NCHRP 25-25 Task 78

Programmatic Agreements for Project-Level Air Quality Analyses

Prepared for:

American Association of State Highway and Transportation Officials
Standing Committee on Environment

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September 2015

The information contained in this report was prepared as part of NCHRP Project 25-25, Task 78, National Cooperative Highway Research Program.

Acknowledgments

This study was requested by the American Association of State Highway and Transportation Officials (AASHTO), and conducted as part of the National Cooperative Highway Research Program (NCHRP) Project 25-25. The NCHRP is supported by annual voluntary contributions from the state Departments of Transportation. Project 25-25 is intended to fund quick response studies on behalf of the AASHTO Standing Committee on the Environment. The report was prepared by Edward Carr, Seth Hartley and Autumn Bordner from ICF International, Inc.; John Zamurs from ZAMURS AND ASSOCIATES, LLC; Roger Wayson from Wyle Aerospace Group; and George Noel from Volpe Transportation Systems Center. The work was guided by a task group chaired by Tim Sexton, Minnesota Department of Transportation, which included Michael J. Brady, California Department of Transportation(retired); Patrick Lentlie, New York State Department of Transportation; Jackie Ploch, Texas Department of Transportation; Dr. Jane Lin, University of Illinois at Chicago; Patricia Trainer, Wisconsin State Department of Transportation; Christopher Voigt, Virginia Department of Transportation; Walt Zyznieuski, Illinois Department of Transportation(retired); Emily Biondi, Federal Highway Administration; Adam Stephenson, Federal Transit Administration; and Meg Patulski, U.S. Environmental Protection Agency. The project was managed by Nanda Srinivasan and Crawford Jencks, National Cooperative Highway Research Program (NCHRP), Transportation Research Board of The National Academies.

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Executive Summary

The research performed under Task 78 was divided into two phases. The first phase involved development of a draft Programmatic Agreement (PA) template and a draft Technical Support Document (TSD) template for project-level carbon monoxide (CO) hot-spot analysis. The second phase consisted of development and exploration of future research areas.

Phase 1: Examination of current state DOT air quality analysis procedures and programmatic agreements

The first phase of research began with an examination of current state DOT air quality analysis procedures and PAs. This research was undertaken to identify the best attributes of existing state DOT PAs and air quality analysis procedures for incorporation into the draft template PA for CO.

Regarding state DOT air quality analysis procedures, it was found that:

- In general, there are two types of project level CO guidance. Most of the procedures reviewed provide protocols and/or input defaults, to varying degrees, for all the elements of the modeling process. A small, but non-trivial, number of the reviewed procedures provide protocols on project conditions that would trigger an analysis, but do not provide protocols on modeling parameters. These triggers typically relate to traffic conditions or roadway changes that would result from a proposed project. If an analysis is deemed necessary, then coordination occurs among traffic and air quality analysts and other involved agencies and parties.

- Some procedures recognize and discuss requirements related to EPA's Motor Vehicle Emission Simulator (MOVES), though few provide specific inputs for MOVES.

- All the procedures reviewed focus on CAL3QHC for dispersion modeling. There is a wide variety in the level of detail of the guidance provided for CAL3QHC inputs. Although a few procedures discuss the AERMOD modeling system, none provide specific guidance on AERMOD inputs.

- The greatest variation across state procedures is in the specification of triggers that determine a need for an air quality analysis. The triggers are generally project-related across all procedures, but tend to focus on different aspects of the project. Even across procedures that have the same trigger, such as traffic volume (hourly, average daily traffic (ADT), or annual average daily traffic (AADT)), there is significant variance in what traffic levels require a CO hot-spot analysis.

- Many state procedures focus on intersections and require an analysis if the level of service (LOS) is D or worse, or will degrade to D or worse as a result of the project. Some of these procedures also have a secondary trigger based on traffic volume increase.

- The most common analysis year is the opening year (also known as the project completion year). The majority of procedures also look at additional years. The most common additional analysis year is the design year.

- For states that do have detailed procedures, “worst-case” CAL3QHC inputs are usually used. Temperature inputs reflect typical January conditions and vary substantially from state to state. Temperature inputs can also vary substantially within a state.

Regarding existing state DOT PAs, three states (Colorado, South Carolina and Virginia) currently have PAs that are specific to air quality. Many other state PAs exist, but are typically designed to standardize and provide certainty for the National Environmental Policy Act (NEPA) and/or state environmental review processes. These agreements mention air quality, among other environmental concerns, but do not provide specifics about the air quality analysis and modeling process. Virginia’s PA was ultimately selected as a model for the draft template PA because it is specific and technical to air quality, applicable to a wide range of project types and conditions, and can be tailored to NEPA or state environmental requirements.

The modeling information extracted from the state DOT air quality analysis procedures and PAs were used to develop modeling scenarios for four project types that are frequently encountered by state DOTs and modeled as part of the environmental review process. These project types are:

- Intersections
- Arterials
- Freeways
- Interchanges

These modeling scenarios build upon the analysis that was conducted for the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* (February, 2014)[1], which analyzed urban intersection projects. This research broadens the FHWA study to include additional project types (arterials, freeways and interchanges) and analyzes both urban and

[1] See: http://www.fhwa.dot.gov/environment/air_quality/conformity/policy_and_guidance/cmcf/

rural conditions for each project type. The number of lanes, vehicle speeds and roadway grades were varied for each project type in order to define specific project conditions that would meet the ambient air quality standards for CO. The model inputs and analytical assumptions are conservative in order to yield results that are applicable nationwide (and therefore, applicable to all state DOTs). For example, conservative assumptions about CO background levels, vehicle volume and fleet mix, fuel parameters, and inspection/maintenance programs were used.

Included in the Final Report are tables that document the project conditions: urban/rural, number of lanes, vehicle speeds, and roadway grades, under which the four project types could not exceed the ambient CO standards. A wide range of project conditions met the ambient CO standards for each of the four project types modeled. There were a greater number of project conditions that met the CO ambient standards under urban conditions than rural conditions, due to greater turbulent mixing, and therefore reduced concentration in urban environments. It should be noted that for the arterial and freeway cases both eleven and twelve-foot lane widths were modeled with no significant difference in the results.

Phase 2: Identification of research areas for Programmatic Agreements on PM and MSATs

The second phase of the research involved identifying future research areas, particularly areas that would aid in developing PAs for MSAT and/or PM analyses. It is recognized that less is known about analyzing these pollutants than about analyzing CO. There are also more technical and analytical challenges associated with the analysis of these pollutants than with the analysis of CO. Embarking on research in the areas identified by this study would likely provide knowledge to help overcome these obstacles. The six research areas that were explored are detailed below:

1. *Examination of projects for which PM hot-spot assessments were conducted*. Most users conducting a PM hot-spot assessment as part of a NEPA study follow EPA's *Transportation Conformity Guidance for Quantitative Hot-spot Analyses in PM2.5 and PM10 Nonattainment and Maintenance Areas* (Transportation and Climate Division Office of Transportation and Air Quality U.S. Environmental Protection Agency, EPA-420-B-13-053, November 2013)[2]. It may be useful to learn further about such projects and the methods they used to analyze PM emissions. Likewise, it would be valuable to examine projects that have engaged in developing emissions estimates for MSATs. The findings of these studies may inform development of PAs for MSAT and PM analyses.

2. *Understanding the evolution of PM emissions over time.* There has been a 90% reduction in diesel PM emissions since the introduction of post-2006 diesel truck engines. Given this, as well as the Tier 2 and Tier 3 gasoline PM emission reductions standards (30 ppb sulfur in gasoline in 2017), it would be worthwhile to explore how PM emissions have

[2] Updated November, 2013. Available at: http://www.epa.gov/otaq/stateresources/transconf/projectlevel-hotspot.htm#pm-hotspot

changed in terms of the highway traffic volumes that often trigger a quantitative analysis.

3. *Understanding the evolution of MSAT emissions over time*. Large reductions in MSAT emissions, particularly diesel PM emissions, have occurred in recent years. A more complete picture of how MSAT emissions have changed and will continue to change in both quantity and source over past, current and future years would be a useful insight for development of a PA for MSATs.

4. *Examination of existing guidance for PM hot-spot analysis.* EPA's current PM hot-spot guidance[3] for a quantitative analysis identifies a 9-step process to determine the conformity of a project. Under NEPA, the approach may be simplified if it can be demonstrated that a particular approach or dataset provides results comparable to those of the prescribed methodology. The research objective is to identify the elements of this 9 step process that will likely show the greatest gains in flexibility with the least increase in conservatism. These elements may inform the conditions under which a project-level analysis for PM would not be warranted for purposes of NEPA in a PA.

5. *Development of a "reference case library" that advances a standard set of inputs of meteorology and land-use data, as well as different project facility types and traffic volumes.* Such a library could serve as guidance and as a QA/QC check for future analyses.

6. *Application of the draft PA and TSD for CO to development of state-specific PAs for CO.* This will identify and address issues with development and implementation of PAs from the template to be used by state DOTs. The research would encompass the entire process of PA development, from start to implementation. Lessons learned from this research could also be used to inform the process of state-specific PA development and implementation for MSATs and PM.

[3] EPA's Transportation Conformity Guidance for Quantitative Hot-spot Analyses in PM2.5 and PM10 Nonattainment and Maintenance Areas (Updated November, 2013). Available at: http://www.epa.gov/otaq/stateresources/transconf/projectlevel-hotspot.htm#pm-hotspot

Introduction and Purpose for the Research

1.1 Background and Need for Research

State DOTs may perform project-level air quality analyses under NEPA for CO, PM_{10}, $PM_{2.5,}$ and/or MSATs. Which pollutants are analyzed depends upon a number of factors including: project scale, project location, project scope, issues identified under scoping, public and community concerns, nearby pollutant sources, etc. Some project-level analyses may only consider only one pollutant, while others address all of the above-mentioned pollutants.

State DOTs have been performing CO project-level hot-spot analyses for several decades and have a good understanding of the technical and modeling aspects of this type of analysis. Due largely to substantial reductions in CO emissions from vehicles as a result of the Federal Motor Vehicle Emissions Control Program, few transportation project air quality analyses predict that projects will result in exceedance of applicable CO ambient air quality standards. On the other hand, particulate matter and MSAT analyses at the project-level are relatively new and present a number of technical and modeling challenges not associated with CO. Newly developed models for MSATS and PM further add to the complexity of project-level air quality analyses.

NEPA project-level air quality analyses provide an opportunity for greater flexibility in analytical approaches than do project-level transportation conformity requirements in nonattainment and maintenance areas. However, many state DOTs follow federal guidance, including EPA transportation conformity guidance, when analyzing potential project-level impacts under NEPA. The federal guidance includes: *Transportation Conformity Guidance for Quantitative Hot-Spot Analyses in* $PM_{2.5}$ *and* PM_{10} *Nonattainment and Maintenance Areas*(Transportation and Climate Division Office of Transportation and Air Quality U.S. Environmental Protection Agency, EPA-420-B-13-053 November 2013; *Using MOVES in Project-Level Carbon Monoxide Analyses*(EPA-420-C-10-041, December 2010); *Guideline for Modeling Carbon Monoxide from Roadway Intersections*(U. S. EPA, EPA-454/R-92-005, November 1992); *Interim Guidance Update on Mobile Source Air Toxic Analysis in NEPA* (Federal Highway Administration, November 2013). These guidance documents are generally considered state-of-the-art, technically sound and complete. Nevertheless, under some conditions (e.g. a PM analysis in an attainment area) there may be an opportunity to streamline or simplify certain aspects of a project-level air quality analysis, rather than adhering strictly to guidance written to assist with meeting the transportation conformity requirements.

Two cost-effective methods to reduce the substantial burden of project-level analyses are to rely on programmatic agreements (PAs) and FHWA's categorical findings (CFs). PAs apply for purposes of NEPA and are established between a state DOT and its corresponding FHWA Division Office, which coordinates as appropriate with the FHWA Headquarters. In some states, regional or local transportation agencies (e.g., Metropolitan planning organizations) and/or air quality agencies can also be party to the PA in those parts of the state where they have particular interests or play a role in project approval. PAs for air quality may be based on studies detailed in a technical support document (TSD) that presents modeling scenarios showing compliance for a wide variety of project types and operating conditions, typically for conservative or worst-case conditions. Projects may then be cleared for purposes of NEPA without project-specific modeling if the technical criteria identified in the TSD and specified in the PA are met. PAs offer state DOTs the opportunity for flexibility in project-level air quality analysis (subject to appropriate agreement amongst relevant agencies), while maintaining a sufficient degree of conservatism in the analysis. PAs also reduce costs by eliminating unnecessary analyses; enhance efficiency and certainty in the in the environmental review process; and help ensure reasonable project scope and scheduling.

The CF, on the other hand, was issued by FHWA and broadly defined project types for which hot-spot analyses for a specific pollutant are unnecessary. Per the transportation conformity rule at 40 CFR 93.123(a) (3), FHWA made a CO categorical hot-spot finding for urban highway projects that include one or more intersections in CO maintenance areas.[4] Pursuant to this finding, project sponsors may be able to rely on the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding (FHWA, February 2014)* in place of conducting their own CO hot-spot analysis as part of a project-level conformity determination in CO maintenance areas.

Both the PAs and CFs serve to streamline the environmental process, minimizing the number of projects (particularly small projects, i.e., ones of limited scope) that would otherwise be subject to project-specific modeling.

The research presented in this document was designed to build on the worked completed as part of the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* (Federal Highway Administration, February 2014) by expanding to other configurations and conditions; providing a useful template for PAs; and presenting findings in a convenient document for state DOTs and other stakeholders to use.

In addition, this project served as an opportunity to identify future research needs for PM and Mobile Source Air Toxics (MSATs) analyses. While the process for CO modeling is well defined and CO analyses have been conducted for more than 20 years, PM modeling is a relatively new requirement and has proven problematic for DOTs at the project-level. Careful development of protocol for project-level analysis of these pollutants is needed, particularly given the continuing air quality attainment problems associated with PM and the growing concerns about

[4] Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding, February 2014. http://www.fhwa.dot.gov/environment/air_quality/conformity/policy_and_guidance/cmcf/hotspot_finding.cfm After the release of this document which was based on MOVES2010, EPA released MOVES2014, FHWA is working on preparing an update to this document based on MOVES2014. During the two-year grace period a project sponsor may continue to rely on the categorical finding for applicable projects that are determined through interagency consultation to be covered by the finding's parameters. New CO hot-spot analyses for conformity purposes begun after the end of the grace period (October 7, 2016) may not rely on the February 2014 CO categorical hot-spot finding because the finding was based on MOVES2010.

air toxic health risks. Exploration of the research areas identified in this project likely will help overcome some of the challenges related to PM and MSAT project-level analyses.

1.2 Research Objectives

The focus of this research was to develop a template PA and TSD for CO. Because CO analysis can be performed using a "worst case" approach, a broad range of project types and worst case modeling inputs were assessed with the objective that state DOTs could then avoid performing unnecessary CO analyses under NEPA. Except in the most extreme cases, the PA template may eliminate the need for future project-specific hotspot analyses for CO. The templates developed from this research can serve as the baseline set to which states can expand or add additional information based on their specific needs.

The objective for PM and MSATs was to outline potential research areas that would support NEPA analyses and help in developing PAs for MSATs and PM. The objective was also to provide approaches for streamlining air quality analyses and to support development of necessary data inputs for emissions and air quality modeling.

1.3 Report Contents

Section 2 of the report provides an overview of the current state of practices for project-level analysis. The findings in this section are based on a review and discussion with sixteen state DOTs that provide procedures for conducting project-level analyses, beyond federal guidance.

Section 3 summarizes the results and findings from current research on project-level air quality analysis**.**

Section 4 describes the emissions and air quality modeling used in the development of a PA for CO project-level analyses. It details the process of a project-level analysis exploring four different project settings: intersections; freeways; arterials; and interchanges, using conservative emissions and worst-case meteorological conditions to predict reasonable and foreseeable maximum CO concentrations.

Section 5 presents a summary of, and recommendations for, additional research related to PAs.

Appendix A provides state CO Project-Level Parameters.

Appendix B provides a template that can be used to develop a state PA.

Appendix C provides a template that can be used to develop a state TSD.

Current State DOT Air Quality Practice for Project-Level Analysis

In order to gain an understanding of current project-level air quality practice, a review of selected state DOT air quality analysis procedures was performed. The research team selected, for procedural review, states that are active in the transportation air quality arena and are therefore likely to have well-developed air quality procedures. The research team used the following factors to identify states for review:

- State DOT representation on NCHRP 25-25 Task 78's review panel. Participation in this review panel suggests that states have air quality issues and procedures in place to address these issues.

- States whose DOTs expressed air quality concerns in discussions during FHWA's "Every Day Counts" workshops.

- States that have maintenance areas for carbon monoxide (CO) and/or nonattainment areas for one or both particulate matter criteria pollutants.

- States that have previously participated in the American Association of State Highway and Transportation Officials (AASHTO) Center for Environmental Excellence's Air Quality Communities of Practice.

Based on these criteria, the research team identified 21 states for consideration. The research team assessed information related to air quality analysis posted on each of the selected states' DOT website. Some state DOTs were then contacted by telephone to address follow-up questions, fill in missing information, and/or verify that the procedures posted on their website were up-to-date.

Five of the 21 selected states did not have published CO procedures. In these states, CO analyses rarely need to be performed for various climatological, administrative, or procedural reasons. If a CO analysis becomes necessary, the analysts, air quality staff, and other agencies or parties collaborate on the analysis approach and inputs. Most defer to federal guidance for direction. Sixteen states were found to have project-level air quality analysis procedures on performing a CO hot-spot analysis in their state.

2.1 Procedures: Findings and Observations

The research team prepared a spreadsheet with column headings for relevant modeling input parameters, including traffic; background; and meteorological conditions for the 16 states found to have project-level air quality analysis procedures. As each state's procedures were reviewed and examined, the spreadsheet was populated with available information from their reported procedures. This allowed the research team to identify commonalities and distinctions among the various state air quality analysis procedures. Appendix A provides a compilation of this information for all sixteen states. Table 2.1 displays the parameters for which each of the

16 State DOTs provides procedures for project-level CO analysis. This information is current through mid-2014.

Based on review of state air quality procedures and conversations with DOT air quality staff from several states, the research team drew the following conclusions:

- The CO analysis procedures vary substantially across states. Much of this variation reflects the differences in climatic and meteorological conditions across states, particularly related to temperature and background concentrations.

- In general, there appear to be two distinct types of project-level CO procedures. The majority of the procedures provide protocols and/or input defaults, to varying degrees of detail, for all the categories of the modeling process (traffic volumes, vehicle speeds, fuel type, inspection/maintenance program, meteorology, background concentrations, persistence factor, receptors, etc.). A small, but non-trivial, subset of the reviewed procedures provide protocols on project conditions that would trigger a possible analysis, but do not provide protocols on modeling parameters. These analysis triggers typically relate to traffic conditions or roadway changes that would result from a proposed project. When an analysis is deemed necessary, coordination occurs among traffic and air quality analysts and other involved agencies and parties to determine appropriate procedures to follow.

- Some procedures recognize and discuss the requirements related to EPA's Motor Vehicle Emissions Simulator (MOVES). However, no information is provided on specific inputs that are unique to MOVES. For example, of the procedures that were reviewed, only Illinois' procedure provides information related to road grade, an important variable in MOVES for determining emissions at the project-level. Most procedures reflect MOBILE6.2 (or earlier versions of MOBILE).

- All of the procedures reviewed were CAL3QHC based for dispersion modeling. There was a wide variety in the level of detail provided for CAL3QHC inputs. Some procedures covered the basics (e.g. meteorological variables) of the model, relying on traffic studies or traffic analysts for some of the traffic variables. Other procedures provide default values for every CAL3QHC input. The refined version of CAL3QHC, CAL3QHCR, typically is not discussed. States generally complete analyses with CAL3QHC and only make use of the refined version if compliance with the CO standards explicitly requires a refined assessment. Although a few protocols discussed AERMOD, none provided specific information on AERMOD inputs. California uses the CALINE4 dispersion model for CO hot-spot assessments[5].

[5] CALINE4 is an updated and expanded version of the CALINE3 model developed by the California Department of Transportation, and is accepted by EPA only for CO modeling use in California. CAL3QHC and CAL3QHCR are also based on CALINE3, but have been more extensively developed by EPA and are used outside of California when line-source dispersion modeling is done if AERMOD is not used.

Table 2.1 - Summary of State CO Project-Level Parameter Specification

	CA	TX	WA	VA	NY	IL	WI	CO	PA	UT	MN	ID	FL	TN	GA	NC
Year (s)	•	•	•	•	•	•			•	•	•	•	•	•	•	•
Traffic Volume (VPH)	•	•	•		•	•	•	•		•	•		•		•	•
Av. Speed (mph)	•	•		•								•	•		•	•
Peak Speed (mph)			•		•						•					
Link Length (m)	•	•			•											
Vehicle Mix	•	•		•	•	•										
Operating. Conditions/ Cold Starts (%)	•			•	•	•	•			•		•				
Temp (F)	•			•	•	•	•		•	•			•			
Background CO (ppm)	•	•	•	•	•	•	•	•	•	•	•	•	•			
Future Background CO	•			•	•		•			•						
Persistence Factor	•	•		•	•	•			•	•		•	•			
Roughness length (m)	•			•	•	•	•			•		•	•			
Stability (A-F)	•	•		•	•	•	•		•	•		•	•			
Wind Speed (m/s)	•	•		•	•	•	•	•	•	•		•	•			
Wind Direction (deg)	•	•		•	•	•	•		•	•		•	•			
Source Height					•		•	•		•		•	•			
Mixing Height (m)	•	•		•	•	•	•	•	•	•		•	•			
Source Receptor Distance (m)	•	•	•	•	•	•			•	•	•	•	•			
Other Receptor Siting Guidance	•				•							•	•	•		
Receptor Height (m)	•			•	•	•	•	•	•	•		•	•			
Grade %																
Level of Service (A-F)	•		•	•							•					
Facility Type	•	•	•	•	•	•	•	•	•	•		•	•	•	•	•
I/M Program	•			•	•	•	•			•			•			

- The greatest variety among state procedures is in the triggers that determine the need for an air quality analysis. Triggers are project related but focus on different aspects of the project. The procedures that have a traffic volume trigger (hourly average daily traffic (ADT) or annual average daily traffic (AADT)) vary widely in terms of traffic levels necessary to trigger a CO hot-spot analysis, from 39,000 to 140,000 vehicles per day[6].

- Many state procedures focus on intersection projects. In general, analyses are triggered if the level of service (LOS) is D or worse, or degraded to be D or worse. Some procedures also have a secondary trigger based on traffic volume increase, while still others trigger a potential CO analysis based solely on traffic levels. Some procedures distinguish between intersections and highway facilities with separate triggers for each type of facility. Others include parking facilities, in addition to intersections and highways. One approach looked at a range of design or operational changes that could increase emissions and/or concentrations at receptors.

- Most states consider at least two analysis years. The most common analysis year is the project completion year (also known as opening year). Most states also look at an additional year beyond the opening year, most commonly the design year. Many states consider a third analysis year, most frequently an intermediate year between the project completion year and the design year.

- In states that do have detailed procedures for use of CAL3QHC model, “worst-case” inputs are typically used for parameters such as wind speed, mixing height, roughness length, and source height. Temperature inputs reflect typical January conditions and vary substantially from state to state. Temperature inputs can also vary substantially within a state.

- EPA’s recommended national default value for persistence factor, 0.7, is widely used. Some states do vary the value of persistence factor, typically based on land use (urban versus rural) or region within the state.

- New York applies “rollback” to CO background concentrations to account for future emission standards and traffic levels.

- Several states reported that they are awaiting the outcome of this study to determine if, and how, to update their procedures.

Below are short summaries of each reviewed state’s procedures. More detailed information may be found in Appendix A.

California – California has detailed procedures for conducting a CO hot-spot analysis. The procedures detail assumptions and defaults to be used for the analysis. Due to the diversity of

[6] Note: These lower values were in some cases determined more than ten years ago and would more than likely benefit from updated CO emission factors.

meteorological and atmospheric conditions within the state, defaults and assumptions vary by land use and/or region. The procedures consider intersections but also specify a percentage increase in traffic volumes that could trigger an analysis. California is the only state that has the potential to use an atmospheric stability of G. The procedures allow for persistence factor to be as high as 0.8. California now has a version of hot-spot analysis procedures that uses the CT-EMFAC 5 model, which is currently under review by EPA for use in conformity. This version, based on EMFAC2011, includes 3 vehicle classes and speciation for MSATs.

- *Texas* – Texas has procedures that specify inputs for many important parameters for a CO hot-spot analysis. Projects that add roadway capacity and have an AADT greater than or equal to 140,000 vehicles per day are candidates for an analysis. In an analysis, the opening year and design year are considered. Texas has developed emission rate look-up tables for MOVES and uses worst-case conditions.

- *Washington* – Washington's procedures provide project conditions that could trigger a hot-spot analysis but do not include analysis specific parameters and inputs. Those parameters and inputs are determined on a project specific case-by-case basis. Typical default assumptions are used when appropriate.

- *Virginia* – The Virginia DOT implemented a programmatic agreement with FHWA in 2009 for project-level air quality studies for CO. The agreement was based on worst-case modeling using MOBILE6.2 and CAL3QHC and focused on intersections (skewed and unskewed), with the details of the modeling presented in an associated technical support document (TSD). The primary technical criteria specified in the 2009 agreement are design year ADT and skew angles, with different ADT levels applying for different intersection skew angles. Other criteria also apply. For example, project-specific CO modeling is typically expected for a project for which an environmental impact statement (EIS) is being prepared, even if the technical criteria (ADT thresholds and skew angles) specified in the agreement are met for the project.

  An update to the 2009 agreement is planned following the completion of this NCHRP study. Following this study, the Virginia DOT update will be based on the new MOVES model and incorporate road grade and additional projects types and configurations. The update will also make use of a new "Resource Document" that the Virginia DOT currently has in development. This "Resource Document" is being designed to provide a comprehensive source of data and information for the models, methods and assumptions to be applied in project-level air quality analyses for CO, $PM_{2.5}$ and MSATs. Electronic files with state-specific modeling inputs are planned to be maintained in an associated online data repository.

- *New York* – New York has detailed procedures for conducting a hot-spot analysis. Although the procedures are currently being updated, many elements of the CO analysis are expected to remain unchanged. New York has a range of "worst case" conditions, depending upon land use or region of the state. New York analyzes the year of highest emissions from among the opening year, project Estimated Time of Completion (ETC) plus 10 years (ETC+10), or the design year. For a project that might impact an intersection considered in the CO state implementation plan (SIP), the two worst case years are analyzed. New York considers a number of design and operational changes that could adversely affect CO emissions and concentrations to determine a need for a project-level analysis. It has recently adopted the federal guidance for PM hot-spots. Previously, New York used a process based on the environmental class of the project and traffic changes to determine whether a PM hot-spot analysis would be undertaken.

- *Illinois* – Illinois has detailed procedures for conducting a hot-spot analysis. It uses a screening and analysis tool: Carbon Monoxide Screen for Intersection Modeling (COSIM) for CO analyses. Illinois' procedures focus on intersections and currently use a trigger of 5,000 vehicles per hour (or 62,500 ADT) in the design year of the project to determine whether an analysis is needed. It considers four years in its analysis procedures: the base year, opening year, ten years after opening, and the design year. Many of the input parameters vary by land use and region of the state. Illinois has updated COSIM (Version 4.0) with MOVES emission factors.

- *Wisconsin* – Wisconsin has detailed procedures for conducting CO hot-spot analyses posted on the state DOT website. However, Wisconsin reports that the procedures provided on the website are outdated. Currently, Wisconsin uses the criteria of the former Indirect Source Permit requirements to determine if a project requires a CO hot-spot analysis. The criteria vary depending on whether the project is in an urban or rural area and whether it involves a new or modified highway. Wisconsin also has criteria for new and modified parking facilities, also differentiated by urban or non-urban area. If a project triggers an analysis, Wisconsin considers whether past analyses of similar projects have sufficiently shown compliance with the CO air quality standards such that analysis of the new project in unnecessary.

- *Pennsylvania* – Pennsylvania has detailed procedures for examining CO hot-spots. Highway volumes of 125,000 AADT and a LOS of D or worse at a signalized intersection in the opening or design year trigger a CO hot-spot analysis. Pennsylvania analyzes one year, preferably the opening year. If data from the opening year are not available then the design year is analyzed. Pennsylvania prefers to use data from air agency site monitors to determine CO background values. However, if no monitor is within 20 miles of the project, Pennsylvania uses default values for rural and urban/suburban project locations.

- *Utah* – Utah has detailed procedures for analyzing potential CO hot-spots. Triggers for a potential analysis include a new road on new alignment, new interchanges, new through or passing lanes, and traffic increase due to intersection or signal improvements. The average winter temperatures in each county are used to determine the "worst-case" temperature. Utah utilizes a wide range of CO background concentrations, from 1 ppm to 6 ppm (eight-hour values), depending on the region and presence or absence of an inspection and maintenance program. Utah analyzes the opening and design years.

- *Minnesota* – Minnesota uses a benchmark AADT of 79,400 vehicles to consider whether a CO hot-spot analysis is appropriate. If a project exceeds that volume, coordination occurs among interested agencies to determine if there is an actual need for analysis and, if so, the appropriate inputs and parameters for that analysis. Generally, an analysis would look at the opening year and the last year of the long-range plan. For CO background concentration, Minnesota uses values measured within the last three years within three miles of the project.

- *Idaho* – Idaho has detailed air quality analysis procedures for determining when and how to perform a CO hot-spot analysis. They focus on intersections at LOS D or worse and intersections where total traffic volume exceeds a threshold volume, which varies by year. Idaho analyzes the project completion year. Idaho assumes there are no vehicles operating in the cold-start mode in the project area because much of Idaho is rural and vehicles would likely have been driven long enough by the time they reach the project area to have "warmed up". The procedures detail a wide range of background concentrations, ranging from 9.6 ppm to 16.7 ppm for a one-hour concentration.

- *Florida* – Florida has detailed CO hot-spot analysis procedures. The procedures focus on intersections with the highest approach volumes and lowest approach speeds to determine potential hot-spot analysis locations. Florida looks at the opening and design years. The procedures assume a certain percentage of left-turning vehicles at the intersection, depending on the configuration of the intersection, and assume left-turn speeds of 20 mph. In general, Florida assumes traffic flows at the cruise speed but will use the posted speed if the cruise speed is unavailable. Florida uses a 0.6 persistence factor and a temperature range of 41-59˚F, depending on the region of the state.

- *Tennessee* – Tennessee has general criteria for when a CO hot-spot may be necessary but does not have detailed procedures as to the inputs and parameters of the analysis. Those values would be determined by discussion among the agencies that have a role in the project. The potential need for a hot-spot analysis differs depending on whether the project is in a CO maintenance or attainment area. In a maintenance area, Tennessee considers intersections that have a LOS of D or worse, or will become D or worse as a result of the project. In attainment areas, they consider intersections that have a design year ADT of 80,000 vehicles or greater and are projected to be at LOS D or worse in the opening or design year. Typically, Tennessee considers the base or design year in the analysis.

- *Georgia* – Georgia does not have detailed procedures for conducting a CO hot-spot analysis. Instead Georgia has general criteria to determine if an analysis may be needed. The actual determination is made among the agencies with an interest in the project. Projects that may be candidates for a hot-spot analysis are those that add capacity and have intersections operating at LOS D or worse. Those locations are then screened to determine if they exceed 10,000 vehicles per day. Georgia typically considers the base and design year if an analysis is done.

- *North Carolina* – North Carolina has general criteria as to when a CO hot-spot may be necessary, but does not have detailed procedures regarding the inputs and parameters of the analysis. In the event an analysis is determined to be necessary, relevant inputs and parameters would be determined by discussion among the agencies that have a role in the project. Generally, North Carolina considers the worst-case intersection in terms of volume or LOS. If an analysis is performed, the opening year, ETC+5, and the design year are examined.

- *Indiana, South Carolina, Maryland, Alaska, Arizona, Connecticut* – These states do not have published guidelines or procedures regarding CO hot-spot analyses. Instead, they rely on intra- and inter-agency coordination to determine if a project needs a CO hot-spot analysis and how that analysis should be conducted.

With regard to PM and MSATs, state DOTs generally follow applicable federal regulations and guidance, which for the latter, includes FHWA's *Interim Guidance Update on Mobile Source Air Toxic Analysis in NEPA* (Federal Highway Administration*,* , November, 2013) and EPA's *Transportation Conformity Guidance for Quantitative Hot-spot Analyses in $PM_{2.5}$ and PM_{10} Nonattainment and Maintenance Areas* (Transportation and Climate Division Office of Transportation and Air Quality U.S. Environmental Protection Agency, EPA-420-B-13-053, November 2013) [7]. Some state DOTs follow federal guidance, but have incorporated local variables and parameters to provide state specific protocols. Other states reference the federal guidance and expect to develop a state specific project-related assessment within the environmental documents for the project as it is advanced.

2.2 State DOTs having Programmatic Agreements Related to Air Quality

Many states have programmatic agreements (PAs) that describe policies and procedures the state DOT will follow with regard to NEPA, other environmental laws, and/or their state specific environmental requirements. These agreements typically include air quality among a host of other environmental topics. In these agreements, air quality is addressed through generic language such as "The action shall conform to all applicable laws, regulations, implementation plans, or other applicable federal and state air quality requirements pursuant to the Federal Clean Air Act or state law.", or "The action will not significantly impact air quality or would cause federal or state ambient air quality standards to be exceeded." Such PAs do not specify how air quality issues are to be treated, and thus they were not further considered in this study.

However, three states (Colorado, South Carolina, and Virginia) do have PAs that are specific to air quality. The PAs for these states are summarized below:

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[7] EPA's Transportation Conformity Guidance for Quantitative Hot-spot Analyses in $PM_{2.5}$ and PM_{10} Nonattainment and Maintenance Areas, Updated November 2013. Available at: http://www.epa.gov/otaq/stateresources/transconf/projectlevel-hotspot.htm#pm-hotspot

Colorado – First developed in 1980 and most recently modified in 1995, this PA is a Memorandum of Agreement (MOA) between the Colorado Department of Transportation (CDOT) and the Air Pollution Control Division (APCD) of the Colorado Department of Public Health and Environment (CDPHE). It applies to Colorado's CO maintenance areas and does not cover PM_{10}, $PM_{2.5}$, or MSATs. The agreement identifies the actions exempt from project level conformity requirements, and specifies modeling, consultation and concurrence requirements for the different levels of NEPA actions (i.e., Environmental Impact Statement, Environmental Assessments and Categorical Exclusions). It closely follows federal transportation conformity regulation regarding project-level analyses. The MOA requires use of EPA's guideline models and consistency with regional conformity analyses. It requires an analysis for intersections operating at LOS D or worse or that are anticipated to operate at LOS D or worse as a result of the project. It also applies to intersections identified in relevant SIPs. Analyses are conducted for the attainment year and the last year of the regional transportation plan. Under the agreement, a project can be considered in conformity with air quality standards when it reduces the highest violation at a receptor and does not increase the number and severity of violations in the area. A project can also be considered in conformity if it reduces the number and severity of violations in the project area in terms of public exposure to exceedances of the standard for the time period of the standard, regardless of the project's effect on the receptor with the highest violation. The MOA includes a provision for the annual review of its effectiveness and revision, as appropriate, to reflect changes in federal requirements. The form of the agreement is a one-page memorandum from the Colorado DOT to the Colorado APCD with an attachment that describes the various procedures and requirements. The memorandum is signed by the Chief Engineer for Engineering, Design and Construction for Colorado DOT and the Acting Deputy Director for the Colorado Air Pollution Control Division of the Department of Public Health and the Environment.

South Carolina – First developed in 1996 and most recently modified in 2008, this programmatic agreement concerning air quality issues is a MOA between the South Carolina Department of Transportation (SCDOT) and South Carolina Department of Health and Environmental Control (SCDHEC), and includes each of the state's MPOs, FWHA (SC office), Federal Transit Administration (FTA), EPA Region 4, and local publically-owned transit agencies not associated with MPOs in areas designated nonattainment or maintenance areas for applicable NAAQS. The MOA specifies the criteria; interagency consultation procedures; and enforceable commitments related to conformity of transportation plans, programs, and projects. The agreement specifies roles and responsibilities of each of the included agencies and closely follows the federal transportation conformity rule. With designations under the 2008 ozone NAAQS, this MOA applies only to a portion of York County designated as nonattainment for that standard (part of the Charlotte – Rock Hill nonattainment area).

Virginia - Virginia has three programmatic agreements relating to air quality that comprehensively cover project-level CO hot-spot analyses:

1. Project-Level Carbon Monoxide Air Quality Studies Agreement (2009): This agreement establishes technical criteria for determining whether project-specific modeling for CO will be needed.

2. No-Build Analysis Agreement for Air and Noise Studies (2009): This agreement provides guidance and criteria for determining whether a no-build scenario must be modeled for carbon monoxide.

3. Procedures for Updating Air Studies When New Planning Assumptions Become Available (2004): This agreement provides guidance for determining if and when an update is needed to an existing project-level analysis for CO.

The technical criteria for the 2009 Agreement for CO include both design year ADT and skew angle. The methodology is presented in a detailed TSD.

Of the three state PAs identified, Virginia's is applicable to a wide range of project types and conditions and can be tailored to NEPA or state environmental requirements. Consequently, Virginia's 2009 PA was chosen as the model for developing the draft PA and Technical Support Document (TSD) templates (described in Development of the Programmatic Agreement and Technical Support Document. These templates are included in this report as Appendices (Appendix B and Appendix C, respectively).

Key Findings from the Literature Review on Project-Level Analysis

3.1 Overview of Literature Review

The research team conducted a literature review of peer reviewed publications and grey literature, which focused on a broad scope of material including project level and hot-spot analysis for carbon monoxide (CO) and particulate matter (PM), and project level analysis for air toxics. Not reviewed here are EPA guidance documents. The review focuses principally on relatively recent studies—published within the past ten years, but also includes several older publications that warranted review because of their particular relevance and historical perspective.

Several hundred studies were initially identified, roughly a fourth of which merited a review of the abstract. Of these, twelve journal articles or technical reports were selected for detailed review. The key findings of these twelve studies are summarized below. The material is organized into two subsets: The first set of summaries provides historical perspective for project level analyses and for the framework under which they are performed. Most of these studies are based upon use of the MOBILE emission factor model or California's EMFAC model, but present information still relevant to this study. The second set of summaries focuses on more recent papers that are based upon use of the MOVES model. The review places greater emphasis on the more recent studies.

3.2 Historical Perspective

In their 1998 paper, "*Project Level Carbon Monoxide Hot-Spot Analysis for Level of Service D Intersections*", Meng and Neimeier introduce the concept of a CO screening methodology based on meteorological situation-oriented reference charts. The purpose of this methodology is to reduce the number of level of service D (LOS D) intersections that require a full hot-spot assessment. The paper reports that these reference charts can be developed for various sets of meteorological data by intersection orientation, signal type (actuated and pre-timed), and fleet characteristics. The effects of meteorological conditions and orientation are approximated by rotating a hypothetical intersection and simulating operation at LOS D using appropriate emissions, traffic volume, and signalization data. Once developed, a set of reference charts can then be used by location. The authors identify that this method, while useful, is limited by EPA's use of intersection LOS as the defining characteristic for screening CO hot-spot intersections. The main drawback is that the LOS criterion lacks an association with the physical configuration and volume of traffic traveling through an intersection. For example, a three-lane approach operating at LOS D will yield CO concentrations dramatically lower than a six-lane approach also operating at LOS D.

A study by Houk and Claggett, (2004) "*Survey of Screening Procedures for Project-Level Conformity Analyses*", presents trends for maximum CO concentrations across the US monitoring network. The study reports a 51 percent decline of the tenth highest 8-hour CO concentration, from 13.6 ppm in 1990 to 6.7 ppm in 2002[8] . The approach used in this study to estimate CO trends was adopted to estimate CO background concentrations in this study, as discussed in 4.6 Background Concentration. Houk and Claggett also compiled a summary of project-level CO screening procedures that used innovative practices to develop advanced project-screening protocols. However, most of the screening level procedures addressed in the study have since been updated or superseded. The screening level procedures currently employed are described in Current State DOT Air Quality Practice for Project-Level Analysis. The study also outlines a procedure for developing an average daily trips (ADT) screen for project level CO evaluation. Many elements of the procedure developed by Houk and Claggett can still be used in conducting emissions and dispersion modeling (i.e., selecting meteorology parameter values such as wind speed and average monthly air temperature). However, the emission factor methodology presented in the study must be updated to incorporate use of the since developed MOVES model with a set of reasonably conservative input assumptions.

A 2006 study by Claggett and Miller, "A *Methodology for Evaluating Mobile Source Air Toxic Emissions Among Transportation Project Alternatives*", makes use of the MOBILE6.2 emission factor model to examine MSAT emissions. This study developed a methodology for computing project level emissions of MSATs among a group of transportation project alternatives. The study also conducted a sensitivity analysis to examine the variability of MSAT emissions based on MOBILE6.2 with calendar year, ambient temperature, fuel Reid vapor pressure, and vehicle speed. The study concludes that the MSAT emissions are extremely sensitive to these parameters, ranging by a factor of ten for each individual MSAT emission factor. A similar study was conducted for two project settings under NCHRP 25-25, Task 70, using MOVES rather than MOBILE6.2. Similar findings were reported, with the additional finding that intersections have higher MSAT concentration levels than mainline highways. The authors posited that this difference was primarily due to the closer receptor placement used in the intersection modeling than the highway modeling.

In a study by Timoshek et al., *"Mobile Source Air Toxic Emissions Sensitivity to Traffic Volume, Fleet Composition and Average Speed*" (2010), the California-specific project-level emissions modeling tool, CT-EMFAC, was used to assess the sensitivity of MSAT emissions to changes in traffic volumes, speeds, and fleet composition. The most relevant finding from this study was the strong dependency of emission rates on vehicle speed for some MSAT emissions. The study reports that, similar to CO, some MSAT emissions show higher emission rates at lower speeds, while, unlike CO, other MSATs—most notably diesel PM—show increases in emission rates at higher speeds. The analysis also indicated that the choice of speed calculation method could result in large variations (in some cases more than a factor of two) for some MSAT emission rates.

NCHRP 25-25, Task 71, "*Templates for Project Level Analysis Using MOVES, CAL3QHC/R and AERMOD*" (2012) developed language that can be used in NEPA environmental documents or project-level conformity determinations. The draft templates were colored coded to indicate

[8] The latest USEPA air quality monitoring trends data reports a decline in the 90th percentile of the maximum 8-hour CO concentration from 9.5 ppm in 1990 to 2.1 ppm in 2012 a 78% decline.

text as being instructions or guidance not to be included in the final document, locations in the final document where project-specific text was to be inserted, boilerplate text that would typically apply for every project, and example text that could be modified or deleted when drafting a final document. The draft templates consider all sections of an air quality report or an environmental document and cover CO for the 1 and 8-hour standards and PM_{10} and $PM_{2.5}$ annual and daily standards. The Task 71 report and draft templates proved a useful guide in developing programmatic agreement language as part of the latter stages of this research.

3.3 MOVES Based Studies

In the study by Ritner et al., "*Accounting for acceleration and deceleration emissions in intersection dispersion modeling using MOVES and CAL3QHC*" (2013), it was found that because MOVES can be used to provide detailed emission rates for vehicles in acceleration and deceleration modes, it can significantly affect the location and concentration of CO near an intersection. The study used the MOVES Link Drive Schedule to determine modal emission rates. The CO acceleration emission factors were found to be significantly higher than cruise emission factors, indicating that acceleration emissions contribute more to total CO concentrations than cruise or idle emissions.

The study also examined the impact of the number of sub-links used to characterize vehicle modal activity around an intersection. The number of sub-links used in modeling can substantially change the predicted concentrations in CAL3QHC. Figure 3.1, from the study, shows that increasing the number of acceleration sub-links increases the modeled peak CO concentrations. Indeed, the study found that increasing from 1 to 4 acceleration links increased modeled CO concentrations by 38%. The increase in links also moves the highest modeled concentration away from the beginning of the acceleration location.

These findings may have important implications for both the location and magnitude of the maximum modeled CO concentrations at intersections. However, the study did not compare results with monitored data, so the effects on model accuracy are unknown.

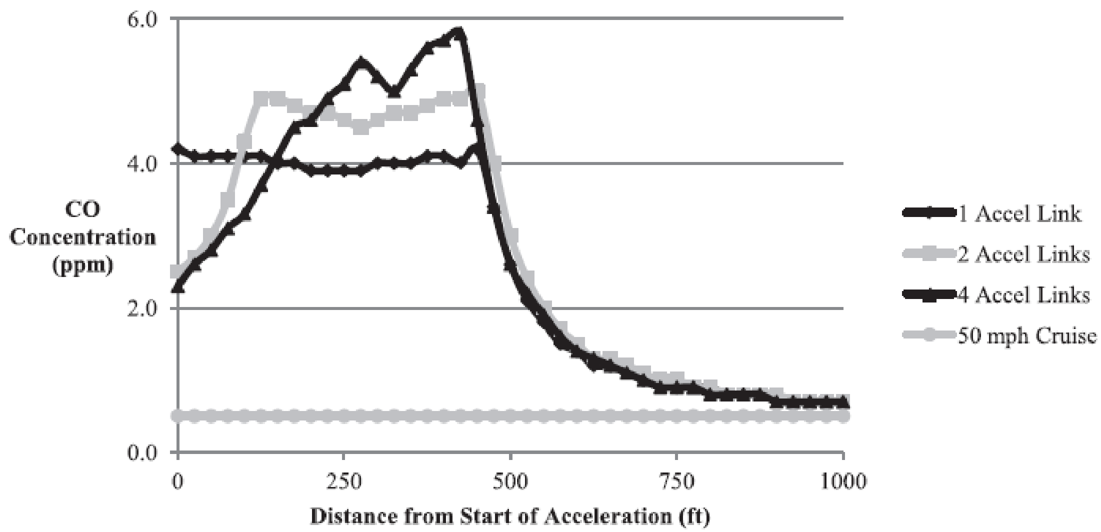

Figure 3.1 - CO Concentrations near a single roadway give a different number of acceleration sub-links (from Ritner et. al, 2013)

In a study by Chamberlin et al., 2011, "*Analysis of MOVES and CMEM for Evaluating the Emissions Impact of an Intersection Control Change*", the output from MOVES for "project-level" analysis of CO and Nitrogen Oxide (NO_x) hot-spots is compared with emissions generated by the Comprehensive Modal Emissions Model (CMEM), developed under NCHRP 25-11. CMEM integrates with existing micro-simulation software packages (Paramics) that generate second-by-second speed and acceleration vehicle profiles. The most relevant portion of the study for this project was the micro-simulation of a 3-leg intersection, modeled for a pre-timed traffic signal under two traffic volume scenarios using CMEM and MOVES. The MOVES model was employed using both average speed and the Link Drive Schedule (LDS). For hot-stabilized CO emission only, the study found that in both the low and high traffic volume scenarios the CMEM results were roughly four times higher than MOVES using average speed. The CMEM results were six times higher than the MOVES results for both scenarios using LDS. The study found very little discrepancy in NO_x results between MOVES using LDS and CMEM. The authors present some thoughts on possible reasons for the discrepancy in model results for CO, with the two most likely being the newer source of emission rates available to MOVES and differences in modeling techniques. CMEM analytically models combustion processes, while MOVES is statistically based on emissions data collected from vehicles grouped by vehicle specific power (VSP) and speed. This research suggests the need for use of an instrumented vehicle to collect empirical measurements of continuous CO tailpipe emissions in order to resolve the discrepancies between the two approaches. This would also allow investigation of the results for CO emission rates when using the operating mode distribution in MOVES.

In their 2012 study, "*Toward Best Practices for Conducting a MOVES Project-Level Analysis*", Chamberlin et al. used output from a micro-scale traffic simulation model (VISSIM) as input to MOVES in order to examine changes in emissions from traffic signal optimization. The study was principally focused on PM emissions. The study found that greater resolution in link geometry (i.e. shorter links) closer to the intersection center results in better characterization of the variation in emissions density[9] and that the use of micro-simulation models can be incorporated into MOVES via pre-processing into the MOVES Operating Mode Distributions format. The study also found that the impact of traffic signal optimization can lead to higher emission densities within the intersection center, but with a corresponding decrease in emissions along the approach links to the intersection. Pure signal optimization showed an overall $PM_{2.5}$ emissions reduction of 6% at the analyzed intersection. However, higher emission density occurred near the intersection center, which could lead to higher $PM_{2.5}$ concentrations.

The study by Chamberlin et al., (2013), "Comparative Analysis of the EPA Operating Mode Generator with 2 Real World Operating Mode Data", used EPA's Operating Mode Distribution Generator (OMDG) tool[10] to develop an operating mode distribution for input to MOVES. The tool converts basic information about traffic operations – idle time, road grade, and average speed – into an operating mode distribution. The paper compares the operating mode distributions obtained from this tool with those from an instrumented vehicle that measured tailpipe emissions. The comparison is made for four signalized intersections on an urban arterial. The analysis showed that the OMDG, when compared to 31 test runs of an instrumented vehicle, was a good predictor of CO emissions with highest accuracy where the grade was either zero or very low and where levels of traffic congestion were high. Inaccuracies were found to be highest for high acceleration operating modes and likely due to the very high emissions rates found in MOVES for these high operating modes. These findings have implications for project level CO analyses as they imply that MOVES model uncertainties are highest for locations where grades are steepest and where acceleration is highest.

In the research report by J. Lin and S. Vallamsundar, "*Transportation Conformity Particulate Matter Hot-Spot Air Quality Modeling*" (2013), and in the two papers by J. Lin and S. Vallamsundar focused on the PM-hotspot analysis: "*MOVES and AERMOD Used for PM2.5 Conformity Hot Spot Air Quality Modeling*" (2012) and "*Sensitivity Test Analysis of MOVES and AERMOD Models*" (2013), several highlights potentially relevant to CO hot-spot analysis were identified. The principal finding from this research, mostly applicable to PM air quality modeling rather than CO, is the identification of possible inconsistencies in the EPA methodology. The researchers found that the predicted peak annual average PM concentration was nearly twice as high using AERMOD versus CAL3QHCR with as close as possible parallel input configurations.

[9] Emission mass per unit area

[10] This tool is no longer available on EPA's website.

Development of the Programmatic Agreement and Technical Support Document

4.1 Introduction

Section 4 describes the emissions and air quality modeling used in developing a draft programmatic agreement (PA) on carbon monoxide (CO) project level analyses for use by all state Departments of Transportation (DOTs) and corresponding Federal Highway Administration (FHWA) Division Offices (with the exception of the state of California). Specifically, this section of the report describes a study undertaken by the research team, which explores modeling of four different project types: intersections, freeways, arterials, and interchanges. Realistic geometry coupled with conservative emissions scenarios and worst-case meteorological conditions were used to predict reasonable CO concentrations. In the following sections are descriptions of the facility types studied, development of the Motor Vehicle Emissions Simulator (MOVES) project-level emission modeling, and development of the CAL3QHC dispersion modeling for all project types. Determination of background CO concentrations and persistence factors for all project types are also described. Finally, the section presents the model results for use in a PA.

4.1.1 Summary of Project Types Studied and Evaluated

The results presented below build on the findings presented in the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* (FHWA, 2014). That report identified the urban intersection operating capacity that would not, when combined with background CO concentrations, produced a CO concentration in violation of the National Ambient Air Quality Standards (NAAQS) for CO. The study presented in this report extends the FHWA analysis to include rural areas; additional approach speeds; and additional project settings for freeways, arterials and urban interchanges. The study is not intended to cover other project types or all projects that may be included in a state DOT's capital program.

4.1.2 Application of Study Results

The findings from the study presented in this report are also incorporated into a draft programmatic agreement (PA) template and a draft technical support document (TSD) template, attached as appendices to this document (Appendix B and Appendix C, respectively). The draft PA and TSD templates can also be used to develop state-specific PAs and TSDs with the inclusion of relevant state-specific data and information. A state or local PA and TSD may include, for example, the appropriate 1- and 8-hour background concentrations and persistence factor for the relevant region, and might expand upon the project types or conditions presented here.

The modeling results are based on national worst-case modeling assumptions and inputs. For some states, based on climatic or other state-specific circumstances, the modeling assumptions and inputs may be overly conservative. Use of state-specific assumptions and inputs could result in a larger set of project types and conditions covered by a PA. A state has the option of using the modeling files (MOVES and CAL3QHC) that are part of this study[11], modifying them to be state-specific, and running the modified files to determine how the outcomes with state specific parameters compare with the modeling results from this study. The state may also model additional project conditions and/or types to determine if those additional projects should be included within their state-specific PA. Suggested project types that may prove fruitful for a state to address include: auxiliary lanes, HOV lanes, metered on-ramps, roundabouts, parking lots, and intersections with moderate skew angles.

4.1.3 Brief Summary of the Programmatic Agreement (PA) Template

The PA template is a relatively brief document that describes the basis for the PA and the types of projects and conditions that are covered by the PA—namely, those projects that do not exceed the CO NAAQS. It also contains examples of administrative items such as time frames, procedures for revising the PA, and possible termination of the PA. The PA is in the form of a memorandum between the state DOT and the corresponding FHWA Division Office. Once signed by both parties, the document officiates an agreement under which project types that fall within the purview of the PA do not require project-specific air quality modeling for CO. Once more, the draft templates of the PA and TSD are provided as guides. It is anticipated that the exact language of a state PA and inclusion of additional elements that may not be in the draft templates will be agreed to by state DOTs and their corresponding FHWA Division Offices.

The draft template was developed based on national inputs and conservative assumptions generally applicable on a national level. A State DOT may elect to modify the PA specific to their situation. It can do so by either performing A) or both A) and B) as described below:

A) Choosing to incorporate local data for persistence factor and background concentrations.

If a state DOT chooses to do this the PA may still be applied provided that it is adjusted as follows:

1. For the project type and condition of interest, determine from Table 4.6, Table 4.8 , and Table 4.9, below whether a one-hour concentration value is listed.
    a. If a one-hour concentration is <u>not</u> listed, project-specific modeling is needed.
    b. If a one-hour concentration is listed, then proceed to step 2.
2. The one-hour concentration listed in the tables below is for the project contribution only. Therefore:
    a. To determine the one-hour concentration for comparison to the NAAQS use the following equation:

       One-hour concentration (ppm) = One-Hour concentration from the table

[11] On July 14, 2015, EPA signed a proposal to revise the Guideline on Air Quality Models. The Guideline provides EPA-recommended models for predicting ambient concentrations of air pollutants. EPA is proposing to replace CALINE3 (and its variants CAL3QHC and CAL3QHCR) with AERMOD as the preferred model for determining near-field impacts for primary emissions from mobile sources, including PM2.5, PM10, and CO hot-spot analyses.   If this proposal is accepted then the TSD would need to be updated to reflect the use of AERMOD.

+ Local Background Concentration (One-Hour)

b. To determine the corresponding eight-hour concentration for comparison to the NAAQS:

Eight-hour concentration (ppm) = One-Hour concentration from the table x Local Persistence Factor + Local Background Concentration (Eight-Hour)

3. Compare the calculated one- and eight-hour concentrations to the applicable NAAQS. If both concentrations are less than the applicable NAAQS, then the project is covered by the PA. The eight-hour NAAQS is typically the limiting value.
4. If the project is covered by the PA with the adjusted persistence factor and/or background concentrations, the qualitative text provided at the end of the PA should be included (modified if needed for the project) in the project record and relevant environmental documents.

B) In addition to deriving state-specific values for persistence factor and background concentration (as described above), performing state specific emissions modeling to account for local vehicle mix, inspection and maintenance (I/M) program, fuel type, etc. In this case, to determine the one-hour concentration for comparison to the NAAQS:

One-hour concentration (ppm)

= One-Hour concentration from the state-specific emissions as input to the state-specific dispersion modeling + Local Background Concentration (One-Hour)

1. To determine the corresponding eight-hour concentration for comparison to the NAAQS:

Eight-hour concentration (ppm)

= One-Hour concentration from above x Local Persistence Factor

+ Local Background Concentration (Eight-Hour)

2. Compare the calculated one- and eight-hour concentrations to the applicable NAAQS. If both concentrations are less than the applicable NAAQS, then the project is covered by the PA. Note the eight-hour NAAQS is typically the limiting value.
3. If the project is covered by the PA with the adjusted persistence factor and/or background concentrations, the qualitative text provided at the end of the PA should be included (modified if needed for the project) in the project record and environmental documents.

4.1.4 Brief Summary of the Technical Support Document (TSD) Template

The draft TSD provides relevant information to fully explain and support the draft PA. It details the basis for using CO emissions analysis, CO emissions inventory, and ambient CO levels to show the decreasing likelihood that CO emissions from the operation of a highway project will result in a CO concentration exceeding ambient air quality standards. It also contains a brief history of CO modeling for highway projects, focusing on the conservative “worst-case” approach to these analyses. The TSD, most importantly, contains detailed information regarding the project setting and traffic activity levels, the MOVES emission modeling, and the CAL3QHC air quality modeling that was done to support the PA. The TSD also includes the model input and output files and provides the basis for selection of the background CO values and persistence factor used in the model. Finally, the TSD lists the four project types and the conditions determined by the modeling results under which the projects could not lead to a violation of CO air quality standards. The results are presented as follows: 1) freeways by grade and number of lanes; 2) arterials by grade and number of lanes; 3) signalized intersections by approach speed; and 4) urban interchanges by distance from the freeway and approach speed at the nearby signalized intersection.

4.2 Types of Facilities

4.2.1 Overview on the Selected Facility Types

Based on the modeling conducted for this study, the project settings that were the most promising candidates for inclusion in a PA were identified. These project types are:

- Freeways
- Arterials
- Intersections
- Interchanges

The analysis presented in this report includes maximum traffic activity and worst-case meteorology for each project setting, leading to the maximum possible CO concentrations for each facility. Details and layouts for each of these project settings are discussed further below.

The identified project types are the four most commonly included in state DOT capital programs and often undergo a hot-spot analysis in environmental documents. The draft PA and TSD templates are only applicable to the project types and conditions modeled for this study and do not apply to other project types and conditions.

4.2.2 Freeways

Both urban and rural freeway restricted roadway settings were evaluated across a number of total lanes, ranging in two lane increments from 2 to 22 total lanes. The lane widths were 12 feet. A sensitivity test was conducted for the 22 lane configuration using 11 foot wide lanes to see if differences in lane width substantially altered associated CO concentrations. A 30 foot clear zone from the edge of pavement to the right-of-way line and a 3.3 foot median were assumed. Receptors were evaluated at the center of the defined link to avoid end effects. The total lane length modeled was 5,000 feet. Receptors were positioned on either side of the road, beginning 30 feet from the roadway edge and moving outward. Additional receptors were positioned at 10 foot intervals (40 and 50 feet from the road edge) and then at intervals of 25 feet out to 180 feet from the road edge. Receptors were also placed at an extreme distance of 295 feet in order to ensure model completeness. The right-of-way was selected at this location based on typical safety considerations as recommended by the American Association of State Highway and Transportation Officials (AASHTO)[12]. Figure 4.1 shows an example 12 lane configuration. Roadway grades of 0, ±2, ±4 and ±7% were evaluated (one direction of traffic was uphill and the opposite direction of traffic was downhill). Maximum traffic volume and speeds were assumed for each lane.

Because heavy-duty diesel trucks are much lower emitters of CO than gasoline vehicles, and to enable the PA to extend to a broader number of settings, the heavy-duty diesel truck percentage was set to zero. The heavy-duty diesel vehicles were shifted to gasoline passenger truck types, which have substantially higher CO emission rates. The 2010 Highway Capacity Model (HCM) was used to evaluate the maximum traffic volumes that could occur for a single lane over the course of an hour. The maximum possible traffic volume with the selected vehicle mix is 2,200 vehicles-per-hour-per-lane. The freeway average speed was set to 74 mph because CO emission rates are highest at this speed down to a speed of 19 mph, at which point the CO emission rate would become higher at lower speeds. Thus, the PA covers facility speeds over the range of 19 to 74 mph.

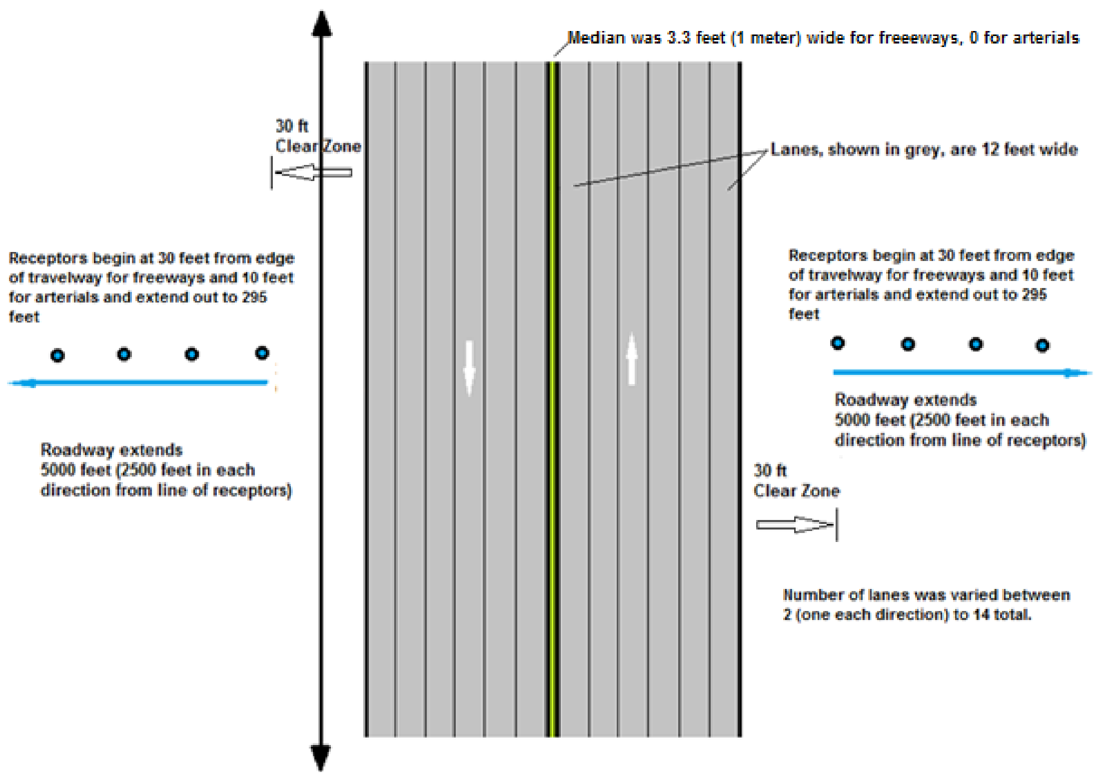

Figure 4.1 - Geometric layout of an example 12 lane facility, median width and receptor placement.

[12] The recommended clear zone are based on a width of 30-32 feet for flat, level terrain adjacent to a straight section of a highway with speed of 60 mph and ADT of 6000 vehicles. AASHTO Roadside Design Guide, 2011.

4.2.3 Arterials

Arterials were modeled in much the same way as freeways, with a few notable exceptions. Where the freeway road type was restricted, the road type for arterials was unrestricted and the average speed was set to 45 rather than 74 mph, with an applicable speed range of 45 mph to 56 mph for both urban and rural settings. The receptor placement began at 10 feet from the roadway edge and extended out in 25 foot increments, ending at 295 feet. Roadway grades of 0, ±2%, and ±4% were evaluated. The total number of lanes evaluated ranged from 2 to 12 total lanes in two lane increments. All other traffic related parameters were the same as those used in the freeway modeling.

4.2.4 Intersections

Similar to the conditions evaluated in the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* (FHWA, February 2014), a large, signalized symmetrical intersection was modeled, with each of the approach and departure lanes at 90 degree angles. The modeled intersection consisted of four approach lanes in each direction, four departure lanes in each direction, and two left turn lanes for each approach. The right lane in each direction was assumed to include both through and right turn movements and idling was assumed. Lanes were held to be 12 feet wide in all cases. The intersection geometry modeled is displayed in Figure 4.2.

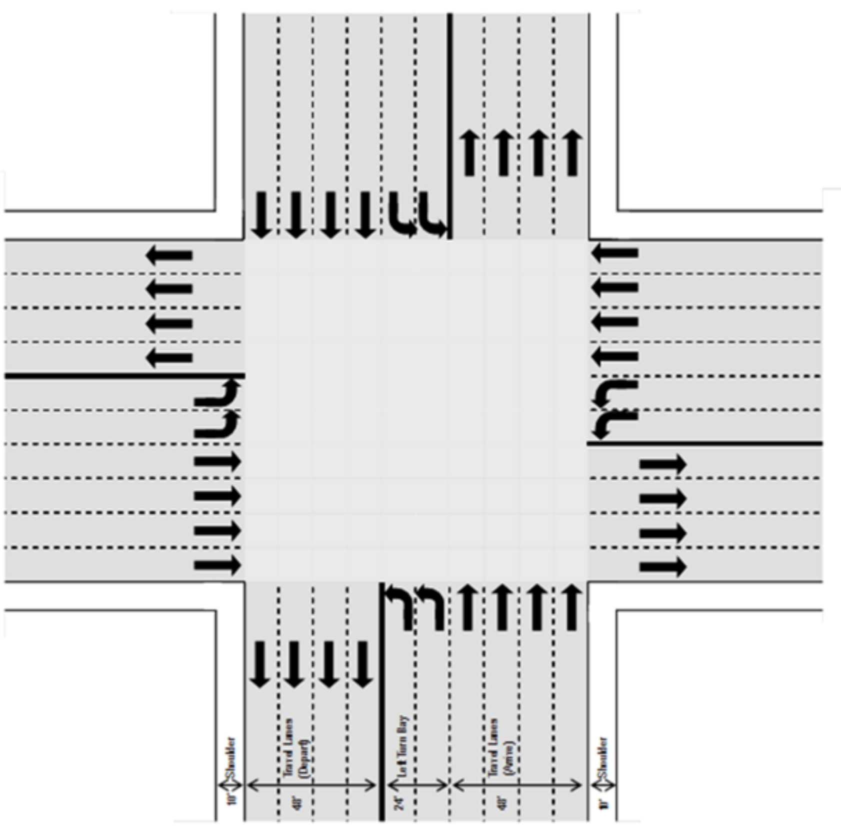

Figure 4.2 - Six-lane four legged intersection layout

The HCM provides a method to calculate the approach volume capacity for a given intersection design. Applying this method from the 2010 HCM, maximum flow rates corresponding to a signalized intersection with operations approaching Level of Service (LOS) F were calculated using the Highway Capacity Software. LOS F is defined as operating with an average control delay greater than 80 seconds per vehicle. It was assumed that all approaches would have equal demand and represent maximum total intersection throughput. The traffic volumes were adjusted to reach an average delay of 80 seconds per vehicle. Total cycle length was 130 seconds, allowing for separate through and left-turn phases for each leg. “Green time” was allocated proportionately for each movement based on demand. The roadway geometry, design flow rate and signal timing used are identical to the conditions modeled in the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* (FHWA, February 2014). Given these specifications and the roadway geometry, a design flow rate of 2,640 vehicles-per-hour was calculated for each approach leg. Of that total, 396 vehicles were assigned to the left-turn lanes. The remaining 2,244 vehicles were assigned to the through lanes, including the shared through-right turn lane. The HCM states that the geometry of an intersection has a significant impact on signal timing and that traffic volume of an intersection is directly related to signal timing. The symmetrical properties and calculated traffic volume of the analyzed intersection were used to determine an average green time of 41 seconds for the through and right turn movements occurring at the same time for opposing approaches. An average green time of 14 seconds was determined for left turn movement.

Three average approach and departure speeds were examined: 15, 25 and 35 mph. The lowest speed (15 mph) resulted in the greatest emission rates and therefore represents the most conservative results. Idle emission rates were also determined using MOVES2010b. Further description is included in the emission factor model discussion (section 4.3 Emission Development). Queue lengths were determined internally by CAL3QHC (version 04244) during the modeling process.

One approach and corresponding departure were assumed to be on an uphill grade of 2% and the parallel approach and departure were assumed to be on a downhill grade of -2%. Crossing streets were assumed to be on a 0% grade. This intersection configuration was examined for both the urban and rural settings.

4.2.5 Interchange

The study examined a six lane interchange configuration consisting of a signalized intersection with perpendicular approaches and departures. This interchange configuration was evaluated assuming a variable number of freeway lanes. As in the case of the freeway facility, the total number of lanes ranged from 2 to 22 in two lane increments. A variety of assumed distances from the edge of the nearest freeway travel lane to the edge of the nearest travel lane on the interchange ramp were also applied to the six-lane configuration (distances of 10, 20, 30, 60, 80, 100, 125, 150, 175, 300, 500 and 1,000 feet). All combinations of freeway distances and number of lanes were modeled and their maximum CO concentrations determined for use in the PA. The interchange layout is shown in Figure 4.3. Thus, a user need only specify the number of freeway lanes, distance from the freeway to the intersection, and the intersection approach speed to determine CO emissions for a given project. Both urban and rural configurations were modeled. However, the results for the rural interchange configuration did not prove useful for the PA, as they exceeded the NAAQS by a considerable margin. Therefore the results for the rural interchange configuration are not presented in this report.

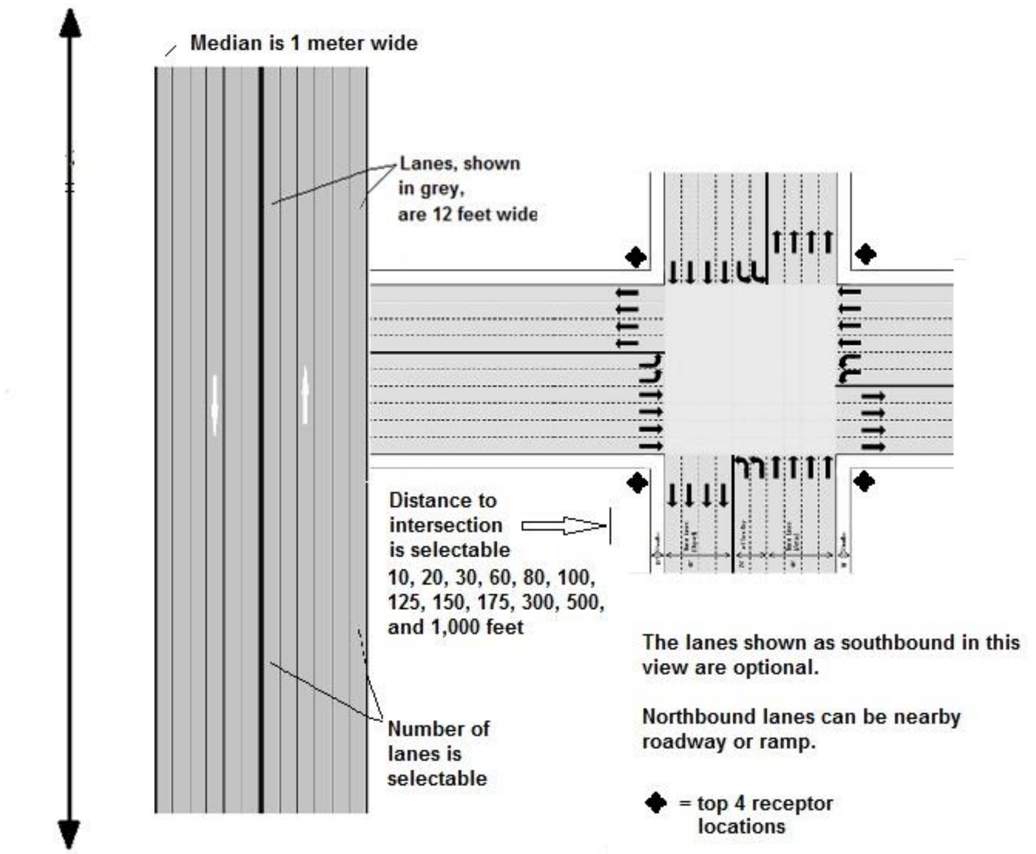

Figure 4.3 - Interchange Configuration with nearby freeway and intersection/ramp layout

4.3 Emission Development

Emissions modeling was performed using the MOVES model (version MOVES2010b)[13]. The emissions parameters for MOVES were specified in the Run Specification file (Runspec) and in the Project Data Manager (PDM). All applications of the MOVES model were conducted at the project level scale. Multiple MOVES runs were conducted for varying roadway grades to establish CO emissions rates. Other MOVES input parameters such as temperature and relative humidity were fixed to be conservative and consistent with the dispersion modeling component of the analysis (See section 4.4 Dispersion Model).

Table 4.1 describes the input parameters that were used in the Runspec and PDM for the MOVES component of the analysis.

[13] EPA released a new version of MOVES on October 7, 2014 as MOVES2014. Future revisions to the PA and TSD should make use of this updated version of MOVES or any subsequent version at the time of update.

4.3.1 Relative Humidity

A value of 100% relative humidity was used, and was only applicable for the emission modeling. It is important to note that for temperatures of 75 degrees Fahrenheit and below relative humidity has no effect on CO emission rates.

Table 4.1 - MOVES input parameters by scenario

Parameter	Freeway	Arterial	Intersection
Scale	Project Level Domain	Project Level Domain	Project Level Domain
Year	2015	2015	2015
Month	January	January	January
Time Span - Hour	12:00 AM	12:00 AM	12:00 AM
Time Span - Day	Weekday	Weekday	Weekday
Geographic Bounds	Custom Domain	Custom Domain	Custom Domain
Temperature	-10° Fahrenheit	-10° Fahrenheit	-10° Fahrenheit
Relative Humidity	100%	100%	100%
Fuel Formulation	Gasoline – Formulation ID - 3812	Gasoline – Formulation ID - 3812	Gasoline – Formulation ID - 3812
	Diesel – Formulation ID - 20011	Diesel – Formulation ID - 20011	Diesel – Formulation ID - 20011
	CNG – Formulation ID - 30	CNG – Formulation ID - 30	CNG – Formulation ID - 30
Fleet Mix	Emission Source Type and Fuel Combinations for 2015 with a Shift to 0% Heavy-Duty Truck Volumes to Reflect Higher CO emission Rates from Gasoline Vehicles (refer to through Table 4.4 - Table C-6))	Emission Source Type and Fuel Combinations for 2015 with a Shift to 0% Heavy-Duty Truck Volumes to Reflect Higher CO emission Rates from Gasoline Vehicles (refer to Table 4.4 - Table C-6)	Emission Source Type and Fuel Combinations for 2015 with a Shift to 0% Heavy-Duty Truck Volumes to Reflect Higher CO emission Rates from Gasoline Vehicles (refer to Table 4.4 - Table C-6))
Age Distribution	2015 National Default	2015 National Default	2015 National Default
Link Source Type Distribution	Variable - Based on 2015 National Default VMT for Urban Restricted Access Road Type	Variable - Based on 2015 National Default VMT for Urban Unrestricted Access Road Type	Variable - Based on 2015 National Default VMT for Urban Unrestricted Access Road Type
Road Type	Urban and Rural Restricted Access	Urban and Rural Unrestricted Access	Urban and Rural Unrestricted Access
Link Average Speed	74 mph	45 mph	15, 25 and 35 mph approach and idle (intersection)
Grade	±7% , ±4%, ± 2%, ± 0% (uphill and downhill grade)	±4%, ± 2%, ± 0% (uphill and downhill grade)	± 2% (cross direction) and 0% grade in other direction (intersection)
Inspection & Maintenance	None	None	None

4.3.2 Temperature

Sensitivity tests with MOVES show that emission rates are not sensitive to cold temperatures for running exhaust and crankcase exhaust emissions (Figure 4.4).[14] A value of -10 degrees Fahrenheit was used in the analysis. Notably, MOVES predicts higher CO at T > 75 degrees Fahrenheit due to air conditioning use. However, because CO is a winter time air pollution problem, this higher emission rate is excessively conservative and thus was not used in the analysis.

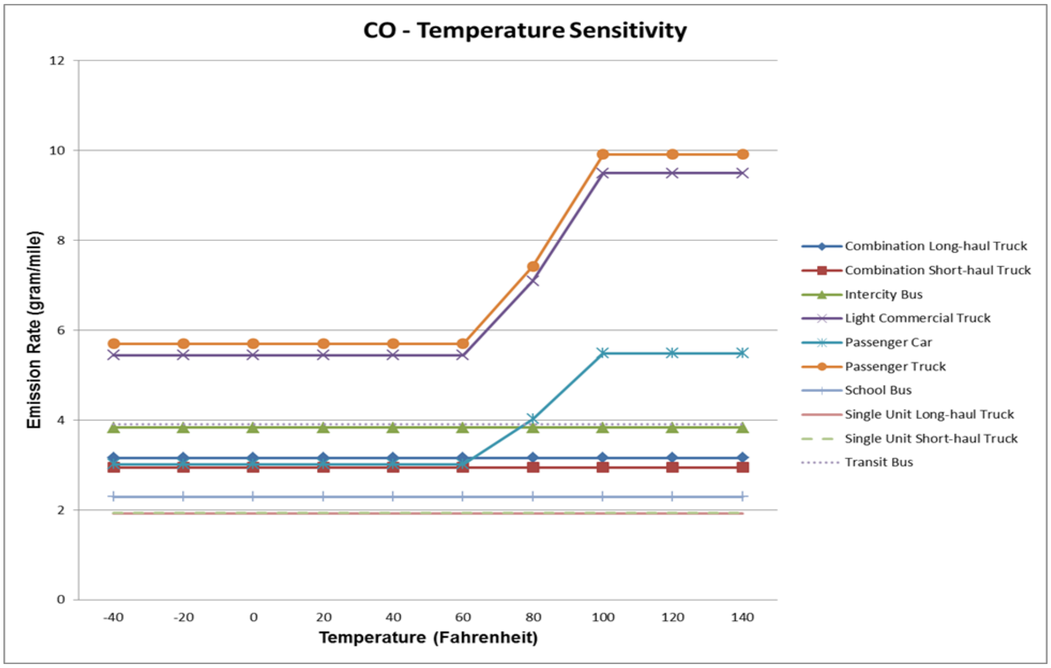

Figure 4.4 - Sensitivity of CO Emission Rates to Temperature[15]

4.3.3 Link Source Type Distribution

The national default Source Type Distribution was obtained from a national scale MOVES run for the 2015 calendar year. Using the vehicle miles traveled (VMT) information from the 'movesactivityoutput' table within the output database, the Source Type Distributions were transformed into a Source Type Hour Fraction for intersection, arterial, and freeway scenarios. To ensure conservative results, the Source Type Hour Fraction was based on the national

[14] See : http://ntl.bts.gov/lib/46000/46500/46598/DOT-VNTSC-FHWA-12-05.pdf and http://www.epa.gov/ttnchie1/conference/ei19/session6/choi.pdf

[15] Differences in emission rates are dependent on the fleet mixture, fuel supply and formulation, grade, and road type that may affect the overall emissions rates results depicted in this figure. However, the emission profile as shown in the figure would remain the same in that it is only temperature dependent above 75 degrees F. Note that data was only reported at 60 degree and 80 degree Fahrenheit making it appear that an emission sensitivity to temperature occurs below 75 degrees F.

default, but adjusted, in two steps, to reflect a higher proportion of vehicles that have higher CO emissions rates. These two steps are detailed below:

- Passenger trucks have the highest CO emission rates of all MOVES source types, except gasoline operated single unit trucks. Passenger cars have the largest fraction of the total national vehicle mix and passenger trucks are the second largest fraction of the total national vehicle mix. To ensure conservative emissions rate estimates for the PA, the Source Type Hour Fraction was adjusted to reflect a 50/50 proportional split between passenger car and passenger truck source types.
- Gasoline vehicle types typically have higher CO emission rates than diesel vehicle types within MOVES. In the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* (FHWA, February 2014), it was assumed that the lowest observed fraction of non-gasoline vehicles was 5% of the total vehicle mix. To provide a more conservative emission rate than used in the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding*, the national default Source Type Hour Fraction was adjusted by reducing combination and single-unit trucks to represent 0% of the total fleet mix. The remaining 5% fraction was added to the passenger truck source type after the conservative 50/50 passenger car to passenger truck split was applied.

These two adjustments are reflected in Table 4.2 for the Link Source Type Fractions utilized for the freeway, arterial, and intersection scenarios. Table 4.3 lists the source type and fuel type combinations that were modeled in all scenarios.

Table 4.2 - Link Source Type Fractions

SourceTypeID	Description	SourceTypeHourFraction
11	Motorcycle	0.005546
21	Passenger Car	0.423629
31	Passenger Truck	0.473629
32	Light Commercial Truck	0.093704
41	Intercity Bus	0.000762
42	Transit Bus	0.000211
43	School Bus	0.00085
51	Refuse Truck	0.000331
52	Single Unit Short-haul Truck	0
53	Single Unit Long-haul Truck	0
54	Motor Home	0.001338
61	Combination Short-haul Truck	0
62	Combination Long-haul Truck	0

Table 4.3 - Fuel types and source types modeled

Source Types	Fuel Type(s)
Motorcycle	Gasoline
Passenger Car	Diesel Fuel and Gasoline
Passenger Truck	Diesel Fuel and Gasoline
Light Commercial Truck	Diesel Fuel and Gasoline
Refuse Truck	Diesel Fuel and Gasoline
Motor Home	Diesel Fuel and Gasoline
School Bus	Diesel Fuel and Gasoline
Transit Bus	Diesel Fuel, Gasoline, CNG
Intercity Bus	Diesel Fuel
Single Unit Short-haul Truck	Diesel Fuel and Gasoline
Single Unit Long-haul Truck	Diesel Fuel and Gasoline
Combination Short-haul Truck	Diesel Fuel and Gasoline
Combination Long-haul Truck	Diesel Fuel

4.3.4 Age Distribution

The 2015 national default age distribution was utilized and is consistent with the analysis year that was modeled. Figure 4.5 shows the national age fault distribution for the four major vehicle categories.

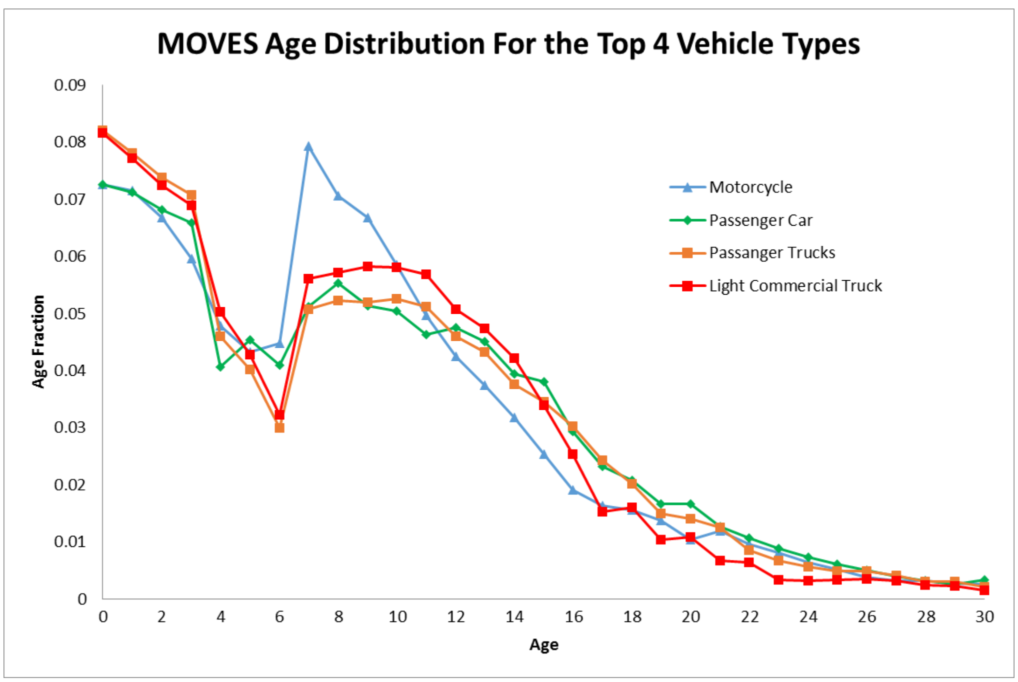

Figure 4.5 - MOVES 2015 National Age Distribution

4.3.5 Fuel Supply and Formulation

Fuel formulation parameters can significantly affect CO emission rates. Joint analyses conducted by FHWA and EPA in the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* (FHWA, February 2014) determined the effects of certain fuel parameters on CO emission rates. Fuel parameters that can effect CO emission rates include Reid vapor pressure (RVP), sulfur content, ethanol (ETOH), percent of fuel evaporated at 200° and 300° Fahrenheit (E200/E300), and distillation parameters T50 and T90. The FHWA study found that fuel formulation ID 3812 yields higher CO emission rates than other relevant fuel formulations. Table 4.4 lists the fuel formulations that were used in both the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* and this analysis.

Table 4.4 - Fuel Formulation Used for the Analysis

Fuel Type	fuelFormulationID	RVP	Sulfur Content (ppm)	ETOHVolume	e200	e300	T50	T90
Diesel	20011	0	11	0	0	0	-	-
Gasoline	3812	15.7	28	10	58.1352	94.8717	183.214	275.447
CNG	30	0	0	0	0	0	0	0

4.3.6 Link Average Speed and Operating Mode Distribution

When average speed is utilized in the 'Links' input file and entered through the MOVES PDM, it creates an operating mode distribution based on the default drive schedules located in the default database. This operating mode distribution was used to represent the freeways, arterials, and intersection scenarios.

4.3.7 Emissions Processes

The 'Running Exhaust' and 'Crankcase Running Exhaust' emissions processes were utilized in the intersection, freeway, and arterial scenarios.

4.3.8 Inspection and Maintenance Program

An Inspection and Maintenance (I/M) program produces CO emissions rate benefits. In order to ensure conservative results, no such programs were included in the analysis.

4.4 Dispersion Model

The inputs for the dispersion modeling followed EPA's 1992 Guidance for CO determinations using CAL3QHC (version 04244) and were consistent with the approach used by the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* (FHWA, February 2014) for intersections. As for emissions modeling, dispersion modeling was performed using conservative underlying assumptions and, in many cases, worst-case inputs and assumptions. These inputs and assumptions are outlined below:

- As a conservative assumption, the wind speed was set to 1.0 m/s (the lower limit of CAL3QHC meaningful input).
- Wind direction was modeled every ten degrees from 0 to 350 degrees.
- A mixing height of 1000 m was used, consistent with standard modeling procedures. Sensitivity testing has shown that due to the close proximity of the receptors, mixing height has negligible influence on dispersion analysis.
- For urban modeling, a surface roughness (z0) of 108 cm was used, corresponding to a single family residential setting. The single family residential setting is the least rough setting for an urban environment and is conservative. The recommended surface roughness in urban areas can vary from 108 to 370 cm. For rural areas, a surface roughness of 1.0 cm was used, which corresponds to a moderately short grass height (6-8 cm) as identified in prairie grass.[16] Shorter grass heights are unlikely to be found in most rural locations.
- The 1992 EPA CO Guidelines specifies a stability class of D (neutral) for urban areas and E (stable) for rural areas. These guidelines were applied in the model.
- Receptor Placement
  - Freeways and Arterials:
    - Receptors were modeled per the CAL3QHC and 1992 EPA Guidance. For both freeways and arterials, receptors were placed on both sides of the roadway extending out to 295 feet from the roadway and were modeled to establish decreasing CO concentrations with distance.
    - For freeways, receptors were located beginning at 30 feet from the outside lane to account for off-road safety clearance.
    - For arterials, receptors were located beginning at 10 feet from roadway edge (where the general public has access and is within the limitations of the model to predict valid concentrations).
  - Intersections and Interchanges:
    - Receptors were modeled per the CAL3QHC and 1992 EPA Guidance and began at 10 feet from roadway edge.
    - A grid of receptors was used in each quadrant to ensure the worst case concentrations were identified. The grid spacing started at 10

[16] Businger, J.A., J.C. Wingaard, Y. U. Isumi and E. F. Bradley, 1971 “Flux Profile Relationships in the Atmospheric Surface Layer”, *J. Atm Sci.,* 28:181-191.

feet from each roadway and then extended in 25 foot increments from the intersection up to 500 feet in order to simulate the mid-block position. To ensure that the maximum mid-block concentration was found a receptor was placed at 2,500 feet from the intersection. This allowed analysis of the intervening values.

- Figure 4.6 shows a typical intersection configuration with link geometry. Figure 4.7 shows the layout of receptor locations for the southeast quadrant.

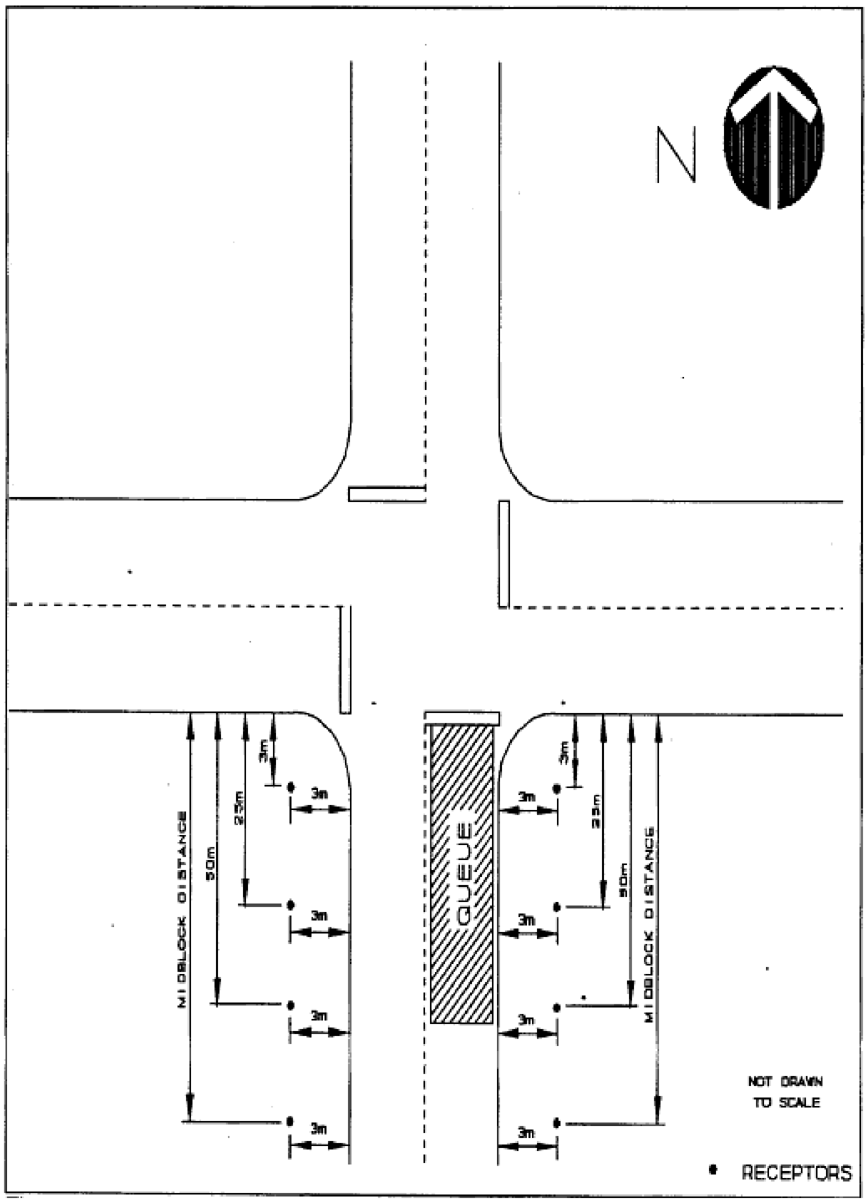

Figure 4.6 - Intersection configuration with link placement

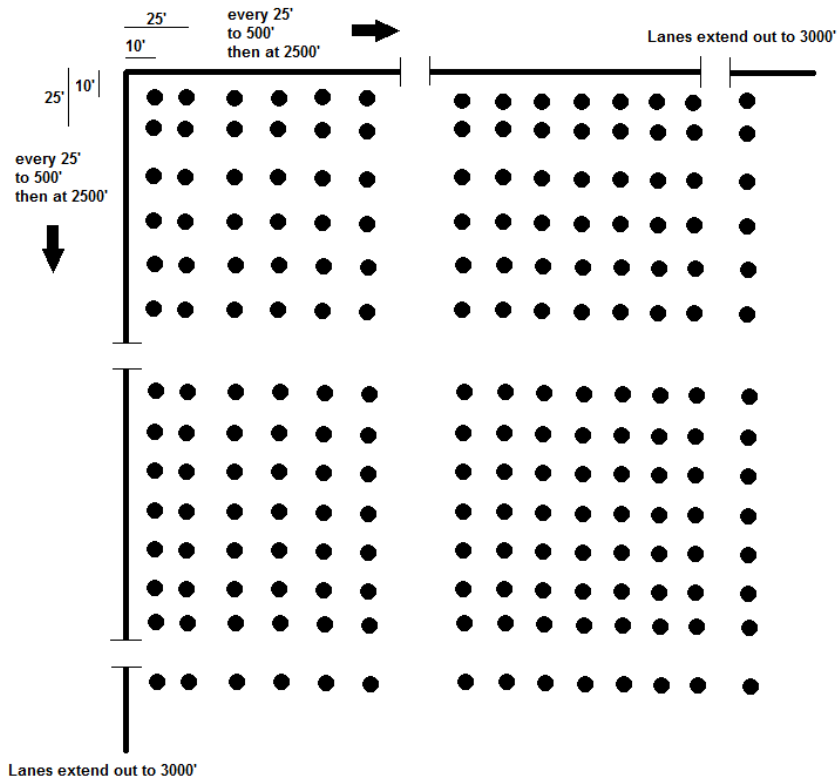

Figure 4.7 - Receptor locations for Southeast quadrant of intersection

4.5 Persistence Factor

To derive an 8-hour CO concentration from the modeled 1-hour CO concentration, a persistence factor was applied to the modeled 1-hour concentration. The persistence factor accounts for variability in traffic and meteorological conditions between the 1-hour time frame and the 8-hour time frame. The persistence factor is the ratio between the maximum 1-hour CO concentration and the resulting maximum 8-hour concentration in the 8-hour time frame containing the maximum 1-hour concentration.

For a local area, EPA recommends using the average of the highest 10 non-overlapping 8-hour CO concentrations from the previous three years as the persistence factor. Where representative monitoring data is not available EPA recommends the use of a persistence factor of 0.7. For this study, the EPA recommended persistence factor of 0.7 was used because the study was on the national scale.

Examination of state air quality monitoring data may yield a persistence factor different than the national default value of 0.7. This could result in a different set of project conditions and types that would be covered under the PA. A state-specific persistence factor can be easily incorporated into a state PA since the results reported in section 4.7 Summary of Modeled Results are all in terms of the one-hour concentration. Thus, simply multiplying the one-hour concentration by the state-specific persistence factor would provide the 8-hour CO concentration.

4.6 Background Concentration

In order to develop a realistic nationwide CO background concentration estimate, the 2nd highest non-overlapping observed 8-hour CO concentrations from each of the nation's CO monitoring stations were extracted from EPA's AirDATA, which is a database of air monitoring data. The data were ranked for each of the three most recent years (2011-2013). The 99th, 95th, and 90th percentiles were calculated and reviewed. Based on this review it was determined that a reasonably conservative value, applicable to almost any location nationwide would be the average of the 95th percentile CO concentration from the past three years. Using this approach, the calculated representative 1-hour background concentration was found to be 5.1 ppm and the representative 8-hour background concentration was found to be 2.6 ppm Table 4.5).

It should be noted that estimating nationwide CO background concentration is not the same as determining the CO concentration for a state or local area. For determining the 8-hour CO background concentration for a state or local air district, where representative monitoring data is available, EPA's current practice is to identify the highest concentration for determining compliance with the 8-hour CO NAAQS as the 2nd highest maximum non-overlapping 8-hour CO concentration from the most recent calendar year of monitoring data.[17] Thus, for a state-specific PA this latter approach could be used in determining the CO background concentration.

Table 4.5 – Nationwide Network of Co Monitoring Stations Ranked Concentrations 2011-2013

	2nd High Maximum Non-overlapping 8-hour CO Concentrations (ppm)			
Percentile	2011	2012	2013	Average
99th	5.8	4.6	4.6	5.0
95th	2.8	2.5	2.5	2.6
90th	2.4	2.1	2.1	2.2
	2nd High Maximum Non-overlapping 1-hour CO Concentrations (ppm)			
99th	15.3	8.0	7.9	10.4
95th	5.5	4.8	5.0	5.1
90th	4.6	3.5	3.5	3.9
Number of monitoring stations with >75% data completeness	286	284	198	

Source: USEPA AIRData (2014)

[17] CO Air Quality Data Update 2014 Design Values, Available at http://www.epa.gov/airtrends/values_previous.html

4.7 Summary of Modeled Results

Presented below are the results of the emissions and dispersion modeling of the four analyzed facilities (freeways, arterials, interchanges, and intersections). A variety of freeway and arterial lanes were evaluated in both urban and rural locations. Intersections were also evaluated for three approach speeds in rural and urban settings. Urban interchanges were evaluated for a broad range of freeway lanes and for a variety of distances between the interchange and freeway. Results consist of maximum predicted 1-hour CO concentrations (not including background concentrations) for this variety of freeway and arterial settings, urban and rural intersections, and urban interchanges.

4.7.1 Freeways and Arterials

Based on the MOVES and CAL3QHC inputs described above, the EPA recommended persistence factor of 0.7, and the 8-hour background concentration of 2.6 ppm, Table 4.6 shows the one-hour modeled concentration lane and grade combinations for arterials and freeways in urban and rural locations that, under these conditions, cannot produce concentrations that could result in violation of the 8-hour CO standard. In all cases, the 8-hour CO standard, as opposed to the 1-hour standard, is the limiting case. Thus, freeway and arterial projects whose lane and grade conditions are less than or equal to those shown in Table 4.7 will not require a project-specific modeling to demonstrate compliance with CO ambient standards.

4.7.1.1 Sensitivity analysis for 11-foot wide urban freeway lanes

To assess the relative importance of lane width to modeled concentration 10, 12, 14, 16, 18, 20 and 22-lane urban freeways were modeled using both the standard 12 foot lane width and an 11 foot lane width. The 22-lane freeway showed the maximum response to this change in lane width. Table 4.7 shows the relative change at each receptor as measured from the edge of the closest lane. The distance from the travel lane to the receptor location remained the same for both the 11 and 12 foot lane widths. The results show that the largest change was a relative increase in concentration of just 2%[18]. Both sides of the freeway showed the same response.

[18] These results provide a sensitivity test on the maximum possible change using 11-foot wide lanes. In developing a PA if a state believes 11-foot wide lanes are not unusual those effects can be included into their TSD. At a maximum the increase relative to what is presented for 12-foot lanes would be 0.2 ppm and in most cases, substantially less.

Table 4.6 - One-hour CO concentrations (not including background concentrations) for freeways and arterials in urban and rural settings of varying lane and grade configuration[19]

			GRADE			
FACILITY TYPE	**LOCATION**	**LANES**	**0**	**2**	**4**	**7**
Arterial	Urban	12	6.7	8.5		
Arterial	Urban	10	6.0	7.6		
Arterial	Urban	8	5.2	6.6		
Arterial	Urban	6	4.3	5.4	7.5	
Arterial	Urban	4	3.2	3.9	5.5	
Arterial	Urban	2	1.8	2.2	3.0	
Arterial	Rural	8	8.7			
Arterial	Rural	6	7.2	8.6		
Arterial	Rural	4	5.4	6.3	8.6	
Arterial	Rural	2	3.1	3.6	4.9	
Freeway	Urban	20	9.0			
Freeway	Urban	18	8.6			
Freeway	Urban	16	7.9			
Freeway	Urban	14	7.2			
Freeway	Urban	12	6.5			
Freeway	Urban	10	5.6	8.0		
Freeway	Urban	8	4.7	6.6		
Freeway	Urban	6	3.7	5.1	7.2	
Freeway	Urban	4	2.7	3.5	4.9	6.2
Freeway	Urban	2	1.4	1.7	2.4	3.1
Freeway	Rural	8	8.0			
Freeway	Rural	6	6.4	8.6		
Freeway	Rural	4	4.5	5.9	8.2	
Freeway	Rural	2	2.4	3.0	4.2	5.3

[19] These findings apply to scenarios with average speed ranging from 45 to 56 mph for arterials and 19 to 74 mph for freeways.

Table 4.7 - Comparison of maximum predicted one-hour CO concentrations (not including background concentrations) for a 22-lane (11 lanes in each direction) urban freeway using a 12- foot and 11-foot lane width

	Distance[1]	Standard 12 foot lane width	11 foot lane width	Difference	Difference
Receptor	(m)	Concentration (ppm)	Concentration (ppm)	Concentration (ppm)	percent
1	10	11.6	11.8	0.2	2%
2	20	10.6	10.8	0.2	2%
3	30	9.6	9.7	0.1	1%
4	55	8.0	8.1	0.1	1%
5	80	6.9	7	0.1	1%
6	105	6.1	6.2	0.1	2%
7	130	5.6	5.6	0.0	0%
8	155	5.1	5.2	0.1	2%
9	180	4.7	4.8	0.1	2%
10	295	3.6	3.6	0.0	0%

[1] Distance from edge of the nearest travel lane

4.7.2 Intersections

Table 4.8 shows the maximum CO concentration for various approach speeds for a 6 approach lane intersection project (2 left turn lanes and 4 through lanes) for which a project-level air quality analysis will not be required to demonstrate compliance with CO ambient air quality standards (NAAQS). These results assume the same background and persistence factors previously discussed, and that the intersection has a 2% grade and a skew angle of 90 degrees. Intersections with grades lower than 2% and fewer than 6 lanes would not be required to demonstrate compliance with CO ambient air quality standards.

In addition to the typical 90 degree angle intersection, an intersection with a 10 degree skew angle was modeled. However, the study found that only for the urban scenario with an approach speed of 35 mph would the 8-hour value NAAQS not be exceeded. As such, the 10 degree skew intersection is not included in the template PA scenarios. However, in practice skew angles of less than 90 degrees may prove useful to include in a PA, especially if skewed intersections are common. Additional modeling for a variety of skew angles would be needed to determine the model response along with careful determination and placement of the receptor locations, which would need to be changed with skew angle.[20]

[20] A graphical user interface for both emission and dispersion modeling being developed under NCHRP 25-48 may facilitate analyses of skew angles.

Table 4.8 - One-hour CO concentrations (not including background concentrations) for rural and urban intersections at varying approach speeds for a six approach lane intersection for each leg at two percent grade.

LOCATION	APPROACH SPEED (MPH)	CONCENTRATION (PPM)
Urban	15	6.5
Urban	25	5.7
Urban	35	5.2
Rural	25	8.8
Rural	35	8.4

4.7.3 Interchanges

Table 4.9 shows the one-hour concentrations that, with the assumed 8-hour CO background level and persistence factor (see sections 4.5 Persistence Factor and 4.6 Background Concentration), cannot, when combined with background CO concentrations, produce concentrations in exceedance of the 8-hour CO NAAQS. As such, these projects will not require a project-level CO analysis to demonstrate compliance with the ambient CO standards. Table 4.9 presents results by the distance from the edge of the nearest freeway travel lane to the edge of the nearest interchange ramp travel lane for varying number of lanes. The intersection geometry is the same as the intersection case, six lanes on each approach (4 approach, 2 left turn) and 4 departure lanes, all with a 2% grade or less. This is a conservative approach for this type of project because freeway interchanges generally have a one- or two-lane ramp approaching or departing from the intersection. The freeway was modeled at a 0% grade in both rural and urban locations. However, because the rural interchange results were considerably higher than would be useful for a PA, only the urban results are presented here.

Table 4.9 - One-hour CO concentrations (not including background concentrations) at varying intersection approach speeds at varying distances from an urban freeway at varying lane configurations

Urban Freeway and Interchange Contribution of CO (PPM) at 15 mph Approach Speed with Increasing Distance from Freeway Pavement Edge (ft)												
Number of Freeway Lanes	**10**	**20**	**30**	**60**	**80**	**100**	**125**	**150**	**175**	**300**	**500**	**1000**
2	8.5	7.8	7.5	7.1	6.9	6.7	6.7	6.6	6.5	6.5	6.3	6.3
4			8.8	8	7.6	7.4	7.2	7.1	7.1	6.7	6.5	6.3
6				8.9	8.4	8.1	7.9	7.6	7.6	7.1	6.8	6.5
8					9.1	8.7	8.4	8.1	8	7.4	7.1	6.7
10							9	8.7	8.5	7.8	7.3	6.8
12								9.1	8.9	8.1	7.6	6.9
14										8.5	7.8	7.1
16										8.8	8	7.2
18										9.1	8.2	7.4
20											8.5	7.5
22											8.7	7.6
Urban Freeway and Interchange Contribution of CO (PPM) at 25 mph Approach Speed with Increasing Distance from Freeway Pavement Edge (ft)												
Number of Freeway Lanes	**10**	**20**	**30**	**60**	**80**	**100**	**125**	**150**	**175**	**300**	**500**	**1000**
2	7.9	7.2	6.9	6.5	6.3	6.1	6.1	6	5.9	5.9	5.7	5.7
4		8.7	8.2	7.4	7	6.8	6.6	6.5	6.5	6.1	5.9	5.7
6				8.3	7.8	7.5	7.3	7	7	6.5	6.2	5.9
8				9.1	8.5	8.1	7.8	7.5	7.4	6.8	6.5	6.1

Urban Freeway and Interchange Contribution of CO (PPM) at 15 mph Approach Speed with Increasing Distance from Freeway Pavement Edge (ft)												
10					9.1	8.7	8.4	8.1	7.9	7.2	6.7	6.2
12							8.8	8.5	8.3	7.5	7	6.3
14								9	8.7	7.9	7.2	6.5
16									9.1	8.2	7.4	6.6
18										8.5	7.6	6.8
20										8.7	7.9	6.9
22										9.1	8.1	7
Urban Freeway and Interchange Contribution of CO (PPM) at 35 mph Approach Speed with Increasing Distance from Freeway Pavement Edge (ft)												
Number of Freeway Lanes	**10**	**20**	**30**	**60**	**80**	**100**	**125**	**150**	**175**	**300**	**500**	**1000**
2	7.3	6.6	6.3	5.9	5.7	5.5	5.5	5.4	5.3	5.3	5.1	5.1
4	9	8.1	7.6	6.8	6.4	6.2	6	5.9	5.9	5.5	5.3	5.1
6			8.6	7.7	7.2	6.9	6.7	6.4	6.4	5.9	5.6	5.3
8				8.5	7.9	7.5	7.2	6.9	6.8	6.2	5.9	5.5
10					8.5	8.1	7.8	7.5	7.3	6.6	6.1	5.6
12						8.7	8.2	7.9	7.7	6.9	6.4	5.7
14							8.8	8.4	8.1	7.3	6.6	5.9
16								8.9	8.5	7.6	6.8	6
18									8.9	7.9	7	6.2
20										8.1	7.3	6.3
22										8.5	7.5	6.4

Recommendations for Additional Research

The preceding sections of this report outline the inputs and guidelines necessary to produce a programmatic agreement (PA) and technical support document (TSD) for carbon monoxide (CO). The development of such documents for CO is possible because CO modeling and analysis techniques are well understood and documented. By contrast, modeling and analysis techniques for mobile source air toxics (MSATs) and particulate matter (PM) emissions are not very well developed and have a much shorter history. Moreover, there are considerably greater technical and analytical challenges associated with PM and MSAT modeling than with CO modeling.

In order, then, to enable development of federal and state level PAs and TSDs for MSATs and PM, additional research must be undertaken. This was the objective of phase 2 of the investigation performed under Task 78: to identify and explore areas of research that would aid in the establishment of PAs and TSDs for MSAT and PM analyses.

Under phase two, five broad areas of research were identified. These are as follows:

1. *Examination of projects for which PM hot-spot assessments were conducted*. Most users conducting a PM hot-spot assessment as part of a NEPA study follow EPA's *Transportation Conformity Guidance for Quantitative Hot-spot Analyses in PM2.5 and PM10 Nonattainment and Maintenance Areas* (Transportation and Climate Division Office of Transportation and Air Quality U.S. Environmental Protection Agency, EPA-420-B-13-053, November 2013)[21]. It may be useful to learn further about such projects and the methods they used to analyze PM emissions. Likewise, it would be valuable to examine projects that have engaged in developing emissions estimates for MSATs. The findings of these studies may inform development of PAs for MSAT and PM analyses.

2. *Understanding the evolution of PM emissions over time.* There has been a 90% reduction in diesel PM emissions since the introduction of post-2006 diesel truck engines. Given this, as well as the Tier 2 and Tier 3 gasoline PM emission reductions standards (30 ppb sulfur in gasoline in 2017), it would be worthwhile to explore how PM emissions have changed in terms of the highway traffic volumes that currently might be subject to a quantitative analysis.

3. *Understanding the evolution of MSAT emissions over time*. Large reductions in MSAT emissions, particularly diesel PM emissions, have occurred in recent years. A more complete picture of how MSAT emissions have changed and will continue to change in

[21] Updated November, 2013. Available at: http://www.epa.gov/otaq/stateresources/transconf/projectlevel-hotspot.htm#pm-hotspot

both quantity and source over past, current and future years would be a useful insight for development of a PA for MSATs.

4. *Examination of existing guidance for PM hot-spot analysis.* EPA's current PM hot-spot guidance[22] for a quantitative analysis identifies a 9-step process to determine the conformity of a project. Under NEPA, the approach may be simplified if it can be demonstrated that a particular approach or dataset provides results comparable to those of the prescribed methodology. The research objective is to identify the elements of this 9 step process that will likely show the greatest gains in flexibility with the least increase in conservatism. These elements may inform the conditions under which a project-level analysis for PM would not be warranted for purposes of NEPA in a PA.

5. *Development of a "reference case library" that advances a standard set of inputs of meteorology and land-use data, as well as different project facility types and traffic volumes.* Such a library could serve as guidance and as a QA/QC check for future analyses.

In addition to these five areas of research specific to PM and MSATs, a sixth, separate, area of research for CO was identified. This is:

6. *Application of the draft PA and TSD for CO to development of state-specific PAs for CO.* This will identify and address issues with development and implementation of PAs from the template to be used by state DOTs. The research would encompass the entire process of PA development, from start to implementation. Lessons learned from this research could also be used to inform the process of state-specific PA development and implementation for MSATs and PM.

This last area of research will enable states to adapt the draft national level PA and TSD for CO (Appendices B and C, respectively) for use at the state level. It is envisioned that most state DOTs would benefit by updating any CO analysis procedures they may have in place. In addition, though not specific to MSATs and PM, this sixth area of research also informs development of state level PAs and TSDs for these pollutants. This report proposes that this area of research be explored as an extension of task 78.

The results of investigation into the first five areas of research and the proposed steps to conduct the sixth area of research are detailed below.

[22] EPA's Transportation Conformity Guidance for Quantitative Hot-spot Analyses in PM2.5 and PM10 Nonattainment and Maintenance Areas (Updated November, 2013). Available at: http://www.epa.gov/otaq/stateresources/transconf/projectlevel-hotspot.htm#pm-hotspot

5.1 Review of Quantitative PM Hot-Spot Assessments

Research area: *Examination of projects for which PM hot-spot assessments were conducted. Most users conducting a PM hot-spot assessment as part of a NEPA study follow EPA's* Transportation Conformity Guidance for Quantitative Hot-spot Analyses in PM2.5 and PM10 Nonattainment and Maintenance Areas *(Transportation and Climate Division Office of Transportation and Air Quality U.S. Environmental Protection Agency, EPA-420-B-13-053, November 2013)*[23]*. It may be useful to learn further about such projects and the methods they used to analyze PM emissions. Likewise, it would be valuable to examine projects that have engaged in developing emissions estimates for MSATs. The findings of these studies may inform development of PAs for MSAT and PM analyses.*

The first step in reviewing previously conducted PM[24] and MSAT project-level assessments is to collect relevant data and establish a robust database of projects that have included a PM and/or MSAT air quality analysis. This would be done by considering NEPA documents. Examination of NEPA documents could reveal technical and analytical approaches performed under different requirements or regulations that, when modified and applied to a transportation air quality situation by a State DOT, could yield an insightful or innovative approach under a NEPA analysis. The research team has identified several data sources that could be used to establish the database:

- *Federal Highway Administration's (FHWA) website of active and inactive Environmental Impact Statements (EISs):* (http://environment.fhwa.dot.gov/projdev/active_eis.asp). This list of EISs would be examined to identify projects that included a PM and/or an MSAT air quality analysis. For those projects that did have a PM and/or MSAT analysis, that air quality analysis would be obtained.

- *A survey of FHWA Division Offices:* Such a survey would bring to light updated information about projects that may not yet be on the FHWA websites as well as projects that may not be included on the websites at all (e.g. projects of a lower environmental class that may have a PM and/or MSAT air quality analysis ongoing or completed).

- *A survey of state DOTs:* This would supplement the sources listed above and would identify PM and/or MSAT analyses conducted for projects outside of the NEPA process (i.e. analyses performed to meet state environmental requirements). The State DOT survey could be undertaken through the auspices of the American Association of State Highway and Transportation Officials (AASHTO) Standing Committee on the Environment's (SCOE) Air Quality, Energy and Climate Change Subcommittee. In order to

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[23] Updated November, 2013. Available at: http://www.epa.gov/otaq/stateresources/transconf/projectlevel-hotspot.htm#pm-hotspot

[24] PM refers to either PM_{10} or $PM_{2.5}$, as appropriate, and, in addition to the PM_{10} daily standard, the term "air quality standard" refers to either the $PM_{2.5}$ daily or annual standard, as appropriate.

not overly burden state DOT staff, this survey would be brief. The following questions would be included:

- Is the state DOT aware of any projects with completed or ongoing PM or MSAT air quality analysis?
- If yes, could they provide project information and PM and/or MSAT analysis?
- Is the state DOT aware of any projects undertaken by other state or local agencies involving a PM and/or MSAT air quality analysis (especially those with a transportation component)?
- If yes, could they provide contact information for that agency?
- Could the state DOT provide appropriate contact information for possible follow-up?

- *USEPA's website documenting EPA reviews of EISs under NEPA:* (http://www.epa.gov/compliance/nepa/eisdata.html). This list of comments on EISs pertains to a range of projects beyond transportation projects. However, a scan of this website would serve to identify transportation projects and projects with transportation components that do not involve FHWA. Review of these comments could also lead to insight on other aspects of a project-level analysis, such as background pollutant levels.

Once the database has been established, information extracted from the data sources listed above could be organized by various parameters. For example:

- PM vs. MSAT analysis
- Facility type (i.e., interchange, freeway, arterial)
- Traffic volume
- Land use
- Rural/urban characteristics
- Exhaust emission levels
- Running losses emission levels

In addition, for PM information could be further organized by:

- Road dust emission source levels
- Brake and tire wear emission source levels
- Background levels
- Nearby sources treatment
- Potential for exceeding an air quality standard

Other parameters for PM and MSAT could be established if additional pertinent parameters are identified during the data review. Carrying out these steps would result in a unique database that other researchers could then examine and use to inform future analyses. The database would also help determine appropriate approaches and parameters for PAs for PM and MSATs on both national and state levels. By compiling and structuring relevant data, the database will also be able to facilitate identification of common features of hot-spot studies which in turn could inform and potentially improve the state of the practice.

5.2 Recent Changes in Mobile Source PM Emissions

Research area: *Understanding the evolution of PM emissions over time. There has been a 90% reduction in diesel PM emissions since the introduction of post-2006 diesel truck engines. Given this, as well as the Tier 2 and Tier 3 gasoline PM emission reductions standards (30 ppb sulfur in gasoline in 2017), it would be worthwhile to explore how PM emissions have changed in terms of the highway traffic volumes that currently require a quantitative analysis.*

Substantial reductions in PM emissions from both diesel and gasoline fueled engines have occurred in recent years. Given the substantial reductions in PM emissions from diesel trucks since 2006, it is likely that many projects will not result in emissions high enough to trigger a quantitative PM assessment under NEPA.

This research area seeks to determine which project types, and under what conditions (road grade, number of lanes, etc.) will not require quantitative PM project-level analysis for NEPA purposes, given the changes in PM emissions. The research would primarily focus on $PM_{2.5}$ but would also include PM_{10}. In particular, the research would characterize how $PM_{2.5}$ emission levels and source contribution (diesel–exhaust, gasoline-exhaust, crankcase, road dust, brake and tire wear) have evolved and determine the potential for a transportation project to cause an exceedance of a PM air quality standard, given these changes in PM emissions. It is expected that this research would be able to exclude a substantial number of project types and conditions, currently being analyzed under NEPA, from a PM hotspot assessment.

In order to explore a highway or expressway setting, the research would require the application of the latest version of EPA's Motor Vehicle Emissions Simulator (currently MOVES2014) with fixed default settings representative of either the national average or a reasonably conservative setting for PM emissions. This application would generate a useful set of project parameters, which could be used to identify project types likely to require a $PM_{2.5}$ project-level assessment.

Below are recommended starting points for various MOVES2014 parameters:

Default settings:

- National default fleet and vehicle age mix
- Conservative fuels with highest sulfur content, leading to highest PM emissions
- Freeways or arterials (whichever is associated with higher PM emissions, as differences are small)
- Urban or rural (whichever is associated with higher PM emissions, as differences are small)

Variable parameters and their ranges (likely to prove useful in identifying boundaries):

- 0 and 2% grade
- Speeds: 55, 60, 65, 70 and 75 mph
- Analysis years: 2017 (30 ppm S in gasoline), 2020, 2025, 2030, and 2035.
- ±1%, ±2% of the national default heavy-duty diesel truck fleet fraction

Outputs from MOVES2014 (would be separated into components for $PM_{2.5}$):

- diesel–exhaust
- gasoline-exhaust
- start
- crankcase
- brake wear
- tire wear

To evaluate the potential emissions for both the 24-hour and annual average PM standards, daily maximum weekday traffic volume and AADT volume should be identified. These metrics can be combined with the appropriate emission factors to estimate maximum daily and annual average emissions.

As part of this research, a preliminary investigation of potential changes in emissions was conducted using MOVES2014. An initial base year (2010) was modeled at 125,000 AADT that was considered sufficient to produce PM emissions which could produce PM concentrations that may be of concern. These levels were then compared with current and projected national defaults for heavy-duty diesel trucks (HDDT)[25] for 2017 (when 30 ppb sulfur gasoline is required) and for 2035. All sources of $PM_{2.5}$ emissions produced by MOVES were included: brake, tire and exhaust.

Table 5.1 summarizes daily $PM_{2.5}$ emissions estimates based on MOVES2014 modeling for 0 and 2% grade urban restricted access roadways for the three years: 2010, 2017 and 2035. As shown in the last column of Table 5.1, despite increasing percentages in HDDT fractions, by 2017 the 0% grade roadways will need approximately 200,000 AADT to have equivalent emissions to 125,000 AADT in 2010 and the 2% grade roadways will need approximately 150,000 AADT. By 2035, traffic volumes of 939,562 and 772,225 AADT are required for a project to have equivalent emissions to 125,000 AADT in 2010 at 0 and 2% grade roadways, respectively. It is likely that no urban restricted roadways with a 2% grade or less will require a $PM_{2.5}$ assessment.

[25] Heavy duty vehicles were assumed to be the diesel fueled single unit short haul (source id=52), single unit long haul (source id =53), combination short haul (source id=61), and combination long haul trucks (source id=62).

Indeed, the maximum AADT nationwide is 374,000 AADT along the I-405 freeway in Los Angeles[26].

Table 5.1 - $PM_{2.5}$ Emissions for Urban Restricted Roadways based on MOVES2014

Year	Roadway Grade	Heavy-Duty Diesel Truck (%)	Daily Average Emissions at 125,000 AADT (kg/day)	Equivalent AADT to 2010 and 0% Grade
2010	0%	8.9	8.15	125,000
2017	0%	9.2	5.04	202,037
2035	0%	10.0	1.08	939,562
2010	2%	8.9	11.08	91,925
2017	2%	9.2	6.82	149,343
2035	2%	10.0	1.32	772,225

Table 5.2 presents the same results as Table 5.1, but for rural, rather than urban, restricted roadways. Rural roads have a much higher percentage of HDDT traffic than their urban counterparts, and the projected AADT levels remain above 125,000 well beyond 2017. However, despite increasing HDDT, emission levels are predicted to continually decrease over time, and by 2035 it is unlikely that either 0 or 2% grade restricted rural roadways will require a PM2.5 assessment.

Table 5.2 - $PM_{2.5}$ Emissions for Rural Restricted Roadways based on MOVES2014

Year	Roadway Grade	Heavy-Duty Diesel Truck (%)	Daily Average Emissions at 125,000 AADT (kg/day)	Equivalent Urban AADT to 2010 and 0% Grade
2010	0%	18.6	15.31	66,509
2017	0%	19.0	9.40	108,298
2035	0%	20.6	1.66	612,672
2010	2%	18.6	21.10	48,250
2017	2%	19.0	12.97	78,499
2035	2%	20.6	2.11	483,444

The projected change in contribution from diesel vehicles to $PM_{2.5}$ emissions produced by the MOVES2014 model also shows a downward shift for both rural and urban restricted roadways.

[26] See: www.fhwa.dot.gov/policyinformation/tables/02.cfm

$PM_{2.5}$ emissions from diesel fueled trucks are predicted to decrease from 86% of total $PM_{2.5}$ mobile source emissions in 2010 and 2017 to roughly 70% in 2035 for rural restricted roadways. Similarly, $PM_{2.5}$ mobile source emissions attributable to diesel fueled trucks on urban restricted roadways are predicted to decrease from 77% in 2010 and 2017 to 50% by 2035. These decreases were found for both 0 and 2% grades. This analysis indicates that for future years (2035) in urban locations, gasoline PM emissions will be equally important as diesel PM emissions. Therefore, in future years both gasoline and diesel need to be considered in $PM_{2.5}$ analyses. This could be an area of further investigation.

Finally, Table 5.3 summarizes PM source contribution changes for urban restricted roadways in future years for the two roadway grades. As $PM_{2.5}$ emissions decrease in future years, the exhaust contribution likewise decreases. However, exhaust remains the dominate source through 2035 and, in fact, becomes responsible for a higher fraction of emissions on the 2% grade roadways. Interestingly, the brake and tire wear emissions are roughly equivalent for 0% percent grades, but the tire wear is almost twice as high for the 2% grade. The results for rural restricted roadway are comparable to those presented for urban roadways.

Table 5.3 $PM_{2.5}$ Emissions for Urban Restricted Roadways based on MOVES2014

Year	Roadway Grade	Exhaust (%)	Brake wear (%)	Tire wear (%)	Total (%)
2010	0%	97.1	1.5	1.4	100
2017	0%	95.3	2.5	2.2	100
2035	0%	73.0	14.3	12.7	100
2010	2%	98.5	0.5	1.0	100
2017	2%	97.5	0.9	1.6	100
2035	2%	84.3	5.6	10.1	100

The findings of this preliminary examination suggests that PM emission reductions resulting from the new standards will be substantial, particularly in more distant years. It is therefore likely that further examination could minimize the number of projects that would undergo a $PM_{2.5}$ hotspot assessment.

It is noted that State DOTs typically use EPA's *Transportation Conformity Guidance for Quantitative Hot-Spot Analyses in $PM_{2.5}$ and PM_{10} Nonattainment and Maintenance Areas* (Transportation and Climate Division Office of Transportation and Air Quality U.S. Environmental Protection Agency, EPA-420-B-13-053, November 2013), which applies in PM nonattainment and maintenance areas to determine a need for a quantitative PM hot spot assessment under NEPA. This research area could identify additional project types that could potentially be excluded from a quantitative hot-spot analysis under NEPA including:

- Expansion of an existing highway or other facility that affects a congested intersection (operated at Level-of-Service D, E, or F) that has a significant increase in the number of diesel trucks.

- Similar highway projects that involve a significant increase in the number of diesel transit buses and/or diesel trucks.

5.3 Recent and Future MSAT Emissions

Research area: *Understanding the evolution of MSAT emissions over time. Large reductions in MSAT emissions, particularly diesel PM emissions, have occurred in recent years. A more complete picture of how MSAT emissions have changed and will continue to change in both quantity and source over past, current and future years would be a useful insight for development of a PA for MSATs.*

Substantial reductions in hazardous air pollutants (HAP) emissions from both diesel and gasoline fueled engines have occurred since FHWA guidance was developed (and updated in November, 2013) for highway projects[27]. That guidance specifies that projects having the potential for meaningful differences in MSAT emissions among project alternatives should conduct a quantitative emissions analysis. For highway projects FHWA identified projects with traffic volumes of 140,000 AADT as subject to more rigorous assessment, including development of localized estimates of MSAT emissions for forecast years. The guidance is based on summing the emissions from the mobile source HAP emissions over a length of 10 miles. This roughly corresponds to the Clean Air Act definition of a major stationary source of hazardous air pollutants totaling 25 tons per year for all HAPs or 10 tons per year for any single HAP.

This research area would focus on changes in HAPs emissions during recent and future years using MOVES2014, which provides emission factors for VOCs (14 species), polycyclic aromatic hydrocarbons (PAHs) (16 species), dioxins and furans (17 species), and metals (7 species). The research objective is to characterize how HAP emissions level, type of HAPs, and source category (exhaust, evaporative and crankcase) have changed and will continue to change as a result of the FHWA guidance. The analysis would also include emissions of diesel particulate matter. This research would aid in better understanding of what project types have the potential for meaningful differences in MSAT emissions and would likely reduce the number of projects requiring a more rigorous quantitative assessment.

In order to explore a highway or expressway setting, the research would require the application of MOVES2014 with fixed default settings representative of either the national average or a

[27] Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding, November 2013. Available at:
http://www.fhwa.dot.gov/environment/air_quality/conformity/policy_and_guidance/cmcf/hotspot_finding.cfm

reasonably conservative setting for HAP emissions. This application would generate a useful set of project parameters, which could be used to clarify and extend the project types that have the potential for meaningful differences in MSAT emissions.

Below are recommended starting points for various MOVES2014 parameters.

Default settings:

- National default fleet and vehicle age mix,
- Conservative fuels with high RVP, high aromatics, high distillation parameters T50 and T90, leading to highest emission factors
- Summer season
- No I/M program
- Freeway or arterials (whichever has the higher emission factor as differences are small)
- Urban or rural (whichever has the higher emission factor as differences are small)

Variable parameters and their ranges (likely will prove useful in identifying boundaries for highway projects):

- 0, 1, 2, 3 and 4% grade
- Speeds: 55, 60, 65, 70 and 75 mph
- Analysis years: 2020, 2025, 2030, and 2035.
- Upper and lower bound in the most volatile gasoline fuels

Outputs from MOVES2014 (should be separated into components for HAPs and would include identification by:

- Toxic pollutants by major vehicle type categories and their source origin:
    - evaporate
    - exhaust
    - crankcase

Identifying the outputs in this way will provide information about the relative importance of different vehicle types and the nature of the source (evaporate, exhaust or crankcase) of those emissions. The emissions should also be expressed using a toxicity-weighted approach. In this approach, emissions are combined with their relative inhalation toxicity to provide an "apples to apples" comparison of air toxic species. This toxicity-weighted approach could help focus emission reduction or mitigation strategies to reduce exposure to the most problematic air toxics.

As most of the emphasis on air toxic emissions is on chronic exposure, traffic related measures should focus on AADT volumes. This information can be combined with the emission factors (g/vehicle-mi) to estimate annual and daily average emissions.

Preliminary investigation of potential changes in emissions was conducted using MOVES2014. The model was run for the current year (2015) and a future year (2035) at the project level to represent current levels of emissions on arterials (unrestricted) and freeways (restricted). The model parameters included a national default fleet mix, no Inspection and Maintenance program, and a speed of 74 mph for 0 and 2% roadway grades. The fuel mix was a national default mix, which varies on a county by county basis for each month of the year. A total of 76 gasoline mixtures are reported in MOVES when run in this mode, with market shares ranging from 0.02 to 11.8%. All gasoline mixtures have a fuel sulfur content of 30 ppm in 2015 and 10 ppm in 2035. Reid vapor pressure (RVP) ranged from 7-12.9 psi, benzene content was 0.61-0.63%, ethanol 10-15%, aromatic content 17-25%, olefin content 5.9-12.5%. Distillation parameters were T50: 171-211, and T90: 277-341. A single diesel fuel mixture was used in the analysis which had a sulfur content of 15 ppm with 5% as biodiesel.

Table 5.4 is a summary of the total HAP emissions[28], diesel PM emissions, and first and second highest individual HAPs based on MOVES2014 modeling for rural and urban restricted access roadways for 0 and 2% grades for the two years analyzed (2015 and 2035). The total emissions are based on the assumption of 140,000 AADT driven over ten miles of roadway. Table 5.4 shows that the current (2015) levels of HAP emissions are at or near the major source HAPs threshold for both urban and rural restricted roadways. However, by 2035 levels drop by over 80% for both HAPs and diesel PM. Thus, it is possible that no restricted roadways will have sufficient emissions to warrant the need for developing an emission inventory because even the maximum nationwide AADT of 374,000[29] would not be sufficient to exceed the major source threshold. By 2035 no single HAP or diesel PM exceeds ten tons per year. The primary HAP emissions are toluene, formaldehyde and xylene. Unrestricted urban and rural roadways show a very similar pattern but with slightly lower (6%) emissions across all categories.

Table 5.4 Total HAPs Emissions for Urban and Rural Restricted Roadways based on MOVES2014

Year	Roadway Grade	Total diesel PM (tons/year)	Total HAPs (tons/year)	Highest Single HAP (% of total)	Second Highest HAP (% of total)
Rural					
2015	0%	32.49	22.52	Toluene (22)	Formaldehyde (20)
2035	0%	3.13	2.87	Formaldehyde (30)	Toluene (17)
2015	2%	52.15	32.43	Toluene (23)	Xylene(19)
2035	2%	4.95	3.85	Formaldehyde (25)	Toluene (19)
Urban					
2015	0%	19.07	20.28	Toluene (26)	Xylene(21)
2035	0%	2.46	2.32	Formaldehyde (21)	Toluene (21)
2015	2%	30.10	29.94	Toluene (27)	Xylene(22)
2035	2%	3.85	3.36	Toluene (23)	Xylene(20)

[28] The summary does not include diesel particulate matter separately as MOVES was not run to separate out gasoline particulates from diesel particulates.
[29] www.fhwa.dot.gov/policyinformation/tables/02.cfm

The findings of this preliminary investigation suggests that HAPs and diesel PM emissions reductions will be substantial in future years. Therefore, further examination for other parameters such as years, grades, and speeds could be useful in establishing boundaries for identifying projects for which meaningful differences in MSAT emissions among project alternatives is unlikely, and thus do not require development of an emission inventory. Other project types that have historically been examined for their potential to have meaningful differences in MSAT emissions among project alternatives include:

- Major intermodal freight facilities that involve a significant number of diesel vehicles
- Existing facilities that accommodate a significant increases in the number of diesel vehicles for an expansion project.

These descriptions could be defined quantitatively in a PA developed by a state DOT to specify when an MSAT analysis will be required for a transportation project.

5.4 Streamline PM Hot-Spot Assessments

Research area: *Examination of existing guidance for PM hot-spot analysis. EPA's current PM hot-spot guidance for a quantitative analysis identifies a 9-step process to determine the conformity of a project. Under NEPA, the approach may be simplified if it can be demonstrated that a particular approach or dataset provides results comparable to those of the prescribed methodology. The research objective is to identify the elements of this 9 step process that will likely show the greatest gains in flexibility with the least increase in conservatism. These elements may inform the conditions under which a project-level analysis for PM would not be warranted for purposes of NEPA in a PA.*

The current guidance for conducting a PM hot-spot analysis: EPA's *Transportation Conformity Guidance for Quantitative Hot-Spot Analyses in* $PM_{2.5}$ *and* PM_{10} *Nonattainment and Maintenance Areas* (Transportation and Climate Division Office of Transportation and Air Quality U.S. Environmental Protection Agency, EPA-420-B-13-053 November 2013) can be found at: http://www.epa.gov/otaq/stateresources/transconf/policy/420b13053-sec.pdf. This guidance is intended for use in completing a hot-spot analysis as part of a project-level conformity determination in PM nonattainment and maintenance areas only. It is a nine-step procedure, starting with determining the need for an analysis and ending with documenting the results of the analysis.

Due to the detailed technical nature of the guidance, it is likely that a state DOT or other entity undertaking a PM hot-spot analysis in a PM attainment area for NEPA or state environmental requirements would follow this guidance as a basis for their analysis. However, for an analysis in an attainment area, the project sponsor has flexibility in how a project is modeled. This flexibility allows for possible streamlining of one or more of the nine steps in the procedure. It also allows for the development of a PA to determine *a priori* how various elements of the analysis will be performed, or to determine use of one or more data elements for the analysis.

Although the guidance contains nine steps, Step 2 ("Determine Approach, Models and Data") offers the greatest opportunity for flexibility and streamlining. Step 2 also provides information (pages 18-23 of the guidance) about subsequent steps that discuss modeling approaches, models, and traffic and air quality data and which relate back to the elements of Step 2 (i.e. Step 3 – "Estimate On-Road Motor Vehicle Emissions"; Step 4 – "Estimate Emissions from Road Dust, Construction and Additional Sources"; Step 5 –"Select Air Quality Model, Data Inputs and Receptors"; and Step 6 – "Determine Background Concentrations"). Accordingly, the elements of Step 2, as well as the elements of related steps are addressed below. The discussion extracts elements from the guidance that a state DOT may consider in order to streamline or simplify the analysis, or to develop data or other information for inclusion as part of a PA. The discussion is intended to identify those elements that offer the best opportunity for an agreement among relevant agencies and standardization of a PM hot-spot analysis for NEPA purposes, and thus could be the focus of a PA. The discussion assumes both a "Build" and "No-Build" analysis for PM_{10} and $PM_{2.5}$. Where distinctions would be made either for the type of analysis or species of pollutant, they are specifically indicated.

This research area is intended to streamline and provide flexibility to a PM hot-spot analysis undertaken to examine potentially significant air quality impacts under NEPA, and not the regulatory requirements under transportation conformity.

Completion of Research Area 1 (5.1 Review of Quantitative PM Hot-Spot Assessments) will likely inform and offer insight towards the successful completion of Research Area 4. This work may result in development of AERMOD improvements or procedural changes that better support those projects that undergo this type of analysis. For example, this work may inform standardization of the approval process (and/or determination of when approval is not needed) for use of parallel processing with AERMOD, approval of specific commercial modeling products for this purpose, etc.

The identified elements of each relevant step are listed below:

Step 2 – Determine Approach, Models and Data: This Step offers several opportunities for streamlining the hot-spot analysis. These include:

- Description of general procedures. This would involve establishing an overall approach to the analysis, perhaps by project type. The overall approach could involve:
    - scale and scope of the analysis (i.e. the "project area")
    - build and no-build analysis
    - applicable PM NAAQS to be evaluated
    - applicable models by project type (e.g. CAL3QHC/R for highway projects, AERMOD for non-highway projects)
        - establish worst-case inputs
        - source of traffic inputs
        - land use and surface characteristics

  - use of project-specific or state-specific data
    - temperature
  - sources of meteorological data
  - receptor placement
  - fuel parameters and I/M program
  - background concentration
    - current and, if needed, future background levels
  - agency coordination and schedule considerations
- Determination of analysis years: year of maximum emissions or multiple years (i.e., Estimated Time of Completion (ETC), ETC+10, ETC+20)
- Sources of PM emissions to be modeled such as: exhaust emissions, running losses emissions, crankcase emissions, brake and tire wear emissions, road dust emissions (for PM_{10}, perhaps for $PM_{2.5}$), and construction emissions
- Year round or peak season analysis.

5.5 Reference Case Library for PM Hot-Spot Inputs

Research area: *Development of a "reference case library" that advances a standard set of inputs of meteorology and land-use data, as well as different project facility types and traffic volumes. Such a library could serve as guidance and as a QA/QC check for future analyses.*

As part of an air quality analysis, meteorology and land use classes are needed to complete the final step: dispersion modeling. Gathering and inputting the necessary information is both confusing and time consuming. In many cases, depending upon the project facility type, inputs are similar in nature and could allow either a partially completed input file to be used directly or a comparison to established value ranges as a quality control measure. Each data type is discussed in detail below.

Meteorology

As a first approach, general trends have been defined for meteorology for the United States and could be used to define typical meteorological inputs for specific areas. Figure 5.1 and Figure 5.2 how these attributes for thermal mixing (based on incoming solar radiation) and wind speed, respectively[30]. Similar data for temperature (minimums and maximum by season), inversion heights, and precipitation are also available. While figures are shown here for clarity, the information is also available in tabular form. This information could be used to develop general inputs for meteorology by area directly, interpolating in some cases (e.g., wind speeds by time of day) and integrating in other cases (e.g., atmospheric stability). In some cases developing such general inputs would be a very straight forward process for State DOTs. In Florida, for example, this would be very easy to implement as similar trends exist throughout the state. In other cases, where meteorology varies substantially across the state, as in California, greater interpolation would be required. The final product would be a tabular listing

[30] Site-specific influences such as valley wind channeling effects, localized sea breezes, urban heat island effects, etc., would need to be evaluated as to their significance in applying this information for a specific project-level assessment.

of geographically defined areas with inputs to be used within the dispersion modeling. Notably, there are different geographic areas across the U.S. with the same characteristics, which could be combined to reduce the overall selection process. These listings could serve two purposes: as a quality control measure and serve as a comparison with similar projects, or as defaults for simple screening analysis.

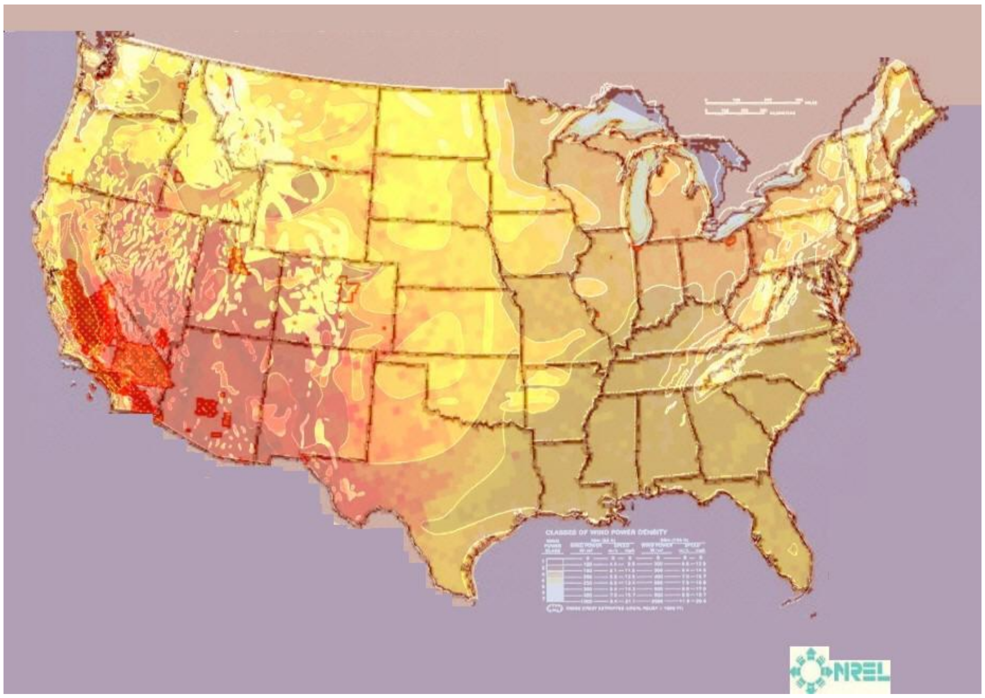

Figure 5.1. Thermal Mixing Potential in 48 Contiguous States [National Renewable Energy Laboratory]

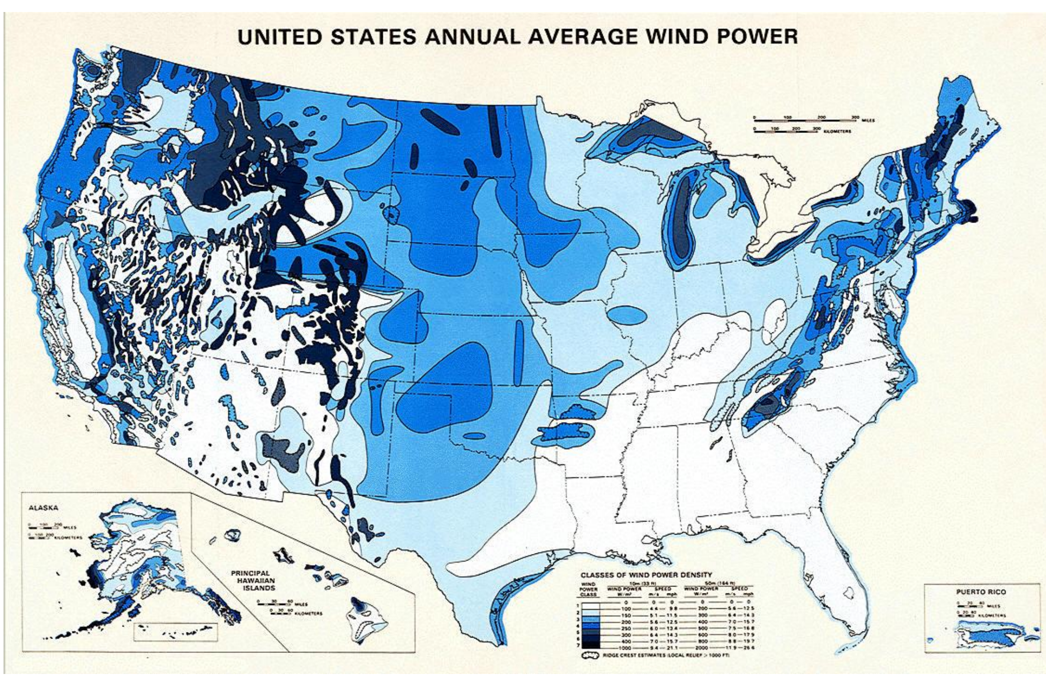

Figure 5.2. Average Wind Power for U.S. [National Renewable Energy Laboratory]

A more rigorous effort could also be undertaken. The National Oceanic and Atmospheric Administration (NOAA) maintains climatology records for most airports and many other local meteorology stations. EPA has used this information in the past to create meteorology input files for the ISC model (the predecessor to AERMOD). This information is currently available on a local air agency basis but could be expanded to include a broader geographic dataset. Use of this meteorological data in AERMOD would require it to be paired with land use information.

Other possibilities, depending upon available resources, include development of a novel methodology with a complexity between the two methods presented above; a combination of the two presented methods; and/or greater geographic resolution using either method by incorporating data from local weather stations. Whatever the method ultimately employed, it is envisioned that the result will be input that will work directly with software being developed under NCHRP 25-48's Transportation Air Quality System (TRAQS), in which the closest proximate meteorological input is used by default, though it may not always be the appropriate choice. This approach may not be accepted for regulatory analyses which would have to be reviewed and agreed upon during the consultation processes.

Land Use Classes and Traffic Characteristics

The true land use for any particular project is unique and cannot be a simple default. However, some characteristics are universal across land use types, and general trends could be defined to reduce input effort. In some cases, this has already been accomplished. For example, in the case of surface roughness, EPA has defined broad categories based on land use. In other cases, classes of land combined with facility types have similar characteristics such as traffic volumes, vehicle mix, average vehicle speeds, roadway geometries, and receptor placement. A few specific examples include:

- Intersections are often at or over capacity in urban situations during rush hour.
- Arterials and freeways are often at or over capacity in urban situations during rush hour.
- Intersections often have very similar operational characteristics in terms of number of lanes, left turn bays, lane width, and signal timing.
- Freeways often have the same clearance distance for safety purposes, establishing a standardized worst-case receptor location.
- Intersection receptor placement has been described by EPA and could be used directly.

A number of other similarities also exist to varying degrees. These could be developed based on a series of key inputs, especially for oversaturated conditions where vehicle density determines the volumes and speeds, which in turn limit overall emissions. These important situations, where violations are most likely to occur, could be categorized for a broad range of facility types and inputs thereby reducing input development time. Under such a scheme, the analyst would select a general input file based on facility type, number of lanes, speed, and other categories based on desired number of selections. This is intended as the next step towards efficiency from the NCHRP 25-48 work (Transportation Air Quality System, TRAQS), in which input files are being created but local information is still needed. In this case, the idea would be extended to reasonably foreseeable worst-case traffic conditions (e.g., over capacity traffic situations) and described as input for use in the TRAQS modeling system.

5.6 A Pilot Program for Streamlining Carbon Monoxide (CO) Project-Level Air Quality Analyses with Programmatic Agreements (PAs)

Research area: *Application of the draft PA and TSD for CO to development of state-specific PAs for CO. This will identify and address issues with development and implementation of PAs from the template to be used by state DOTs. The research would encompass the entire process of PA development, from start to implementation. Lessons learned from this research could also be used to inform the process of state-specific PA development and implementation for MSATs and PM.*

As mentioned above, in addition to the five research areas related to PM and MSATs, a logical extension of Task 78 would be implementation of the phase 1 results to state-specific PAs for CO hot-spot analyses. Upon successful completion of such Task 78 extension research, similar work could be performed for any state DOT that would benefit from having a state-specific PA in place for CO hot-spot analysis. It is envisioned that most state DOTs would gain benefit by updating any CO analysis procedures they currently have in place. The following description outlines the concept of the proposed Task 78 extension research.

The NCHRP 25-25 Task 78 study (2015) successfully developed templates for a PA and associated TSD that are designed to be implemented by state DOTs to streamline project-level air quality analyses for CO. The proposed study is for a pilot program that would apply the NCHRP templates for two or three state DOTS, starting from the beginning of the analysis process, making revisions to the templates as needed (e.g., to cover additional project types and/or configurations, and to use state-specific modeling inputs), and continuing through necessary approvals and subsequent execution with FHWA for each state DOT in the pilot program. Lessons learned in this initiative would inform and assist the subsequent implementation of the templates (with any revisions as appropriate) for state DOTs across the nation.

Background:
Project-level CO hot-spot analyses have been undertaken to satisfy environmental requirements for the past several decades. Over this period, different modeling approaches have been developed and used to determine whether a transportation project has the potential to violate the CO ambient air quality standards.

The MOBILE series of models have traditionally been used for emissions modeling until the release of the first version of the MOVES model in 2010. Other models have been developed (such as modal based emissions models[31]) but were not widely used because first the MOBILE series and later MOVES were developed and approved by USEPA.

Similarly, dispersion models have undergone changes over this time period. Highway sources have historically been treated as line sources using Gaussian dispersion to deliver CO from the source to the receptor. The HIWAY and CALINE series of models were developed to allow for roadways to be modeled in this way. Over time, it was realized that congested intersections, where vehicles experience idling; acceleration; and deceleration associated with a traffic signal, may be more of a concern for CO levels than free-flowing highways.

Over this period of time, many states developed guidance and procedures describing situations or project types that require a project-specific analysis and prescribed state-specific modeling inputs and other assumptions (e.g. background concentrations) to be used in the analysis. Most recently, Task 78 developed templates for a national level PA for CO project-specific analysis. As this template is at the national level, conservative inputs and national default values were used, many of which would likely be less conservative when applied at a state-specific level.

Potential Benefits:
With state-specific assumptions and inputs (such as background concentration, persistence factor, fleet mix, fuel mix, Inspection and Maintenance program, etc.), more project types (i.e., park and ride lots, skewed intersections, roundabouts, etc.) and/or more project conditions (i.e., road grade or number of lanes) could be shown to meet the CO NAAQS in each state. NCHRP 25-25 Task 78 modeled 4 project types: freeways, arterials, intersections and interchanges. This proposed research would build upon the work of Task 78 and develop and implement a state-specific CO project-level PA in 2-3 states. Information from this research could then be used to shorten and simplify the process for PA development and implementation for other state DOTs. This would benefit other state DOTs that wish to develop a CO project-level PA by enabling them to avoid or work around procedural, administrative or technical issues that were encountered and solved during this proposed research.

Research objectives:
Research is needed to identify and address issues with development and implementation of PAs to be used by state DOTs for determining which project types do not require a project-level CO analysis. It is expected that this research would require a number of project types and conditions to be modeled and analyzed with state-specific inputs and data. The research would encompass the entire process of PA development and implementation, from start through needed approvals and finally to implementation. Lessons learned from this research could then be used to inform the process for PA development and implementation for other state DOTs.

[31] MOVES now provides this capability.

Research Tasks:

The tasks for this proposed research would be developed in consultation with the state DOT to ensure that they would best meet the needs of the DOT. However, in general, the research would likely consist of the tasks outlined below:

1. Ascertain state DOT's issues, past procedures, needs, etc. related to CO project-level analysis in their state.
2. Obtain and analyze CO monitoring data to develop state-specific background concentrations and persistence factor(s).
3. Perform emissions and dispersion modeling for selected project types and conditions.
4. Apply background concentrations and persistence factors to modeled results in order to determine which project types and conditions meet CO ambient air quality standards.
5. Using Task 78 templates and results of analyses, complete state-specific PA (and Technical Support Document, as needed)
6. Assist state DOT with PA approvals and implementation, as needed.
7. Develop final report documenting issues and obstacles encountered and solutions used to finalize the PA.

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Appendix A. State CO Project-Level Parameters

Table A-1 - State CO Project-Level Parameter Specification

	TX	WA	VA	CO	PA	UT	MN	GA	NC
Year (s)	ETC & design year	existing year, estimated year of completion, & design year (end year of current transportation plan)	base, peak emission & design years		opening year (ETC) preferred, design year (ETC+20) if opening year not available	opening & design year	opening year & last year of long range plan	base & design year	ETC, ETC +5, design year
Traffic Volume	*	*	*	peak hour traffic volumes & turning movements for existing & future conditions	*	field measurement for existing, travel model for future years for hourly traffic volume	benchmark AADT: 79,400	approach traffic volumes	projected AADT
Av. Speed	*	*	average operating speed	*	*	*	*	speeds based on LOS	anticipated speed limit, average operating speeds
Peak Speed	*	*	*	*	*	*	free flow traffic speeds	*	*
Link Length (m)	*	*	*	*	*	*	*	*	*
Vehicle Mix	*	*	from traffic studies	*	*	*	*	*	*
Op. Conditions/ Cold Starts (%)	*	*	consistent with conditions of peak one-hour traffic	*	*	excluded	*	*	*
Temp (F)	*	*	22 –to 32 degrees, dependent on region	*	minimum, maximum & average temperatures for January	average winter temperature for each county	*	*	*
Background CO	0.3 to 3.0 (8 hour background), depending on region	*	1.5 ppm - 2.5 ppm 8-hour background, depending on area	provided as needed	representative PaDEP monitor; if no monitor within 20 miles, a one-hour background concentration for rural conditions should be assumed at 2.0 parts per million (ppm). For urban / suburban conditions, a typical one-hour background concentration of 3.0 ppm should be assumed, & a typical eight-hour background concentration of 1.5 ppm should be assumed.	1 ppm to 6 ppm for 8-hour value, dependent on location & I/M program	ambient background CO concentrations measured within the previous three years, at a location within three miles of the project area	*	*
Future Background CO	*	*	no adjustment for future years	*	*	when more precise background values	*	*	*

	TX	WA	VA	CO	PA	UT	MN	GA	NC
						are required, the background concentration may be adjusted by the ratio of future to existing vehicle miles of travel (VMT) in the county times the ratio of future existing emission rates.			
Persistence Factor	0.6	*	0.7	*	0.7	0.7	*	*	*
Roughness length	*	*	urban - 175 centimeters, Rural – 11 centimeters	*	*	10 cm to 175 cm, depending on l & use	*	*	*
Stability (A-F)	stable	*	urban – D, Rural – E	*	urban - Stability Class D; Rural – Stability Class E	5 or E	*	*	*
Wind Speed	1 meter per second	*	1 meter/second	1.0 meters/second	1.0 meters/second	1.0 meters/second	*	*	*
Wind Direction	Blowing parallel to roadway	*	5 degree increments	*	0 to 350 degrees at 10 degree increments	10 degree increments for first run	*	*	*
Source Height	*	*	*	0.0 meters	*	at grade (1 foot)	*	*	*
Mixing Height	1000 meters	*	1000 meters	1000 meters	1000 meters	1000 meters	*	*	*
Source Receptor Distance	on right of way.	*	3 m from edge of roadway	*	each approach on both sides of the road where queues develop	at least 10 feet from the outside-most travel lane or where the public has access; located near the corner & at mid-block for each approach & departure of the intersection. Receptors should be placed on both sides of the roadway	where people might be for an extended period of time (i.e. gas station, homes, businesses, ROW line	*	*
Other Receptor Siting Guidance	*	*	*	*	*	*	*	*	*
Receptor Height	*	*	1.8 meters	1.8 meters	1.8 meters	6 feet	*	*	*
Grade %	*	D, E or F in existing or design year	LOS F	*	*	*	D or below	*	*

	TX	WA	VA	CO	PA	UT	MN	GA	NC
Level of Service (A-F)	The project is adding capacity & the design year AADT is equal to or greater than 140,000 vehicles per day	"Affected intersections" have at least a 10 percent increase in volumes or a degradation of LOS to D or worse with the project.	Peak ADT, greater than 59,000 ADT for non-intersection/ interchange roadway projects; 39,000 - 59,000 ADT for intersections/ interchanges, depending on roadway skew angle	A deficient future LOS of D, E or F or a degraded LOS from an existing LOS C or better to a deficient LOS	Mainline traffic volume of 125,000 AADT in opening/design year & opening/design year LOS D, E or F at signalized intersection or mainline un-signalized approach	Increased traffic volumes due to intersection or signal Improvements, widening for additional through or passing lanes, new interchanges, new road on new alignment	*	Determine if project adds capacity; Determine Level of Service (LOS) for intersections. Evaluate those with a LOS of D or worse; Screen design year traffic volumes to determine whether they exceed 10,000 vehicles per day (vpd)	worst-case signalized intersection along the project (i.e., intersection that carries the highest volume & / or the worst intersection LOS).
Facility Type	*	*		*	*	dependent on county	*	*	*
References	TxDOT Project Development Air Quality Toolkit . http://www.txdot.gov/inside-txdot/division/environmental/compliance-toolkits/air-quality.html.	Chapter 425 of the Environmental Procedures Manual http://www.wsdot.wa.gov/environment/air/ ; Air Quality Analysis - Reviewer Checklist	http://www.virginiadot.org/business/environmental.asp, Consultant Guide, Air Quality Project-Level Analysis, May 2009. Note: A major update is in progress (2015), which will supersede the 2009 Guide.	CDOT Air Quality Procedures - http://www.coloradodot.info/programs/environmental/air-quality/Air%20Quality%20-10%20Revisons.pdf/view ; CDOT Air Quality Program Book - http://www.coloradodot.info/programs/environmental/air-quality/air-quality-program-book.html	Project-Level Air Quality H &book, Publication 321, Sept, 2012, http://www.dot.state.pa.us/Internet/Bureaus/pdDesign.nsf/DesignHomepage?OpenFrameset&frame=main&src=EQADpubs?OpenForm	UDOT Environmental Process Manual of Instruction, Chapter 6 - Project Impact Analysis, revised May, 2010 http://www.udot.utah.gov/main/f?p=100:pg:0:::1:T,V:1328, Air Quality Hot Spot Manual, 2003, www.udot.utah.gov/main/uconowner.gf?n=200309081521212	Air Quality HPDP / Scoping / Subject Guidance,http://dotapp7.dot.state.mn.us/edms/download?docId=647184; Information required to conduct a Carbon Monoxide Analysis,http://dotapp7.dot.state.mn.us/edms/download?docId=644953, September, 2009	Environmental Procedures Manual, February 2012, Chapter V.6.2. For projects of air quality concern: http://www.fhwa.dot.gov/environment/air_quality/conformity/practices/ga_procedures/index.cfm	Conduct Air Quality Analysis, January, 2008, https://connect.ncdot.gov/resources/Environmental/Pages/Environmental-Compliance-Guides.aspx

Table A-2 - State CO Project-Level Parameter Specification (continued)

	CA	NY	IL	TN	FL	WI	ID
Year (s)	build year for all projects; build year = time following project completion when traffic on new facility is projected to stabilize. For projects whose design year is within two years of the attainment year, predicted concentrations should also be calculated for the region's attainment year.	critical analysis year (worst case of ETC, ETC+10 or ETC+20)	existing year (for no-build scenario), time of completion (TOC) (build &F no-build scenarios), TOC+10 years (build & no-build scenarios), & design year (build & no-build scenarios).	base or design year	opening year & design year		project completion
Traffic Volume	estimates of traffic volume for future years should be based on the most recent planning assumptions. Design hour volumes	peak hour traffic			vehicles per hour on each intersection approach, assume certain percentage left turns, depending on intersection configuration	project specific, vehicles per hour	
Av. Speed	average cruise speed = speed of the vehicle when it is not delayed by the signal & it is also known as the average running speed. Speed is dependent on urban, suburban or rural setting	*	Peak hour speeds observed at intersection*	*	assume left turn speed of 20mph, intersection cruise speeds, posted speeds, if unavailable		30 mph free flow speed, 2.5 mph queue speed
Peak Speed	*	running speed, preferred, average speed or typical free flow speed, acceptable	*	*	*	*	*
Link Length (m)	150 meters for approach & departure links, generally 1km for other links	1000 meters, 100 meters for cross streets at intersections	*	*	*	*	*
Vehicle Mix	light duty auto 69.0; light duty trucks 19.4; med duty trucks 6.4; heavy duty trucks (Gas) 1.2; heavy duty trucks (diesel) 3.6; buses 0.0; motorcycle 0.5 Varies by air basin	project specific or variable, based on region & season	dependent on area of state	*	*	*	*
Op. Conditions/ Cold Starts (%)	1-60% range. Increasing the number of vehicles operating in cold start mode by as little as 2% should be considered potentially significant.	project specific or 20%-65%, depending on facility type	20.6% cold starts, 27.3% hot starts	*	*	10.5% to 51.8%, depending on peak hour & rural or urban l & use for catalyst equipped vehicles. Although guidance discusses non-catalyst vehicles, only information	no cold starts

	CA	NY	IL	TN	FL	WI	ID
						on catalyst equipped vehicles is shown here due to retirement of non-catalyst vehicles from the fleet.	
Temp (F)	add temperature adjustment (see Table B.7) to the lowest January mean minimum temperature over a representative three-year period, depends upon four geographic locations & time of day	30 degrees to 50 degrees, depending on region	obtain temps corresponding to the 10 highest non-overlapping 8-hour CO concentrations for the last three years; determine the average temperatures over each 8-hour period, & then average the 10, 8-hour values to obtain the worst case temperature. Another simplified approach is to use the average temperature in January.	*	January minimum temperature, 41 degrees to 59 degrees, depending on region.	20 degrees F	*
Background CO	see Figure B.1; for each of the most recent two years, find the second maximum (non- overlapping) 8-hour CO background concentration & choose the higher of the two as the 8- hour CO background concentration for the site.	2.2 ppm to 3.8 ppm, depending on region	1-hour average background concentrations of 3.0 ppm for urban areas & 2.0 ppm for rural areas.	*	1 to 3 ppm, depending on l & use	From Department of Natural Resources	9.6 ppm to 16.7 1-hour background, depending on area
Future Background CO	future background estimates based on estimated future emissions or Future background estimates based on present trend.	rollback adjustment based on current to future emission trends	*	*	*	adjust for future emission factor & VMT changes	*
Persistence Factor	0.6 to 0.8, dependent on urban, suburban or rural setting	0.6 to 0.81, depending on region	0.7	*	0.6	*	38% to 55% depending on area
Roughness length	100 cm	0.03 cm to 370 cm, depending on l & use	.03-370 cm, depending on l & use	*	10 cm to 175 cm. depending on l & use	3.0 to 400 cm, depending on l & use	175 cm default
Stability (A-F)	D or G	D for urban, E for suburban or rural	D for urban, E for rural	*	E rural, D urban & suburban	E for urban areas, F for rural areas	E is default
Wind Speed	0.5-1.0 m/s, depends upon four geographic locations & time of day	1 m/s	1.0 m/s	*	1.0 m/s	1.0 meter/second	1.0 meter/sec
Wind Direction	The CALINE4 option to search for the worst wind angle should be used unless there are sufficient meteorological data to substantiate the use of specific ranges of wind	5 degree increments, if result is greater than 8.0 ppm, re-run at 1 degree increments	0 to 360 degrees in at least increments of 10 degrees	*	360 degrees by 5degree increments	0 to 360 degrees	360 degrees in 10 degree increments

	CA	NY	IL	TN	FL	WI	ID
	direction.						
Source Height	*	0.0 for at grade roadways, actual elevation above or below terrain up to 10 m for elevated or depressed sections, respectively; 10 m for elevations above or below grade greater than 10 m	*	*	0 m	-33 to 33 ft, depending on project	0.0 m
Mixing Height	Sigma theta: 5 to 30 degrees	1000 meters	1000 meters	*	1000 meters	1000 meters	1000 meters
Source Receptor Distance	3 meters; if site fails, 7 meters	3.01 m from edge of roadway	building or location where the general public may be expected to remain for the duration of the period specified by the NAAQS	*	closest location, minimum 10 feet from edge of roadway	*	10 foot offset from travel way at intersection & 100 feet from intersection for each approach. Sidewalks, Vacant lots adjacent to intersections, Parking lots, Sensitive buildings & properties, such as residences, hospitals, nursing homes, schools, & playgrounds.
Other Receptor Siting Guidance	Table B.12	sidewalk at corner of intersection an 25m intervals up to mid-block; if no sidewalk at nearest edge of property line or parking lot but no closer than 3 m from edge of roadway	*	Laterally, the receptors should be located as found on the ground but no closer than the edge of the mixing zone (3.01 meters outside the traveled way).	48	*	At the intersection corner, 2.25 meters from the intersection corner, 3.50 meters from the intersection corner, & 4m at mid-block.
Receptor Height	1.8 meters	1.8 meters	6 feet	*	6 ft	0.0 meters	1.8 meters
Grade %	Projects that would lead to worsening the level of service of a signalized intersection to E, or F, represent a potential for a CO violation & require further analysis.	*	*	*	*	*	*
Level of Service (A-F)	Generally, signalized intersections. Increases in traffic volumes in excess of 5% should be considered potentially significant. Increasing the traffic volume by less than 5% may still be potentially significant if there is a corresponding reduction in average speeds	Intersections & roadways impacted by the project & exhibiting ETC, ETC+10, or ETC+20 build LOS D, E, or F will be screened by the following criteria: a 10 % or more reduction in the source-receptor distance; any increase in the number of queued lanes for ETC, ETC+10 or ETC+20; a 20% reduction in speed, when build estimated average speed	2) a 10 % or more increase in traffic volume on affected roadways for ETC, ETC+10 or ETC+20;	in maintenance areas, Level-of-Service D or worse or those that will change to Level-of-Service D or worse because of increased traffic volumes related to the project; in CO attainment areas, the project is a signalized intersection with a projected design year average daily traffic (ADT) volume greater than 80,000 vehicles per day &	intersection with a combination of the highest intersection approach volume & lowest approach speed	3) a 10% or more increase in vehicle emissions for ETC, ETC+10 or ETC+20; Increases in vehicle emissions can be due to speed changes, changes in operating conditions (hot/cold starts), changes in vehicle mix, etc.	Los D or below for intersections or total intersection volume (varies by year)

	CA	NY	IL	TN	FL	WI	ID
		is at 30 mph or less. For SIP sites, reduction in previous percentages by one-half.		the intersection is projected to operate at Level-of-Service D or worse in the base year or the design year with the project; or,the project is controversial due in part to the potential air quality impacts of the project.			
Facility Type	Yes, with areas that have an I/M program	yes, depending on region of state	Dependent on region of state	*	No	yes	*
References	http://www.dot.ca.gov/ser/vol1/sec3/physical/ch11air/chap11.htm, http://www.dot.ca.gov/hq/env/air/pages/coprot.htm, FHWA guidance for PM & MSAT, Transportation Project-Level Carbon Monoxide Protocol Revised December, 1997, UCD-ITS-RR-97-21 December 1997. New version of CT-EMFAC under review.	NYSDOT Environmental Procedures Manual, Chapter 1.1 Environmental Analysis Bureau January, 2001	The Illinois Department of Transportation (IDOT) & Illinois Environmental Protection Agency (IEPA) "Agreement on Microscale Air Quality Assessments for IDOT Sponsored Transportation Projects." Bureau of Design & Environment Manual, 2010, Chapter 26, Section 14; Illinois Center for Transportation, CARBON MONOXIDE SCREEN FOR SIGNALIZED INTERSECTIONS COSIM, VERSION 4.0: Note: COSIM 4.0 had been update with MOVES emission factors.	Tennessee Environmental Procedures Manual, Chapter 5.3.5, June 2011, http://www.tdot.state.tn.us/epm/	Project Development & Environmental Manual, Chapter 16, Air Quality Analysis, http://www.dot.state.fl.us/emo/pubs/pdeman/pdeman1.shtm, FDOT's latest Screening Model (currently CO Florida 2004), CO Florida 2004, www.dot.state.fl.us/research-center/...Proj/.../FDOT_BD550_02_rpt.pdf	Facilities Development Manual, Chapter 22, February 1998, http://roadwayst&ards.dot.wi.gov/st&ards/fdm/hidden/downloads/index.htm. Wisconsin DOT reports that much of this guidance is outdated. If a project meets the criteria in Column Y, then if there was a similar project for which an analysis was done & shows that the analysis for that project was a "worse-case" & still was below the NAAQS, then no analysis is done.	ITD Air Screening Policy (Nov/Dec 2007) http://itd.idaho.gov/enviro/air/air.htm

Appendix B. Programmatic Agreement Template

The coloring scheme in the draft PA template, and its associated TSD, is as follows:

Black text = Text that generally will not need to be modified and can be used for a national PA and for individual state PAs;

Red text = Information (e.g. report or study citations) at a Federal or state level that is not yet complete and can be added at a later date when a national PA or state PA is finalized;

Blue text = Text to be added containing information relevant to a particular state in order to allow completion of a state –specific PA and its associated TSD.

STATE DOT LETTERHEAD

Date

From: Chief Engineer (or other appropriate Executive), State Department of Transportation
To: FHWA Division Administrator, State Division

The purpose of this memorandum is to establish a Programmatic Agreement (PA) between the STATE Department of Transportation (DOT) and the STATE Division of the Federal Highway Administration (FHWA). The PA is related to analysis of potential carbon monoxide (CO) impacts of certain highway projects currently undergoing environmental studies to meet requirements of the National Environmental Policy Act (NEPA). Other relevant agencies (list) have participated in the development and/or review of this PA and support its use. This PA establishes the types of projects and project conditions that will not require project-specific modeling or a quantitative air quality analysis to document that they do not cause a violation of the National Ambient Air Quality Standards (NAAQS) for CO. Rather, these project types and conditions will require only a general qualitative statement to meet project-level air quality requirements that references this agreement and the associated technical support document (TSD), which presents worst-case modeling results for CO that would cover the specific project type and condition.

Basis of Agreement: This PA was developed based on an extensive history of modeling potential CO impacts for highway projects. In support of its capital program, STATE DOT has been performing CO emissions analyses of highway projects since the late 1970s. These analyses, in the vast majority of cases, have not resulted in identification of violations of CO air quality standards as a result of the completion of a highway project. As evidenced by ongoing reductions in monitored ambient CO concentrations and the continuing implementation of the Federal Motor Vehicle Emission Control Program, future project-level CO analyses are expected to find little, if any, possibility of potential violations of CO ambient air quality standards caused by the completion of a highway project.

Recent efforts at the national level reinforce this conclusion. The *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* (FHWA, February, 2014)[32] documented conditions for urban intersections in CO maintenance areas that did not require a specific project-level conformity determination but could rely on the categorical finding to make a project-level conformity determination. Similarly, the National Cooperative Highway Research Project (NCHRP) study: *Programmatic Agreements for Project-Level Air Quality Analyses (2015)*[33], which provides the primary basis for this agreement, built upon the technical analysis presented in the 2014 categorical finding and examined a wider variety of

[32] See: http://www.fhwa.dot.gov/environment/air_quality/conformity/policy_and_guidance/cmcf/

[33] E. Carr, et al. NCHRP 25-25/Task 78, "*Programmatic Agreements for Project-Level Air Quality Analyses*", 2015. See: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3311

project types and conditions in order to identify those project types and conditions that could not result in violation of current CO ambient air quality standards. These studies tested the remote possibility of a CO ambient air quality standard violation using worst-case modeling and following appropriate EPA guidance for modeling CO hot-spots (e.g., *Guideline for Modeling Carbon Monoxide from Roadway Intersections*, U. S. EPA, EPA-454/R-92-005, November 1992; *Using MOVES in Project-Level Carbon Monoxide Analyses*, U.S.EPA, EPA-420-C-10-041 December 2010). The studies also used EPA-approved emission and dispersion models. (MOVES2010b as the emission model and CAL3QHC (version 04244) as the dispersion model).

Application of the PA: The PA may be applied directly with no additional calculations if the following are applicable:

1. If the project meets the minimum technical criteria for the PA to be applied, namely:
    a. Background concentration not more than the default of 2.6 ppm (eight-hour standard) that was taken for this PA.
    b. Persistence factor not greater than the EPA default of 0.7 that was taken for this PA.
    c. The CO NAAQS have not changed from what was in effect at the time when this agreement was implemented and upon which the modeling was based (35 ppm for the one-hour and 9 ppm for the eight-hour.
2. If, for the project configuration and conditions of interest (road grade, speed, etc.), a one-hour concentration value is listed in the appropriate attached table (Table B-1 for freeways and arterials; Table B-2 for intersections; Table B-3 for interchanges). If it is listed, then the project is covered by the PA, provided that the minimum criteria specified above are also met.
3. If the project is covered by the PA, the qualitative text provided at the end of this document should be included (modified as appropriate for the project) in the project record and relevant environmental documents.

Project Types and Conditions: This PA applies to the following project types and associated project conditions:

Freeways and Arterials

Table B-1, attached, shows the conditions for urban and rural arterials and freeways that would meet the one- and eight-hour NAAQS and would be covered by this PA[34]. The table shows one-hour concentrations, not including background concentrations. The populated cells of the table correspond to the lane and grade combinations for arterials and freeways which, even under worst-case conditions, would not result in exceedances of the 8-hour NAAQS for CO. Where the table entries are *blank*, the corresponding configuration would *not* meet the NAAQS based on

[34]These findings apply to scenarios with average speed ranging from 45 to 56 mph for arterials and 19 to 74 mph for freeways.

worst-case modeling and would *not* be covered by this PA. Project-specific modeling would typically need to be conducted to show compliance with the NAAQS in these cases.

For example, for a transportation improvement project for a freeway for which the build scenario has 10 total lanes, average road grades of 2% or less, and peak hour (congested) operating speeds of 50 mph, Table B-1 shows a contribution of 8.0 ppm for the one-hour CO standard. Since a CO concentration is shown in the table for this project type and configuration, the project is covered by this PA and does not require project-specific modeling for CO. Conversely, the same freeway with 12-lanes would *not* be covered by this PA, as the table entry is *blank* for that configuration.

The values shown in Table B-1 were determined using conservative or worst-case modeling inputs and assumptions for MOVES and CAL3QHC (see Technical Approach discussion, below). Concentrations for comparison to the eight-hour NAAQS were determined from the one-hour values shown using a national average eight-hour background concentration of 2.6 ppm along with the EPA recommended persistence factor of 0.7. The resulting eight-hour concentrations were used to identify which arterial and freeway configurations would meet the eight-hour NAAQS.

Note: this PA covers lanes widths of 11 feet or more for freeway and arterial project types.

Intersections

Intersections were examined using the same approach (other than geometrics) as in freeway and arterial cases. That is, the same MOVES and CAL3QHC model inputs and assumptions were used. The intersection analysis assumes six approach lanes on each leg of the intersection, with two of the approach lanes becoming left-turn lanes at the intersection. Four lanes are assumed on each departure leg. The intersection case was modeled at a grade of 2%.

Table B-2, attached, shows the maximum 1-hour CO concentrations for urban and rural intersections that, with the applied 8-hour CO background level of 2.6 ppm and persistence factor of 0.7, do not produce modeled CO concentrations that could result in exceedances of the 8-hour CO NAAQS.

In other words, these findings indicate that a project for an intersection with a grade of 2% or less, six approach lanes or less, and forecast approach speeds not less than 15 mph would not produce modeled concentrations that would result in exceedances of the 8-hour CO NAAQS. Any such project would be covered by this PA and would not require project-specific CO modeling to demonstrate compliance with the CO NAAQS. Conversely, for example, a project with seven approach lanes, a 3% grade and/or a 10 mph approach speed would *not* be covered by this PA.

Note: The intersections were modeled as 90 degree intersections, that is, with roadways intersecting at right angles. Skewed intersections (those whose approaches do not intersect at right angles) are not included in PA. Similarly, highly congested intersections (where the approach speed is less than 15 mph) and intersections with five or more legs are also not included in the PA.

Interchanges with an Adjacent Intersection

Interchanges were analyzed using the MOVES and CALQHC models, with the same traffic inputs and assumptions as in the previous cases. The interchange scenarios were modeled at a 0% grade in an urban location. The total number of interchange lanes analyzed ranged from 2 to 22 in 2 lane increments. For the adjacent intersection, a variety of distances from the edge of the nearest freeway travel lane to the edge of the nearest travel lane on the interchange ramp were also examined. The geometry of the adjacent intersection was also modeled as having six approach lanes, including two left turn lanes, and four departure lanes.

Note: This is a very conservative approach for ramp intersections adjacent to freeway interchanges, which typically have only one- or two-lane ramps approaching or departing from the intersection.

Table B-3, attached, shows 1-hour CO concentrations for these interchange scenarios that, with the applied 8-hour CO background level and persistence factor, do not produce modeled concentrations that could result exceedances of the 8-hour NAAQS for CO. Where the table entries are *blank*, the corresponding configuration would *not* meet the NAAQS based on worst-case modeling and would *not* be covered by this PA. Project-specific modeling would typically need to be conducted to show compliance with the NAAQS in these cases.

For example, looking at the first section of Table B-3 for which approach speeds are not less than 15 mph, a 12-lane freeway with an adjacent intersection that is located not less than 150 feet from the nearest edge of the freeway lanes has a one-hour concentration listed of 9.1 ppm. Since a concentration is listed for this project type, approach speed and configuration, the project would be covered by this PA and not require project-specific modeling. Conversely, the table entry is *blank* for a 14 lane freeway with an intersection at 150 feet that has an approach speed of not less than 15 mph. Thus, that configuration would *not* be covered by this PA.

A State DOT may consider the following text in a state-specific PA:

Projects of De Minimis Scope: Projects that do not change (add, remove or relocate) roadway capacity or transit services do not require either qualitative or quantitative project-level air quality analyses for purposes of NEPA.

Exempt Projects: Projects that would qualify as exempt under one or more of the categories specified in the federal transportation conformity rule (whether or not conformity applies for the area in which the project is located) do not require project-specific modeling for CO for purposes of NEPA. In the case of these exempt projects, a qualitative statement as provided below is to be included in the project environmental document or record.

Project Alternatives: This PA is intended to cover all build alternatives for the above-listed projects, as well as the no-build alternative. If one or more alternatives are not included in the list of project types above, STATE DOT and STATE Division of FHWA will coordinate to determine the applicability of the PA to that alternative(s). It may be that one alternative that is covered by the PA would effectively represent the worst-case for all of the alternatives, e.g., if one alternative has more congested conditions than the others. As appropriate and as both agencies agree, other agencies (such as the Regional EPA office or the STATE Air Agency) may be brought in to assist in the coordination.

Project Types Not Covered by This PA: Examples of project types that are not specifically covered by this PA include but are not limited to: park and ride lots, parking garages, new intermodal transfer yards, tunnels, intersections that have more than four legs, and intersections with approach speeds less than 15 mph. If a project type is not covered by the PA, project-specific air quality modeling may be needed.

For those project types and conditions where applicability of this PA is not certain, STATE DOT and STATE Division of FHWA will coordinate to determine the applicability. As appropriate and as both agencies agree, other agencies (such as the Regional EPA office or the STATE Air Agency) may be brought in to assist in the coordination.

Years of Analysis: This PA covers projects of the types and conditions listed above whose opening year (year of completion) is 2015 or later.

Technical Approach: The modeling and the assumptions used in the modeling to support this PA are described in detail in the accompanying Technical Support Document (TSD). In general, a worst-case modeling approach was applied following EPA guidance. In all cases EPA's MOVES2010b emission model was used to generate emission estimates and CAL3QHC (version 04244) was used for the dispersion analysis. EPA's current guidance for modeling CO Hot-Spots (*Guideline for Modeling Carbon Monoxide from Roadway Intersections*, U. S. EPA, EPA-454/R-92-005, November 1992) was also applied. The assumptions and inputs used in the model were worst-case or highly conservative, leading to higher emission estimates and less dispersion (that is, greater forecast ambient concentrations) than would be expected under real-world conditions. Consequently, if a project does not cause a modeled exceedance of the NAAQS with these worst-case or conservative inputs and assumptions, then it may be stated with high confidence that an exceedance under real-world conditions would not be expected. Finally, STATE DOT consulted with the STATE AIR AGENCY to determine appropriate values for CO background concentrations and persistence factor. These values were used to arrive at an 8-hour total CO concentration for comparison with the 8-hour CO ambient air quality standard.

Administrative Record: For the project's environmental document or record, the STATE DOT will include a statement that the project under review meets the project types and conditions covered in the PA and will conclude with one of the two following statements (or similar):

> "The project does not exceed the project types and conditions listed in the agreement between the Federal Highway Administration and the STATE Department of Transportation for streamlining the project-level air quality analysis process for carbon monoxide. Modeling using "worst-case" parameters has been conducted for these project types and conditions. It has been determined that projects such as this one cannot significantly impact air quality and cannot cause or contribute to a new violation, increase the frequency or severity of an existing violation, or delay timely attainment of the National Ambient Air Quality Standards for carbon monoxide."

Or

> "An air quality analysis is not necessary as this project will not increase traffic volumes, reduce source-receptor distances, or change other existing conditions to such a degree as to jeopardize attainment of the National Ambient Air Quality Standard for carbon monoxide."

Future Revisions: STATE DOT and STATE Division of FHWA recognize that project level air quality analysis methodologies may change over time. This may include new or updated emission or dispersion models, background CO levels, and/or associated worst-case modeling assumptions. STATE DOT will consult as appropriate with STATE Division of FHWA regarding any changes.

Termination of Agreement: Should either the STATE DOT or the STATE Division of FHWA determine it is necessary to terminate the PA, they may do so by written notification to the other party. The PA will terminate 30 days after the date of the notification. Projects that have been cleared on the basis of the PA before the effective termination date may maintain that clearance and not require project-specific modeling for CO.

Value of the PA: The PA is beneficial to both STATE DOT and STATE Division of FHWA. It reduces costs by eliminating unnecessary analyses, enhances efficiency and certainty in the environmental review process, and helps ensure project scope and scheduling.

Attachment to the Programmatic Agreement

Table B-1. One-hour CO concentrations (ppm) for freeways and arterials[1] in urban and rural locations of varying lane and grade configuration (not including background concentrations)

			GRADE			
FACILITY TYPE	**LOCATION**	**LANES**	**0**	**2**	**4**	**7**
Arterial	Urban	12	6.7	8.5		
Arterial	Urban	10	6.0	7.6		
Arterial	Urban	8	5.2	6.6		
Arterial	Urban	6	4.3	5.4	7.5	
Arterial	Urban	4	3.2	3.9	5.5	
Arterial	Urban	2	1.8	2.2	3.0	
Arterial	Rural	8	8.7			
Arterial	Rural	6	7.2	8.6		
Arterial	Rural	4	5.4	6.3	8.6	
Arterial	Rural	2	3.1	3.6	4.9	
Freeway	Urban	20	9.0			
Freeway	Urban	18	8.6			
Freeway	Urban	16	7.9			
Freeway	Urban	14	7.2			
Freeway	Urban	12	6.5			
Freeway	Urban	10	5.6	8.0		
Freeway	Urban	8	4.7	6.6		
Freeway	Urban	6	3.7	5.1	7.2	
Freeway	Urban	4	2.7	3.5	4.9	6.2
Freeway	Urban	2	1.4	1.7	2.4	3.1
Freeway	Rural	8	8.0			
Freeway	Rural	6	6.4	8.6		
Freeway	Rural	4	4.5	5.9	8.2	
Freeway	Rural	2	2.4	3.0	4.2	5.3

[1]These findings apply to scenarios with average speed ranging from 45 to 56 mph for arterials and 19 to 74 mph for freeways

Table B-2. One-hour CO concentrations (not including background concentrations) for rural and urban intersections at varying approach speeds for a six approach lane intersection for each leg at two percent grade.

LOCATION	APPROACH SPEED (MPH)	CONCENTRATION (PPM)
Urban	15	6.5
Urban	25	5.7
Urban	35	5.2
Rural	25	8.8
Rural	35	8.4

Table B-3. One-hour CO concentrations at varying intersection approach speeds at varying distances from an urban freeway at varying lane configurations (not including background concentrations)

Urban Freeway Contribution of CO (PPM) at 15 mph Approach Speed with Increasing Distance from Freeway Pavement Edge (ft)												
NUMBER OF LANES	**10**	**20**	**30**	**60**	**80**	**100**	**125**	**150**	**175**	**300**	**500**	**1000**
2	8.5	7.8	7.5	7.1	6.9	6.7	6.7	6.6	6.5	6.5	6.3	6.3
4			8.8	8	7.6	7.4	7.2	7.1	7.1	6.7	6.5	6.3
6				8.9	8.4	8.1	7.9	7.6	7.6	7.1	6.8	6.5
8					9.1	8.7	8.4	8.1	8	7.4	7.1	6.7
10							9	8.7	8.5	7.8	7.3	6.8
12								9.1	8.9	8.1	7.6	6.9
14										8.5	7.8	7.1
16										8.8	8	7.2
18										9.1	8.2	7.4
20											8.5	7.5
22											8.7	7.6

Urban Freeway Contribution of CO (PPM) at 25 mph Approach Speed with Increasing Distance from Freeway Pavement Edge (ft)												
NUMBER OF LANES	**10**	**20**	**30**	**60**	**80**	**100**	**125**	**150**	**175**	**300**	**500**	**1000**
2	7.9	7.2	6.9	6.5	6.3	6.1	6.1	6	5.9	5.9	5.7	5.7
4		8.7	8.2	7.4	7	6.8	6.6	6.5	6.5	6.1	5.9	5.7
6				8.3	7.8	7.5	7.3	7	7	6.5	6.2	5.9
8				9.1	8.5	8.1	7.8	7.5	7.4	6.8	6.5	6.1
10					9.1	8.7	8.4	8.1	7.9	7.2	6.7	6.2
12							8.8	8.5	8.3	7.5	7	6.3
14								9	8.7	7.9	7.2	6.5
16									9.1	8.2	7.4	6.6
18										8.5	7.6	6.8

Urban Freeway Contribution of CO (PPM) at 15 mph Approach Speed with Increasing Distance from Freeway Pavement Edge (ft)												
20										8.7	7.9	6.9
22										9.1	8.1	7
Urban Freeway Contribution of CO (PPM) at 35 mph Approach Speed with Increasing Distance from Freeway Pavement Edge (ft)												
NUMBER OF LANES	**10**	**20**	**30**	**60**	**80**	**100**	**125**	**150**	**175**	**300**	**500**	**1000**
2	7.3	6.6	6.3	5.9	5.7	5.5	5.5	5.4	5.3	5.3	5.1	5.1
4	9	8.1	7.6	6.8	6.4	6.2	6	5.9	5.9	5.5	5.3	5.1
6			8.6	7.7	7.2	6.9	6.7	6.4	6.4	5.9	5.6	5.3
8				8.5	7.9	7.5	7.2	6.9	6.8	6.2	5.9	5.5
10					8.5	8.1	7.8	7.5	7.3	6.6	6.1	5.6
12						8.7	8.2	7.9	7.7	6.9	6.4	5.7
14							8.8	8.4	8.1	7.3	6.6	5.9
16								8.9	8.5	7.6	6.8	6
18									8.9	7.9	7	6.2
20										8.1	7.3	6.3
22										8.5	7.5	6.4

Appendix C. Technical Support Document Template

As described earlier, the coloring scheme in the draft PA template, and its associated TSD, is as follows:

Black text = Text that generally will not need to be modified and can be used for a national PA and for individual state PAs;

Red text = Information (e.g. report or study citations) at a Federal or state level that is not yet complete and can be added at a later date when a national PA or state PA is finalized;

Blue text = Text to be added containing information relevant to a particular state in order to allow completion of a state –specific PA and its associated TSD.

FHWA-STATE DOT AGREEMENT ON PROJECT-LEVEL CARBON MONOXIDE AIR QUALITY ANALYSIS

TECHNICAL SUPPORT DOCUMENT

Prepared by

STATE DOT

Environmental Office

Date

Contents

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C-1 Executive Summary

This Technical Support Document (TSD) provides background and technical information in support of the Programmatic Agreement (PA) between the STATE DOT and the STATE Division of FHWA related to project level carbon monoxide (CO) air quality analysis. This TSD and the associated PA establish which project types and conditions are not expected to exceed CO National Ambient Air Quality Standards (NAAQS) and therefore do not require a quantitative air quality analysis.

The PA was developed as a result of:

- A long history of analyzing highway projects for potential CO impacts by the STATE DOT
- Ongoing reductions in vehicle emissions
- Ongoing reductions in measured CO concentrations
- Recent activities at the federal level, which document the infeasibility of CO ambient air standards being exceeded by certain transportation project types and conditions.

The analyses described in this TSD demonstrate, with a high degree of confidence, that implementation of these project types under the conditions listed could not cause or contribute to a violation of the ambient air standards for CO. The project types covered are: freeways, arterials, interchanges and intersections.

It is recognized that, from time to time, new emission or dispersion models may be developed and approved or that underlying ambient or technical conditions may change. As necessary, this TSD will be updated to reflect these changes.

C-2 Background

C-2.1 Air Quality Standards for CO

Under the Clean Air Act, EPA is required to set National Ambient Air Quality Standards for six principal air pollutants, including CO (Table C-1). The standards are set to avoid adverse impacts to public health and the environment. The Clean Air Act identifies two types of national ambient air quality standards. Primary standards provide public health protection, including protecting the health of "sensitive" populations such as asthmatics, children, and the elderly with an adequate margin of safety. Secondary standards provide public welfare protection, including protecting against decreased visibility and damage to animals, crops, vegetation, and buildings. There are currently no secondary standards for CO.

Table C-1 - Current National Ambient Air Quality Standards (NAAQS) for Carbon Monoxide (CO)

Pollutant [final rule cite]	Primary/ Secondary	Averaging Time	Level	Form
Carbon Monoxide [76 FR 54294, Aug 31, 2011]	primary	8-hour	9 ppm	Not to be exceeded more than once per year
		1-hour	35 ppm	

Source: http://www.epa.gov/air/criteria.html

EPA designates geographic regions as in attainment or nonattainment of the NAAQS. Generally, regions that met NAAQS when the standards were promulgated and have continued to meet those standards for a given pollutant are designated attainment areas. Regions that were deemed out of compliance when NAAQS were promulgated and that continue to exceed the NAAQS for a given pollutant are designated nonattainment areas. Regions that were previously out of compliance with the standard but have since come into compliance are designated maintenance areas. As of September 27, 2010, all former CO nonattainment areas were determined to be in compliance for CO, and so have been re-designated as maintenance areas.

States with nonattainment or maintenance areas were required under the Clean Air Act to develop State Implementation Plans (SIPs) adopting transportation conformity requirements at least as stringent as the federal requirements. Some states also adopted additional requirements beyond those prescribed under the Clean Air Act. INSERT INFO ABOUT STATES COMPLIANCE STANDING. INSERT STATE REQUIREMENTS FROM CONFORMITY SIPS, IF ANY.

C-2.2 Highway Projects & CO Requirements

Nationally, annual CO emissions in the US total over 82 million short tons. Mobile sources, including gasoline fueled cars, trucks, buses and off-road vehicles, are responsible for approximately 51% of this total (Figure C-1).

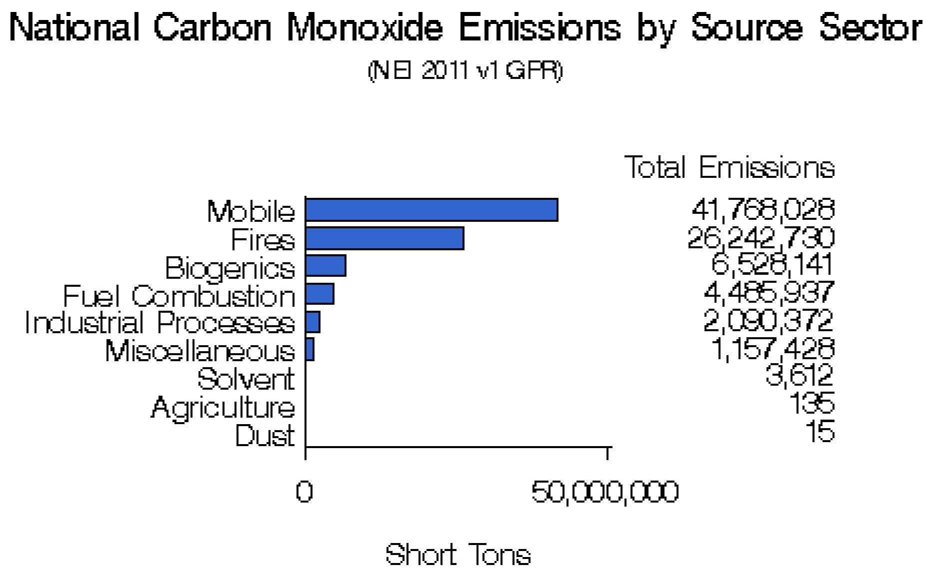


Figure C-1 – National Carbon Monoxide Emission Inventory

Source: http://www.epa.gov/cgi-bin/broker?_service=data&_debug=0&_program=dataprog.national_1.sas&polchoice=CO

A similar situation exists at the state level. In STATE – INSERT IFORMATION ON STATE CO INVENTORY AS APPROPRIATE.

INSERT FIGURE OR TABLE ON STATE CO INVENTORY

Because of the significant CO pollution attributable to mobile sources, transportation agencies have been required to examine the effect of their highway projects on CO levels in the project area. Indeed, under Section 176(c) of the Clean Air Act (the conformity provision), in order to proceed, certain highway projects are required to demonstrate that the incremental addition of CO emissions as a result of the project will not cause or contribute to a violation of the CO NAAQS. The analysis necessary to demonstrate this is typically performed during the environmental studies undertaken to examine environmental impacts of the project.

In addition, the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* (FHWA, February, 2014)[35] documented conditions for urban intersections in CO maintenance areas that did not require a specific project-level hot-spot analysis, but could instead rely on the categorical finding to determine whether the project was in compliance. This finding was the result of steadily declining ambient CO concentrations over the past several decades.

For transportation projects involving federal funding or action, the environmental analysis is performed pursuant to the requirements of the National Environmental Policy Act (NEPA). Enacted on January 1, 1970, NEPA established a national environmental policy focused on

[35] See: http://www.fhwa.dot.gov/environment/air_quality/conformity/policy_and_guidance/cmcf/

federal activities with the goal of balancing a sustainable environment with other essential present and future needs. NEPA established a requirement for federal agencies to consider the potential environmental consequences of their proposals, document the analysis, and make this information available to the public for comment prior to implementation. NEPA also requires Federal agencies to use an interdisciplinary approach in planning and decision making for any action that adversely impacts the environment. As implemented by FHWA, this means investigating and avoiding potential impacts to the social and natural environment (such as a violation of the CO NAAQS) when considering approval of proposed transportation projects. FHWA's policy and regulations implementing NEPA are found at 23 CFR § 771.105.

Many states have enacted a state version of NEPA to cover state actions and funding. Similar to NEPA, the state versions typically require an examination of potential environmental impacts and appropriate action to mitigate these impacts to the extent practicable. INSERT HERE INFORMATION ABOUT STATE ENVIRONMENTAL REQUIREMENTS.

As mentioned above, regions of the nation that had did not meet the NAAQS for CO when the standards were promulgated were designated as nonattainment areas under the Clean Air Act. Those areas have since all reached attainment of the CO standard based on monitoring or modeling studies and most are now designated as maintenance areas. However, under Section 176(c) of the Clean Air Act (the transportation conformity provision), certain transportation projects in maintenance areas are required to demonstrate that the project will not cause or contribute to a violation of the CO standard. However, the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* (FHWA, February 2014) documents conditions for urban intersections in CO maintenance areas that do not require a specific project-level hot-spot analysis but can instead rely on the categorical finding.

C-2.3 Decline in CO Concentrations

The likelihood of highway projects leading to violations of the CO NAAQS has been significantly reduced over the last few decades. Indeed, while vehicle miles traveled (VMT) have seen a long term general increase over time. Recently, however, within the last five years or so, there been a leveling off and decline of VMT.

Figure C-2 shows the trend in VMT at a national level. This has also been the case at the state level.

Background CO concentrations are also critical in determining a project's impact in terms of NAAQS. At the national level, background CO concentrations have seen significant decreases over the past ~25 years. Indeed, the nationwide network of CO air quality monitoring sites have reported a 78% decline in the 90th percentile of maximum 8-hour CO concentration from 9.5 ppm, above the NAAQS for CO (9 ppm—see 9.5 Table C-1) in 1990 to 2.1 ppm, well below the NAAQS for CO, in 2012 (Figure C-3). This significant decrease in CO background concentrations allow much higher traffic volumes to be screened out under the programmatic agreement. Similar reductions have been found at the state level.

INSERT INFORMATION AND FIGURE OR TABLE, IF APPLICABLE, REGARDING STATE CO MONITORING DATA.

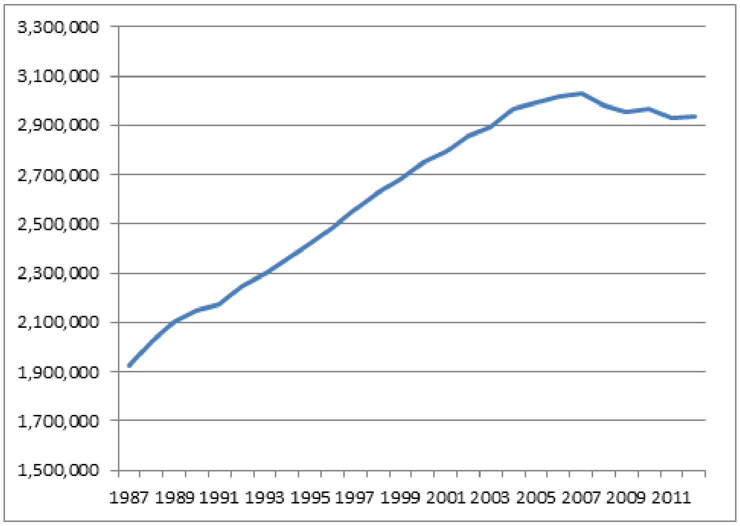
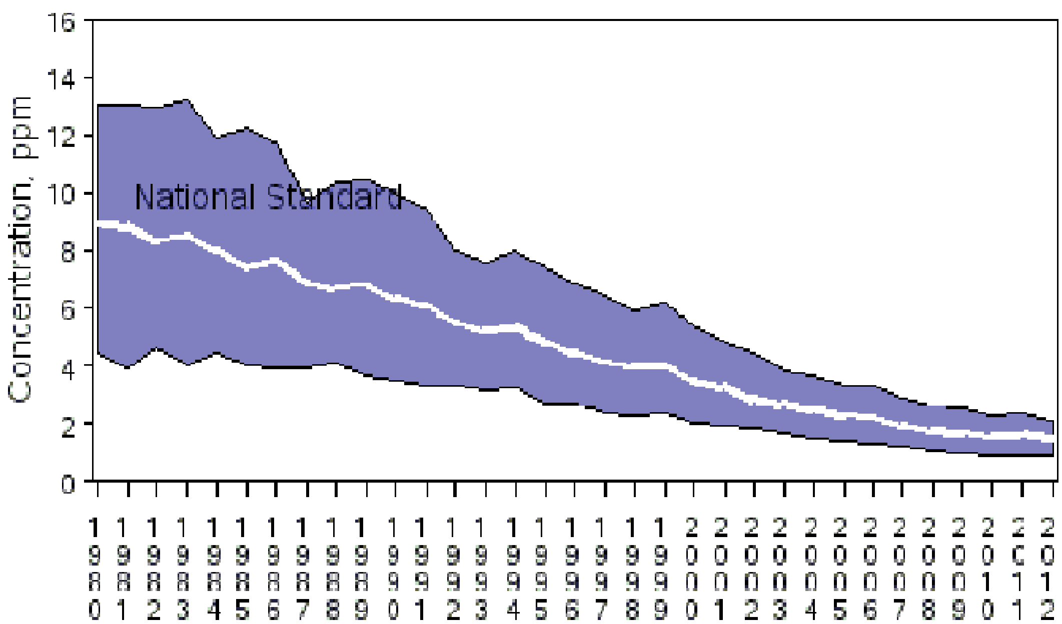


Figure C-2 - Total VMT (in millions) for the United States. Source: State Smart Transportation Initiative.

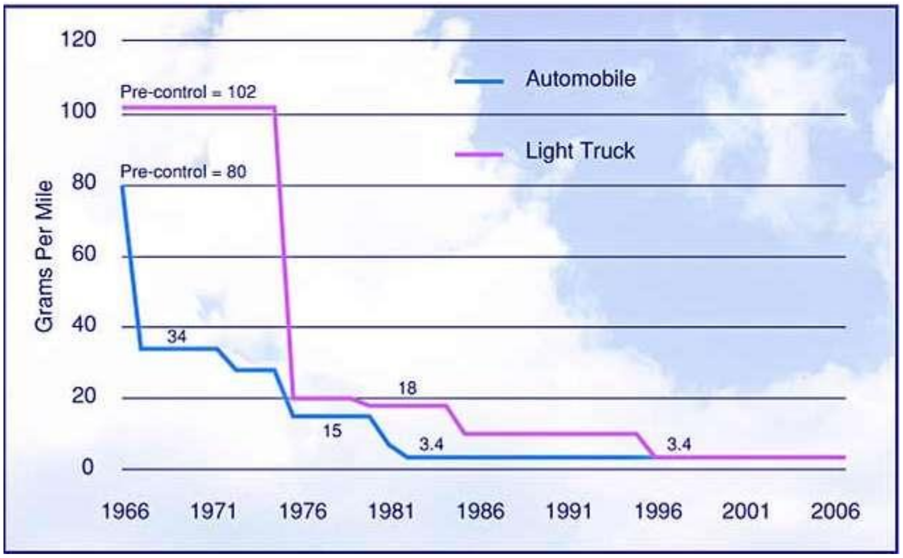


Source: http://www.epa.gov/airtrends/carbon.html

Figure C-3 - National Trends in CO Concentration. 1980-2012 (Annual 2nd High 8-hour average N=89). The white line represents the average of all sites, the top of the shaded region represents the 90th percentile concentration and the bottom represents the 10th percentile

The largest contributor to the substantial reductions in CO concentrations has been the Federal Motor Vehicle Emission Control Program, which sets emission limits for on-road vehicles. This program has been responsible for a 95% reduction in CO emissions from light-duty vehicles. Comparably large reductions have also been realized in emissions from light-duty trucks (Figure C-4). Additional CO emissions reductions are expected to result from EPA's Tier 3 Control Program, enacted in April 2014, which places limits on the sulfur content of gasoline. Although

CO emission rates are not directly regulated under the Tier 3 Control Program, the additional stringency on sulfur content in gasoline will reduce CO emissions by extending the effective life of vehicle catalysts. When fully implemented, by 2030, Tier 3 is expected to produce an additional 24% reduction in CO emissions (Table C-2).



Source:
http://www.fhwa.dot.gov/environment/air_quality/publications/fact_book/page14alt3.cfm

Figure C-4 - Reductions in allowable engine CO emission rates per mile by model year

Table C-2 - Projected CO Reductions from EPA's Tier 3 Program

	[Annual U.S. tons]	
	2018	**2030**
Reduction from pre-Tier 3 fleet due to sulfur standard	122,171	17,734
Reduction from Tier 3 fleet due to vehicle and sulfur standards	156,708	3,440,307
Total reduction	278,879	3,458,041
Percent reduction in on road CO emissions	2%	24%

Source: https://www.federalregister.gov/articles/2014/04/28/2014-06954/control-of-air-pollution-from-motor-vehicles-tier-3-motor-vehicle-emission-and-fuel-standards

The low ambient CO concentrations and the anticipated continued decline of these concentrations suggest that violations of the current CO NAAQS are unlikely today and into the future. As a result, any changes to local CO concentrations resulting from highway projects are highly unlikely to cause or contribute to a violation of these standards. It is efficient, therefore, to reduce CO analyses for highway projects to the maximum extent reasonable while still monitoring situations that could lead to high levels of ambient CO concentrations.

C-3 Status of CO Analyses

For highway projects involving federal funding or action, project-level CO analyses are performed pursuant to the requirements of the National Environmental Policy Act (NEPA). Enacted on January 1, 1970, NEPA established a national environmental policy requiring federal agencies to take consideration of the environmental impact of proposed projects in their planning and decision making. Specifically, NEPA established a requirement for federal agencies to perform an environmental assessment that considers the potential environmental consequences of their proposed projects. If the environmental assessment finding is that the project will have significant impact, then the federal agency must prepare an environmental impact statement (EIS). The EIS details the environmental consequences of the project and provides reasonable alternatives or amendments that would mitigate these impacts. NEPA requirements encompass any project, public or private, that receives federal funding, though it is the burden of the federal agency to perform the analysis. When applied to FHWA highway projects, NEPA requires consideration of potential environmental impacts—including violation of CO NAAQS, when considering approval of the projects. FHWA's policy and regulations implementing NEPA are found at 23 CFR § 771.105.

Nineteen states have enacted a state version of NEPA to cover state and state funded projects. Thus, for state level highway projects, CO analysis may be required in accordance with state NEPA analogues. Like NEPA, the state versions typically require an examination of potential environmental impacts and proposal of efforts to mitigate these impacts to a practical extent. States may also require CO analyses in order for a project to comply with transportation conformity requirements. Project transportation conformity requirements are found in 40 CFR Parts 51 and 93. INSERT HERE INFORMATION ABOUT STATE ENVIRONMENTAL REQUIREMENTS.

Guidance related to performing these analyses may be found in the FHWA Technical Advisory T6640.8A (October 30, 1987). With respect to air quality, the guidance recognizes that microscale air quality analyses may be performed for some projects but does not offer any methodological guidance beyond adding background concentrations to the project contribution or the preferred alternative to arrive at a total CO concentration for comparison to the NAAQS. Using this general guidance, many states developed their own guidelines and procedures tailored to state policies and air quality status.

The *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* (FHWA, February 2014) documented conditions for urban intersections in CO maintenance areas that did not require a project-specific hot-spot analysis but could instead rely upon the categorical finding. The finding was based on extensive modeling of atmospheric, geometric, and traffic situations associated with urban intersections. The modeling procedures used to make this finding are detailed below.

C-4 Description of Modeling

The models used in CO air quality analysis have evolved over time. For emissions, the MOBILE series of models were used predominantly until the 2010 release of the first version of MOVES (Motor Vehicle Emission Simulator). Similarly, dispersion models have undergone changes over time. Highway sources have historically been treated as line sources using Gaussian dispersion to deliver CO from the source to the receptor. The HIWAY and CALINE series of models were developed to allow for modeling of roadways. However, it was realized that congested intersections, with most vehicles experiencing idling and acceleration and deceleration associated with a traffic signal, may be more of a concern for CO levels than free-flowing highways. To account for intersection scenarios, queuing algorithms were added to dispersion models, resulting in the current series of CAL3QHC and CAL3QHC(R) models. This analysis used MOVES (version MOVES2010b) and CAL3QHC (version 042440) for emissions and dispersion modeling, respectively.

INSERT TEXT OF STATE SITUATION. TOPICS COULD INCLUDE: CHRONOLOGY OF GUIDANCE AND PROCEDURES, PREVIOUS AGREEMENTS, DOCUMENT STATUS OF PROJECT-LEVEL MODELING. A DISCUSSION ON THE CAPITAL PROGRAM (I.E. TYPES OF PROJECTS, MAJOR VS MINOR PROJECTS) WITHIN THE STATE TO SHOW SMALL PERCENTAGE OF PROJECTS WITH NEED FOR AIR QUALITY ANALYSIS

The assumptions and inputs to the modeling process were conservative and/or worst-case. Conservative here refers to a modeling approach that, by design, has a tendency to over-estimate concentrations. This approach leads to higher concentrations than might otherwise be expected. If a project does not cause a violation with these conservative inputs and assumptions, then a violation under “real-world” conditions is extremely unlikely to occur. This is standard practice in transportation air quality modeling. Further discussion of how this conservative emissions and air dispersion modeling was conducted is provided in the remainder of this section.

C-4.1 MOVES Modeling

Emission modeling was performed using the MOVES model (version MOVES2010b). The emissions parameters for MOVES were specified in the Run Specification file (Runspec) and in the Project Data Manager (PDM). All applications of the MOVES model were conducted at the project level scale. Multiple MOVES runs were conducted for varying roadway grades to establish CO emissions rates. Other MOVES input parameters such as temperature and relative humidity were fixed to be conservative and consistent with the dispersion modeling component of the analysis (see section C-5 Background Concentration). Table C-3 describes the input parameters that were used in the Runspec and PDM for the MOVES component of the analysis.

Table C-3 - MOVES input parameters by scenario

Parameter	Freeway	Arterial	Intersection
Scale	Project Level Domain	Project Level Domain	Project Level Domain
Year	2015	2015	2015
Time Span- Month	January	January	January
Time Span - Hour	12:00 AM	12:00 AM	12:00 AM
Time Span - Day	Weekday	Weekday	Weekday
Geographic Bounds	Custom Domain	Custom Domain	Custom Domain
Temperature	-10° Fahrenheit	-10° Fahrenheit	-10° Fahrenheit
Relative Humidity	100%	100%	100%
Fuel Formulation	Gasoline – Formulation ID - 3812	Gasoline – Formulation ID - 3812	Gasoline – Formulation ID - 3812
	Diesel – Formulation ID - 20011	Diesel – Formulation ID - 20011	Diesel – Formulation ID - 20011
	CNG – Formulation ID - 30	CNG – Formulation ID - 30	CNG – Formulation ID - 30
Fleet Mix	Emission Source Type and Fuel Combinations for 2015 with a Shift to 0% Heavy-Duty Truck Volumes to Reflect Higher CO emission Rates from Gasoline Vehicles (refer to Table C-4 through Table C-6)	Emission Source Type and Fuel Combinations for 2015 with a Shift to 0% Heavy-Duty Truck Volumes to Reflect Higher CO emission Rates from Gasoline Vehicles (refer to Table C-4 through Table C-6)	Emission Source Type and Fuel Combinations for 2015 with a Shift to 0% Heavy-Duty Truck Volumes to Reflect Higher CO emission Rates from Gasoline Vehicles (refer to Table C-4 through Table C-6)
Age Distribution	2015 National Default	2015 National Default	2015 National Default
Link Source Type Distribution	Variable - Based on 2015 National Default VMT for Urban Restricted Access Road Type	Variable - Based on 2015 National Default VMT for Urban Unrestricted Access Road Type	Variable - Based on 2015 National Default VMT for Urban Unrestricted Access Road Type
Road Type	Urban and Rural Restricted Access	Urban and Rural Unrestricted Access	Urban and Rural Unrestricted Access
Link Average Speed	74 mph	45 mph	15, 25 and 35 mph approach and idle (intersection)
Grade	±7% , ±4%, ± 2%, ± 0% (uphill and downhill grade)	±4%, ± 2%, ± 0% (uphill and downhill grade)	± 2% (cross direction) and 0% grade in other direction (intersection)
Inspection & Maintenance	None	None	None

C-4.1.1 Relative Humidity

A value of 100% relative humidity was used for the emission modeling. It is important to note that for temperatures of 75 degrees Fahrenheit and below, relative humidity has no effect on CO emission rates.

C-4.1.2 Temperature

Sensitivity tests with MOVES show that emission rates are not sensitive to cold temperatures for running exhaust and crankcase exhaust emissions (Figure C-5)[36]. A value of -10 degrees Fahrenheit was used in the analysis. Notably, MOVES predicts higher CO at T > 75 degrees Fahrenheit due to air conditioning use. However, because CO is a winter air pollution problem, this higher emission rate is excessively conservative and thus was not used in the analysis.

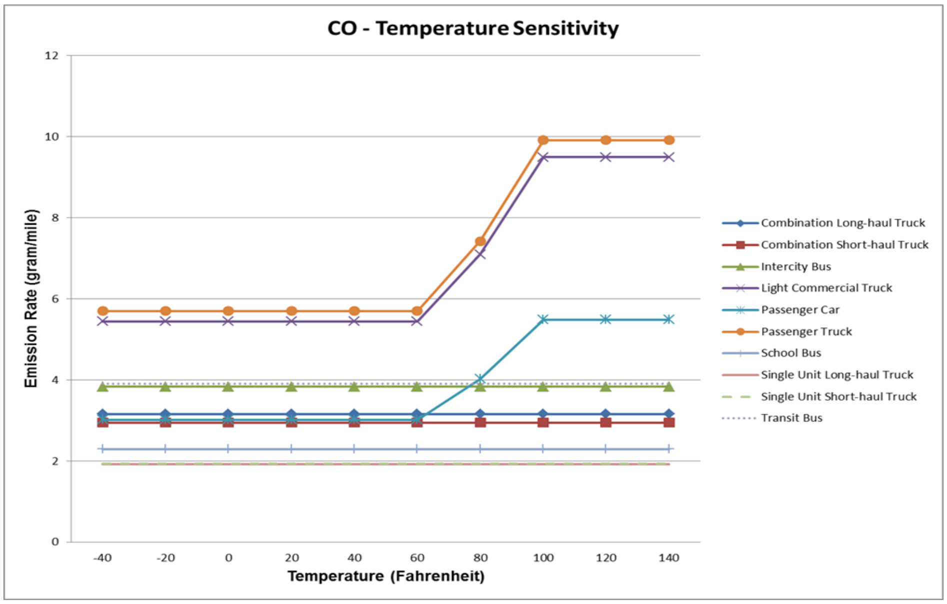


Figure C-5 - Sensitivity of CO Emission Rates to Temperature

C-4.1.3 Link Source Type Distribution

The national default Source Type Distribution was obtained from a national scale MOVES run for the 2015 calendar year. Utilizing the vehicle miles traveled (VMT) information from the 'movesactivityoutput' table within the output database, the Source Type Distributions were transformed into a Source Type Hour Fraction for intersection, arterial, and freeway scenarios. To ensure conservative results, the Source Type Hour Fraction was based upon the national default, but adjusted, in two steps, to reflect a higher proportion of vehicles that have higher CO emissions rates. These two steps are detailed below:

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[36] See http://ntl.bts.gov/lib/46000/46500/46598/DOT-VNTSC-FHWA-12-05.pdf and http://www.epa.gov/ttnchie1/conference/ei19/session6/choi.pdf

- Passenger trucks have the highest CO emission rates of all MOVES source types, except gasoline operated single unit trucks. Passenger cars have the largest fraction of the total national vehicle mix and passenger trucks are the second largest fraction of the total national vehicle mix. To ensure conservative emissions rate estimates for the PA, the Source Type Hour Fraction was adjusted to reflect a 50/50 proportional split between passenger car and passenger truck source types.
- Gasoline vehicle types generally have higher CO emission rates than diesel vehicle types within MOVES[37]. In the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* (FHWA, February 2014), it was assumed that the lowest observed fraction of non-gasoline vehicles was 5% of the total vehicle mix. To provide a more conservative emission rate than used in the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding,* the national default Source Type Hour Fraction was adjusted by reducing combination and single-unit trucks to represent 0% of the total fleet mix. The remaining 5% fraction was added to the passenger truck source type after the conservative 50/50 passenger car to passenger truck split was applied.

These two adjustments are reflected in:

Table C-4 for the Link Source Type Fractions utilized for the freeway, arterial, and intersection scenarios.

Table C-4 - Link Source Type Fractions

sourceTypeID	Description	SourceTypeHourFraction
11	Motorcycle	0.005546
21	Passenger Car	0.423629
31	Passenger Truck	0.473629
32	Light Commercial Truck	0.093704
41	Intercity Bus	0.000762
42	Transit Bus	0.000211
43	School Bus	0.00085
51	Refuse Truck	0.000331
52	Single Unit Short-haul Truck	0
53	Single Unit Long-haul Truck	0
54	Motor Home	0.001338
61	Combination Short-haul Truck	0

[37] For temperatures below 60°F combination long-haul diesel trucks, intercity and transit diesel buses are higher than gasoline passenger cars but are lower than gasoline passenger trucks and gasoline light commercial trucks.

sourceTypeID	Description	SourceTypeHourFraction
62	Combination Long-haul Truck	0

Table C-5 lists the source type and fuel type combination that were modeled in all scenarios.

Table C-5 - Fuel types listed for source types

Source Types	Fuel Type(s)
Motorcycle	Gasoline
Passenger Car	Diesel Fuel and Gasoline
Passenger Truck	Diesel Fuel and Gasoline
Light Commercial Truck	Diesel Fuel and Gasoline
Refuse Truck	Diesel Fuel and Gasoline
Motor Home	Diesel Fuel and Gasoline
School Bus	Diesel Fuel and Gasoline
Transit Bus	Diesel Fuel, Gasoline, CNG
Intercity Bus	Diesel Fuel
Single Unit Short-haul Truck	Diesel Fuel and Gasoline
Single Unit Long-haul Truck	Diesel Fuel and Gasoline
Combination Short-haul Truck	Diesel Fuel and Gasoline
Combination Long-haul Truck	Diesel Fuel

C-4.1.4 Age Distribution

The 2015 national default age distribution was utilized and is consistent with the analysis year that was modeled.

C-4.1.5 Fuel Supply and Formulation

Fuel formulation parameters can significantly affect the CO emission rates. Joint analyses conducted by FHWA and EPA in the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* determined the effects of certain fuel parameters on CO emission rates. Fuel parameters that can effect CO emission rates include Reid vapor pressure (RVP), sulfur content, ethanol (ETOH), percent of fuel evaporated at 200 degrees and 300 degrees Fahrenheit (E200/E300), and distillation parameters T50 and T90. Those analyses determined that fuel formulation ID 3812 yields higher CO emission rates than other relevant fuel formulations. Table C-6 lists the fuel formulation that was used in both the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* and this analysis.

Table C-6 - Fuel formulation used for the analysis

Fuel Type	fuelFormulationID	RVP	Sulfur Content (ppm)	ETOHVolume	e200	e300	T50	T90
Diesel	20011	0	11	0	0	0	-	-
Gasoline	3812	15.7	28	10	58.1352	94.8717	183.214	275.447
CNG	30	0	0	0	0	0	0	0

C-4.1.6 Link Average Speed and Operating Mode Distribution

When average speed is utilized in the 'Links' input file, entered through the MOVES' PDM, MOVES creates an operating mode distribution based upon the default drive schedules located in the default database. This operating mode distribution was used represent the freeways, arterials and intersection scenarios. The speeds used in the analysis for each facility type are shown in Table C-3.

C-4.1.7 Emissions Processes

The 'Running Exhaust' and 'Crankcase Running Exhaust' emissions process were utilized in the intersection, freeway, and arterial scenarios.

C-4.1.8 Inspection and Maintenance Program

An inspection and maintenance (I/M) program produces CO emissions rate benefits. As a conservative assumption, I/M programs were not included in the analysis.

C-4.2 Dispersion Modeling: CAL3QHC

The inputs for the dispersion modeling followed EPA's 1992 Guidance for CO determinations using CAL3QHC (version 04244) and were consistent with the approach used by the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* for intersections. As for emissions modeling, the dispersion modeling used conservative and, in many cases, worst-case inputs and assumptions. The modeling approach is described in greater detail below:

C-4.2.1 Intersections, Freeways, and Arterials

- As a conservative assumption, the wind speed was set to 1.0 m/s (the lower limit of CAL3QHC meaningful input)
- Wind direction was modeled every ten degrees from 0 to 350 degrees.
- A mixing height of 1000 m was used, consistent with standard modeling procedures. Sensitivity testing has shown that due to the close proximity of the receptors, mixing height has negligible influence on the dispersion analysis.
- For urban modeling, a surface roughness (z0) of 108 cm was used, corresponding to a single family residential setting. The single family residential setting is the least rough setting for an urban environment and is conservative. The recommended surface roughness in urban areas can vary from 108 to 370 cm. For rural areas, a surface roughness of 1.0 cm was used,

which corresponds to a moderately short grass height (6-8 cm) as identified in the Kansas prairie grass[38]. Shorter grass heights are unlikely to be found most rural locations.

- The 1992 EPA CO Guidelines specifies a stability class of D (neutral) for urban areas and E (stable) for rural areas. These guidelines were applied in the model.
- Receptor Placement
    - Freeways and Arterials:
        - Receptors were modeled per the CAL3QHC and 1992 EPA Guidance and were located starting at 30 feet from the outside lane for freeways to account for off-road safety clearance. Receptors were located starting at 10 feet from roadway edge for arterials (where the general public has access and within the limitations of the model to predict valid concentrations).
        - Receptors were placed on both sides of the roadway extending out to 295 feet from the roadway and were modeled to establish decreasing CO concentrations with distance.
    - Intersections:
        - Receptors were modeled per the CAL3QHC and 1992 EPA Guidance and began at 10 feet from roadway edge.
        - A grid of receptors was used in each quadrant to ensure the worst case concentrations were identified. The grid spacing started at 10 feet from each roadway and then extended in 25 foot increments from the intersection up to 500 feet in order to simulate the mid-block position. To ensure that the maximum mid-block concentration was found a receptor was placed at 2,500 feet from the intersection. This allowed analysis of the intervening values.
        - Intersections were modeled per the CAL3QHC and 1992 EPA Guidance, beginning at 10 feet from roadway edge.
        - Figure C-6 shows a typical intersection configuration with link geometry. Figure C-7 shows the layout of receptors for the southeast quadrant.
- Link Geometries and Activity Levels
    - Freeways and Arterials
        - 5,000 foot links were evaluated to avoid end effects.
        - Receptors were evaluated at the center of the defined link to avoid end effects.

[38] Businger, J.A., J.C. Wingaard, Y. U. Isumi and E. F. Bradley, 1971 "Flux Profile Relationships in the Atmospheric Surface Layer", *J. Atm Sci.,* 28:181-191.

- Facilities were evaluated from 2 to 14 total lanes.
- Median width was 3.3 feet for freeways and 0 feet for arterials
- Lane width was 12 feet and sensitivity testing was performed using 11 foot lane width.
- Traffic volumes were conservatively modeled as 2,200 vehicles-per-lane-per-hour.
- Figure C-8 shows a typical modeling scenario.

o Intersections.

- Approach and departure links extended 2,500 feet from the center of the intersection to ensure end effects at receptor locations are not encountered.
- Links were input for the start and end locations per the guidance in the CAL3QHC User Manual. Figure C-9 shows an example of the link placement.
- Queue lengths were as established during modeling.
- Turn lanes were modeled per suggested guidance in the AASHTO Green Book.

C-4.2.2 Interchanges

The CAL3QHC dispersion model results from the six-lane intersection (2 left turn lanes and 4 through lanes) were used to develop threshold PA CO concentration levels for the interchange configuration. A variable number of freeway lanes (even number of lanes ranging from 2 -22 lanes) were simulated. Likewise, various distances from the edge of the nearest freeway travel lane to the edge of the nearest travel lane of the interchange ramp (10, 20, 30, 60, 80, 100, 125, 150, 175, 300, 500 and 1,000 feet) were simulated. Figure C-10 shows the layout of the interchange. As a result, the CO contribution for an interchange project for any given combination of the modeled number of freeway lanes and distances from the freeway to the interchange can be estimated. The total of the freeway contribution, intersection contribution, and background can then be directly compared to the CO NAAQS.

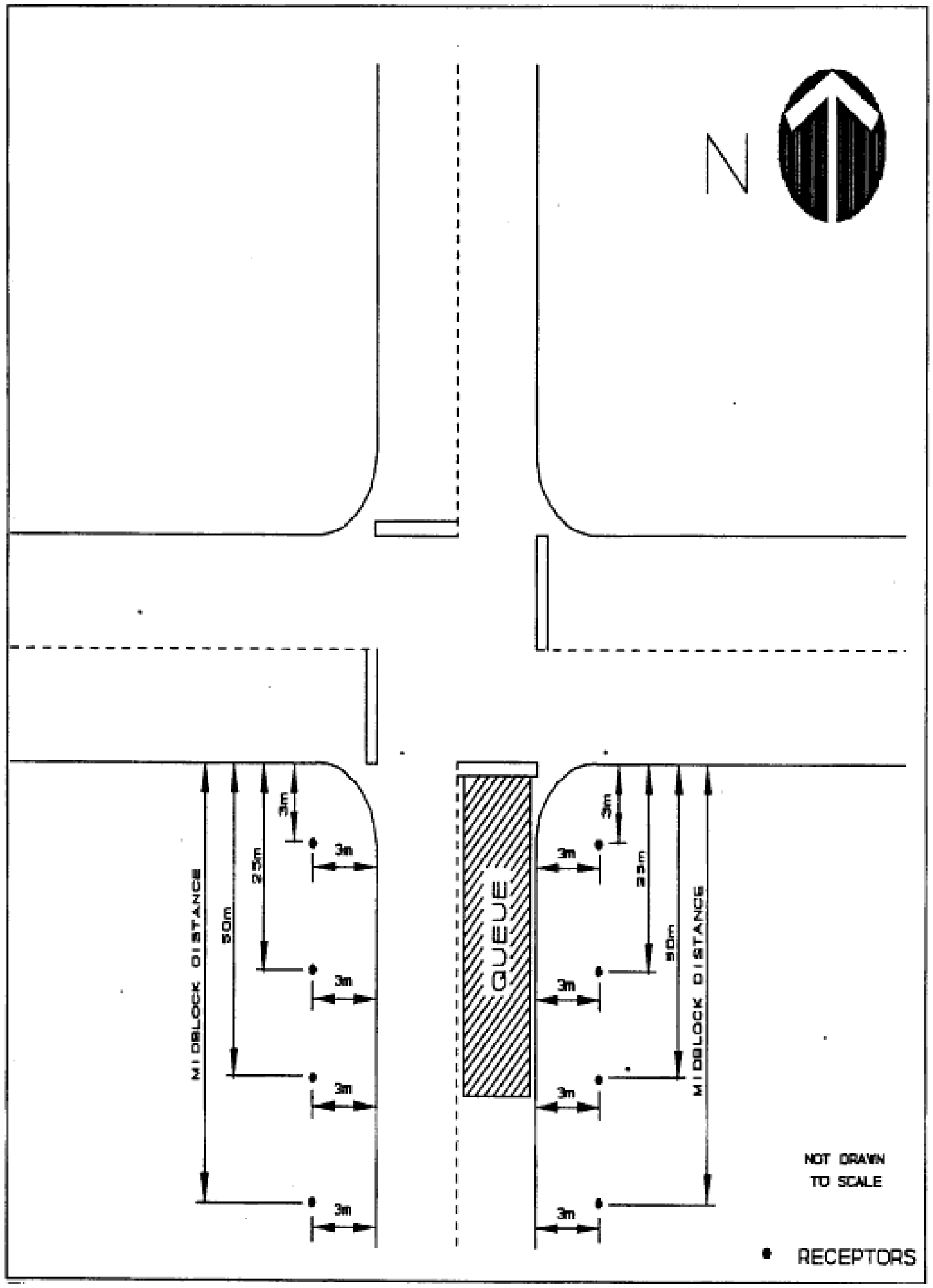

Figure C-6 - Intersection configuration used for modeling with link placement

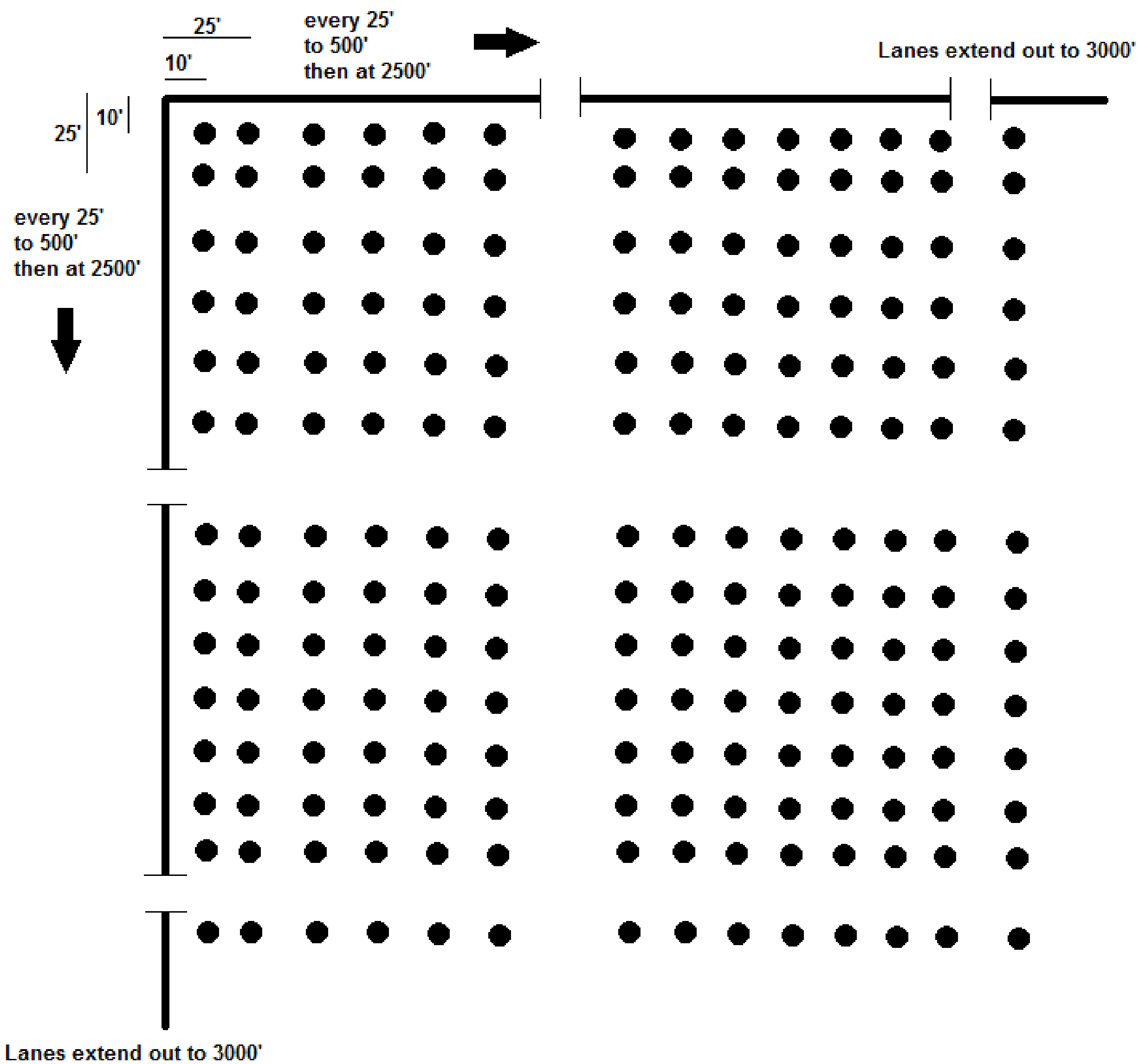

Figure C-7 - South-West Quadrant Receptor Grid Used for Intersection Modeling

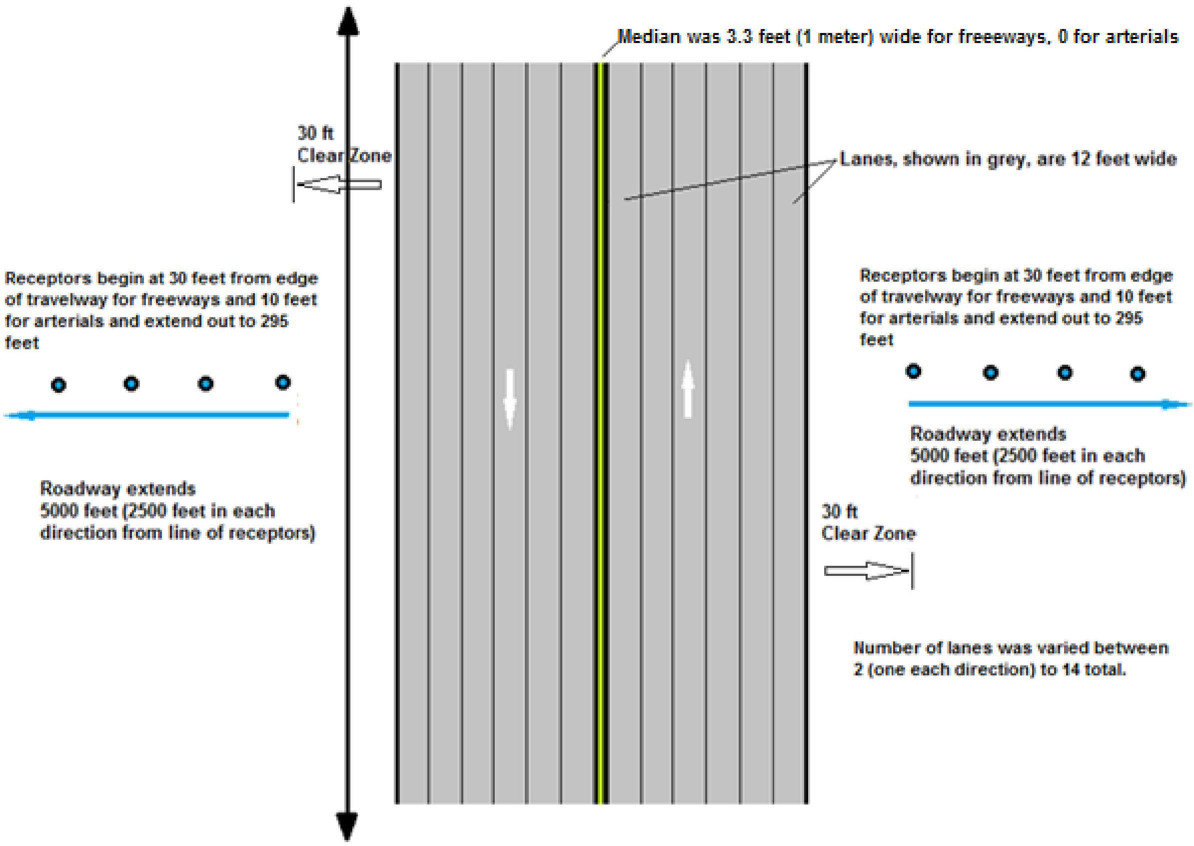

Figure C-8 - Typical Modeling Layout for Freeways and Arterials

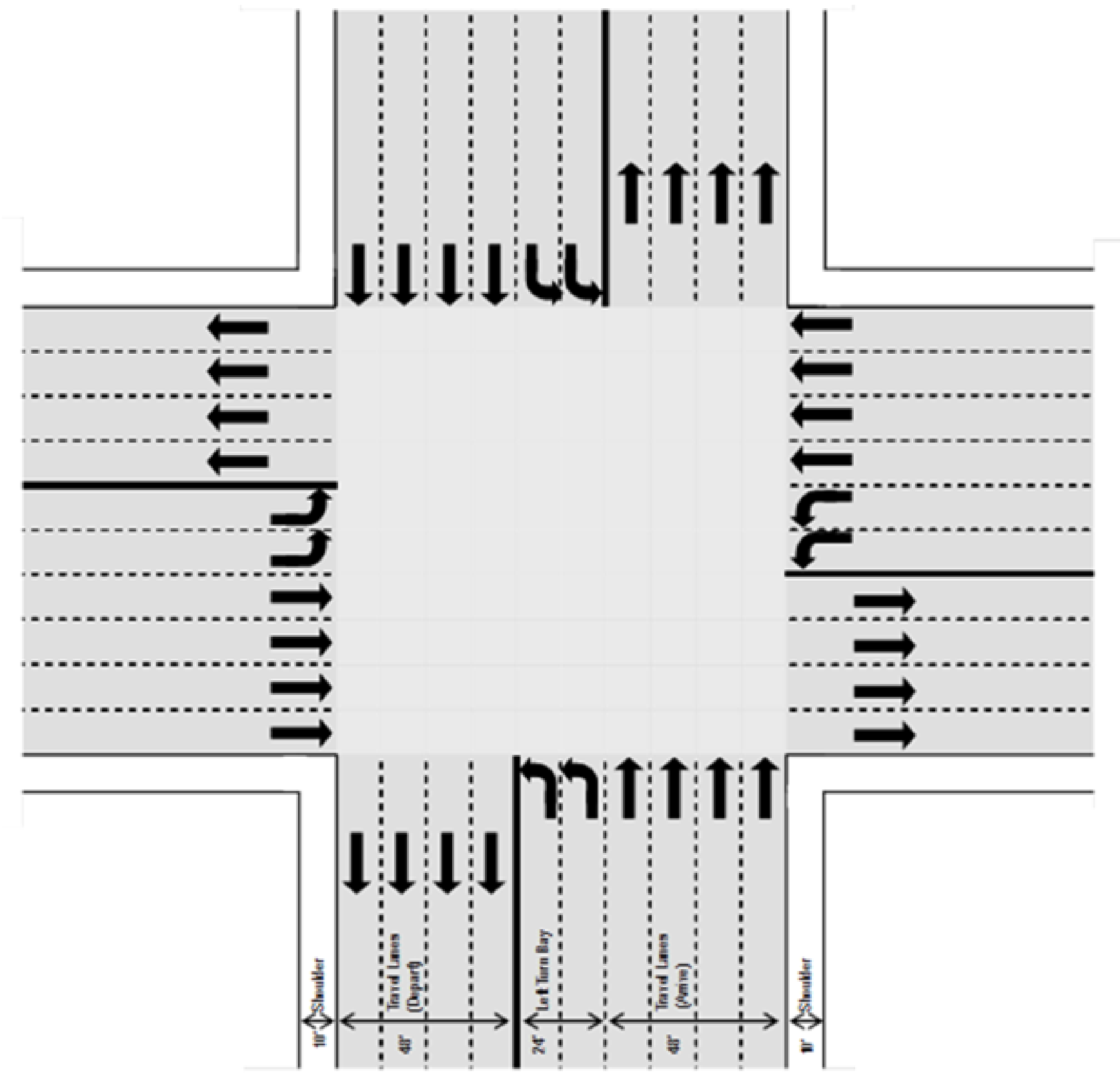

Figure C-9 - Intersection Geometry Modeled. Each oncoming direction has 4 approach and 2 left turn lanes as well as 4 departure lanes.

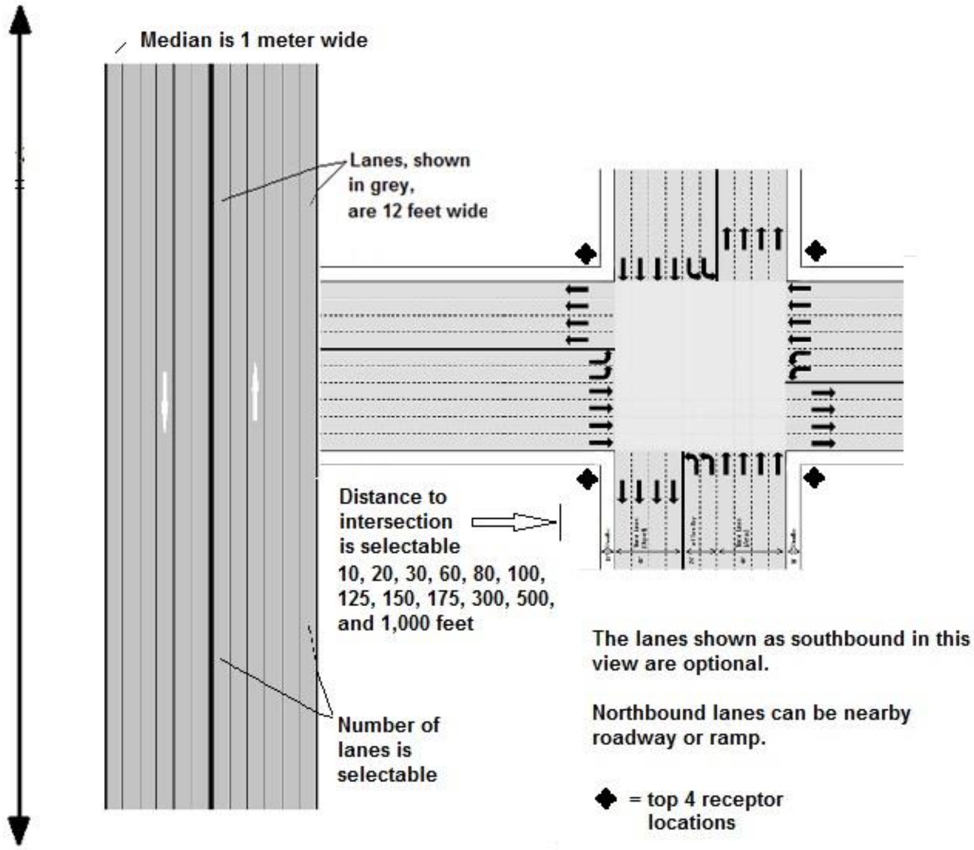

Figure C-10 - Interchange Configuration with nearby freeway and intersection/ramp layout

C-5 Background Concentration

THE BACKGROUND DISCUSSION CAN EITHER USE THE FIRST PARAGRAPH IF STATE CO MONITORING DATA IS USED TO DETERMINE BACKGROUND OR THE SECOND PARAGRAPH WHICH USED THE NATIONAL BACKGROUND.

Background concentrations were determined from data collected over the previous calendar year by STATE AIR AGENCY operated ambient CO monitors. The 2nd highest non-overlapping representative monitored CO concentrations from the most recent calendar year was used to arrive at a background concentration value to be used for project analysis. This method produced a 1-hour background concentration of 5.1 ppm and an 8-hour background concentration of 2.6 ppm.

FOR NATIONAL BACKGROUND

To develop a realistic nationwide CO background concentration, the 2nd highest non-overlapping observed CO concentrations from each of the nation's CO monitoring stations were ranked for each of the three most recent years (2011-2013). These data were extracted from EPA's AIRS database. The 99th, 95th and 90th percentiles for each year were calculated and reviewed. Based on this review, it was determined that a reasonably conservative value, applicable to almost any location nationwide, is the highest 95th percentile CO concentration from the past three years (Table C-7). Using this value, the representative 1-hour background concentration was determined to be 5.1 ppm and the representative 8-hour background concentration was determined to be 2.6 ppm.

Table C-7 – Nationwide Network of CO Monitoring Stations Ranked Concentrations 2011-2013

	2nd High Maximum 8-hour CO Concentrations (ppm)			
Percentile	2011	2012	2013	Average
99th	5.8	4.6	4.6	5.0
95th	2.8	2.5	2.5	2.6
90th	2.4	2.1	2.1	2.2
	2nd High Maximum 1-hour CO Concentrations (ppm)			
99th	15.3	8.0	7.9	10.4
95th	5.5	4.8	5.0	5.1
90th	4.6	3.5	3.5	3.9
Number of CO monitoring stations with > 75% completeness criteria	286	284	198	

Source: USEPA AIRData (2014)

FUTURE BACKGROUND

For future years mobile sources will remain the primary source of CO emissions nationwide. To adjust for future CO concentrations as a result of emissions rate changes in the mobile source fleet, the changes in CO emissions as projected by MOVES using the conservative gasoline fleet mix were explored. Based on the emission trends as shown in Figure C-4 and Table C-2, a further decrease in CO concentrations in the range of 30-40% relative to the 2015 fleet is anticipated by 2030, with concentrations anticipated to remain unchanged for future years. VMT is also projected to remain flat nationwide as shown in Figure C-2. The projected changes in the nationwide gasoline consumption via the US Energy Information Agency were examined to see if an adjustment would be required to account for increased or decreased gasoline fuel consumption (assuming no new control technology is introduced to reduce CO emissions). Overall, these trends suggest a reduction in future CO emissions. However to preserve the conservative, "worst-case" approach, no reductions in future background levels were assumed for this study. Thus, the results presented in the following Section C-7 Results are representative of 2015 and later years.

C-6 Persistence Factor

In order to derive an 8-hour CO concentration from the modeled 1-hour CO concentration, a persistence factor was applied to the modeled 1-hour concentration. The persistence factor accounts for variability in traffic (i.e., less traffic during off peak hours) and meteorological conditions (i.e., changes in wind speed, wind direction, and temperature) between the 1-hour time frame and the 8-hour time frame. The persistence factor is the ratio between the maximum 1-hour concentration and the resulting maximum 8-hour concentration in the 8-hour time frame containing the maximum 1-hour concentration. The persistence factor recommended by EPA for a local area is derived from the average of the highest 10 non-overlapping 8-hour CO concentrations over the previous three years.

Where representative monitoring data is not available, EPA recommends the use of a persistence factor of 0.7. For this study, the persistence factor was determined from an examination of the ambient CO monitors operated by the STATE AIR AGENCY. Examination of CO monitoring data for the latest three years yielded a persistence factor of 0.7. OR based on EPA recommended factor of 0.7 as local representative CO monitoring data was unavailable.

EXAMINATION OF STATE OR LOCAL AIR QUALITY MONITORING DATA MAY YIELD PERSISTENCE FACTORS THAT ARE DIFFERENT THAN THE NATIONAL DEFAULT VALUE OF 0.7. IF A STATE OR LOCAL SPECIFIC PERSISTENCE FACTOR IS DEVELOPED, IT WOULD BE MULTIPLIED BY THE MAXIMUM 1-HOUR CONCENTRATION AND ADDED TO THE STATE OR LOCAL SPECIFIC 8-HOUR BACKGROUND CONCENTRATION TO DETERMINE COMPLIANCE WITH THE 8-HOUR CO NAAQS.

C-7 Results

The results of the emissions and dispersion modeling, coupled with the selected background concentrations and persistence factor values produce an estimate of the impact of a given highway project in terms of CO concentration. These results can then be added to the representative background concentration and compared to NAAQS to determine if a potential project cannot produce CO concentrations high enough to result in an exceedance of the NAAQS, and would therefore eligible for the programmatic agreement. The results for the project types and conditions discussed above are presented here.

C-7.1 Comparison to NAAQS

Results from the dispersion modeling for each facility type, possible geometries, and number of lanes, grade and volume were added to the representative background concentration value. These combined results were compared with the current 1 and 8-hour CO NAAQS to determine if the scenario met or exceeded the standard. The comparison began with project scenarios that yield the highest concentrations and were iterated downward to determine which scenario first passes. The results from the comparison are a set of tables which identify those projects which pass a specific scenario. These results are the basis for the highway project types and conditions identified in the programmatic agreement.

In order to compare results to the 1-hour CO standard, the total CO concentration for a given scenario is derived by adding the 1-hour CO background concentration to the 1-hour modeled project contribution CO concentration:

$$Total\ 1-hr\ CO = 1-hour\ background\ +\ 1-hour\ project\ contribution$$

In order to compare results to the 8-hour CO standard, the total CO concentration for a given scenario is derived by multiplying the 1-hour modeled project contribution CO concentration by the persistence factor and then adding the 8-hour CO background concentration:

$$Total\ 8-hour\ CO = 1-hour\ project\ contribution\ \ x\ \ persistence\ factor\ +\ 8-hour\ background$$

C-7.2 Freeway and Arterials

Based on the MOVES2010b and CAL3QHC (version 04244) inputs and assumptions described above, the maximum 1-hour CO concentrations for urban and rural arterials and freeways were calculated for varying lane and grade combinations. Table C-9, attached, shows the lane and grade combinations for arterials and freeways in urban and rural locations that do not produce emissions sufficient to result in an exceedance of the 8-hour CO standard[39]. In all cases, the 8-

[39] Based on an 8-hour CO background concentration of 2.6 ppm and a persistence factor of 0.7

hour CO standard is the limiting case. Thus, freeway and arterial projects with lane and grade conditions less than or equal to those shown in Table C-9 also do not require project-specific modeling to demonstrate compliance with CO ambient standards

C-7.2.1 Sensitivity Analysis for 11-foot Wide Urban Freeway Lanes

To assess the impact of lane width on modeled concentration, 10, 12, 14, 16, 18, 20 and 22-lane urban freeways were modeled using an 11 foot lane width. The 22-lane freeway showed the maximum response to this change in lane width, with a relative increase in concentration of 2%. Both sides of the freeway showed the same response. Table C-8 shows the relative change at each receptor between the 11 and 12 foot lane widths, as measured from the edge of the closest lane, for the 22-lane scenario. Note that the distance from the travel lane to the receptor location remains the same for both the 11 and 12 foot lane width. Based on this minimal impact on CO levels between the 11 and 12 foot lanes, both widths are covered by the draft PA and TSD templates for freeway and arterial project types.

Table C-8 - Comparison of maximum predicted one-hour CO concentrations (not including background concentrations) for a 22 lane (11 in each direction) urban freeway using 12-foot and 11-foot lane widths

	Distance[1]	Standard 12 foot lane width	11 foot lane width	Difference	Difference
Receptor	**(m)**	**Concentration (ppm)**	**Concentration (ppm)**	**Concentration (ppm)**	**percent**
1	10	11.6	11.8	0.2	2%
2	20	10.6	10.8	0.2	2%
3	30	9.6	9.7	0.1	1%
4	55	8.0	8.1	0.1	1%
5	80	6.9	7	0.1	1%
6	105	6.1	6.2	0.1	2%
7	130	5.6	5.6	0.0	0%
8	155	5.1	5.2	0.1	2%
9	180	4.7	4.8	0.1	2%
10	295	3.6	3.6	0.0	0%

[1] Distance from edge of the nearest travel lane

C-7.3 Intersections

Table C-10, attached, shows the maximum 1-hour CO concentration for various approach speeds for a six approach lane intersection project (2 left turn lanes and 4 through lanes) for which a project-level air quality analysis will not be required to demonstrate compliance with CO ambient air quality standards (NAAQS). These results assume the same background and persistence factors previously discussed (sections C-5 Background Concentration and C-6 Persistence Factor) and that the intersection has a 2% grade and a skew angle of 90 degrees. Consequently, intersections with grades lower than 2% and fewer than 6 lanes will also not require project-specific modeling to demonstrate compliance with CO ambient air quality standards. The state may also want to conduct modeling for intersections with skew angles other than 90 degree to include in the PA. That discussion would be inserted here. The STATE also conducted modeling for a XX skew angle. The results presented are in Table XX (attached).

The intersection was modeled as a 90 degree intersection, meaning that the roadways intersect at right angles. Skew angle intersections—intersections with approaches that do not intersect at right angles, are not included in the current PA, although they may be added in a future update. Highly congested intersections (whose approach speed is less than 15 mph) are also not covered by the PA, although they too may be added in a future update.

C-7.4 Interchanges

Table C-11, attached, shows the one-hour CO concentrations that, with the assumed 8-hour CO background level and persistence factor, do not produce concentrations that would cause or contribute to an exceedance of the 8-hour CO ambient air standard (NAAQS) and therefore will not require project-specific CO modeling to demonstrate compliance with the ambient CO standards (NAAQS). The table columns represent varying distances from the edge of the nearest freeway travel lane to the edge of the nearest interchange ramp. The table rows represent varying numbers of travel lanes. The intersection geometry is the same as in the intersection case, with six lanes on each approach (4 approach, 2 left turn) and 4 departure lanes, all with a 2% grade or less. This is a conservative approach for this type of project because freeway interchanges generally have a one- or two-lane ramp approaching or departing from the intersection.

The freeway was modeled at a 0% grade in both rural and urban locations. However, because the rural interchange results were considerably higher than would be useful for a PA, only the urban results are presented here. Thus, an urban interchange project where the freeway with the appropriate lane configuration is at least as far from the nearby intersection with speeds greater than the slowest speed shown in Table C-11 does not exceed the 8-hour CO standard and therefore does not require project-specific CO modeling to demonstrate compliance with the ambient CO standards.

C-8 Terms of Agreement

For the project types and conditions listed above, project environmental documentation will not require a quantitative air quality analysis for CO. Due to the extensive modeling work performed for the *Federal Highway Administration (FHWA) Carbon Monoxide (CO) Categorical Hot-Spot Finding* (FHWA, February 2014)[40] and the National Cooperative Highway Research Project 25-25, Task 78: *Programmatic Agreements for Project-Level Air Quality Analyses* (2015)[41], highway projects that meet the above-listed project conditions and types may address air quality requirements qualitatively with statements such as:

> "The proposed project does not exceed the project types and conditions listed in the Programmatic Agreement between the Federal Highway Administration and the STATE Department of Transportation for streamlining the project-level air quality analysis process for carbon monoxide. Modeling using "worst-case" parameters has been conducted for these project types and conditions. It has been determined that projects, such as this one, for which the conditions are not exceeded, would not significantly impact air quality and would not cause or contribute to a new violation, increase the frequency or severity of an existing violation, or delay timely attainment of the National Ambient Air Quality Standards for carbon monoxide."

Or

> "An air quality analysis is not necessary as this project will not increase traffic volumes, reduce source-receptor distances, or change other existing conditions to such a degree as to jeopardize attainment of the National Ambient Air Quality Standards for carbon monoxide."

The technical analysis to support the Programmatic Agreement between the STATE Division of FHWA and the STATE Department of Transportation only extends to the project types and conditions listed above. Projects of different types or project having different conditions (i.e., freeways having more than the number of lanes shown in Table C-9 may require a project-specific modeling to document compliance with the CO NAAQS.

The STATE Department of Transportation will coordinate with STATE Division of FHWA (and the STATE AIR QUALITY AGENCY) when underlying assumptions related to the Programmatic Agreement may change. This could include, but is not limited to:

- Project types and/or conditions not covered by the Programmatic Agreement;
- Updates to emission or dispersion models or release of new, relevant models;
- Updates to model inputs and/or planning assumptions.

[40] See: http://www.fhwa.dot.gov/environment/air_quality/conformity/policy_and_guidance/cmcf/
[41] E. Carr et al., NCHRP 25-25/Task78,"Programmatic Agreements for Project-Level Air Quality Analyses", 2015. See: http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3311

Attachment to the Technical Support Document

Table C-9 - One-hour CO concentrations (not including background concentrations) for freeways and arterials in urban and rural settings of varying lane and grade configuration*

			GRADE			
FACILITY	**LOCATION**	**LANES**	**0**	**2**	**4**	**7**
Arterial	Urban	12	6.7	8.5		
Arterial	Urban	10	6.0	7.6		
Arterial	Urban	8	5.2	6.6		
Arterial	Urban	6	4.3	5.4	7.5	
Arterial	Urban	4	3.2	3.9	5.5	
Arterial	Urban	2	1.8	2.2	3.0	
Arterial	Rural	8	8.7			
Arterial	Rural	6	7.2	8.6		
Arterial	Rural	4	5.4	6.3	8.6	
Arterial	Rural	2	3.1	3.6	4.9	
Freeway	Urban	20	9.0			
Freeway	Urban	18	8.6			
Freeway	Urban	16	7.9			
Freeway	Urban	14	7.2			
Freeway	Urban	12	6.5			
Freeway	Urban	10	5.6	8.0		
Freeway	Urban	8	4.7	6.6		
Freeway	Urban	6	3.7	5.1	7.2	
Freeway	Urban	4	2.7	3.5	4.9	6.2
Freeway	Urban	2	1.4	1.7	2.4	3.1
Freeway	Rural	8	8.0			
Freeway	Rural	6	6.4	8.6		
Freeway	Rural	4	4.5	5.9	8.2	
Freeway	Rural	2	2.4	3.0	4.2	5.3

*These findings apply to scenarios with average speed ranging from 45 to 56 mph for arterials and 19 to 74 mph for freeways.

Table C-10 - One-hour CO concentrations (not including background concentrations) for rural and urban intersections at varying approach speeds for a six approach lane intersection for each leg at two percent grade.

LOCATION	APPROACH SPEED (MPH)	CONCENTRATION (PPM)
Urban	15	6.5
Urban	25	5.7
Urban	35	5.2
Rural	25	8.8
Rural	35	8.4

Table C-11 - One-hour CO concentrations at varying intersection approach speeds and distances from an urban freeway at varying lane configurations

Urban Freeway Contribution of CO (PPM) at 15 mph Approach Speed with Increasing Distance from Freeway Pavement Edge (ft)												
NUMBER OF LANES	**10**	**20**	**30**	**60**	**80**	**100**	**125**	**150**	**175**	**300**	**500**	**1000**
2	8.5	7.8	7.5	7.1	6.9	6.7	6.7	6.6	6.5	6.5	6.3	6.3
4			8.8	8	7.6	7.4	7.2	7.1	7.1	6.7	6.5	6.3
6				8.9	8.4	8.1	7.9	7.6	7.6	7.1	6.8	6.5
8					9.1	8.7	8.4	8.1	8	7.4	7.1	6.7
10							9	8.7	8.5	7.8	7.3	6.8
12								9.1	8.9	8.1	7.6	6.9
14										8.5	7.8	7.1
16										8.8	8	7.2
18										9.1	8.2	7.4
20											8.5	7.5
22											8.7	7.6
Urban Freeway Contribution of CO (PPM) at 25 mph Approach Speed with Increasing Distance from Freeway Pavement Edge (ft)												
NUMBER OF LANES	**10**	**20**	**30**	**60**	**80**	**100**	**125**	**150**	**175**	**300**	**500**	**1000**
2	7.9	7.2	6.9	6.5	6.3	6.1	6.1	6	5.9	5.9	5.7	5.7
4		8.7	8.2	7.4	7	6.8	6.6	6.5	6.5	6.1	5.9	5.7
6				8.3	7.8	7.5	7.3	7	7	6.5	6.2	5.9
8				9.1	8.5	8.1	7.8	7.5	7.4	6.8	6.5	6.1
10					9.1	8.7	8.4	8.1	7.9	7.2	6.7	6.2
12							8.8	8.5	8.3	7.5	7	6.3
14								9	8.7	7.9	7.2	6.5
16									9.1	8.2	7.4	6.6
18										8.5	7.6	6.8

Urban Freeway Contribution of CO (PPM) at 15 mph Approach Speed with Increasing Distance from Freeway Pavement Edge (ft)												
20										8.7	7.9	6.9
22										9.1	8.1	7

Urban Freeway Contribution of CO (PPM) at 35 mph Approach Speed with Increasing Distance from Freeway Pavement Edge (ft)												
NUMBER OF LANES	**10**	**20**	**30**	**60**	**80**	**100**	**125**	**150**	**175**	**300**	**500**	**1000**
2	7.3	6.6	6.3	5.9	5.7	5.5	5.5	5.4	5.3	5.3	5.1	5.1
4	9.0	8.1	7.6	6.8	6.4	6.2	6	5.9	5.9	5.5	5.3	5.1
6			8.6	7.7	7.2	6.9	6.7	6.4	6.4	5.9	5.6	5.3
8				8.5	7.9	7.5	7.2	6.9	6.8	6.2	5.9	5.5
10					8.5	8.1	7.8	7.5	7.3	6.6	6.1	5.6
12						8.7	8.2	7.9	7.7	6.9	6.4	5.7
14							8.8	8.4	8.1	7.3	6.6	5.9
16								8.9	8.5	7.6	6.8	6
18									8.9	7.9	7	6.2
20										8.1	7.3	6.3
22										8.5	7.5	6.4