicted with enough accuracy to provide useful information to decision makers and the general public for better understanding of the project's impact. Projections may be more reliable

for certain MSATs (e.g., benzene) than other MSATs (diesel particulate matter). (As noted above, the current emissions model is not recommended for use as an emissions analysis tool for smaller projects.) Therefore, smaller projects are not of sufficient size to determine if they have “significant adverse impacts on the human environment.” However, if the project is of sufficient size and/or proximity of exposure is increased then an evaluation of the emission impacts is a reasonable method based on supporting scientific methods and understanding and available information for estimating MSAT emissions.

Level 4—Quantitative Air Toxic Risk Assessment

This assessment will follow the same procedures as outlined in the Level 3 analysis, but will involve additional air quality modeling of ambient pollutant concentrations to provide the reviewer with a better perspective on the relative impact of the increased air toxic risk of the proposed project relative to existing air toxic risk. The analysis will use the available information on the proposed action and its alternatives in conjunction with the best available emission factors to quantitatively estimate the impact on MSAT emissions, and then conduct dispersion modeling and assess the cumulative air toxic risk for the proposed action. The projects that fall into this category have not only shown a high potential for MSAT emissions to concentrate at high enough levels to be of potential concern, but have been raised as a public concern during the scoping process.

The analysis should focus on the priority MSATs, as these are the most likely principal contributors to any significant increase in exposure. The analysis of the proposed action and its alternatives will provide decision makers with information to discriminate between project alternatives as well as information on the relative impact of the action in comparison with existing air toxic concentrations.

The *primary steps* for this analysis will follow the same steps discussed under the Level 3 analysis, but with expanded capabilities to address the spatial risk assessment aspects through air quality modeling. The *primary steps* are described as follows:

- 1) Quantitatively assess the change in transportation-related parameters which will result from the proposed action and alternatives. These include how the project and the alternatives will affect traffic volume, speed, and vehicle fleet mix. Of these parameters, speed and vehicle fleet mix can be used in the most currently available emission factor model to produce reliable estimates of differences in project-level emissions between alternatives. See the discussion on Level 4 Recommended Tools for the methodology of conducting this analysis. For each of the priority MSATs, discuss how these three parameters are affected by the project action and alternatives.
- 2) Assess how the project may alter current and future traffic patterns in the vicinity of the project. The project may lead to increased traffic in some locations and decreased traffic in other locations. Traffic pattern changes may also impact exposure distance, especially to sensitive receptors.
- 3) For each alternative, quantitatively summarize the expected change in emissions and conduct air quality modeling to assess cancer risk, providing information on the maximum exposed individual, sensitive receptors and population-weighted risk. This analysis will provide decision makers with information on the relative differences in terms of cancer risk between the various alternatives.

- 4) Obtain background MSAT concentrations for the location using the most recent NATA National Scale Assessment Study for the particular county where the project is located and the land use setting. This data may be expressed as a range of concentrations using information on the project setting as a discriminating value. This information will provide an assessment of the likely current situation at the location of the project setting.

- 5) Summarize the current national emission trends for MSATs. This discussion should compare national trends for MSATs relative to the project's proposed completion date with the near term (5 years), mid-term (10-15 years) and project life (25-30 year). The discussion should identify that the national overall trend is downward through 2015, even with increasing VMT due to fuel regulations and engine technologies regulations, but that the proposed action of alternative will likely slow the downward trend (depending upon project specific change in VMT, fleet mix, speed). See discussion on the MSAT Emission Trends (2005-2040) in the Level 4 Recommend Tools Section.

- 6) Conduct air quality modeling for the project using an appropriate air quality model. Project emissions should be spatially and temporally allocated. The model should use the best available meteorology data that reasonably characterize the project location. Careful attention should be placed on the selection of locations where concentrations are to be modeled (receptor locations). These should include both sensitive receptor locations as well as locations to where the public may have potential access. The receptors should have their project-related risk determined from the combined concentration and risk for each priority MSAT. The aggregate

risk for the project is the sum of the risk from each of the priority MSATs. A discussion should be developed that summarizes the increase in risk associated with the project and alternatives. See discussion on the *Use of Air Quality Models to Estimate Impacts* in the Level 4 Recommended Tools Section.

- 7) **Conclusion:** Discuss the likely range in current background risk and estimate future background²⁹ for the project setting from the information gathered in Step 4 and 5 above. Identify the risk impact associated with the project relative to the no action and various action alternatives. Because this project has a high potential to result in a local toxic hotspot, discussion should be developed on the limitations of the currently available tools for assessing the risk impact. This is a requirement under Council of Environmental Quality (CEQ, which implements NEPA) regulations (40 CFR 1502.22(b)). See discussion on the *Unavailable Information for Project Specific MSAT Impact Analysis* in the Level 4 Recommended Tools Section.

Level 4 Recommended Tools

- **Methods for Estimating Emissions for Key Parameters.** For the speed and fleet mix parameters, the latest available emission factor model should be used to show how priority MSAT emissions change with these parameters. This information will then form the basis for discussion of the change in MSATs under the proposed action and alternatives.
 - **Speed.** Currently the best available tool for estimating emission factors for MSATs is EPA's MOBILE6.2 emission factor model. While the model has

²⁹ EPA intends to have available by mid-2007 NATA-like assessment tools that can be used to estimate future year background concentrations. It is also possible that some states may develop an estimate of future background concentrations and these could potentially be used in an analysis.

limitations in estimating emissions for a particular vehicle for a particular speed, it can provide a reliable approach for comparing emissions under proposed project alternatives. In most cases the decision maker will want information on how projected emissions vary between the proposed action and alternatives. In providing this estimated average speed³⁰ information from the proposed action provides suitable information for comparing project alternatives. EPA anticipates releasing a new mobile emission factor model called **MO**tor **V**ehicle **E**mission **S**imulator (MOVES) in 2007 suitable for estimating modal emissions at the project level specific to varying locations within the project. Until the release of MOVES, the assessment should be made through the use of average speeds for each proposed project alternative.

- **Fleet mix.** Here again, the best available current tool for estimating emission factor changes as a result of fleet mix changes from the proposed action is by using EPA's MOBILE6.2 emission factor model. While the basis of the model is somewhat limited to older technologies, most MSAT emission changes are associated with VOC emissions, and the model has incorporated more recent engine emission reduction technology making it suitable for assessing project alternatives. Until MOVES becomes available, the assessment should be made using the appropriate fleet mix as a MOBILE6.2 input for each project alternative.
- **Background Concentrations.** An estimate should be made of the background MSAT concentration at the proposed location of the transportation project. This will provide a reviewer with useful information on the likely air toxic concentration in the vicinity

³⁰ Note that estimates of speeds are subject to significant uncertainty at high level of service which affects the size of emission impact of a proposed action and alternatives.

- of the proposed project. Ideally, local site-specific ambient monitoring data are available³¹. However, because it is cost prohibitive to conduct air toxic monitoring at all locations in the U.S., EPA has assessed the current conditions at the census tract level through air quality modeling. This assessment is known as the National Air Toxic Assessment—National Scale Assessment (NATA-NSA). The most current results of its national-scale assessment were released in February 2006 based on a 1999 emissions inventory. The assessment identifies the concentration for each priority MSAT (as well as many other MSATs) as a distribution with values reported at the 5th, 10th, 25th, 50th, 75th, 90th, and 95th percentile for each county in the U.S. In the absence of site-specific ambient monitoring data, the transportation analyst can select the appropriate percentile to use for the estimated background concentration based on a local understanding of the county-level emission densities. For locations where this is not known or unavailable, a GIS spatial analysis of census tract block group population density can be used as a surrogate for estimating the emission density distribution within the county to determine the appropriate percentile ranking.
- **Mobile Source Air Toxics Emissions Trends.** EPA is the lead federal agency for administering the Clean Air Act and has certain responsibilities regarding the health effects of MSATs. EPA issued a Final Rule on Controlling Emissions of Hazardous Air Pollutants from Mobile Sources, 66 FR 17229 (March 29, 2001). This rule was issued under the authority in Section 202 of the Clean Air Act. In this rule, EPA examined the impacts of existing and newly promulgated mobile source control programs, including its reformulated gasoline (RFG) program, its national low

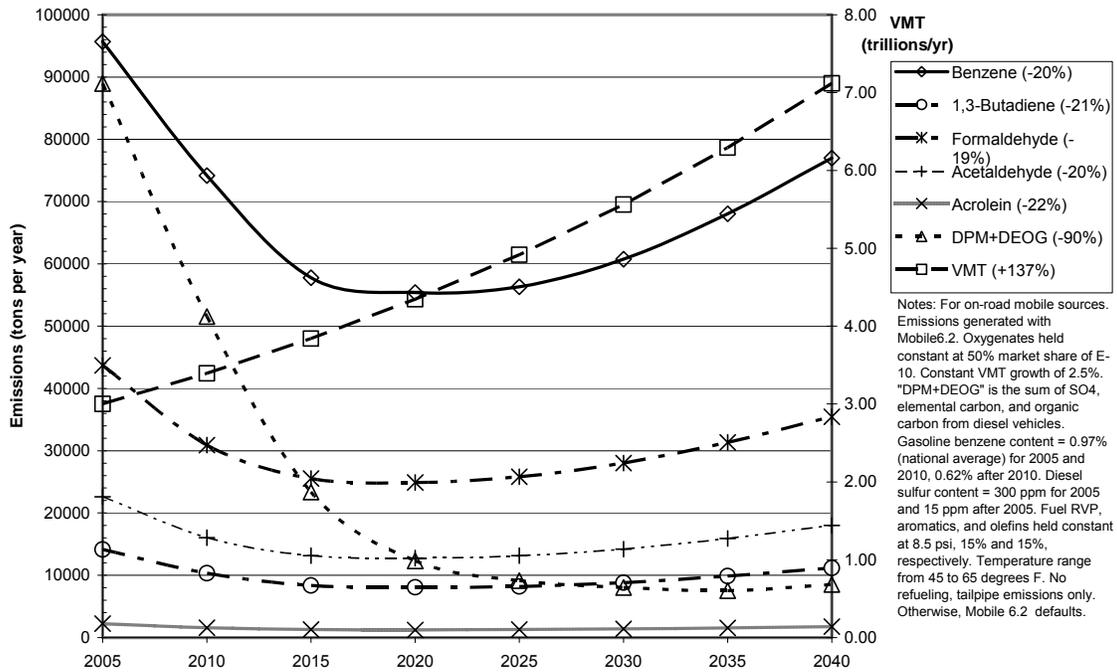
³¹ In some circumstances it may be possible to use ambient monitoring data for background concentration. This data can be obtained from AirData website (<http://www.epa.gov/air/data/index.html>)

emission vehicle (NLEV) standards, its Tier 2 motor vehicle emissions standards and gasoline sulfur control requirements, and its proposed heavy duty engine and vehicle standards and on-highway sulfur control requirements for diesel fuel. The rule established toxic emissions performance standards for gasoline refiners and committed to additional rulemaking to evaluate the need for and feasibility of additional controls. On February 9, 2007, EPA issued a final rule to reduce hazardous air pollutants from mobile sources. The new standards would significantly lower emissions of benzene and other air toxics by: (1) lowering benzene content in gasoline; (2) reducing exhaust emissions from passenger vehicles operated at cold temperatures (under 75 degrees F); and (3) reducing emissions that evaporate from, and permeate through, portable gasoline containers (this last proposed measure does not directly affect on-road emission of MSATs).

Based on these regulations, in the near-term (between 2005 and 2010) there are projected reductions in on-highway emissions of acrolein, benzene, formaldehyde, 1,3-butadiene, and acetaldehyde of 22 percent to 30 percent, and on-highway reductions of diesel PM emissions of 42 percent, even with a 13 percent increase in VMT (see Figure 47). The highest emissions reduction projections occur in the mid-term (between 2005 and 2020), where projected on-highway emissions reductions of acrolein, benzene, formaldehyde, 1,3-butadiene, and acetaldehyde are 40 percent to 42 percent, and projected reductions for on-highway diesel PM emissions are 74 percent, even with a 28 percent increase in VMT. However, the long-term emissions reduction projections show smaller decreases for the gas-only air toxics as the increase in VMT overtakes the regulatory reductions. Between 2005 and 2040 on-highway emissions of acrolein,

benzene, formaldehyde, 1,3-butadiene, and acetaldehyde are projected to decrease between 19 percent to 22 percent, but on-highway diesel PM emissions are projected to fall by 90 percent, even with a 138 percent increase in VMT as shown in Figure 47.

Figure 47. U.S. Annual Vehicle Miles Traveled (VMT) vs. Mobile Source Air Toxics (MSAT) Emissions (2005–2040)
(ICF International, NCHRP 25-25 Task 18)



- Use of Air Quality Dispersion Models to Estimate Impact.** To estimate ambient concentrations for project-level assessments, air dispersion models have been routinely used in air quality assessments. Recommendations are provided in Table 28 on the most appropriate air quality model to use for air toxic risk assessment based on an understanding of the current models' strengths and weaknesses in transportation settings.

Table 28. Best Available Air Quality Modeling Tools for use in Analyzing MSATs under NEPA (ICF International, NCHRP 25-25 Task 18)

Facility/Project Type	Primary Air Quality Model	Secondary Air Quality Model	Comments
Roadway Widening	CALINE4	CALINE3	
HOV Lane Addition	CALINE4	CALINE3	
Roadway Intersection	CAL3QHC(R)	HYROAD	With the release of the MOVES model HYROAD may be the preferred choice as the model can be directly linked to the modal emission factors.
Interchange/Ramp	CALINE4	CALINE3	Carefully consideration should be given to the emission factors under grade or acceleration environment.
Freight Terminal/ Intermodal Transfer Parking/ Travel Center/	AERMOD	ISC3	If facility is located where unusual meteorological conditions (fumigation, stagnation) occur then CALPUFF is the preferred model.

These air quality models require the usual representative meteorological data consisting of wind speed, wind direction, and atmospheric stability and are coupled with the emission factors, as described earlier, from the MOBILE6.2 model. For air toxics applications, consideration should be given to reactive decay for the chemically active MSAT species³². For the priority MSATs, the following first-order reactive decay rates should be assigned:

- 1,3 butadiene: half-life 3 hours (Howard, 1989)
- Primary formaldehyde: half-life 12 hours (Howard, 1989)
- Primary acetaldehyde: half-life 15 hours (CARB, 2001)
- Primary acrolein: half-life 12 hours (Howard, 1989)

The remaining priority MSAT pollutants can be considered chemically inert.

In applying the air quality models the analyst should place receptors (locations where modeled concentrations are determined) at the nearest public access points. This would include locations such as sidewalks and yards of residential housing. Receptors should also be placed at sensitive locations such as schools, daycare centers, nursing homes or assisted living facilities. These sensitive subpopulations may be of more concern than the general population. Receptor locations should remain the same between the action and no action alternative to enable the determination of the proposed project impact. However, some types of projects (e.g., roadway widening) may bring the receptor closer to the roadway and associated emissions. In this case the receptors for the proposed action should be placed at the closest reasonable distance from the proposed roadway and compared with the receptors from the no action.

³² The effect of chemical reactivity in the near roadway environment is small. For the most reactive pollutant, 1,3 butadiene, the decrease in ambient concentration under low wind speed conditions (0.5 ms^{-1}) at 400-m from the roadway would reduce the ambient concentration level by only 5% percent.

- **Use of Toxicity Weighted Risk Assessment.** In order to determine the cancer risk from the proposed project the modeled air concentrations at each receptor location for each priority MSAT must be multiplied by their individual unit risk level. While each MSAT does not target the same organ, a conservative approach is to assume that they do so that the sum of the risks from each MSAT is the maximum increased cancer risk. The receptor location which has the highest risk should be identified as the maximum individual cancer risk.

Unavailable Information for Project-Specific MSAT Impact Analysis. Available technical tools have limitations in their ability to assess project-specific health impacts from the emission changes associated with project alternatives. Due to these limitations, the following discussion should be included in accordance with CEQ regulations (40 CFR 1502.22(b)) regarding incomplete or unavailable information:

- **Information That Is Incomplete.** At this level of assessment, evaluating the environmental and health impacts from MSATs on a proposed highway project involves emissions and pollutant concentration modeling in order to compare emissions and air quality between different alternatives. This assessment raises some specific issues of concern regarding limitations with emission factor and air quality model estimation methodology.
 - **Emissions.** The current EPA tool to estimate MSAT emissions from motor vehicles, MOBILE6.2, is not sensitive to vehicle speed for a specific location, but is considered to give reliable estimates using average speed over a trip, and hence is more appropriate for estimating emissions on a regional basis. This means that MOBILE6.2 has limited capability to estimate emission factors for a specific

operating condition for a specific facility type. Because of this limitation, MOBILE6.2 is less certain in estimating emission effects for a local assessment than for a region wide or corridor study. For diesel particulate matter, MOBILE6.2 emission factors do not change with vehicle speed, although the other MSAT emission rates do vary with speed as expected. Also, the basis for the emissions rates used in MOBILE6.2 for both diesel particulate matter and MSATs are based on a limited number of vehicle test engines built in the early 1990s. These issues are being addressed in the EPA's new emission factor model, MOVES. However in the interim, these limitations do not prevent an emission analysis from being conducted as the model still represents a reasonable understanding of how a project will affect MSAT emissions, particularly for the larger scale projects which are considered under this level of analysis. These limitations reduce the certainty of MOBILE6.2 MSAT emissions projections, but remain an adequate tool for projecting emissions trends and for conducting comparative emission analyses between project alternatives.

- **Air Quality Models.** Historically model performance studies of air quality models have found observed and model concentrations to generally be within a factor of two or better. However, many of these performance evaluation studies focused on short-term (24-hour or less) averaging periods. Modeling evaluation studies for longer averaging periods (1-year) have generally shown better model performance. Recent modeling studies for air toxic assessment have found that improved bottom-up emissions inventories have produced improved model performances and found model results often within the range of the uncertainty of

the observations. Further, air quality models used in transportation assessments have been shown to be sensitive to key parameters such as VMT and source/receptor distances, making them a useful tool for assessing relative impacts between project alternatives even in light of the incomplete information on mobile source emission behavior.

Summary of Existing Scientific Evidence Relevant to Evaluating the Adverse Impacts of MSATs. Research on the health impacts of MSATs has been ongoing for over twenty years. For different MSATs, there are a variety of studies showing either statistically associated adverse health outcomes through epidemiological studies and/or animal studies (typically rats) which demonstrate adverse health outcomes. Research on long-duration low exposure studies is on-going.

The EPA, as well as state agencies, has assessed the risks associated with emissions of priority MSATs. The EPA's Integrated Risk Information System (IRIS) is a database of human health effects that may result from exposure to various substances found in the environment. The IRIS database is located at <http://www.epa.gov/iris>. The toxicity information for the six prioritized MSATs is identified in the IRIS database and summarized for cancer-causing potential based on a "weight of evidence characterization for carcinogenicity." The following bullets present a summary of EPA's most current evaluations of the potential cancer-related hazards for the five chemicals and the diesel particulate matter mixture. (The IRIS web site should be reviewed during preparation of the NEPA document to see if updates have been made to this information.)

- **Benzene** is characterized as a *known human carcinogen* based upon convincing human evidence as well as supporting evidence from animal studies. This is EPA's strongest statement on scientific evidence to support carcinogenic risk association.

Both epidemiologic studies and case studies provide clear evidence of a causal association between exposure to benzene and leukemia as well as blood disorders, anemia and Hodgkin's lymphoma. These human data are supported by animal studies. The animal data add to the argument that exposure to benzene increases the risk of cancer in multiple species at multiple organ sites (blood cells, oral and nasal, liver, stomach, lung, ovary, and mammary gland). Recent evidence supports the viewpoint that there are likely multiple mechanistic pathways leading to cancer. A range of 2.2×10^{-6} to 7.8×10^{-6} is the estimated increase in the lifetime cancer risk of an individual who is exposed for a lifetime to $1 \mu\text{g}/\text{m}^3$ benzene in air.

- **1, 3-butadiene** is characterized as *known carcinogenic to humans* by inhalation. The characterization is supported by the total weight of evidence provided by: (1) sufficient evidence from epidemiologic studies of the majority of U.S. workers occupationally exposed to 1,3-butadiene; (2) sufficient evidence in laboratory animal studies showing that 1,3-butadiene causes tumors at multiple sites in mice and rats by inhalation; and (3) numerous studies consistently demonstrating that 1, 3-butadiene is metabolized by experimental animals and humans. The inhalation cancer risk of 3×10^{-5} is the increase in the lifetime cancer risk of an individual who is exposed for a lifetime to $1 \mu\text{g}/\text{m}^3$ 1,3 butadiene in air.
- The potential carcinogenicity of **acrolein** cannot be determined because the existing data are inadequate for an assessment of human carcinogenic potential for either the oral or inhalation route of exposure.
- **Formaldehyde** is a *probable human carcinogen*, based on limited evidence in humans, and sufficient evidence in animals. Human data include nine studies that

show statistically significant associations between site-specific abnormal growth of tissue in the respiratory system and exposure to formaldehyde or formaldehyde-containing products. Animal studies have shown an increased incidence of nasal cell carcinomas in long-term inhalation studies in rats and in mice. The inhalation cancer risk of 1.3×10^{-5} is the increase in the lifetime cancer risk of an individual who is exposed for a lifetime to $1 \mu\text{g}/\text{m}^3$ formaldehyde in air.

- **Acetaldehyde** is a *probable human carcinogen* based on increased incidence of nasal tumors in male and female rats and laryngeal tumors in male and female hamsters after inhalation exposure. Inadequate evidence is available from human epidemiological studies. The inhalation cancer risk of 2.2×10^{-6} is the increase in the lifetime cancer risk of an individual who is exposed for a lifetime to $1 \mu\text{g}/\text{m}^3$ acetaldehyde in air.
- **Diesel exhaust (DE)** is *likely to be human carcinogenic* though inhalation from environmental exposures. The characterization is supported by the total weight of evidence provided by: (1) strong but less than sufficient evidence for a causal association between DE exposure and increased lung cancer risk among workers in varied occupations where exposure to DE occurs; (2) extensive supporting data demonstrating mutagenic and/or chromosomal effects of DE and its organic constituents; and (3) evidence of carcinogenicity of DPM and the associated organic compounds in rats and mice by other routes of exposure (dermal, tracheal, and just beneath the skin). Diesel exhaust is the combination of diesel particulate matter and diesel exhaust organic gases. No quantitative inhalation cancer risk value has been established by EPA at this time, as available data are considered too uncertain for a confident quantitative dose-response analysis and subsequent derivation of cancer unit risk for DE.

The priority MSATs also have chronic non-cancer health issues. Again, information is available from IRIS which describes the EPA's most current understanding of health impacts from chronic exposures. To characterize the health impacts health researchers have developed the inhalation Reference Concentration (RfC) which is based on the assumption that thresholds exist for certain toxic effects such as cellular necrosis. The inhalation RfC considers toxic effects for both the respiratory system and for effects peripheral to the respiratory system. It is generally expressed as a concentration. The RfC is an estimate, with uncertainty (both plus and minus) typically spanning an order of magnitude, of the daily inhalation exposure of the human population, including sensitive subgroups, that is likely to be without an appreciable risk of a negative effect during a lifetime of exposure. The following bullets present a summary of EPA's most current evaluations of the potential chronic (non-cancer) hazards associated with the five chemicals and the diesel particulate matter mixture. (The IRIS web site should be reviewed during preparation of the NEPA document to see if updates have been made to this information.)

- **Benzene.** The inhalation RfC considers toxic effects for both the respiratory system and for effects peripheral to the respiratory system. Benzene was found to decrease lymphocyte blood count. The overall confidence in this RfC assessment is medium with an RfC of $30 \mu\text{g}/\text{m}^3$.
- **1,3-Butadiene.** The most critical effect from chronic inhalation exposure was ovarian atrophy in female mice and testicular atrophy in male mice. The overall confidence in the assessment is medium with an RfC of $2.0 \mu\text{g}/\text{m}^3$.
- **Acroleins.** Exposure has found to impair lung function as well as nasal effects. The overall confidence in this RfC assessment is medium with an RfC of $2 \times 10^{-2} \mu\text{g}/\text{m}^3$.
- **Formaldehyde.** Insufficient data upon which to develop an RfC.

- **Acetaldehyde.** The most critical effect from chronic inhalation exposure was degeneration of olfactory tissue. The overall confidence in the assessment is low with an RfC of 9.0 $\mu\text{g}/\text{m}^3$.
- **Diesel Exhaust (DE).** Has chronic respiratory effects and is the principal non-cancer hazard to humans from DE exposure. Prolonged exposures may also impair pulmonary function and could produce symptoms, such as cough, phlegm, and chronic bronchitis. Respiratory effects are considered the "critical effect" for the derivation of a chronic RfC for DE. The overall confidence level in the RfC is considered medium in a range of low to high confidence with an RfC of 5.0 $\mu\text{g}/\text{m}^3$.

There have been other studies that address MSAT health impacts in proximity to roadways. The Health Effects Institute, a non-profit organization funded by EPA, FHWA, the Coordinating Research Council, and engine manufacturers is providing research funding for studies focused on better understanding of: diesel exhaust and associated impact on asthma and respiratory inflammation; atmospheric transformation of diesel emissions; occupational exposures to aldehydes, 1,3 butadiene, and multiple air toxics as well as studies on traffic-related exposures at toxic hotspots; respiratory impairment; and significance of toxic secondary emissions. In addition HEI is embarking on a study of the emissions from the latest diesel engine technology designed to meet EPA's 2007 exhaust PM emission standards for heavy duty diesel trucks. After peer review and publication these studies will be available to IRIS and will be used to update or revise the agency's best understanding of the possible adverse human health impact. This should be viewed as a continuing effort to better understand the association between exposure and health effects.

California’s Office of Environmental Health Hazard Assessment (OEHHA) has made cancer risk assessments following procedures generally similar to those used by the EPA. The approach uses both animal and human data, when available, as part of the dose-response assessment. The approaches have been peer reviewed by advisory committee of scientists from outside California’s State government (the California Air Resources Board’s Scientific Review Panel) using a formalized process. Table 29 provides a comparison between MSAT cancer risk values developed by OEHHA and by EPA in IRIS. Some of the differences are due to California’s use of more recent studies which the state has reviewed and used in their assessment, superseding EPA information. This is the case for both 1,3-butadiene and formaldehyde. California is working to harmonize the findings as part of the recommendations made by California’s Risk Assessment Advisory Committee (RAAC) regarding harmonization within Cal/EPA and with U.S. EPA.

Table 29. Comparison of Priority Mobile Source Air Toxic Cancer Unit Risk Values—California Based Toxic Air Containment Program and Corresponding US EPA IRIS Cancer (ICF International, NCHRP 25-25 Task 18)

Chemical	Unit Risk Values *			
	California Hot Spots Unit Risk ($\mu\text{g}/\text{m}^3$) ⁻¹	IRIS Unit Risk ($\mu\text{g}/\text{m}^3$) ⁻¹	HS/IRIS Ratio	
Acetaldehyde	TAC	2.7 E-6	2.2 E-6	1.2
Acrolein		N/A	N/A	N/A
Benzene	TAC	2.9 E-5	7.8 E-6	3.7
1,3-Butadiene	TAC	1.7 E-4	3.0 E-5	5.7
Diesel Exhaust	TAC	3.0 E-4	N/A	N/A
Formaldehyde	TAC	6.0 E-6	1.3 E-5	0.5

N/A—Not available; insufficient information upon which to base a risk value

TAC—California Toxic Air Contaminant Program

* Upper end unit risk values if range is given, as of 1 June 2006

In addition to cancer risks, California has also developed reference concentration levels (RfC) following procedures documented in California's Air Toxics Hot Spots Program Risk Assessment Guidelines, Part III: *The Determination of Chronic Reference Exposure Levels for Airborne Toxicants*, which presents a method for deriving inhalation exposure levels to protect the public from a lifetime of exposure to hazardous airborne substances. The guidelines incorporate many of the EPA's procedural recommendations. The values for the priority MSATs are given in Table 30 below. The concentration for diesel PM is the same as the value listed in EPA's IRIS and the value for acrolein is three times higher. With the exception of acrolein, for which no unit risk values is available, these concentrations are much higher than a value triggering a one in a million cancer risk.

Table 30. Comparison of Priority Mobile Source Air Toxic Chronic Reference Concentration Levels with California Reference Concentration Levels (ICF International, NCHRP 25-25 Task 18)

Chemical	Reference Concentration Level*			
	California RfC	IRIS RfC	CA/IRIS Ratio	
	(µg/m ³)	(µg/m ³)		
Acetaldehyde	TAC	9.0	9.0	1.0
Acrolein	TAC	0.06	0.02	3.0
Benzene	TAC	60	30	2.0
1,3-Butadiene	TAC	20	2	10.0
Diesel Exhaust	TAC	5.0	5.0	1.0
Formaldehyde	TAC	3.0	N/A	N/A

TAC—California Toxic Air Contaminant Program

N/A—Not available; insufficient information upon which to discern a reference concentration level

Some recent studies have reported that proximity to roadways is related to adverse health outcomes—particularly respiratory problems (John Hopkins School of Public Health, 2004). Many of these studies have been published in peer reviewed journal articles and have shown a strong association between elevated MSAT concentrations and roadway proximity and, in a number of cases, with adverse health outcomes—particularly for sensitive subpopulations. While these studies are retrospective, they are suggestive of the linkages between MSAT emissions and the motor vehicle activity projected for this level of analysis and indicate that adverse health impacts may be possible.

While no one study is definitive, these studies in aggregate are suggestive that reasonable scientific evidence is available that indicates an adverse impact may occur as a result of MSAT emissions, particularly at locations in close proximity to concentrated motor vehicle activity. Based on the current understanding and potential for adverse effects, it appears that a prudent course of action is to provide an estimate of the potential emission changes under a proposed action given the existing evidence to support the possibility of an adverse health outcome.

Relevance of Incomplete Information to Evaluating Reasonably Foreseeable Significant Adverse Impacts on the Human Environment and Evaluation Of Impacts Based Upon Research Methods Generally Accepted In The Scientific Community. Because of the limitations in currently available emission models as discussed above, a quantitative assessment of the air toxic emissions cannot be made for relatively small projects. Tools are available that allow reasonable emissions change estimates to be developed to compare alternatives under larger projects. The amount of MSAT emissions from each of the project alternatives can be predicted with enough accuracy to provide useful information to decision makers and the general public for better understanding of the project's impact. Projections may be more reliable for

certain MSATs (e.g., benzene) than other MSATs (diesel particulate matter). (As noted above, the current emissions models are not capable of serving as a meaningful emissions analysis tool for smaller projects.) Therefore, smaller projects are not of sufficient size to determine if they have “significant adverse impacts on the human environment.” However, if the project is of sufficient size and/or proximity of exposure is increased then an evaluation of the emission impacts is a reasonable method based on supporting scientific methods and understanding and available information for estimating MSAT emissions.

Level 5—Quantitative Exposure Assessment

This assessment will follow the same procedures as outlined in the Level 4 analysis, but will add an additional component following the air dispersion modeling that incorporates exposure assessment techniques. This analysis will provide the reviewer more information as to the population exposed to the increased risk. The analysis will still use the available information on the proposed action and its alternatives in conjunction with the best available emission factors to quantitatively estimate the impact for MSAT emissions and then conduct dispersion modeling for the proposed action. The projects that fall into this category have not only shown a high potential for MSAT emissions to concentrate at high enough levels to be of potential concern, but have been raised as a public concern during the scoping process, as well as having sufficient local information available on nearby population and human activity levels to conduct the exposure assessment.

Exposure Assessment. Exposure models combine information about the geographic pattern of pollutant concentrations (typically from an air dispersion model) with information about population activities. In exposure model applications the receptor is a person, population subgroup, or specific area. The simplest models estimate inhalation exposure using ambient

concentrations (monitored or modeled) and residential population distributions, with the implicit assumption that the populace is outside at home at all times. This assumption may bias exposure estimates for certain population cohorts, particularly for air toxics that exhibit strong diurnal concentration patterns, and/or in cases where indoor concentrations are considerably lower than outdoor concentrations³³.

More complete models combine concentration data with time-activity data. Activity profiles specify a schedule of movements among specified locations (e.g., indoors at home, outdoors at a neighborhood park) and activities (e.g., sleeping, walking the dog) for an individual over a period of time. Specified locations where the activities take place are generally referred to as microenvironments. A microenvironment is a location within which the pollutant concentration is assumed to be uniform at any time interval, although it may vary over time and may vary with the associated activity.

Risk characterization combines the results of the dose-response assessment with the exposure assessment to estimate the likelihood of adverse effects occurring. For carcinogens, the results may be characterized in several different ways. Examples are the average risk to the population as a whole, the average risk to various subsets defined by residential location or other demographic factor, or the number of people subject to an individual risk level above a given threshold. For chronic and acute effects, the risk is typically characterized by the number of people exposed above the concentrations that exceed the threshold.

The overall objective for this level of assessment is to develop a refined estimate of exposure by taking into account the different concentrations in different locations (or microenvironments) in which people in the project area interact with the MSATs. Results from

³³ Note that these cases are exceptions to most situations.

the air dispersion modeling are combined with demographic data to evaluate population exposure to pollutants. There are several options for exposure assessment. The simplest is to assume that outdoor concentrations in the vicinity of one's residence are equal to exposure concentrations from outdoor sources. However, this approach may produce unacceptable levels of risk and a more refined approach may be necessary.

An example of a more refined approach is conducting a detailed assessment with a population exposure model, such as EPA's Hazardous Air Pollutant Exposure Model (HAPEM). The HAPEM is a stochastic model; that is, most of its input variables are chosen from data distributions. The latest version of the model, called HAPEM6, has been modified to readily accept concentration estimates provided by air quality models. The time-activity data for use in HAPEM6 were obtained from the Consolidated Human Activity Database (CHAD). CHAD is comprised of approximately 17,000 person-days of 24-hour time-activity data developed from eight surveys from activity dairies, metabolic and physiological parameters³⁴.

Another exposure model developed by the EPA is the Total Risk Integrated Methodology (TRIM.Expo) model also known as APEX. The TRIM model is a new generation of environmental risk and exposure models that facilitates analyses of the impacts of chemical transfers and/or ambient pollution concentrations on human health and the environment. The TRIM system includes both an exposure module and a risk characterization module. The TRIM modeling system comes with a national database that can be used for most applications in the U.S. This includes the CHAD, population files (2000 tract-level census counts, tract locations, employment probabilities by age), and commuting database (adult commuting patterns based on

³⁴ This approach was used by HAPEM in the National Air Toxics Assessment (NATA) National-Scale Assessment (NSA) for analyzing exposure to motor vehicle emissions for the near roadway microenvironment (e.g., in-vehicle).

the 2000 census). More detail on APEX and HAPEM5 models can be found on EPA's website at <http://www.epa.gov/ttn/fera/>

Communication of MSAT Analysis Results and Health Impacts

The human health risk assessment literature discusses communication of analysis results through interpretation of health risk assessment (HRA) results, discussion of uncertainty in HRA, and overall presentation of the results. Considerable literature exists on how to communicate risk to the public (<http://www.epa.gov/ecocommunity/bib.htm>); the points below are limited to risk analyses of MSATs for transportation projects under NEPA. These points also apply in concept to MSAT analyses that do not include a full HRA.

- Describe the project emission sources, the relevant MSATs, and the types of cancer and non-cancer health risks they pose.
- Define clearly the criteria for a significant impact of the project in the NEPA context.
- Explain and reference the source of information on toxicity, exposure, and dose-response that the transportation agency takes as given for purposes of the analysis.
- Identify, document the source, and explain any health studies or ambient air toxic measurements undertaken in the project area that are relevant to the MSAT analysis.
- Distinguish clearly among the types of health risks and their health metrics (e.g., unit risk factor, cancer risk, reference concentration level, hazard quotient, etc.) used in the analysis.
- For each impact metric, show a comparison of the results for each project alternative and the selected criterion of significance.

- Compare project impacts to other exposure information, such as regional or county-level MSAT emission inventories and measured MSAT concentrations.
- Show MSAT results and comparisons in easy-to-understand graphical formats where possible. Use clear; concise writing; and discussion of issues and impacts in proportion to their significance.
- The discussion on MSAT analysis should provide a consistent theme with the other portions of the EIS based on what the project is trying to accomplish.
- Provide a careful discussion of uncertainty. Cover the sources of uncertainty as discussed in the next section as applicable. The uncertainty discussion must adequately support the agency's decision on what level of MSAT analysis to prepare.
- The discussion of uncertainties should include the level of confidence in toxicity information, modeled concentrations, and exposure estimates.
- Provide benchmarks to assist the reader in putting the project-related risks into perspective. Commonly-used benchmarks include everyday risks and sources of hazard such as the probability of having an auto accident, getting struck by lightning, or being injured in a fall at home.

Quality Data Assurance

Much of the data used in developing the MSAT analysis comes from existing sources, also known as secondary sources. This existing data provides more detailed and exhaustive information than the project would be able to generate. This longer period of record provides

additional information and improves the understanding of the situation and provides an improved basis for decisions. Typical sources of existing information include:

- Meteorological data,
- Traffic related parameters (volume, speed, turn movements)
- Data from publicly available databases, such as data from the Census Bureau;
- Ambient air toxics data from EPA's AIRS database;
- Data from published literature, reports, and handbooks;
- Results from unpublished research;
- Data obtained from previously performed pilot studies;
- Geographical Information System (GIS) layers, plots, photographs

Any secondary data should be assessed as to its applicability for use in the MSAT analysis. Existing data from other studies may not have been generated to meet the specific quality criteria established for an MSAT analysis. Even though some existing data sources may be appropriate for its original use, such data still should be evaluated for the appropriateness for use in an MSAT analysis. When using existing data, limitations with the data should be determined and how these may impact their use relative to the project's objectives. For example, ambient air toxic data collected at a "hot spot" that differs from your project setting may not be appropriate for use as background data for a project level assessment. Another example is the case of data generated from analytical methods that yield large measurement errors or used detection limits that are higher than are applicable for the MSAT analysis. Lack of sufficient information about the quality of the data for an existing data source may be a reason not to use

the data. Conversely, previously documented limitations on a data set may or may not prove to be limitations relative to a project level assessment needs.

Existing data sources should be evaluated relative to the quality needs of the analysis. The rigor of this evaluation should be determined based on the importance of those data relative to the intended use in the analysis. Do not use any data without accessing whether they meet the needs of the project.

Uncertainty in MSAT Analysis

The health risk assessment literature contains extensive coverage of the uncertainties involved in human health risk assessment. A number of discussions of uncertainties for MSATs in particular have appeared in agency guidance documents. Some recent EISs have included discussions of uncertainties to comply with the CEQ regulations addressing incomplete and unavailable information (40 CFR 1502.22). (For further detail see Claggett and Houk 2006, Claggett and Miller 2005, FAA 2001, FAA 2003, FAA2005a, and FHWA 2006.) Appendix E identifies and discusses recent information on uncertainty that is applicable to analyses of transportation-related MSATs under NEPA. Based on the review of this information and the current state of the science, the following conclusions may be drawn concerning the treatment of uncertainty in NEPA project analyses:

- Transportation projects vary widely in the need for and usefulness of MSAT analysis. Uncertainty is a substantive issue for larger projects.
- Use of health risk assessment, with its attendant uncertainties, is warranted for some of the larger projects.

- The primary purpose of NEPA is disclosure of information to facilitate selection among alternatives. This purpose includes disclosure of information to the public to support informed commenting on the analysis.
- The public demand for information in NEPA documents may exceed the level of analysis in which the agency has confidence for purposes of alternative selection and impact assessment. Thus, agencies may need to educate the public about uncertainties in the analysis to forestall comment that seeks to stop the project rather than guide the selection of alternatives under NEPA.
- The regulatory driver for discussion of uncertainty within the NEPA document is the CEQ regulations addressing incomplete and unavailable information (40 CFR 1502.22).
- A large uncertainty range in MSAT results does not automatically invalidate their use in comparing alternatives. Relative (not absolute) differences among alternatives, when calculated by consistent methodology, are generally valid for purposes of ranking alternatives.
- Many MSAT analyses show a decline in emissions over time regardless of the project, and the difference between future alternatives is typically much less than the overall secular reduction. This result does not relieve the agency of its responsibilities under NEPA to characterize the differences among the project alternatives, even in the presence of uncertainty.

CHAPTER 3. Conclusion and Suggested Research

Conclusions

This study enables transportation agencies to effectively evaluate and communicate the impacts of toxic air pollutants emitted from surface transportation sources. These toxic air pollutants are collectively known as mobile source air toxics or MSATs. The study provides guidance to the transportation analyst in the following areas:

- MSAT impacts for transportation projects and programs under the National Environmental Policy Act (NEPA, 42 U.S.C. 4321 et seq.);
- Best practices in applying air quality and emission factor models and other technical methods in the analysis of MSAT assessments;
- A health based MSAT screening procedure for the level of detail needed in the analysis that balances the level of detail, analytic rigor, and resource requirements with the likely magnitude and significance of project impacts;
- How to communicate MSAT project level impacts in the NEPA documents that is consistent with the limitations and uncertainties with current modeling tools and in the absence of National Ambient Air Quality Standards (NAAQS)

In addition, the study provides to the transportation community as a whole an approach which:

- Promotes consistency among MSAT evaluation methods so that the relative impacts of roadway projects and programs can be compared and;
- Assure that the quality of MSAT analysis for NEPA documents is sufficient to meet statutory and regulatory requirements, to support agency decision-making, and to adequately inform the public about the air quality impacts of projects in the NEPA context.

Suggested Future Research

Recommendations are provided on future research needs to support the development of the basis and procedures for analyzing mobile source air toxics in the NEPA process. Studies which would widely benefit the transportation community include:

- Acquire and review the “Kansas City” MSAT emission study data recently collected by USEPA. Discuss and review with EPA on how this data will be incorporated into the MOVES model.
- Develop case study examples for an MSAT analysis under NEPA for three to five projects for varying levels of complexity.
- Support development of an air quality model evaluation study, for a well characterized MSAT such as benzene, to extensively evaluate the adequacy of modeling tools for project level MSAT assessments.
- Identify procedures and guidance for collecting and/or developing emission inventories for non-road and other sources (e.g., point sources) for the “Affected Environment” portion of the environmental impact statement to provide the reader with background information on current and future conditions within the local study area.
- Investigate the coupling of a microscopic traffic simulation model using output from a regional travel demand model for use in a project level impact assessment for quantifying both emissions and air toxic impacts.
- Consider examining MSAT from alternative fueled vehicles such as hybrid-electric, CNG and hydrogen vehicles. Prioritize based on projections of the overall future fleet fraction.

- When the MOVES model becomes available studies should be conducted on the use of the model in project-level analysis for MSATs and possibly paired with the HYROAD model for intersection analysis.
- Collect and develop information such as a white paper for the transportation community on the current research and findings associated with the emissions from ultra fine particles (particles with a mean mass diameter less than 0.1 micron). While ultrafine particles are not listed as an air toxic, a growing body of studies is strongly suggestive of negative health effects (SCAQMD, 2006) and public awareness is growing.

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Appendix A.
Agency Approaches to HAP/MSAT Analysis

Public agencies with air quality responsibilities have developed a number of approaches to HAP analysis. Though the agency methods usually do not differentiate between MSATs and other HAPs, the principles are valid for any pollutant. These approaches can be distinguished by whether they employ the principles of human health risk assessment (HRA). This Appendix summarizes the characteristics of selected agency approaches that are relevant for developing MSAT analysis methods for NEPA studies. This Appendix is not a complete compendium of public agency HAP approaches, but those herein are chosen for their completeness, originality, or exemplary status, as well as potential applicability to the development of MSAT analysis approaches.

Agency Guidance That Recommends HRA

USEPA—Risk Assessment Guidance for Superfund (EPA 1989).

EPA developed this guidance under the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA or the Superfund Act). The *Risk Assessment Guidance for Superfund* (or “RAGS”) is part of a set of EPA manuals for use in the remedial investigation/feasibility study process for Superfund hazardous waste sites. The process of HRA given in RAGS was adapted from well-established chemical risk assessment principles and procedures. Although RAGS is oriented toward waste sites, the HRA procedures and principles are valid for mobile sources. The HRA process comprises four steps:

- 1) *Data Collection (Hazard Identification)*: identifies the substances that may present a hazard due to the project and, for air quality studies, characterizes their emission rates.
- 2) *Exposure Assessment*: estimates the magnitude, frequency, and duration of potential human exposures. Pollutant concentrations in the project region are estimated using dispersion modeling. Demographic and spatial data for the project region are used to assess exposure to the estimated concentrations by location and over time. For most NEPA air quality studies the inhalation pathway is the only appreciable route of exposure.
- 3) *Toxicity (Dose-Response) Assessment*: considers the types of adverse effects associated with the substances identified, the relationship between magnitude of exposure and adverse effects, and related uncertainties such as the weight of evidence of a substance’s carcinogenicity in humans. NEPA air quality studies almost always rely on published agency data for this step rather than conducting new research.

- 4) *Risk Characterization*: combines the outputs of the exposure and toxicity assessments to define the project-related risk in qualitative and quantitative terms. The potential for adverse effects to occur is characterized in terms of cancer risks (probabilities) and noncancer hazard quotients (HQ). The hazard quotient is an index that expresses potential exposure levels relative to threshold levels at which health effects are not known to occur. The HQs are aggregated to derive a Hazard Index (HI). The risk characterization also includes an evaluation of the origins and amounts of uncertainty or error in the risk estimates.

California EPA—The Air Toxics Hot Spots Program Guidance Manual for Preparation of Health Risk Assessments (CalEPA 2003)

California's statewide guidance released by the CalEPA Office of Environmental Health Hazard Assessment (OEHHA) sets forth the algorithms, recommended exposure parameters, and cancer and noncancer health values needed to perform a health risk assessment under the Air Toxics Hot Spots Information and Assessment Act of 1987 ("Hot Spots" or California Assembly Bill 2588). This very detailed guidance is officially applicable to stationary sources but has also been applied to mobile sources.

The OEHHA guidance uses the traditional four-step HRA method and presents a tiered approach for performing HRAs. The tiers provide for increasing levels of refinement in the HRA. The four tiers primarily apply to residential cancer risk assessment. There is only a Tier 1 option for determining noncancer risks since these are expressed as hazard quotients calculated from the acute and chronic toxicity values (Reference Exposure Levels or RELs) and the modeled short-term maximum and annual average air concentrations. In addition, no exposure duration adjustment is made for noncancer assessment.

Tier 1 is a standard point estimate approach using average and high-end point-estimate concentrations from modeling, and recommended default point estimates in the document to estimate exposure. Locations that must be identified include:

- 1) The maximum estimated off-site impact, or Point of Maximum Impact (PMI),
- 2) The maximum exposed individual at an existing residential receptor, or Maximally Exposed Individual Resident (MEIR), and
- 3) The maximum exposed individual at an existing occupational worker receptor, or Maximally Exposed Individual Worker (MEIW).

Tier 2 involves the use of site-specific exposure information to develop point estimates that are more appropriate to use in the site-specific HRA than the Tier 1 default point estimates.

For Tiers 3 and 4, OEHHA developed a stochastic approach to risk assessment that utilizes distributions for exposure parameters such as breathing rate rather than a single-point estimate of each parameter. The variability in exposure can be propagated through the risk assessment model using the distributions as input to a Monte Carlo model or similar method. The result of such an analysis is a range of risks that at least partially characterizes variability in exposure. In *Tier 3*, a stochastic approach to exposure assessment is used with default data distributions for exposure factors which are presented in the guidance. The exposure factor distributions apply only to a residential receptor and are used only for the determination of cancer risk.

Tier 4 is also a stochastic approach but allows for utilization of site-specific distributions if they are justifiable and more appropriate for the site under evaluation than the defaults recommended in the guidance. The Tier 3 and Tier 4 analyses show a distribution of cancer risk indicating the percent of the population exposed to various levels of risk. This type of analysis

provides an illustration of population risk. The results from this type of analysis can also be used to show what percentage of the population would be protected with various risk management options.

Table A-1 below, adapted from CalEPA (2003) Table 8.1, summarizes OEHHA’s recommendations for the four Tiers of HRA.

Table A-1. OEHHA Tiers for Cancer and Noncancer Hot Spots HRA

OEHHA Tier	Estimate Type	Exposure Parameters	Risk Type		
			Cancer	Chronic Noncancer	Acute Noncancer
1	Point	Default	●	●	●
2	Point	Site-specific	●	●*	
3	Stochastic	Default	●		
4	Stochastic	Site-specific	●		

* *Noninhalation pathway only.*

Other, in some cases more recent methods have built on the earlier approaches and, in the case of MATES, have included monitoring as a verification of estimates. Some exemplary guidelines are discussed below.

South Coast Air Quality Management District—CEQA Air Quality Handbook (SCAQMD, 1993).

The California Environmental Quality Act (CEQA) is the state’s equivalent to NEPA. A project subject to CEQA must prepare a disclosure document such as an Environmental Impact Report (EIR) which is similar to a NEPA EIS. All of California’s Air Quality Management Districts have issued some type of CEQA guidance, and SCAQMD’s guidance is the most comprehensive. The SCAQMD *CEQA Air Quality Handbook* chapter on air toxics discusses HAPs in the contexts of land use, sensitive receptors, and permitting, and refers the project

proponent to relevant guidance such as SCAQMD Rule 1401 and the OEHHA Hot Spots program. The Handbook states that the CEQA EIR, at a minimum, should:

- Identify all potential land uses emitting toxics within a quarter mile surrounding the proposed project;
- List the types of pollutants most commonly associated with these uses;
- Check the OEHHA database and identify any risk levels that have been reported; and
- Perform HRA for a specific list of HAPs of concern for acute exposure, and for any other HAPs as required by Rule 1401 or other regulations.

The Handbook does not specifically treat mobile sources. However, SCAQMD's current guidance for projects with diesel-fueled mobile sources use SCAQMD's *Health Risk Assessment Guidance for Analyzing Cancer Risks from Mobile Source Diesel Idling Emissions for CEQA Air Quality Analysis* (SCAQMD, 2003), reviewed next, to quantify potential cancer risks from the diesel particulate emissions.

South Coast Air Quality Management District—Health Risk Assessment Guidance for Analyzing Cancer Risks from Mobile Source Diesel Idling Emissions for CEQA Air Quality Analysis (SCAQMD, 2003)

This guideline implements the OEHHA guidance (CalEPA, 2003) for HRA in the special cases of idling diesel engines such as those found at port terminals, warehouse distribution centers, intermodal facilities and travel centers. The SCAQMD guideline defines the “impact area” as the area within which project-related risks are greater than 1 in a million. Among the suggested mitigation measures are a minimum buffer zone of 300 meters between truck traffic and sensitive receptors. The 300-meter criterion does not appear to be based on any specific risk level, but it provides a perspective on the potential size of the study area for a project-level HRA for MSATs under NEPA.

South Coast Air Quality Management District—Risk Assessment Procedures for Rules 1401 and 212 (SCAQMD 2000)

In June 1990, SCAQMD developed risk assessment procedures, including procedures for a simple risk screening, for the adoption of Rule 1401—New Source Review for Toxic Air Contaminants. Rule 1401 specified limits for maximum individual cancer risk (MICR) and excess cancer cases for new, relocated, or modified equipment which emits carcinogenic or noncarcinogenic air contaminants. Rule 1401 applies only to stationary source permitting but the HRA procedures could be adapted for mobile source analysis. The Rule 1401 procedures continue to be revised and updated.

The document provides several tiers for preparing a risk assessment, from a quick look-up table to a detailed risk assessment involving air quality modeling analysis. Permit applicants may use any of these tiers to demonstrate compliance with the risk limits of Rule 1401. If compliance cannot be demonstrated using one tier, the permit applicant may proceed to the next tier. A permit applicant who can show compliance by using a lower tier does not need to perform the higher tiers. The tiers are:

- 1) *Screening Emission Levels*—a simple look-up table in which the equipment's emissions are compared to Screening Levels by pollutant.
- 2) *Screening Risk Assessment*—a screening risk assessment, which includes procedures for determining the level of risk from a source for MICR, Cancer Burden, and Acute and Chronic Hazard Indices. If the estimated risk from Tier 2 screening is below a specified level of concern, then a more detailed evaluation is not necessary.
- 3) *Screening Dispersion Modeling*—Tier 3 uses EPA-approved dispersion modeling software to estimate risk. Consultation with SCAQMD is recommended. Tier 3

screening modeling should only be used for a single emission source. If there are multiple emission sources, Tier 4 must be used.

- 4) *Detailed Risk Assessment*—Tier 4 is a detailed risk assessment using an EPA-approved refined dispersion model. This step is an option if neither Tier 2 nor 3 can demonstrate compliance. Consultation with SCAQMD is recommended.

As a permitting document, the SCAQMD Rule 1401 guidance does not apply to mobile sources. However, the screening concepts that define Tiers 1 through 4 above could be adapted to NEPA MSAT analyses.

Previous Agency Guidance Not Based on HRA

FHWA Interim Guidance

In February 2006, FHWA issued interim guidance for analysis of MSATs in NEPA documents (FHWA 2006). FHWA developed a tiered approach in which, depending on the specific project circumstances, a project would undergo one of three levels of analysis:

- 1) **Exempt Projects or Projects with No Meaningful Potential MSAT Effects—No MSAT analysis.** For projects that are categorically excluded under FHWA regulations (23 CFR 771.117(c)), no analysis or discussion of MSATs is necessary. For other projects with no or negligible traffic impacts, regardless of the class of NEPA environmental document, no MSAT analysis is required. However, the project record should document the basis for the determination of “no meaningful potential impacts” with a brief description of the factors considered.
- 2) **Projects With Low Potential MSAT Effects—Qualitative MSAT analysis.** The types of projects included in this category are those that serve to improve operations

of highway, transit, or freight without adding substantial new capacity or without creating a facility that is likely to meaningfully increase emissions. FHWA suggests minor widening projects and new interchanges as examples. FHWA anticipates that most highway projects will fall into this category.

The qualitative assessment would compare, in narrative form, the effect of the project on traffic volumes, vehicle mix, or routing of traffic, and the associated changes in MSAT emissions for the project alternatives, based on vehicle-miles traveled, vehicle mix, and speed. It would also discuss national trend data projecting substantial overall reductions in emissions due to stricter engine and fuel regulations issued by EPA. FHWA expects that because the emission effects of these projects are low, there would be no appreciable difference in overall MSAT emissions among the project alternatives.

- 3) **Projects With Higher Potential MSAT Effects—Quantitative MSAT analysis consisting of an emissions inventory.** FHWA anticipates that few projects will fall into this category. FHWA defined two criteria that a project must meet in order to be analyzed under this category. The first criterion has two parts based on project size and transportation mode. The second criterion is based on source-receptor proximity.
- a. The project creates or significantly alters a *major intermodal freight facility* that has the potential to concentrate high levels of diesel particulate matter in a single location;
or

- b. The project creates new or adds significant capacity to *urban highways* such as interstates, urban arterials, or urban collector-distributor routes with projected traffic volumes in the range of 140,000-150,000+ average annual daily traffic (AADT) by the design year;

and

The project is located in proximity to populated areas or concentrations of vulnerable populations (e.g., schools, nursing homes, hospitals).

FHWA anticipates that projects in Level 3 have the potential for meaningful differences among project alternatives. FHWA suggests a quantitative analysis to estimate the level of emissions for the priority MSATs for each alternative, to use as a basis of comparison. This analysis also may address the potential for cumulative impacts. The document would also include language addressing incomplete and unavailable information as required by CEQ regulations (40 CFR 1502.22).

Several features of the FHWA guidance are noteworthy. The first criterion in Level 3(A) specifies “major intermodal freight facility” and clearly is aimed at impacts of idling by heavy diesel vehicles. Other types of facilities such as truck stops, freight warehousing and distribution facilities, and bus terminals also can involve large numbers of idling diesels but are not specifically identified in the FHWA criteria.

The second criterion in Level 3(A) specifies a threshold of 150,000 AADT on “urban highways.” FHWA developed this threshold value to be roughly equivalent to the CAA definition of a major HAP source (25 tons per year for all HAPS or 10 tons per year for any single HAP) which is not a health-based threshold. The FHWA guidance cautions that significant variations in conditions such as congestion or vehicle mix could warrant a different (presumably

lower) AADT threshold for this criterion. A lower threshold of 125,000 AADT where 8% of the AADT is diesel truck traffic is suggested in the Preamble to EPA's recent amendments to the Transportation Conformity Rules (EPA 2006a). Level 3 also does not account for the possibility that a highway might hold an FHWA classification of "rural" rather than "urban," yet still meet both the Level 3(A) AADT threshold and the Level 3(B) population proximity threshold.

The FHWA document does not provide guidance on what quantitative values might constitute "proximity" and "concentrations" for purposes of applying the Level 3(B) population threshold. It does however; recommend contacting the FHWA Office of Planning, Environment, and Realty for assistance in developing a specific approach for assessing impacts. Since the Level 3(B) threshold would likely be applied in terms of distance from a highway alignment to areas where population density exceeds some selected value, the vague language of Level 3(B) creates a potential for great inconsistency in the application of this guidance to projects and in the extent of the study area for those projects to which the guidance is applied.

FHWA's position is that the current state of the science is not sufficient to produce reliable estimates of ambient MSAT concentrations or health risks due to a project. This position is based largely on a review of recent FHWA projects which shows that the percentage differences in MSAT emissions among the project alternatives is likely to be small. From this result FHWA concluded that MSAT analysis results are unlikely to figure heavily in the final selection of an alternative. FHWA prefers to emphasize that MSAT emissions are declining over time, independently of any project, as a result of EPA regulation of engines and fuels. Nevertheless, NEPA's mandate is to compare project alternatives to each other rather than to secular (non-project related) trends, regardless of how minor the project's impact may appear with secular trends as a backdrop.

FAA Interim Guidance

The Federal Aviation Administration (FAA) has taken a position similar to FHWA's with respect to modeling and health risk assessment. As with FHWA, the FAA has received increasing numbers of requests for analysis of HAPs in the context of NEPA for airport projects. FAA issued a literature review (FAA 2003) that evaluated EPA NATA data to identify 29 HAPs that are associated with aircraft and airport operations. The FAA list includes pollutants that are specifically associated with aircraft gas turbine engines, as jet aircraft generally account for the largest proportion of airport HAP emissions, with motor vehicles usually contributing the second-largest share. Comparison of the EPA's 21 MSATs identified in the MSAT Rule with the FAA list (Table 1-1) shows considerable overlap, an expected result given the emissions from vehicles accessing airports, and because of chemical similarities between on-road and aircraft fuels.

In 2005 FAA issued interim air quality guidance for NEPA studies of airports that addressed the same questions facing FHWA regarding modeling and risk assessment (FAA 2005b). Like FHWA, the FAA believes that the current state of the science does not warrant assessment of ambient concentrations or health risks of HAPs. In implementing this position the FAA guidance is prescriptive not only in what to include in the analysis but in what to exclude. For those EISs that warrant a HAP analysis, the approach FAA recommends is performing a HAP emissions inventory, identified using a specific methodology for aircraft emissions. The FAA guidance does not discuss non-aircraft mobile sources, leaving the methodology for these sources up to the analyst.

FAA's guidance specifies that HAP inventories be provided in a technical appendix and not discussed in the Environmental Consequences chapter of the EIS. No interpretation of the HAP inventory results, nor toxicity weighting or priority ranking of HAPs, is to be provided. The HAP inventory results should not be compared to other airport inventories. The results of the HAP inventory are to be put into context with available regional inventories and ambient

monitoring results. Trends should also be presented and discussed. Uncertainties and limitations of HAP analyses must be discussed in detail.

References

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- **FAA 2003.** U.S. Department of Transportation, Federal Aviation Administration, Office of Environment and Energy. *Select Resource Materials and Annotated Bibliography On The Topic of Hazardous Air Pollutants (HAPs) Associated With Aircraft, Airports, and Aviation*. Technical Directive Memorandum D01-010. Washington, DC. July 1, 2003.
- **FAA 2005b.** U.S. Department of Transportation, Federal Aviation Administration, Office of Environment and Energy. *Interim Aircraft-HAPs Methodology—National Consistency*. Mr. Ralph Iovinelli (AEE-300), e-mail to APP-600. Washington, DC. September 26, 2005.
- **FHWA 2006.** U.S. Department of Transportation, Federal Highway Administration. *Interim Guidance on Air Toxic Analysis in NEPA Documents*. Memorandum from Cynthia Burbank to Division Administrators. February 3, 2006. <http://www.fhwa.dot.gov/environment/airtoxic/020306guidmem.htm>.

- **SCAQMD 1993.** South Coast Air Quality Management District, *California Environmental Quality Act (CEQA) Air Quality Handbook*, Diamond Bar, CA, November 1993. <http://www.aqmd.gov/ceqa/oldhdbk.html>.
- **SCAQMD 2000.** South Coast Air Quality Management District. *Risk Assessment Procedures for Rules 1401 and 212*. Diamond Bar, CA. Version 6.0, August 2000. <http://www.aqmd.gov/prdas/pdf/riskassessmentprocedures-v7.pdf>.
- **SCAQMD 2003.** South Coast Air Quality Management District. *Health Risk Assessment Guidance for Analyzing Cancer Risks from Mobile Source Diesel Idling Emissions for CEQA Air Quality Analysis*. Diamond Bar, CA. August 2003. http://www.aqmd.gov/ceqa/handbook/mobile_toxic/diesel_analysis.doc.

Appendix B
Recent Studies Evaluating the Performance of Emission Factor and Air Quality Dispersion
Models Focused on Transportation Air Quality Issues

Abdul-Wahab, Sabah A. 2004. *An Application and Evaluation of the CAL3QHC Model for Predicting Carbon Monoxide Concentrations from Motor Vehicles Near a Roadway Intersection in Muscat, Oman*, Sultan Qaboos University, College of Engineering, Sultan of Oman, Environmental Management Vol. 34, No. 3, pp. 372–382, July 2004.

Abstract: The CAL3QHC model was used to predict carbon monoxide (CO) concentrations from motor vehicles at an existing urban intersection (Star Cinema in Muscat area, Oman). The CO concentrations predicted from the model were compared with those measured in the field. Predicted average CO concentrations were found to compare favorably with measured values obtained at all eight receptors considered within the modeled intersection. In general, the comparison indicates good agreement with some underprediction for CO. For receptor 6, the model overpredicts the average CO concentration. This overprediction is associated with the presence of trees and green area in the location of receptor 6. In general, the measurements and the model results indicated that the highest CO concentrations were found to occur close to the intersection and, hence, a decrease in the concentration levels was seen as the distance from the road increased. The results indicated that the levels of CO were well below the ambient air quality standard and that probably no health risk was present in areas adjacent to the star cinema intersection. However, the predicted worst-case 1-h CO concentrations assuming inversion atmospheric stability conditions (class F) and wind speed of 1 m/s indicated that the levels of CO were close to or higher than the Oman's National Ambient Air Quality Standards (NAAQS) value of 35 ppm at all receptors considered. The results of this study are useful in transport development and traffic management planning.

Biancotto R, Coraluppi L., Liguori F., Lorenzet K., Maffei G. R., Pillon S, Pistollato S, Rosa M, and Tarabotti E. 2004. *Model Simulation of Venezia-Mestre Ring Road Air Pollution: Experimental Check and Model Intercomparison*, 9th Int. Conf. on Harmonization within Atmospheric Dispersion Modeling for Regulatory Purposes, Garmisch-Partenkirchen, Germany, June 1-4, 2004, pp 141-146.

Abstract: Ambient monitoring of CO, benzene and PM₁₀ pollution from motor vehicles along the Mestre Ring Road, City of Venice, Italy are compared with air quality modeling using the ADMS-Urban model, CALINE4, AERMOD (version 99351), and CALPUFF (version 5.7 dated 030402). Emission sources were divided into 57 links for the six-lane motorway of 8 km length. Traffic emissions were estimated based on the COPERT3 methodology, adding emissions factors proposed by International Institute for Applied Systems Analysis and TNO for PM₁₀ tire, brake and resuspended road dust. The monitoring site measured meteorological parameters in addition to air quality. Comparisons are made between monitoring data and model simulations over a six day period starting 28 November 2003. During this period only 1% of the hours experienced calm wind conditions. Comparison between observed and predicted benzene observations was best for the CALINE4 model. The suite of models had mixed performance for CO with the need for additional testing during the frequent low wind speed conditions that occur in the Vento region when highest CO concentrations are observed.

Bluett, J. and Fisher, G., 2005. *Validation of A Vehicle Emission Model Using On-Road Emission Measurements*, 17th Clean Air and Environment Conference, Hobart, New Zealand, 3-6 May, 2005.

Abstract: The effect emissions from roadways have on air quality is an increasingly important environmental issue. As a result regulators and developers are being required to invest large amounts of resources into managing and assessing roadway effects on air quality. Good information on vehicle emission inventories and dispersion modeling assessments is largely dependent on knowing the amount of pollutants being discharged from the on-road vehicle fleet. It is common practice to use emission models (e.g. USEPA MOBILE6) to estimate the rate at which pollutants are discharged from vehicles. Vehicle emission models often do not provide accurate estimates of real-world emissions. This paper undertakes a comparison between modeled and measured vehicle emissions of carbon monoxide (CO). In Auckland, during April 2003, the tailpipe emissions from over 35,000 vehicles were measured using remote sensing technology. The measured vehicle emissions of CO are compared to modeled emissions provided by the New Zealand Traffic Emission Rate database (NZTER). Roadside air quality and traffic monitoring data and a roadway dispersion model (CALINE4) are used to assess the effect of the different sources of emission data (NZTER and measured emission factors). The results show that the effects of vehicle sourced air pollution can be quantitatively assessed with a reasonable degree of confidence using both measured and modeled CO emission data.

Hartley, W.S. Carr, E.L. and Bailey, C., 2006. *Modeling Hotspot Transportation-Related Air Quality Impacts Using ISC, AERMOD, and HYROAD*, Presented at the Guideline on Air Quality Models: Applications and FLAG Developments –An AWMA Specialty Conference, Denver, CO, April 2006.

Abstract: Presently, EPA requires particulate matter (PM) “hot-spot” reviews for transportation projects in nonattainment or maintenance areas; major federal projects may also require an environmental review under NEPA. While historically this has been done qualitatively for PM, EPA is considering requiring quantitative hotspot analysis. This study was designed to develop for EPA technical support information needed for PM₁₀ and PM_{2.5} hotspot modeling assessments. In particular, the study explored the effects of various levels of input data quality in several dispersion and emissions models and compared the results to observations in a project-level transportation air quality setting.

The study focused on near-source concentrations at the interchange of I-40/I-75 and Watt Road in western Knox County, TN. The average daily traffic at this location is 83,000 vehicles per day, of which 27% are heavy-duty diesel vehicles. Additionally, the area includes three travel centers in an approximate 2.5 km² area providing overnight parking for up to 700 HDDVs, many of which continually idle their engines. Two dispersion models - ISCST3 and AERMOD - were compared with on-site PM_{2.5} as a function of the quality of available input data, including on-site meteorological data. The ISC and AERMOD models used emissions determined with MOBILE6.2, and temperature-dependent extended idle emissions to study the 2.5 km² area. Near-roadway (< 75-m) concentrations were also simulated with HYROAD (an EPA-alternative model for near-surface transportation emissions) using emission factors from MOBILE6.2 and anticipated MOVES-like speed- and acceleration-dependent emission factors.

Key findings of the study include:

- Using similar, best-available inputs, the AERMOD model outperforms ISC. This is likely a result of better near field dispersion characterization from AERMET.
- The default method for distributing emissions in HYROAD was bypassed to allow MOVES-like emission factors to be included. The findings suggest that significant improvements are possible when speed and acceleration dependencies of the emissions, as a function of location, are included in the model.

Held, T., Chang, D.Y. P., Niemeier, D.P., 2003. *UCD 2001: An Improved Model To Simulate Pollutant Dispersion From Roadways*, Atmospheric Environment 37 (2003) 5325–5336, 2003.

Abstract: An improved dispersion model, UCD 2001, designed to estimate pollutant concentrations near roadways was developed and its performance evaluated. The UCD 2001 model internally represents a highway link as a three dimensional array of point sources that simulates a roadway mixing zone which extends 2.5m above a highway link. Dispersion from each point source is estimated with the Huang dispersion solution. The Huang equation is a simplified solution to the semi-empirical advection diffusion equation; its derivation permits vertical profiles of wind speed and eddy diffusivity in the boundary layer to be approximated by power law functions. The UCD 2001 model was calibrated with one-half of the General Motors (GM) SF6 tracer study data base and resulted in a selection of eddy diffusivity parameters that did not vary with ambient meteorology. This parameterization is consistent with several independent studies which indicate that the atmosphere is well-mixed and neutrally stratified immediately downwind of a roadway with significant vehicular activity. UCD 2001 model performance was evaluated and compared to the CALINE3 and CALINE4 dispersion models using the GM data base. UCD 2001 adequately simulates near parallel, low wind speed (less than 0.5 m/s) meteorological scenarios, whereas the CALINE models significantly over predict most receptor concentrations for these conditions. The UCD 2001 model results in approximately 80–90 percent reduction in squared residual error when compared to the CALINE3 and CALINE4 models. In addition, the UCD 2001 model exhibits better agreement in simulating the top forty observed concentrations than either CALINE model. Lastly, the UCD 2001 model requires less user input and modeler expertise than most roadway dispersion models, and should result in more consistent and robust pollutant field estimations.

Indale, G.T., 2005. *Effects of Heavy-Duty Diesel Vehicle Idling Emissions on Ambient Air Quality at a Truck Travel Center and Air Quality Benefits Associated with Advanced Truck Stop Electrification Technology*, Doctor of Philosophy Dissertation, Department of Civil Engineering, University of Tennessee, Knoxville, May 2005.

Abstract: United States Department of Transportation (DOT) requires truck drivers to rest for 10 hours after every 14 hours of driving. During this time and while waiting for loading and unloading of their trucks, truck drivers idle their engine to provide heat or air conditioning for the cab and sleeping compartment, keep the engine warm during cold climate, and provide electrical power for their onboard appliances. At large truck stops, 200 or more trucks may be

idling at the same time. At these truck stops idling emissions can significantly contribute to the concentrations of NO_x and PM_{2.5} pollutants in the ambient air in the vicinity of the truck stop.

In this study monitoring of ambient air at the Petro truck travel center located at I40/I75 and Watt Road interchange was performed between mid December 2003 and August 2004. Concentrations of PM_{2.5} and NO_x were measured continuously at two locations. Computer modeling was also performed using EPA's ISCST3 model to predict ambient concentrations of PM_{2.5} and NO_x at the truck stop. Ambient concentrations of NO_x and PM_{2.5} were found to be higher at nighttime and early morning hours compared to daytime. The number of trucks idling at the truck travel center was also found to have similar trend as that of ambient concentrations of considered pollutants. Average ambient concentrations of 276 ppb and 213 ppb of NO_x and 35 µg/m³ and 29 µg/m³ of PM_{2.5} were monitored at the two selected locations over the course of this research. The monitored concentrations of PM_{2.5}, and NO_x were then compared to the predicted values in an effort to verify and calibrate the model. The ISCST3 model was used to predict annual average and maximum 24-hour average NO_x and PM_{2.5} and concentrations in the Watt Road area and three hot-spots corresponding to the three truck travel centers at the area were observed. If sufficient number of IdleAire electrification units were provided to accommodate all trucks (that would otherwise idle), the ambient concentrations (not considering background concentrations) would be lower by 70% and 48% at the two monitoring locations as predicted by ISCST3 model.

Karakitsios, S.P., Delis, V.K., Kassomenos, P.A., Pilidis, G.A. 2006. *Contribution to ambient benzene concentrations in the vicinity of petrol stations: Estimation of the associated health risk*, Atmospheric Environment (2007), doi:10.1016/j.atmosenv.2006.10.052.

Abstract: This work examines the contribution of petrol stations to the ambient benzene concentrations and attempts to estimate the possible health risks for the people living in the vicinity of such installations. Three monitoring sites (urban, suburban, and rural) were used as reference points and the benzene concentrations were recorded at several distances along their perimeter. In order to evaluate the net contribution of the petrol station to the ambient benzene concentrations, the urban background concentration, measured by passive samplers and the contribution of the roads, estimated with both the COPERT and the linear source model CALINE 4, were deduced. Validation and optimization of the modeling system COPERT and CALINE4 was done in advance to ensure the reliability of the results. It seems that petrol stations have a significant contribution to ambient benzene concentrations in their vicinity. Finally, a risk assessment evaluation was attempted in terms of increased cancer risk due to the presence of the petrol stations in an area. The results show remarkable increase of the population risks in the vicinity, ranging from 3% to 21% in comparison to the population in the rest of the town.

Kim, B.Y., Wayson, R., Fleming, G, 2006. *Development of the Traffic Air Quality Simulation Model (TRAQSIM)*, Paper Presented to the Transportation Research Board, 85th Annual Meeting, Washington, DC. January 22-26, 2006.

Abstract: The United States (US) Environmental Protection Agency (EPA) currently promulgates the use of CAL3QHC to model concentrations of carbon monoxide (CO) near

roadway intersections. The steady-state and macroscopic methods used in this model represent rough approximations of the physical phenomena occurring at intersections and are unintuitive for the users. Therefore, the Traffic Air Quality Simulation Model (TRAQSIM) was developed to create a theoretically more realistic (more natural), easier to understand, and more flexible modeling environment than CAL3QHC. Instead of steady-state plume equations used in CAL3QHC, TRAQSIM models dispersion through the use of Gaussian puffs emitted from discrete moving sources in a traffic simulation environment. Although most of the components incorporated in TRAQSIM are not new, the combination of these components within a fully integrated environment is new and provides the potential for more direct (more logical) expansion of modeling capabilities. As part of an initial validation assessment, a relative comparison of CAL3QHC and TRAQSIM results showed that TRAQSIM produced more intuitively correct spatial allocation of concentrations. The validation assessment also showed good agreement by both models when compared to measured data with overall R² values of 0.721 for CAL3QHC and 0.605 for TRAQSIM. Although this appears to favor CAL3QHC, analyzing individual cases show mixed results (i.e., 6 cases favoring CAL3QHC and 5 cases favoring TRAQSIM). Therefore, additional assessments with larger datasets will need to be conducted before any definitive conclusions can be made. This paper describes the data and methodologies used to develop TRAQSIM and the initial validation work.

Levtin, J., Härkönen, J., Kukkonen, J., Nikmo, J. 2005. *Evaluation of the CALINE4 and CAR-FMI models against measurements near a major road*, Atmospheric Environment 39 (2005) 4439–4452.

Abstract: This study evaluates and inter-compares two atmospheric dispersion models against the results of a measurement campaign that was conducted near a major road at Elimäki in southern Finland from 15 September to 30 October 1995. The campaign was specifically designed for model evaluation purposes. The concentrations of NO_x, NO₂ and O₃ were measured simultaneously at three locations, at three heights (3.5, 6, and 10 m) on both sides of the road. Traffic densities and relevant meteorological parameters were also measured on-site. The models evaluated were the Gaussian finite line source models California line source dispersion model, version 4 (CALINE4) and Contaminants in the Air from a Road—Finnish Meteorological Institute, version 3 (CAR-FMI); the latter was used in combination with the MPP-FMI meteorological pre-processing model. The agreement of measured and predicted datasets was good for both models, as measured using various statistical parameters. For instance, for the hourly NO_x and NO₂ data and predictions, analyzed separately at two distances from the road (17 and 34 m), each of these at two heights (3.5 and 6 m), the index of agreement values range from 0.77 to 0.88, and from 0.83 to 0.92 for the evaluations of the CAR-FMI and CALINE4 models, respectively. The performance of both models was better at a distance of 34 m, compared with that at a distance of 17 m. We also analyzed the difference between the model predictions and measured data in terms of the wind speed and direction. The performance of both models in most cases deteriorated as the wind speed decreased, and as the wind direction approached a direction parallel to the road.

Mishra, V. Padmanabhamutry, B. 2003. *Performance evaluation of CALINE3, CAL3QHC and PART5 in predicting lead concentration in the atmosphere over Delhi*, Atmospheric Environment 37 (2003) 3077–3089.

Abstract: Prediction of ground level lead concentration was made at five traffic intersections in Delhi, India, by the two highway models, viz., CALINE3, CAL3QHC, and one particulate emission factor model PART5, where lead was actually monitored. The predicted values were compared with the monitored data at all the five monitoring sites. The CAL3QHC was found to be most suitable for the predictions at the signalized intersections.

Nadim, F., Iranmahboob, J., Holmen, B. Hoag, G., Perkins, C. and Dahmani, A. 2003. Iranian Academic Association (IAA) *Conference on the Application of Technology in Urban Development, December 21 – 28, 2003*

Abstract: Gasoline and diesel fuel powered motor vehicles are the major sources of air pollutant emissions in urban areas. A sustainable air quality management program requires an accurate estimate of automotive emissions. The United States Environmental Protection Agency (USEPA) employs a computer model called ‘MOBILE’ to estimate emission factors (CO, NO_x, SO_x, NH₃, particulate matter, and certain air toxic pollutants) for on-road mobile sources. Emissions are given in terms of gram/mile for twenty-eight classes of vehicles.

The California Department of Transportation (CALTRAN) developed an air quality model called CALINE4. This model is based on the Gaussian diffusion equation and employs a mixing zone concept to characterize pollutant dispersion over the roadways. The purpose of CALINE4 is to assess pollutant concentrations for receptors located within a certain distance of the roadways. The model has the capability of predicting concentrations of CO, NO₂, and particulate matter.

In this study, the capabilities and drawbacks of ‘MOBILE’ and ‘CALINE4’ simulation models are discussed. Some of the simulation runs processed with MOBILE6.2 were compared with actual field measurements conducted at seven sampling locations in the State of Connecticut. The discussion will include means of controlling the emissions of toxic pollutants from mobile sources.

Pratt, G. Chun, Y. Bock, D. Adgate, J. Ramachandran, G., Stock, T., Morandi, M., and Sexton, K., 2004. *Comparing Air Dispersion Model Predictions with Measured Concentrations of VOCs in Urban Communities* Environ. Sci. Technol. 2004, 38, 1949-1959

Abstract: Air concentrations of nine volatile organic compounds were measured over 48-h periods at 23 locations in three communities in the Minneapolis-St. Paul metropolitan area. Concentrations at the same times and locations were modeled using a standard regulatory air dispersion model (ISCST3). The goal of the study was to evaluate model performance by comparing predictions with measurements using linear regression and estimates of bias. The modeling, done with mobile and area source emissions resolved to the census tract level and characterized as model area sources, represents an improvement over large-scale air toxics modeling analyses done to date. Despite the resolved spatial scale, the model did not fully

capture the spatial resolution in concentrations in an area with a sharp gradient in emissions. In a census tract with a major highway at one end of the tract (i.e., uneven distribution of emissions within the tract), model predictions at the opposite end of the tract overestimated measured concentrations. This shortcoming was seen for pollutants emitted mainly by mobile sources (benzene, ethylbenzene, toluene, and xylenes). We suggest that major highways would be better characterized as line sources. The model also failed to fully capture the temporal variability in concentrations, which was expected since the emissions inventory comprised annual average values. Based on our evaluation metrics, model performance was best for pollutants emitted mainly from mobile sources and poorest for pollutants emitted mainly from area sources. Important sources of error appeared to be the source characterization (especially location) and emissions quantification. We expect that enhancements in the emissions inventory would give the greatest improvement in results. As anticipated for a Gaussian plume model, performance was dramatically better when compared to measurements that were not matched in space or time. Despite the limitations of our analysis, we found that the regulatory air dispersion model was generally able to predict space and time matched 48-h average ambient concentrations of VOC species within a factor of 2 on average, results that meet regulatory model acceptance criteria.

Singh, R., Desloges, C., and Sloan, J. 2006 *Application of a Microscale Emission Factor Model for Particulate Matter to Calculate Vehicle-Generated Contributions to Fine Particulate Emissions*, J. Air & Waste Manage. Assoc. **56**:37–47

Abstract: This paper discusses the evaluation and application of a new generation of particulate matter (PM) emission factor model (MicroFacPM). MicroFacPM that was evaluated in Tuscarora Mountain Tunnel, Pennsylvania Turnpike, PA shows good agreement between measured and modeled emissions. MicroFacPM application is presented to the vehicle traffic on the main approach road to the Ambassador Bridge, which is one of the most important international border entry points in North America, connecting Detroit, MI, with Windsor, Ontario, Canada. An increase in border security has forced heavy-duty diesel vehicles to line up for several kilometers through the city of Windsor causing concern about elevated concentrations of ambient PM. MicroFacPM has been developed to model vehicle-generated PM_{2.5} and coarse PM₁₀ from the on-road vehicle fleet, which in this case includes traffic at very low speeds (10 km/h). The Windsor case study gives vehicle generated PM_{2.5} sources and their breakdown by vehicle age and class. It shows that the primary sources of vehicle-generated PM_{2.5} emissions are the late-model heavy-duty diesel vehicles. We also applied CALINE4 and AERMOD in conjunction with MicroFacPM, using Canadian traffic and climate conditions, to describe the vehicle-generated PM_{2.5} dispersion near this roadway during the month of May in 2003.

Tang, U and Wang, Z. 2002. *Spatial Patterns of CO Vehicular Pollutant in Macao Peninsula*, Journal of Geospatial Engineering, Vol. 4, No. 1, pp.51-58 (June 2002).

Abstract: This paper describes a new approach to assess high-resolution carbon monoxide (CO) distribution for the peninsula of Macao Special Administrative Region (S.A.R.). Firstly, two widely used vehicular pollution models, namely Danish Operational Street Pollution Model (OSPM) and United States intersection vehicular pollution model (CAL3QHC), were applied to

evaluate the roadside CO concentration from vehicular emission. It was found that the OSPM was more suitable in this region. Therefore, the OSPM was adopted to simulate such pollutants in front of each building block in the Macao peninsula. Geographic Information System (GIS) was utilized to run all model cases and store the model results automatically. The spatial pattern of CO distribution in all the main streets of Macao peninsula was found and the influence of traffic loading was shown by a spatial comparison of the CO concentration and traffic loading.

Thomas, G.W., and Dudley, 2001. *Steps in Conducting an Urban Air Toxics Assessment: Methodology for Converting Emission Inventories into Model-Ready Input Files*, 10th International Emission Inventory Conference - "One Atmosphere, One Inventory, Many Challenges, May 2001.

Abstract: In the fall of 1999, the Environmental Protection Division (EPD) of the Denver Department of Environmental Health began conducting an urban air toxics assessment for the Denver area. The assessment was designed to include air dispersion modeling, historical monitoring data, and emission inventory data for various categories of sources, including stationary, mobile and area sources. Emissions for mobile and area sources were obtained from the 1996 National Toxics Inventory (NTI). Stationary source emissions were obtained from the Colorado Department of Health and Environment (CDPHE). A significant amount of processing is required to convert these inventories into model-ready input files. The results presented here show how different methodologies can affect the modeled concentrations.

Timothy M. C. LaBreche, Robert B. Jacko, Barry K. Partridge, William Schneider, and Ahmed Soliman, 2002. *Effectiveness of the Borman Expressway ITS Program on Local Air Quality*, Purdue University, Prepared in cooperation with the Indiana Department of Transportation and Federal Highway Administration, FHWA/IN/JTRP-2002/5, September 2002.

Abstract: Particulate Matter less than 2.5 μm in diameter (PM_{2.5}), carbon monoxide (CO), and meteorological parameters were monitored at 10 second averaging intervals adjacent the Borman Expressway in Northwestern Indiana before and during the implementation of an Intelligent Transportation System. Traffic data was collected from sensors on the expressway. The high-resolution data permitted the expressway contribution to local air quality to be separated from background components of local air quality and significant correlations were made between pollutant flux and traffic flow and pollutant flux and highway occupancy. Traffic incidents (accidents / congestion) were shown to have a rapid impact on local air quality. In many examples, during-incident pollution flux increased 2 to 3 times pre-incident levels. Oversaturated traffic operating conditions deleteriously affected local air quality and if avoided by ITS or other methods would significantly improve local air quality.

Yura, E, Kear, T., Niemeier, D. 2006. *PM_{2.5} Modeling Capabilities of CALINE*, Presented the 85th Annual Meeting of the Transportation Research Board, Paper 06-1170, January 22-26, 2006, Washington, D.C.

Abstract: This paper explores the range of CALINE4's PM_{2.5} modeling capabilities by comparing previously collected PM_{2.5} data with CALINE4 predicted values. The PM_{2.5} data were collected to be representative of three receptors adjacent to an intersection in Sacramento, CA. We looked at the predicted concentrations graphed against the observed concentrations; the percentage of points falling within the factor-of-two prediction envelope was expected to be greater or equal to 75%. Data estimated for the receptor located next to the roadway near the ground were closest to observed values. The other two receptors were located near the road (at a higher position from the ground), and further from the roadway, and produced similar results: both did not fall within the 75% factor-of-two envelope. Although greater discrepancies were observed in the data furthest from the emission source, the three receptors combined produced results that fell within the acceptable factor-of-two percentage envelope. A reverse dispersion test was also conducted using observed and calculated emission factors, and although it showed correlations between the observed values and CALINE4 predicted values, it could not conclusively prove that the model is accurate at predicting PM_{2.5} concentrations. Although this study's results suggest that CALINE4 PM_{2.5} predictions may be reasonably close to observed values, the data set used to verify the model was small; therefore, findings should be considered exploratory and additional testing should be conducted.

Appendix C.
Screening Threshold Analysis for Chronic Exposure Assessment

Of the priority MSAT pollutants, benzene is the pollutant with the highest combination of an EPA-recognized cancer risk factor and emission rate. Additionally, benzene is classified as a *known human carcinogen* and emission rates are considered well characterized by MOBILE6.2. Thus benzene was chosen as the air toxic pollutant for which a cancer-based risk screening analysis would be most appropriate. Other MSATs could contribute, but the combination of high emissions and relatively high unit risk factor makes benzene the dominant “risk driver” in most mobile source situations and the best candidate for a single screening parameter. For non-cancer screening analysis, diesel PM was identified as the MSAT with the greatest potential to create a high “hotspot” concentration³⁵.

³⁵ The other pollutant with a potential for concentrations to exceed the reference concentration level (RfC) is acrolein. However, analysis of the potential for acrolein to trigger a “hotspot” concentration, due only to mobile sources, showed that a project would need a traffic volume in excess of 200,000 vehicles per day. While acrolein is considered the “risk driver” in the NATA assessments for non-cancer health effects, the on-road mobile source contribution is on average less than 15 percent of the total emissions. Also, the NATA results for acrolein assessment are considered questionable as the ambient monitoring methods for acrolein have not been considered reliable and have lead to efforts to develop an effective ambient monitoring test method.

Settings

The cancer risk screening analysis used information from an FHWA-sponsored study (FHWA, 2006) that gathered information from states and metropolitan planning organizations (MPOs) on vehicle fleet age, vehicle miles traveled, and fleet mix, as well as diurnal profile information for PM_{2.5} nonattainment areas throughout the United States. Traffic volume, heavy-duty truck fractions, and operational speeds for three transportation setting scenarios (*freeway*, *arterials*, and *intersections*) were developed based on this information plus typical posted speeds and level of service. This information was then used to develop traffic volume using equations from long-range transportation planning techniques, Chapter 9, NCHRP Report 387 (NCHRP, 1997). The traffic volume information was then used in testing reasonably foreseeable traffic scenarios for screening threshold modeling. The three transportation settings considered the following settings to determine when traffic volume was sufficient for cancer risk to reach a one in a million risk level:

- **Freeway:** The number of lanes ranged from 4 to 8 (that is 2, 3 or 4 lanes in each direction) in an urban setting (much closer receptors than in a rural setting) using a daily average 5% heavy-duty diesel vehicle (HDDV) fraction (gasoline engines produce more benzene than diesel), at level of service D. The nearest receptor was set at an average exposure distance of 100 meters³⁶ from the outer shoulder edge for freeways.
- **Arterials:** The number of lanes ranged from 2 to 6 lanes (that is 1, 2 or 3 lanes in each direction) in a rural setting (slightly higher speeds result in more emissions per vehicle) using a daily average 6% HDDV fraction (gasoline engines produce more benzene than

³⁶ The distance of 100-m for freeways and 50-m for arterials correspond to the two distances identified in two studies referenced in Chapter 3 of the MSAT rule page 107 (Draft Regulatory Impact Analysis: Control of Hazardous Air Pollutants from Mobile Sources, EPA-450/ EPA420-D-06-004, February, 2006) in which a significant increase in premature mortality was found for adults living within 100 meters of a highway and 50 meters of a major urban roadway.

diesel on a per mile basis), at level of service D. The nearest receptor was set at an average exposure distance of 50 meters from the outer shoulder of the arterial.

- **Intersections:** The number of lanes ranged from 4 to 6 lane symmetric intersection (that is 2 or 3 lanes in each direction) with a single left turn bay in an urban setting (has higher gasoline vehicle fraction than rural setting and receptors are closer) using a 3% HDDV fraction (gasoline engines produce more benzene than diesel on a per mile basis), operating at level of service D. Traffic signalization information was used in calculating speeds and level of service for intersections based on the 2000 version of the Highway Capacity Manual (TRB, 2000) along with an assumed saturation traffic flow for the intersection of 1,600 vehicles per hour. The clearance lost time was set at 3.0 seconds. Signal cycle was set to a 90 second cycle time with an average red time length of 50 seconds. Progression was modeled as “average” based on the traffic volumes for the scenarios. The nearest receptor was set at 10 meters (in close proximity) from the outer lane of the intersection.

The non-cancer risk screening analysis was based on plausible scenarios where large concentrations of idling diesel vehicles may congregate leading to ambient concentrations in excess of the diesel reference concentration level (RfC) of $5 \mu\text{g}/\text{m}^3$. Examples of potential settings where extensive diesel truck idling may occur include trucks waiting at port facilities for cargo deliveries or pick-up, truck travel centers, and intermodal transfer stations. This assessment determined the number of truck-hours per day which could lead to concentrations in excess of the screening threshold level.

Trucks were assumed to be located in 3-m wide lanes with an average distance of 10 meters. Each lane was up to five trucks long with additional lanes added in parallel until the

diesel concentration exceeded the RfC. The nearest receptor was set at 10 meters (in close proximity) from the outer lane.

Meteorology

As a screening assessment approach all possible combinations of atmospheric stability and wind speed were used with the wind direction perpendicular to the roadway. While the near parallel condition can give very high concentrations, it is well known that the transportation models (CAL3QHC and CALINE3) tend to significantly over-predict concentrations (due to lack of parameterization for near field wake effects and channeling during low wind speed conditions), and thus were deemed inappropriate for screening.

Emissions Modeling

EPA's MOBILE6.2 model was used to estimate tailpipe emissions and evaporative running losses of benzene for all vehicle types. MOBILE6.2 was also used to estimate tailpipe diesel particulate emissions (DPM) from diesel-fueled vehicles. All modeling was done for the near term future calendar year of 2008 using national default fleet age distribution.

Benzene

VMT for all non-HDDV vehicle classes were distributed as a proportion of non-HDDV by MOBILE6.2 defaults, with HDDV proportionally distributed by national defaults within the HDDV category. A weighted average of all the emission rates in grams per mile was used to calculate a composite vehicle emission rate based on the percentage of HDDV. The road type for the MOBILE6.2 modeling was defined as "arterial" except for estimating freeway emissions when the "freeway" road type was used. Minimum and maximum daily temperatures were set to 45° F and 65° F to represent a "typical" day or annual average. To determine idling benzene

emissions in grams per hour, MOBILE6.2 was run using an average fleet speed of 5 miles per hour and the grams per mile output emission rates were multiplied by 5 miles per hour. Benzene emissions were estimated using MOBILE6.2's "AIR TOXICS" function. MOBILE6.2 requires a fuel benzene percentage as input and each scenario was modeled twice, once with 1% benzene (approximate 2005 national average) and also with 2% benzene (upper end estimate). Table 1 shows the values of other inputs used in MOBILE6.2 modeling.

Table C-1: Inputs Used in MOBILE6.2 Benzene Modeling

Function	Input
Fuel RVP	9.5 psi ^a
Gas Aromatics	30%
Gas Olefins	25%
E200 ^b	55%
E300 ^c	90%
Oxygenates	50% E-10 ^d

^a Tang et al. (2003) recommends 12.5 psi, which is slightly more conservative. Using 12.5 rather than 9.5 resulted in emissions increases of less than 2%.

^b E200 is the percentage of fuel in the vapor phase at 200° C.

^c E300 is the percentage of fuel in the vapor phase at 300° C.

^d E-10 is "gasohol," 10% ethanol and 90% petroleum gasoline. This was the only oxygenate used because California and New York have already banned MTBE and many other states are promoting ethanol as an alternative to MTBE because of the water contamination problem.

Diesel

Idling DPM emissions were directly output by MOBILE6.2. DPM emissions were estimated using MOBILE6.2 defaults using 15 ppm diesel fuel sulfur content (ultra low sulfur diesel). A size cutoff of 2.5 microns (mean mass diameter) was set so all particulates were modeled as PM_{2.5}.

Air Quality Modeling

Freeway and Arterial

EPA's recommended screening model, CALINE3 (California DOT, 1979), was used to estimate screening level air quality impacts from benzene emitted from traffic on freeways and arterials. In either case, the roadway was modeled as northbound and southbound at-grade links with winds coming from the east and receptors due west of the facility. CALINE3 was run with a 60 minute averaging period, with no settling or deposition, and 200 cm surface roughness. Source heights were specified at 0.3 meters to simulate a typical light-duty gasoline vehicle release height. The mixing zone was set at 3 meters. Traffic volumes varied from 60,000 to 130,000 vehicles per day for freeways and from 35,000 to a little over 100,000 for arterials. Because one-hour worst-case conditions were simulated, a screening factor of 0.1 (USEPA, 1992a) was used to estimate a conservative annual average concentration.

Intersection

EPA's recommended screening model, CAL3QHC (USEPA, 1992b), was used to estimate worst-case local air impacts from benzene from traffic at intersections. In general, the same parameters and meteorological conditions used for CALINE3 were used with CAL3QHC. There are, however, additional input parameters required to model intersections and a more

complex geometry. The intersection links were modeled to pass through the intersection traveling north, south, east, and west. Receptors were placed approximately every 12-m along the 45° line extending northeast from the center of the intersection out to a distance of about 100-m. Winds were allowed to come from any direction at ten degree intervals. Approach volumes were symmetric in all four directions. Traffic volumes varied from 15,000 to 90,000 vehicles per day with a third of the vehicles executing left turn movements. Because one-hour worst-case conditions were simulated, a screening factor of 0.1 (USEPA, 1992a) was used to estimate a conservative annual average concentration.

Diesel Particulate Matter “HotSpot”

To examine the effect of a high density of idling heavy duty diesel vehicles, as may occur in a travel center or freight handling facility, diesel particulate emissions were modeled using EPA’s recommended screening tool for point, area, and volume sources, SCREEN3 (USEPA, 1995)³⁷. Emissions were modeled as an area source with a four meter release height (approximate stack height plus plume rise for typical heavy duty diesel trucks). Additional 3-m lanes were added in parallel to each row until the modeled concentration was found to exceed the diesel PM RfC. Receptors were placed every 5-m starting at 10-m out to 100-m.

Results

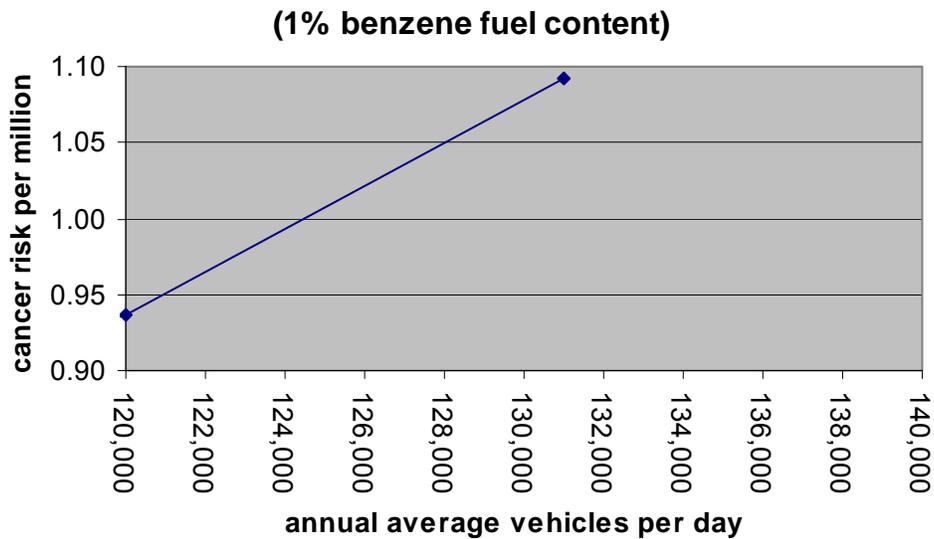
Benzene

For each of the three settings (freeway, arterials, and intersections) the benzene concentration was multiplied by the unit risk factor of $7.8 \times 10^{-6} (\mu\text{g}/\text{m}^3)^{-1}$ to estimate the cancer risk screening value. The value represents a conservative estimate of the vehicle activity level for

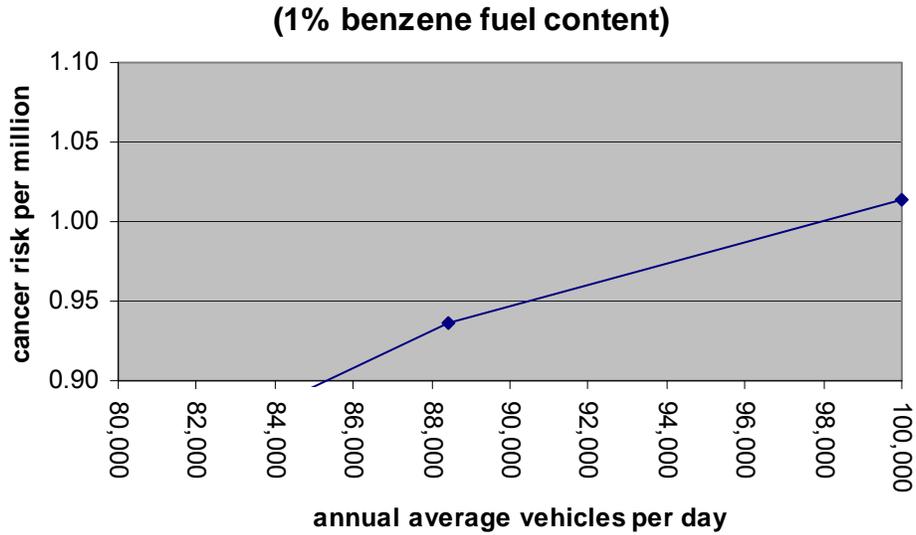
³⁷ SCREEN3 is scheduled to be replaced with AERSCREEN, which is based on the new preferred dispersion model, AERMOD. AERSCREEN is not yet available as of the time of this study in June 2006.

which sufficient emissions may be released to result in concentrations to be of possible health concern, assuming one in a million risk is acceptable. Figures 1 through 3 show the vehicle activity levels at which cancer risk exceeds the one in a million threshold level. One percent gasoline benzene content was chosen as a reasonable foreseeable higher-end benzene fuel content, as it is currently the national average and will likely be reduced further below this level after 2010 if EPA's proposed a rule to reduce hazardous air pollutants from mobile sources is adopted as proposed (EPA, 2006).

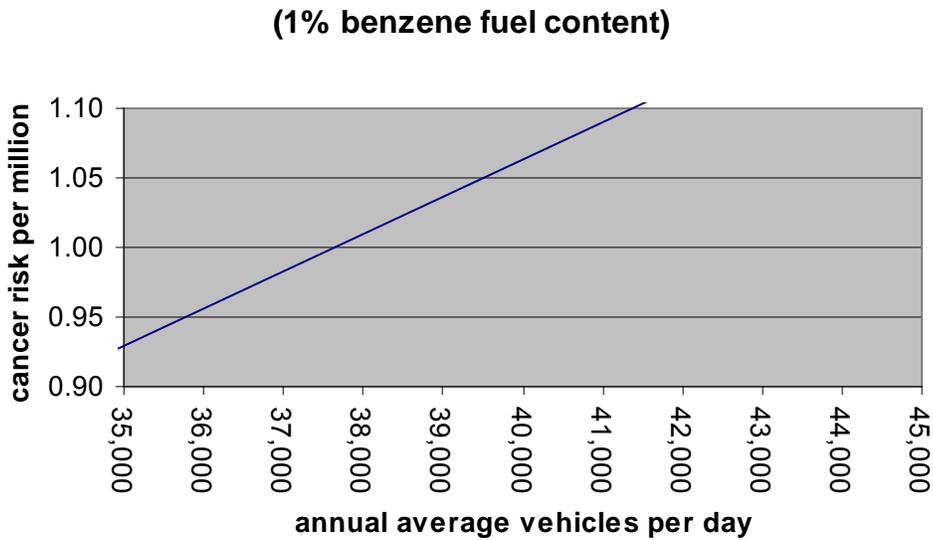
**Figure C-1. Vehicle Activity Level for Freeways and Associated Risk
(ICF International, NCHRP 25-25 Task 18)**



**Figure C-2. Vehicle Activity Level for Arterials and Associated Risk
(ICF International, NCHRP 25-25 Task 18)**



**Figure C-3. Vehicle Activity level for Intersections and Associated Risk
(ICF International, NCHRP 25-25 Task 18)**

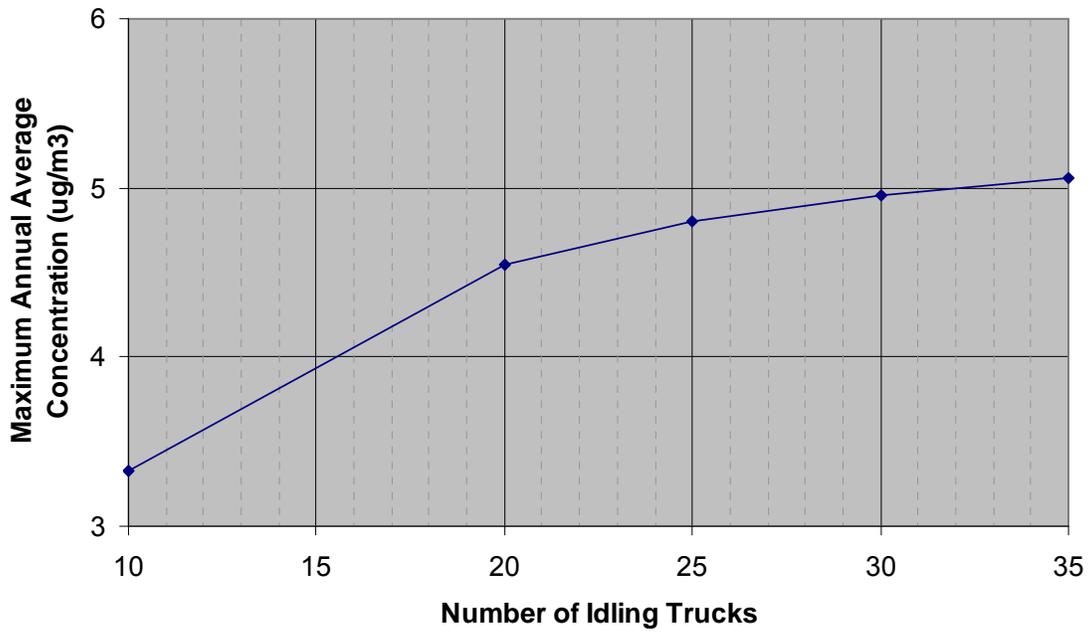


The results show that intersections have the lowest threshold level due to a combination of closer proximity and higher emissions from idling. However, the threshold level of approximately 40,000 vehicles per day represents an intersection with considerable activity and appears as a reasonable threshold level for conducting a more thorough analysis under NEPA. Arterials and freeways may also trigger the need for a more detailed NEPA assessment if activity levels are sufficiently high at 100,000 AADT for arterials and 125,000 AADT for freeways.

Diesel PM

Idling heavy duty trucks were modeled to determine the activity level at which ambient levels of diesel PM may approach the reference concentration level of 5 ug/m³ for diesel PM, which is the non-cancer health level of concern. Figure 4 shows the vehicle activity level at which the diesel PM concentration level exceeds the reference concentration level. The threshold reference concentration level exceedance occurs at 32 heavy duty diesel trucks idling continuously per day, which is equivalent to 768 (=32x24) idling truck hours per day. This threshold represents a very high level of sustained emissions activity likely seen only at large trucks stops or large intermodal transfer facilities and represents a reasonable threshold level for conducting a more thorough analysis under NEPA for non-cancer health effects.

**Figure C-4. Vehicle Activity for Idling Heavy-Duty Diesel Trucks
(ICF International, NCHRP 25-25 Task 18)**



Reference

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[\(<http://www.epa.gov/oms/regs/toxics/ria-sections.htm>\)](http://www.epa.gov/oms/regs/toxics/ria-sections.htm)

Appendix D
MOBILE6.2 Air Toxic Emission Rates National Defaults for Freeways and Arterials
(Calendar Year 2010)

Table D-1. MOBILE6.2 Air Toxic Emission Rates for Freeways Using National Default, Low Diesel Fleet Fractions and High Diesel Fleet Fractions (Calendar Year 2010)

Distribution	Speed (mph)	Benzene (mg/mi)	1,3 Butadiene (mg/mi)	Formaldehyde (mg/mi)	Acetaldehyde (mg/mi)	Acrolein (mg/mi)	DPM/10 (mg/mi)
Typical	2.5	72.17	9.01	26.05	9.28	1.38	1.38
Typical	5	47.66	6.06	19.18	6.84	1.00	1.38
Typical	7.5	35.91	4.61	15.22	5.44	0.79	1.38
Typical	10	30.04	3.89	13.24	4.73	0.68	1.38
Typical	12.5	25.89	3.36	11.50	4.12	0.59	1.38
Typical	15	23.13	3.01	10.34	3.71	0.53	1.38
Typical	17.5	22.16	2.86	9.57	3.44	0.49	1.38
Typical	20	21.43	2.74	8.99	3.23	0.46	1.38
Typical	22.5	20.86	2.65	8.47	3.05	0.43	1.38
Typical	25	20.41	2.58	8.06	2.90	0.41	1.38
Typical	27.5	20.04	2.51	7.69	2.77	0.39	1.38
Typical	30	19.74	2.46	7.39	2.67	0.38	1.38
Typical	32.5	19.30	2.40	7.09	2.56	0.36	1.38
Typical	35	18.92	2.34	6.83	2.47	0.35	1.38
Typical	37.5	18.77	2.31	6.65	2.40	0.34	1.38
Typical	40	18.64	2.28	6.49	2.34	0.33	1.38
Typical	42.5	18.50	2.26	6.35	2.29	0.32	1.38
Typical	45	18.38	2.24	6.23	2.25	0.32	1.38
Typical	47.5	18.25	2.22	6.14	2.22	0.31	1.38
Typical	50	18.15	2.20	6.04	2.18	0.31	1.38
Typical	52.5	18.03	2.18	5.98	2.16	0.30	1.38
Typical	55	17.93	2.17	5.92	2.14	0.30	1.38
Typical	57.5	17.84	2.16	5.89	2.13	0.30	1.38
Typical	60	17.76	2.16	5.88	2.11	0.30	1.38
Typical	62.5	17.68	2.16	5.88	2.11	0.30	1.38
Typical	65	17.61	2.15	5.89	2.11	0.30	1.38
low diesel frac	2.5	75.30	8.92	20.19	7.12	1.13	0.33
low diesel frac	5.0	49.56	5.88	13.85	4.88	0.77	0.33
low diesel frac	7.5	37.27	4.43	10.60	3.73	0.59	0.33
low diesel frac	10.0	31.12	3.71	8.97	3.16	0.49	0.33
low diesel frac	12.5	26.81	3.20	7.73	2.73	0.42	0.33
low diesel frac	15.0	23.95	2.86	6.90	2.45	0.38	0.33
low diesel frac	17.5	22.99	2.74	6.50	2.31	0.36	0.33
low diesel frac	20.0	22.27	2.64	6.21	2.21	0.34	0.33
low diesel frac	22.5	21.71	2.57	5.96	2.12	0.32	0.33
low diesel frac	25.0	21.27	2.51	5.76	2.06	0.31	0.33
low diesel frac	27.5	20.92	2.45	5.58	2.00	0.30	0.33
low diesel frac	30.0	20.62	2.41	5.45	1.95	0.29	0.33
low diesel frac	32.5	20.18	2.36	5.29	1.89	0.28	0.33
low diesel frac	35.0	19.80	2.31	5.15	1.85	0.28	0.33
low diesel frac	37.5	19.66	2.29	5.08	1.82	0.27	0.33
low diesel frac	40.0	19.54	2.27	5.01	1.79	0.27	0.33
low diesel frac	42.5	19.41	2.25	4.95	1.78	0.26	0.33
low diesel frac	45.0	19.29	2.24	4.89	1.76	0.26	0.33
low diesel frac	47.5	19.16	2.22	4.85	1.74	0.26	0.33
low diesel frac	50.0	19.06	2.20	4.80	1.72	0.25	0.33
low diesel frac	52.5	18.94	2.19	4.77	1.71	0.25	0.33
low diesel frac	55.0	18.84	2.18	4.74	1.70	0.25	0.33
low diesel frac	57.5	18.75	2.17	4.73	1.70	0.25	0.33
low diesel frac	60.0	18.67	2.17	4.73	1.69	0.25	0.33
low diesel frac	62.5	18.58	2.16	4.73	1.69	0.25	0.33
low diesel frac	65.0	18.51	2.16	4.74	1.69	0.25	0.33
High diesel frac	2.5	69.09	9.10	31.80	11.40	1.63	2.4
High diesel frac	5.0	45.79	6.23	24.41	8.76	1.22	2.4
High diesel frac	7.5	34.58	4.78	19.76	7.11	0.98	2.4
High diesel frac	10.0	28.98	4.06	17.43	6.28	0.86	2.4
High diesel frac	12.5	24.99	3.52	15.20	5.48	0.75	2.4
High diesel frac	15.0	22.33	3.16	13.71	4.95	0.67	2.4
High diesel frac	17.5	21.35	2.98	12.58	4.54	0.62	2.4
High diesel frac	20.0	20.61	2.85	11.73	4.24	0.58	2.4
High diesel frac	22.5	20.03	2.74	10.94	3.96	0.54	2.4
High diesel frac	25.0	19.57	2.65	10.32	3.73	0.51	2.4
High diesel frac	27.5	19.19	2.57	9.76	3.53	0.48	2.4
High diesel frac	30.0	18.87	2.50	9.30	3.37	0.46	2.4
High diesel frac	32.5	18.44	2.43	8.86	3.21	0.44	2.4
High diesel frac	35.0	18.06	2.36	8.48	3.07	0.42	2.4
High diesel frac	37.5	17.90	2.33	8.19	2.97	0.41	2.4
High diesel frac	40.0	17.76	2.30	7.94	2.88	0.40	2.4
High diesel frac	42.5	17.61	2.27	7.73	2.80	0.38	2.4
High diesel frac	45.0	17.49	2.24	7.55	2.74	0.37	2.4
High diesel frac	47.5	17.36	2.22	7.40	2.68	0.37	2.4
High diesel frac	50.0	17.25	2.19	7.26	2.63	0.36	2.4
High diesel frac	52.5	17.13	2.18	7.16	2.59	0.36	2.4
High diesel frac	55.0	17.03	2.16	7.07	2.56	0.35	2.4
High diesel frac	57.5	16.94	2.16	7.04	2.55	0.35	2.4
High diesel frac	60.0	16.87	2.15	7.01	2.53	0.35	2.4
High diesel frac	62.5	16.79	2.15	7.01	2.53	0.34	2.4
High diesel frac	65.0	16.72	2.14	7.02	2.53	0.35	2.4

Note: Min/Max temperatures of 88.0 degrees Fahrenheit and 100.0 degrees Fahrenheit and benzene fuel content of 1.5%. Fuel RVP set to 8.5 pounds per square inch.

Table D-2. MOBILE6.2 Air Toxic Emission Rates for Arterials Using National Default, Low Diesel Fleet Fractions and High Diesel Fleet Fractions (Calendar Year 2010)

Distribution	Speed (mph)	Benzene (mg/mi)	1,3 Butadiene (mg/mi)	Formaldehyde (mg/mi)	Acetaldehyde (mg/mi)	Acrolein (mg/mi)	DPM/10 (mg/mi)
Typical	2.5	72.17	9.01	26.05	9.28	1.38	1.38
Typical	5	47.66	6.06	19.18	6.84	1.00	1.38
Typical	7.5	37.53	4.78	15.57	5.56	0.80	1.38
Typical	10	32.46	4.15	13.76	4.92	0.70	1.38
Typical	12.5	28.60	3.65	12.09	4.33	0.62	1.38
Typical	15	26.04	3.32	10.97	3.94	0.56	1.38
Typical	17.5	24.17	3.08	10.01	3.60	0.51	1.38
Typical	20	22.77	2.89	9.28	3.34	0.47	1.38
Typical	22.5	21.68	2.74	8.65	3.11	0.44	1.38
Typical	25	20.81	2.62	8.15	2.93	0.42	1.38
Typical	27.5	20.26	2.54	7.74	2.79	0.39	1.38
Typical	30	19.80	2.47	7.40	2.67	0.38	1.38
Typical	32.5	19.33	2.40	7.09	2.56	0.36	1.38
Typical	35	18.92	2.34	6.83	2.47	0.35	1.38
Typical	37.5	18.77	2.31	6.65	2.40	0.34	1.38
Typical	40	18.64	2.28	6.49	2.34	0.33	1.38
Typical	42.5	18.50	2.26	6.35	2.29	0.32	1.38
Typical	45	18.38	2.24	6.23	2.25	0.32	1.38
Typical	47.5	18.25	2.22	6.14	2.22	0.31	1.38
Typical	50	18.15	2.20	6.04	2.18	0.31	1.38
Typical	52.5	18.03	2.18	5.98	2.16	0.30	1.38
Typical	55	17.93	2.17	5.92	2.14	0.30	1.38
Typical	57.5	17.84	2.16	5.89	2.13	0.30	1.38
Typical	60	17.76	2.16	5.88	2.11	0.30	1.38
Typical	62.5	17.68	2.16	5.88	2.11	0.30	1.38
Typical	65	17.61	2.15	5.89	2.11	0.30	1.38
low diesel frac	2.5	75.31	8.92	20.19	7.12	1.13	0.33
low diesel frac	5	49.56	5.88	13.85	4.88	0.77	0.33
low diesel frac	7.5	38.99	4.62	10.97	3.87	0.60	0.33
low diesel frac	10	33.70	3.99	9.53	3.36	0.52	0.33
low diesel frac	12.5	29.70	3.51	8.36	2.96	0.46	0.33
low diesel frac	15	27.04	3.19	7.58	2.69	0.41	0.33
low diesel frac	17.5	25.13	2.97	6.97	2.48	0.38	0.33
low diesel frac	20	23.69	2.79	6.52	2.32	0.35	0.33
low diesel frac	22.5	22.58	2.66	6.14	2.19	0.33	0.33
low diesel frac	25	21.69	2.55	5.85	2.09	0.32	0.33
low diesel frac	27.5	21.15	2.48	5.64	2.02	0.30	0.33
low diesel frac	30	20.69	2.42	5.46	1.95	0.29	0.33
low diesel frac	32.5	20.22	2.36	5.29	1.89	0.28	0.33
low diesel frac	35	19.80	2.31	5.15	1.85	0.28	0.33
low diesel frac	37.5	19.66	2.29	5.08	1.82	0.27	0.33
low diesel frac	40	19.54	2.27	5.01	1.79	0.27	0.33
low diesel frac	42.5	19.41	2.25	4.95	1.78	0.26	0.33
low diesel frac	45	19.29	2.24	4.89	1.76	0.26	0.33
low diesel frac	47.5	19.16	2.22	4.85	1.74	0.26	0.33
low diesel frac	50	19.06	2.20	4.80	1.72	0.25	0.33
low diesel frac	52.5	18.94	2.19	4.77	1.71	0.25	0.33
low diesel frac	55	18.84	2.18	4.74	1.70	0.25	0.33
low diesel frac	57.5	18.75	2.17	4.73	1.70	0.25	0.33
low diesel frac	60	18.67	2.17	4.73	1.69	0.25	0.33
low diesel frac	62.5	18.58	2.16	4.73	1.69	0.25	0.33
low diesel frac	65	18.51	2.16	4.74	1.69	0.25	0.33
High diesel frac	2.5	69.09	9.10	31.80	11.40	1.63	2.4
High diesel frac	5	45.79	6.23	24.41	8.76	1.22	2.4
High diesel frac	7.5	36.09	4.95	20.09	7.23	1.00	2.4
High diesel frac	10	31.24	4.31	17.92	6.46	0.89	2.4
High diesel frac	12.5	27.52	3.79	15.75	5.68	0.78	2.4
High diesel frac	15	25.05	3.45	14.31	5.17	0.70	2.4
High diesel frac	17.5	23.23	3.18	12.99	4.69	0.64	2.4
High diesel frac	20	21.87	2.98	12.00	4.34	0.59	2.4
High diesel frac	22.5	20.79	2.82	11.11	4.02	0.55	2.4
High diesel frac	25	19.94	2.69	10.40	3.76	0.51	2.4
High diesel frac	27.5	19.39	2.59	9.80	3.55	0.48	2.4
High diesel frac	30	18.93	2.51	9.31	3.37	0.46	2.4
High diesel frac	32.5	18.46	2.43	8.86	3.21	0.44	2.4
High diesel frac	35	18.06	2.36	8.48	3.07	0.42	2.4
High diesel frac	37.5	17.90	2.33	8.19	2.97	0.41	2.4
High diesel frac	40	17.76	2.30	7.94	2.88	0.40	2.4
High diesel frac	42.5	17.61	2.27	7.73	2.80	0.38	2.4
High diesel frac	45	17.49	2.24	7.55	2.74	0.37	2.4
High diesel frac	47.5	17.36	2.22	7.40	2.68	0.37	2.4
High diesel frac	50	17.25	2.19	7.26	2.63	0.36	2.4
High diesel frac	52.5	17.13	2.18	7.16	2.59	0.36	2.4
High diesel frac	55	17.03	2.16	7.07	2.56	0.35	2.4
High diesel frac	57.5	16.94	2.16	7.04	2.55	0.35	2.4
High diesel frac	60	16.87	2.15	7.01	2.53	0.35	2.4
High diesel frac	62.5	16.79	2.15	7.01	2.53	0.34	2.4
High diesel frac	65	16.72	2.14	7.02	2.53	0.35	2.4

Note: Min/Max temperatures of 88.0 degrees Fahrenheit and 100.0 degrees Fahrenheit and benzene fuel content of 1.5%. Fuel RVP set to 8.5 pounds per square inch.

Appendix E
The Uncertainty in MSAT Analysis

Introduction

Any impact assessment and modeling process involves uncertainties both in the input values supplied and in the science and parameters on which the models are based. (For a detailed treatment of model-based uncertainties, see Irwin *et al.* 2001.) Uncertainty in forecasting source activity (e.g., traffic volumes) is also an important source of potential error, but forecast uncertainty applies to nearly all components of NEPA analysis and will not be discussed here. For an MSAT project-level analysis under NEPA, the results of the traditional HRA Step 1 (Hazard Identification) and Step 3 (Dose-Response Assessment) usually are taken as reported by the health assessment community, but the uncertainties in the data values still must be considered in evaluating the final result. For NEPA MSAT projects, in which stochastic techniques are not usually applied, each input data value represents the mean of some distribution of values. The shape of the distribution of those values may be known but often is not. Under these typical conditions the analysis represents the mean of an unknown but extremely wide distribution. In statistical terms the confidence level is considered very low.

Currently, there is not a consensus on the usefulness of MSAT analyses for making NEPA project decisions under these conditions of uncertainty. Considerable support exists for the use of comparisons of relative impacts across project alternatives, while there is much less support for the use of the estimated absolute magnitudes of impacts or risk. Agency guidelines not based on HRA generally take the position that analysis of MSAT concentrations and health risk, and sometimes emission inventories as well, are not meaningful for comparing NEPA alternatives because the uncertainty in the results exceeds the potential differences among the alternatives themselves.

On the other hand, when HRAs are performed for NEPA projects, they are based on an assumption (usually implicit) that non-project, secular conditions and trends that are not included in the analysis will not change across alternatives or over time, i.e., “all else is equal.” Using this

assumption, the potential variations or distributions underlying the health data values, and the behavior of the models used, are expected to remain constant for all project alternatives and calendar years analyzed. This assumption is consistent with the NEPA scoping principle that the scope of the analysis need not consider impacts that are not “reasonably foreseeable.” (40 CFR 1502.22 as amended. See also *Supplementary Information* for the amendment issued at 51 FR 80:15618-15626, April 25, 1986.) In many cases the use of the “all else equal” assumption allows alternatives to be compared or ranked meaningfully—at least in a relative sense—based on MSAT emissions, concentrations, or risks. The trends in the results among the project alternatives are likely to be valid even if it would not be meaningful to compare absolute levels of emissions, concentrations, or risks to each other or to numerical criteria.

Table E-1 lists examples of the sources of uncertainty within the risk assessment process.

Table E-1. Sources of Uncertainty in the Air Quality Risk Assessment Process

Risk Assessment Step	Potential Sources Of Uncertainty
1. Hazard Identification	Generally not applicable to MSAT analysis, since the priority MSATs identified by EPA are taken as reported by the health assessment community.
2. Exposure Assessment	<ul style="list-style-type: none"> • Emission rate modeling assumptions and model limitations • Source activity levels (traffic volume, level of service, speeds) • Air dispersion modeling assumptions and model limitations • Exposure estimates (population, human activity levels and duration)
3. Dose-Response Assessment	<ul style="list-style-type: none"> • Animal-to-human toxicity extrapolation • Large-dose to small-dose extrapolation • Subchronic to chronic extrapolation • Variation in human sensitivity
4. Risk Characterization	Additive assumptions (i.e., the assumption that the total risk to a person equals the sum of all individual risks) ignore synergisms and antagonisms between different cancer and non-cancer pathways, sources, and pollutants.
1.-4. Overall HRA	Tracking uncertainty, i.e., the combined effect of individual uncertainties.

Both CalEPA (2003) and EPA (1989) name tracking uncertainty as a potential source of uncertainty. Tracking uncertainty is defined as additional uncertainty arising as a result of the uncertainties in Steps 1-4 magnifying as they propagate through the analysis process. For each source of uncertainty, these guidelines suggest listing key assumptions and indicating the impact of each assumption on overall cancer and non-cancer risk in terms of direction (over- or under-estimation), and degree (e.g., order of magnitude).

Both CalEPA (2003) and EPA (1989) suggest that the uncertainties listed in Table E-1 could be described quantitatively—e.g., with probability distributions. But both guidelines note that such analytical rigor is often infeasible, and instead suggest providing qualitative descriptions of uncertainty or quantitative sensitivity analysis.

Assessing Uncertainty in MSAT Analysis

Reviews of the modeling and estimation tools typically used in MSAT project analyses have identified a number of issues that are relevant to discussions that might be included in an EIS.

Pollutant Interactions

Scientific understanding of the dispersion and transformation of substances in the atmosphere varies by pollutant. While carbon monoxide is essentially inert at the time and distance scales that are relevant for project-level analyses, other pollutants may not be. Gas phase MSATs are known to undergo chemical reactions in the atmosphere at varying rates. The assessment of formaldehyde is especially difficult because formaldehyde concentrations at a given receptor may be affected not only by project-related emissions of formaldehyde, but also by background levels, temperature, sunlight, and project emissions of nitrogen oxides, methane and some VOCs. However, first order approximation of the decay rate for formaldehyde on an annual basis may be

included in a modeling analysis. Similarly, other species such as 1,3-butadiene and acetaldehyde have known reactive decay rates and these effects can be included in a modeling analysis.

Travel Forecasting

Current travel demand models are not especially accurate at forecasting localized volumes and speeds; they are more accurate at the regional scale. Travel models are not effective at predicting speeds on highly-congested (Level of Service F) facilities. This factor compromises the ability to compare emissions of projects that promise to reduce congestion. However, microscopic-scale traffic simulation models do hold promise at forecasting speeds and volumes when used in conjunction with a travel demand model.

Forecasting of traffic volumes and other transportation project variables is subject to all of the uncertainties inherent in projecting future population, land use, and economic growth, as these drive the demand for transportation facilities and services.

Emissions Modeling

The primary software tool for estimating motor vehicle emission rates, which is required by EPA for projects except those in California, is MOBILE6.2 (EPA 2004). The California counterpart, EMFAC2002 (CARB 2003), is similar to MOBILE6.2 and generally is subject to the same types of uncertainties. Reviewers have noted the following characteristics of MOBILE6.2 that influence the uncertainty of MSAT calculations:

- MOBILE6.2 is a regional-scale, trip-based model that was designed to support emission inventories for State Implementation Plans and national scale inventory development. Due to the driving cycle testing used in the vehicle tests from which the MOBILE6.2 data are derived, the model results are best used in regional-scale estimates. The model was not principally designed to produce good estimates of

emissions at any particular speed on any particular roadway segment. At the regional scale, the size of the study area is likely to capture a wide range of travel behavior and conditions, so the regional-average output of MOBILE6.2 is considered representative of the larger scale.

- This local-scale limitation makes MOBILE6.2 less appropriate to characterize small transportation projects, predict emissions at any one specific location, or estimate absolute emissions for use in dispersion modeling or the remaining steps in HRA which depend on dispersion modeling.
- MOBILE6.2 is useful for relative comparisons between years and alternatives for larger projects, in which errors inherent in using MOBILE6.2 output for individual roads may offset each other when aggregated over the entire study area.
- MOBILE6.2 estimates of DPM emission rates are insensitive to vehicle speed, engine starts, or acceleration/deceleration. MOBILE6.2 does not calculate starting emissions separately from running emissions for DPM. The emissions of other MSATs are tied to vehicle speed and starts but not acceleration.
- For VOC-based MSATs, the speciation distributions in MOBILE6.2 are based on limited testing of pre-1994 vehicles. The VOC speciation profile for newer technology vehicles are assumed to be similar to these older vehicles but may actually be different.
- MOBILE6.2 emissions of all pollutants from heavy duty diesel trucks and buses are not sensitive to ambient temperature or cold starts. Some projects involve starts and cold operation of heavy diesels which should be accounted for in the analysis.

Engines certified to non-highway vehicle standards may have a role in some transportation project analyses. Non-road engines are used widely in transportation refrigeration units, auxiliary power units onboard vehicles, construction equipment, intermodal freight handling equipment, ships and boats, and some passenger rail vehicles (known as diesel multiple units). The models available to calculate emissions from non-highway engines are NONROAD (EPA 2005) in the 49 states except for California and OFFROAD (CARB 2006b) in California. NONROAD and OFFROAD are subject to many of the same limitations as MOBILE6.2 and EMFAC2002. The uncertainties in estimating emissions from gas turbine engines used in transportation (for aircraft, the EDMS 4.5 model (FAA 2006)) are probably larger than for motor vehicle engines, and are known to be especially large for PM.

Dispersion Modeling

Dispersion models have historically been unable to predict concentrations for a particular time and place with great reliability for short-term averages. EPA's Guideline on Air Quality Models (40 CFR 51 Appendix W) notes that for stationary source modeling:

(1) Models are more reliable for estimating longer time-averaged concentrations than for estimating short-term concentrations at specific locations (for MSATs the period of interest is usually the longer time period) and (2) the models are reasonably reliable in estimating the magnitude of highest concentrations occurring sometime, somewhere within an area. For example, errors in highest estimated concentrations of ± 10 to 40 percent are found to be typical, i.e., certainly well within the often quoted factor-of-two accuracy that has long been recognized for these models. However, estimates of concentrations that occur at a specific short-period of time and site may be poorly correlated with actually observed concentrations.

Exposure Adjustments

Using the worst-case assumption that people will be exposed to a given concentration for an entire year or an entire lifetime (70 years) grossly overestimates exposure and risk, especially for near-roadway locations. For an annual (chronic) analysis, exposure adjustment should consider: daily travel to work, school, shopping etc.; exposure while in vehicles (in-vehicle exposure to MSATs often greatly exceeds that at residences); school hours; working hours at workplaces; length of stay at hospitals or nursing homes; length of school year; and duration of tourist visits. For a lifetime or life-stage analysis, population information must be gathered on length of time at a given residence, school, or workplace. National average exposure data are now available if using EPA's exposure models APEX (TRIM.Expo) or HAPEM5 (<http://www.epa.gov/ttn/fera/>).

These adjustments do not address exposure to other sources of the same pollutants, especially indoor air where most people spend most of their time. Indoor MSAT concentrations can be higher or lower than outdoor levels depending on local outdoor conditions as well as emission sources in the building.

Dose-Response Assessment

As noted in Table E-1, extrapolation from clinical studies generates several sources of uncertainty. Human populations vary in their sensitivity to MSATs. These uncertainties, which are often quite wide, have been covered extensively in the health science literature, and are normally taken as reported by the health assessment community and used in the project-level MSAT analysis.

Associated Health Effects: Risk Characterization

The most significant limitation for project MSAT analyses is the lack of a URF for DPM. (All other priority MSATs, except acrolein, have a URF.) EPA has classified DPM as a likely

human carcinogen but has not published a formal risk estimate. California has issued a risk estimate that was used in the MATES II study and all California's AB2588 Toxic Hot-Spot Studies, but EPA and the Health Effects Institute do not believe sufficient information is available to quantify a URF. The current EPA view of risk from diesel particulate is summarized in EPA 2002 as follows:

An exploratory risk analysis shows that environmental cancer risks possibly range from 10^{-5} to nearly 10^{-3} , while a consideration of numerous uncertainties and assumptions also indicates that lower risk is possible and zero risk cannot be ruled out. These risk findings are only general indicators of the potential significance of the lung cancer hazard and should not be viewed as a definitive quantitative characterization of risk or be used to estimate an exposure-specific population impact.

To the extent that this statement reflects EPA's position on DPM, project-level DPM analyses that are subject to EPA review would be inconsistent with EPA policy if they include a full HRA. EPA has taken a similar position on HAP analysis for airport projects under NEPA (FAA 2005). EPA's position on HRA for HAPs in general is less conservative, as the RAGS document for waste sites indicates. EPA has not taken an official position on HRA for MSATs, other than DPM, for ground transportation projects. Table E-2 summarizes the error ranges associated with the various sources of uncertainty.

Table E-2 Error Ranges Associated with Analysis Tools

Type of Assessment	Approximate Error Range
Emissions	<ul style="list-style-type: none"> • On-road sources (MOBILE6.2): \pm 30-50% depending on pollutant • Off-road sources except aircraft (NONROAD): Error similar to MOBILE6.2 • Gas turbine sources (aircraft in EDMS 4.5): Greater error than MOBILE6.2; error is largest for PM
Ambient Concentrations: Dispersion Models	<ul style="list-style-type: none"> • Plus or minus a factor of two
Exposure (if no adjustments are made for exposure)	<ul style="list-style-type: none"> • 24-hour: up to a factor of 2-3 (overpredict); some situations may underestimate • Annual: factor of 3-4 (overpredict); some situations may underestimate • 70 year: factor of 10 (overpredict) for most situations
Risk factors (RfC and RSDs)	<ul style="list-style-type: none"> • Safety factor of 10 for volatile organic MSATs • Safety factor of 100+ for DPM (70-year risk for on-road DPM)

Estimating Uncertainty

An ideal approach to estimating uncertainty would follow the tracking of uncertainty for each step as it propagates through the risk analysis as shown in Table E-1. This bottom-up approach using probability distributions as suggested by both CalEPA (2003) and EPA (1989) would provide a quantitative analysis and be based on a rigorous analytical approach. However, such an approach would demand a large amount of information, time and resources as well as highly skilled analysts, making such an approach infeasible. An alternative approach may be used based on a top-down methodology. In this approach a comparison may be made between the modeled results and monitored results to evaluate the relative uncertainty through the exposure assessment step.

This top-down approach was used in the most recent National Air Toxic Assessment (NATA) study to provide an estimate on the uncertainty associated with the NATA study (EPA 2006). The assessment found that for the key MSAT pollutants, good agreement was found

between observed and modeled concentrations (Table E-3). Both benzene and acetaldehyde had nearly half their values within 30% of the observed and nearly three-fourths within a factor of two. However, there was a small tendency to underestimate concentrations, which would result in an underestimation of exposure and risk. This same approach was used in the Portland Air Toxic Assessment (PATA 2005), which involved a metropolitan-wide assessment of air toxics. The study included five mobile source air toxics and found significant variation between modeled to monitored values by pollutant. The best agreement was found for benzene, which showed an overprediction bias ranging from 40 to 90%³⁸ with a slightly higher range for 1,3-butadiene. The results for POM showed an underprediction bias ranging from nearly 0 to 70% (Table E-4).

A similar approach to estimating model uncertainty could be applied when conducting an MSAT analysis at the project level if monitored data are available. The approaches used in the PATA and NATA assessments provide upper bounds on the range of uncertainty as a project-level assessment would more than likely have better and more detailed information on emissions and roadway geometry, along with air quality models specifically focused on modeling dispersion from traffic³⁹.

Table E-3. 1999 National Air Toxic Assessment (NATA) Modeled to Monitored Concentrations for Available MSAT Pollutants.

Pollutant	Number of sites	Median of Ratios	Within Factor of Two	Within 30%	Underestimated
Acetaldehyde	68	0.92	74%	44%	56%
Benzene	115	0.95	72%	43%	52%
Formaldehyde	68	0.64	60%	28%	76%

³⁸ The benzene emissions factor used in the PATA study for residential wood combustion was recently updated and was substantially lowered so these overprediction bias are for the non heating season (June-August) when residential wood combustion is minimal.

³⁹ Isakov and Venkatram (2006) concluded in their neighborhood scale study of Wilmington, CA that improved local traffic and activity data for road links in an air quality modeling domain will substantially reduce uncertainty in ambient concentrations.

**Table E-4. Annual Average Portland Air Toxic Assessment (PATA) Concentrations
Derived from Available Measurements and Modeled Concentrations.**

Pollutant	Site	Monitored Concentration	CALPUFF Prediction		Model-to-Monitor Ratios*
		Mean	At Site	Within 4 Km of Site	Mean
1,3-Butadiene	Beaverton	0.11	0.31	0.30	2.6
	Downtown	0.19	0.84	0.35	1.8
	N Roselawn	0.14	0.23	0.29	2.0
	NW Post Office	0.14	0.37	0.38	2.6
	SE Lafayette	0.14	0.23	0.27	1.8
Acetaldehyde***	Beaverton	1.9	0.7	0.6	0.3
	Downtown	3.0	2.2	1.0	0.3
	N Roselawn	2.4	0.5	0.6	0.3
	NW Post Office	2.1	0.7	1.1	0.5
	SE Lafayette	2.0	0.5	0.5	0.3
Benzene** (June-August)	Beaverton	1.1	2.2	2.2	1.9
	Downtown	1.9	5.4	2.7	1.4
	N Roselawn	1.4	1.9	2.1	1.4
	NW Post Office	1.4	2.8	2.7	1.9
	SE Lafayette	1.5	2.1	2.3	1.5
Formaldehyde***	Beaverton	1.9	1.5	1.5	0.7
	Downtown	3.8	4.7	2.2	0.6
	N Roselawn	3.2	1.4	1.7	0.5
	NW Post Office	2.5	1.6	2.4	0.9
	SE Lafayette	2.4	1.4	1.5	0.6
POM** (as 16-PAH) (June-August)	Beaverton	0.012	0.014	0.012	1.0
	Downtown	0.061	0.115	0.020	0.3
	N Roselawn	0.024	0.010	0.014	0.6
	NW Post Office	0.055	0.016	0.022	0.4
	SE Lafayette	0.023	0.010	0.011	0.5

* Ratios of CALPUFF annual average concentration from receptors within 4 km of the monitoring site to the average monitored concentration.

** Emission factors for benzene and POM from residential wood combustion were found to be overestimated based on outdated residential wood combustion information. Since residential wood combustion is at a minimum during summer months modeled to monitored results were compared to the third quarter (June-August).

*** CALPUFF predictions for acetaldehyde include the primary component only, and for formaldehyde include the primary and background components only.

Major sources of uncertainty in the cancer risk estimates can be summarized as follows:

- 1) The number and quality of the supporting human and animal studies that are used to characterize dose-response relationships. Some MSATs are known to be carcinogens in animals but lack data in humans. In these cases, the MSATs have been assumed to be human carcinogens.
- 2) According to EPA's cancer risk assessment guidelines, in the absence of evidence indicating non-linear dose-response for a given compound air toxics are assumed to have linear relationships between exposure and the probability of cancer (i.e., effects at low exposures were extrapolated from higher, measurable exposures by a straight line).
- 3) Estimates of cancer risk are considered to be best estimates of cancer risk (those based on human data); others are "upper bound" estimates (usually based on animal data but sometimes based on human data). In the former case, the estimate of risk is equally likely to overestimate risk as underestimate risk. In the latter case, the estimate is more likely to overestimate risk. Most, but not all, of the cancer risk estimates that EPA develops are "upper bound" estimates. However, EPA cancer risk estimates for benzene are "best estimates."

Estimates of uncertainties vary with each MSAT pollutant and are continually updated as part of the ongoing science of air toxics. From a national perspective, the best source of information documenting the uncertainties is EPA's IRIS database (<http://www.epa.gov/iris/>). Each MSAT can be reviewed for the latest information on Unit Risk Level (URL) as well as the

associated discussion on confidence in the URL. Providing a discussion on the confidence of the URL in NEPA documents will provide perspective on the associated risk to reviewers⁴⁰.

Major sources of uncertainty in the non-cancer risk estimates can be summarized as follows:

- 1) Sources of uncertainty in the development of Reference Concentrations (RfCs) generally are intraspecies extrapolation (animal to human) and interspecies extrapolation (average human to sensitive human).

- 2) Additional sources of uncertainty can come from using a lowest-observed adverse effect level in place of a no-observed adverse effect level (the latter is preferred)⁴¹.

The above uncertainties are taken into account in the derivation of the RfCs. Estimates of non-cancer uncertainties vary with each MSAT pollutant and are continually updated as part of the ongoing science of air toxics. From a national perspective, the best source of information documenting the uncertainties is EPA's IRIS database (<http://www.epa.gov/iris/>). Each MSAT can be reviewed for the latest information on Reference Concentrations (RfC) as well as the associated discussion on the confidence in the RfC. A discussion on the confidence of the RfC in NEPA documents will provide perspective on the associated risk to reviewers.

⁴⁰ Note that focusing on the health end points upon which the URL are based introduces uncertainty associated with unquantifiable risks, such as underweight birth associated with maternal PAH inhalation exposures during pregnancy (e.g., Perera et al., 2002-2006), and a variety of near-roadway health effects from epidemiology studies with non-specific exposure indices, may be relevant here, but at present unquantified.

⁴¹ The lowest-observed adverse effect level represents a level at which adverse effects are first observed a more health protective value is a concentration at which no observed adverse health effects are observed.

Example of an Uncertainty Discussion for Cancer Risk ⁴²

Project Example: A 4-through lane (both directions) urban arterial operating at LOS D during the peak hour, with an anticipated 12% heavy-duty diesel vehicle fleet fraction during the base year of 2010.

Analysis of the intersection finds that the peak total volume during the 2010 base year is estimated at 2,964 vehicles per hour. A proposed action is to improve signal cycle synchronization along this corridor and expand the roadway to 6-through lanes. Analysis of this action finds that through the improved synchronization and additional lanes, idle queue lengths are reduced, traffic progression is improved, and a small improvement occurs in the average speed resulting in overall reduced emissions (particularly from idle) at the intersection and reduced stop delay (but with increased traffic volume).

A quantitative MSAT analysis of the proposed action using air dispersion modeling finds that principal risk drivers are for the air toxics benzene and 1,3 butadiene and that their maximum receptor concentrations are $2.9 \mu\text{g}/\text{m}^3$ and $0.47 \mu\text{g}/\text{m}^3$, respectively. The upper-end IRIS URL for benzene ($7.8\text{E-}06/\mu\text{g}/\text{m}^3$) would yield a cancer risk of 23 per million population and the upper-end IRIS URL for 1,3-butadiene ($3.0\text{E-}05 \mu\text{g}/\text{m}^3$) would yield a cancer risk of 14 per million population. Reviewing the IRIS database shows that the low end URL for benzene ($2.2\text{E-}06 \mu\text{g}/\text{m}^3$) would assess the benzene risk at 6 per million and the low end URL for 1,3 butadiene ($1.5\text{E-}05/\mu\text{g}/\text{m}^3$) would assess the 1,3 butadiene risk at 7 per million. Assuming that the cancer endpoints are additive, the cancer risk range would range from 13 to 37 per million. These ranges would represent the range of equally probable risk values with the more likely risk falling near the

⁴² Discussion does not include uncertainty associated with project-level and regional traffic modeling tools as these are generally smaller than the uncertainty associated with the URL, however additional analysis and discussion could include: use of default speed curves and associated parameters (e.g. capacity) as well as the uncertainty associated with the projected traffic properties (e.g., project traffic volume, %truck).

middle of these ranges. The cancer risk of the project could then be prepared with the no action alternative demonstrating whether the proposed action will increase or decrease risk.

Example of an Uncertainty Discussion for Non- Cancer Risk

Project Example: A travel plaza and truck stop facility with some 200 overnight parking spaces used primarily by long-haul heavy-duty diesel trucks.

On average the travel plaza has about 40 heavy-duty diesel trucks idling during the overnight hours (10 pm to 6 am) and 25 during the remainder of the day. A proposed action is to significantly expand the facility to allow up to 700 overnight parking spaces. It is estimated that the number of idling trucks overnight will increase to an average of 130 and during the day to about 90. Analysis of the action finds that the facility will exceed 750 idle hours per day and that a quantitative assessment is needed for non-cancer health effects.

A quantitative non-cancer health effects analysis of the proposed action using air dispersion modeling finds that the nearest offsite receptor has a diesel PM maximum concentration of $11.2 \mu\text{g}/\text{m}^3$. The RfC for diesel PM is $5 \mu\text{g}/\text{m}^3$. Reviewing the IRIS database⁴³ shows that the highest human equivalent dose associated with no apparent effect (NOAEL) is $144 \mu\text{g}/\text{m}^3$. To obtain the RfC the NOAEL was divided by two types of uncertainty factors: a factor of 3⁴⁴ recognizing residual interspecies (i.e., rat to human) extrapolation uncertainties and a factor of 10 reflecting uncertainties⁴⁵ about inter-individual human variation in sensitivity. The non-cancer health effect for the project could then be compared with the no action alternative demonstrating how the action will potentially increase non-cancer health effects.

⁴³ USEPA's Integrated Risk Information System: <http://www.epa.gov/IRIS/subst/0642.htm#refinhal>

⁴⁴ The use of 3, the full amount of this uncertainty factor addressing only interspecies differences in pharmacodynamics, is supported by several studies suggesting that humans may be as sensitive or somewhat more so than rats for respiratory tract inflammation.

⁴⁵ In the absence of mechanistic data, a default value of 10 is considered appropriate to account for possible human variability in sensitivity, particularly for children and people with preexisting respiratory conditions. The spectrum of the population that may have a greater susceptibility cannot be better characterized until there is additional knowledge about mode of action.

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