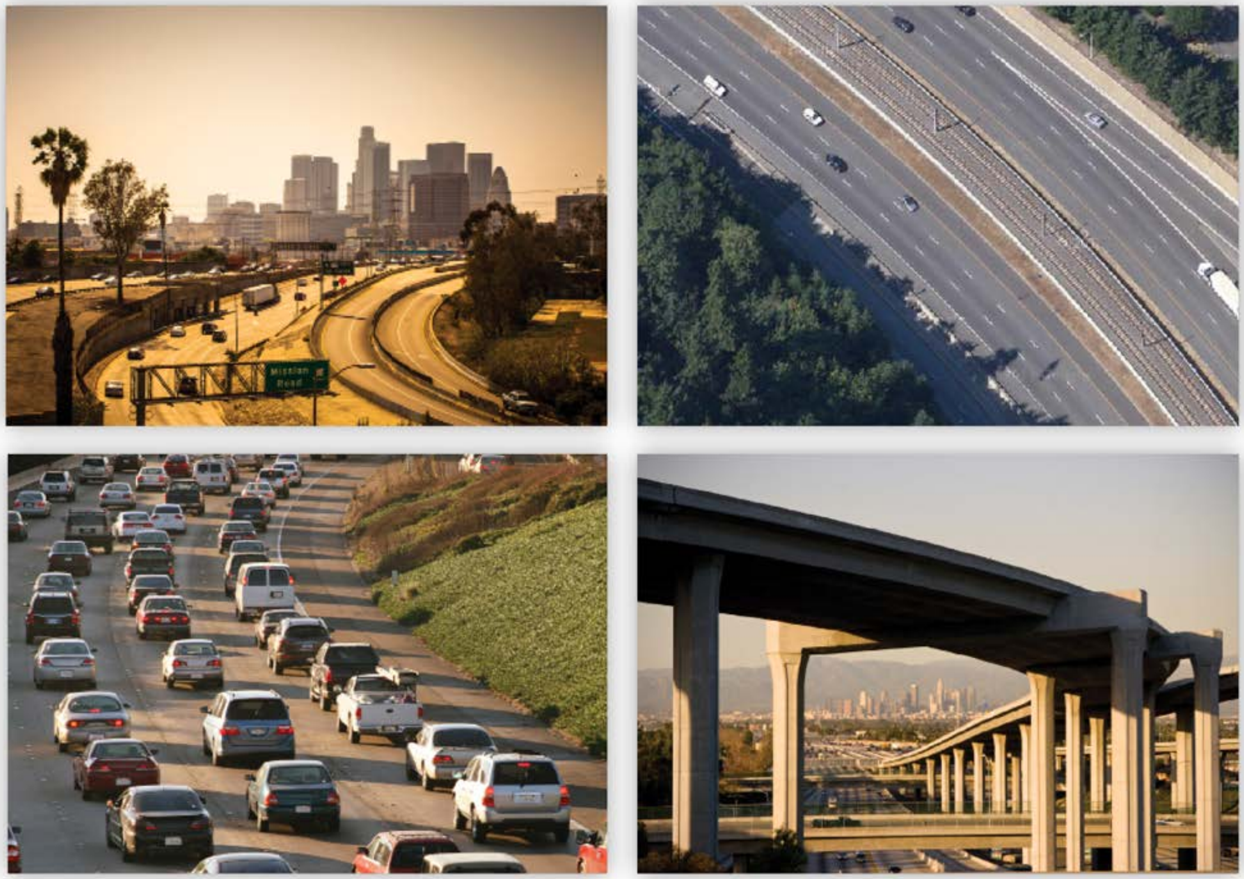
Scoping Study to Identify Potential Project Types and Situations That Will Not Create PM Hot Spots



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Prepared by

Stephen B. Reid, QEP
Song Bai, PhD, PE
Douglas S. Eisinger, PhD
Garnet B. Erdakos, PhD
Yuan Du
Lynn Baringer

Sonoma Technology, Inc.
1455 N. McDowell Blvd., Suite D
Petaluma, CA 94954-6503
Ph 707.665.9900 | F 707.665.9800
sonomatech.com

Prepared for

Karin Landsberg

WSDOT
310 Maple Park Ave. SE
Olympia, WA 98501
Ph 360.705.7491
wsdot.wa.gov

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Abstract

The work presented here was completed as part of the Near-Road Air Quality Research Pooled Fund, TPF-5(284), under the U.S. Federal Highway Administration (FHWA) Transportation Pooled Fund Program. The lead agency for TPF-5(284) is the Washington State Department of Transportation. Other participants include FHWA and the Arizona, California, Texas, and Virginia Departments of Transportation. Sonoma Technology, Inc. (STI) provides TPF-5(284) participants with technical, planning, facilitation, and website support.

Scoping Study to Identify Potential Project Types and Situations That Will Not Create PM Hot Spots

Background: In PM_{10} and $PM_{2.5}$ nonattainment and maintenance areas, quantitative particulate matter (PM) hot-spot analyses are required to assess near-road air quality impacts of transportation projects that are identified as "projects of local air quality concern (POAQC)." In its 2006 rulemaking on quantitative PM hot-spot analyses, the U.S. Environmental Protection Agency (EPA) identified examples of projects that would likely be POAQCs, including a new highway project with annual average daily traffic (AADT) greater than 125,000 and at least 8% diesel truck traffic. The objective of this study was to identify sample project types and project characteristics that, when combined in a project, can reasonably exclude the project from consideration as a POAQC and, therefore, relieve it from the necessity of completing the extensive travel activity, emissions, and air quality modeling analysis work associated with a quantitative PM hot-spot analysis.

Methods: The project team performed scenario analyses for a hypothetical transportation project that featured a freeway with high-occupancy vehicle (HOV) lanes being added in each direction and baseline traffic activity of 125,000 AADT and 8% diesel truck traffic. The MOVES and EMFAC mobile source emissions models were used to quantify PM_{10} and $PM_{2.5}$ emissions associated with a 2006 analysis year for the hypothetical project, and to evaluate the impact of fleet turnover and truck percentages on project-level emissions by evaluating various analysis years from 2006 to 2035.

Results: For projects in $PM_{2.5}$ nonattainment areas, fleet turnover effects sharply reduce project-level emissions over time. For example, for an analysis year of 2015, impacts from a highway project with 125,000 AADT and 8% trucks are approximately 50% less than impacts from such a project in 2006. However, for projects in PM_{10} nonattainment areas, fleet turnover effects do not provide significant emissions reductions, as re-entrained road dust emissions and tire wear and brake wear emissions increasingly dominate project-level inventories over time, and these emissions vary little by analysis year. In addition, modeling results showed, for a given vehicle fleet, a linear relationship exists between traffic activity and PM emissions. This linear relationship, combined with the various scenarios analyzed for this study, may allow project analysts to quickly estimate PM impacts associated with their project and compare those impacts with the 2006 EPA sample highway project.

1. Introduction

In March 2006, U.S. Environmental Protection Agency (EPA) issued a final rule on *$PM_{2.5}$ and PM_{10} Hot-Spot Analysis in Project-Level Transportation Determinations for the New $PM_{2.5}$ and Existing PM_{10} National Ambient Air Quality Standards* (NAAQS; PM hot-spot rule) (U.S. Environmental Protection Agency, 2006). With the final PM hot-spot rule, the EPA and the Federal Highway Administration (FHWA) also jointly released *Transportation Conformity Guidance for Qualitative Hot-spot Analyses in $PM_{2.5}$ and PM_{10} Nonattainment Areas*, which served as interim guidance until appropriate methods could be developed for quantitative assessments (U.S. Environmental Protection Agency and Federal Highway Administration, 2006). In 2010, the EPA issued *Transportation Conformity Guidance for Quantitative Hot-Spot Analyses in $PM_{2.5}$ and PM_{10} Nonattainment and Maintenance Areas* (PM quantitative hot-spot analysis guidance) (U.S. Environmental Protection Agency, 2010).

The 2006 PM hot-spot rule, supported by the 2010 guidance, requires quantitative particulate matter (PM) hot-spot analyses to assess near-road air quality impacts of selected transportation projects in PM_{10} and $PM_{2.5}$ nonattainment and maintenance areas. The goal of these quantitative hot-spot analyses is to demonstrate that a transportation project meets Clean Air Act (CAA) transportation conformity requirements established by the EPA. These requirements ensure that federally supported transportation projects will meet state and local goals with respect to attaining relevant NAAQS. Quantitative PM hot-spot analyses are required for "projects of local air quality concern (POAQC);" POAQCs typically include projects with substantial diesel truck or bus activity.

The EPA's March 2006 final rule (see 40 CFR 93.123(b)(1)) lists types of projects that are of air quality concern and states that the interagency consultation process among departments of transportation (DOTs), EPA, and state and local agencies should be used to identify projects needing PM hot-spot analyses (U.S. Environmental Protection Agency, 2006). Determining whether a project is a POAQC and, where needed, conducting a PM hot-spot analysis requires a significant amount of work: gathering diesel and gasoline vehicle travel data, estimating emissions via the MOVES model (or the EMFAC model in California), acquiring and processing meteorological and background PM data, running a dispersion model such as AERMOD, and processing model output.

The study findings described here can help inform the interagency consultation process to identify project types and characteristics that, when combined in a project, can reasonably exclude the project from consideration as a POAQC. The information provided here is meant to help state DOTs and their partner agencies determine if a particular project can be reasonably excluded from being a POAQC and therefore not subject to the extensive travel activity, emissions, and air quality modeling analysis work associated with a quantitative PM hot-spot analysis. The work presented in this report uses a POAQC illustration described in EPA's final PM hot-spot analysis rule as the basis for scenario analyses. As described by the EPA in its 2006 rulemaking, a new highway with annual average daily traffic (AADT) greater than 125,000 vehicles and at least 8% diesel truck traffic (i.e., 10,000 trucks per day) would likely be a POAQC. The analyses described in this report focus on freeway-based case studies that illustrate the emissions impacts of such a sample project and how those impacts change as parameters such as traffic volumes, diesel traffic, and analysis year vary.

These analyses provide answers to questions such as:

- Given the 2006 rulemaking year, what PM_{10} and $PM_{2.5}$ emission levels might be expected of a 2006 project with AADT of 125,000 and at least 8% diesel truck traffic?
- How would a 2030 project with AADT of 125,000 and 8% trucks compare to the 2006 project in terms of PM emission levels?
- What is the influence of diesel truck percentage on project-level PM emissions, and how might fleet turnover effects offset those impacts?
- What is the contribution of non-exhaust emissions processes (e.g., re-entrained dust, tire wear, brake wear) to project-level emissions, and how do those contributions vary for different analysis years?

The evaluation approaches used in this work also illustrate best practices to complete project assessments. The study findings, which are research-oriented, are intended to inform interagency transportation conformity consultation regarding POAQC determinations and should not be regarded as establishing new POAQC criteria.

As such, when reviewing the findings presented here, readers are encouraged to focus on the relative, rather than the absolute, changes that are shown regarding PM emissions. Transportation projects are unique, and modeled emissions can vary substantially from one project to another, even with similar overall traffic volumes. The illustrations presented here shed light on the relative changes that occur when modeling constant traffic conditions across analysis years, or when modifying fleet mix to vary truck fractions. These relative changes can be benchmarked against a 2006 baseline that corresponds to the conditions EPA identified as meriting a POAQC determination.

Section 2 of this report provides background information on key issues related to POAQC determinations. Section 3 describes the results of analyses evaluating the relationship between diesel truck activity levels and PM emissions, which are also summarized in a lookup table in Appendix A. Section 4 presents conclusions and recommendations.

2. Background

This section provides background material on EPA guidance related to POAQCs and a summary of analysis steps required for PM hot-spot analyses.

2.1 Requirements that Describe POAQCs

The March 2006 PM hot-spot rule (U.S. Environmental Protection Agency, 2006) requires a quantitative PM hot-spot analysis as part of project-level conformity determinations for POAQCs (40 CFR 93.123(b)(1)), including[1]

- New or expanded highway projects that have a significant number of or significant increase in diesel vehicles;
- Projects affecting intersections that are at Level-of-Service D, E, or F with a significant number of diesel vehicles, or those that will change to Level-of-Service D, E, or F because of increased traffic volumes from a significant number of diesel vehicles related to the project;
- New bus and rail terminals and transfer points that have a significant number of diesel vehicles congregating at a single location;
- Expanded bus and rail terminals and transfer points that significantly increase the number of diesel vehicles congregating at a single location; and
- Projects in or affecting locations, areas, or categories of sites that are identified in the PM_{10} or $PM_{2.5}$ applicable implementation plan or implementation plan submission, as appropriate, as sites of violation or possible violation.

In the preamble to this rulemaking, EPA provided some examples to illustrate potential POAQCs:

- A project on a new highway or expressway that serves a significant volume of diesel truck traffic, such as facilities with AADT greater than 125,000, where 8% or more of such AADT is diesel truck traffic
- New exit ramps and other highway facility improvements to connect a highway or expressway to a major freight, bus, or intermodal terminal
- 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 diesel trucks

[1] The interagency consultation process is an important part of determining whether or not a specific project is considered a POAQC.

2.2 Analysis Steps for POAQCs

The EPA's PM quantitative hot-spot analysis guidance outlines the technical requirements for completing these project-level assessments. Specifically, the EPA's guidance describes the following nine analysis steps:

1. **Determine the need for a PM hot-spot analysis** – This step involves identifying whether the project of interest is a POAQC, which would trigger the need for a hot-spot analysis. This determination must be made according to transportation conformity regulation requirements, including interagency consultation. The main purpose of this study is to offer insights that help with making POAQC determinations.
2. **Determine the approach, models, and data to be used** – This step determines general analysis scales and approaches, such as the relevant PM NAAQS, the project area to be analyzed, emissions and dispersion models to be used, project-specific data sources, and the schedule for conducting the analysis and for points of consultation.
3. **Estimate on-road motor vehicle emissions** – This step focuses on emissions modeling, which includes preparing project-level traffic data and using the EPA's MOVES model or the California Air Resources Board's (CARB) EMFAC model to estimate exhaust, tire wear, and brake wear emissions from on-road vehicles.
4. **Estimate emissions from road dust, construction, and additional sources** – This step involves estimating emissions from other emissions sources, such as re-entrained road dust, when applicable. Typically, road dust is of concern for PM_{10} impacts rather than $PM_{2.5}$ impacts.
5. **Select an air quality model, data inputs, and receptors** – This step involves using detailed meteorological data and an air dispersion model (e.g., AERMOD) to estimate PM concentrations in the project area.
6. **Determine background concentrations from nearby and other sources** – This step requires identifying one or more representative air quality monitors in the project area that will be used to determine background concentrations.
7. **Calculate design values and determine conformity** – This step involves combining background concentrations and modeled concentrations to estimate a design value for the project. This design value is then compared to the appropriate NAAQS to determine whether a project conforms.
8. **Consider mitigation or control measures** – This step involves identifying and analyzing mitigation or control measures, as needed, to reduce PM emissions.
9. **Document the PM hot-spot analysis** – The final step involves documenting the analysis in sufficient detail to support the conclusion that the project meets conformity requirements.

Taken together, these steps involve data collection efforts and complex modeling tasks that could require several months of calendar time. Moreover, the proposed project and its build alternatives may by revised during the analysis process, requiring additional data collection and modeling work.

Therefore, project analysts require information that can help identify projects that are not likely to be POAQCs, and therefore, are not subject to the analysis requirements listed in Steps 2–9 above.

To help provide such information, the project team performed scenario analyses for a hypothetical transportation project, which was based on a sample project developed by the EPA for its PM hot-spot training class. This hypothetical project features a freeway with high-occupancy vehicle (HOV) lanes being added in each direction; traffic activity data developed by the EPA was adjusted to match the POAQC example of 125,000 AADT and 8% diesel truck traffic.[2] From this starting point, the project team:

- Used the MOVES and EMFAC models to quantify the mobile source PM_{10} and $PM_{2.5}$ emissions associated with a 2006 analysis year for the hypothetical project.
- Used methods from the EPA's AP-42 emission factors handbook to estimate PM_{10} and $PM_{2.5}$ emissions from re-entrained road dust.
- Performed additional emissions modeling with MOVES, EMFAC, and AP-42 methods for analysis years ranging from 2007 to 2035, and for a range of truck percentages.
- Compared scenario-specific emissions results with the 2006 baseline results to evaluate the impact of fleet turnover and truck percentages (e.g., What diesel truck activity in 2020 is required to produce the same PM emissions as a 10,000-truck-per-day activity level in 2006?).

[2] Additional details on the hypothetical transportation project are provided in Appendix B.

3. Diesel Traffic and PM Emissions

3.1 EPA-Based Scenario for "Significant" Diesel Traffic

For a hypothetical freeway project with 125,000 AADT and 10,000 diesel trucks (8% of the AADT), we estimated mobile source PM_{10} and $PM_{2.5}$ emissions for 2006 and later analysis years (2010 through 2035) using the MOVES2014 and EMFAC2014 emissions models. The 2006 analysis serves as a baseline comparison point for all other analysis scenarios; the project's traffic activity corresponds to what the EPA identified as a POAQC in its 2006 PM hot-spot rule. For this project-level assessment, both models were used to generate emission rates (e.g., grams of $PM_{2.5}$ per mile) for exhaust, tire wear, and brake wear processes. These emission rates were then combined with project-level activity data to estimate emissions. In addition, re-entrained dust emissions were calculated using a CARB method for paved-road dust emissions that is based on Chapter 13.2.1 of the EPA's AP-42 emission factors handbook (California Air Resources Board, 1997). The AP-42 road dust emissions equation requires several inputs, including the roadway silt loading, the average weight of vehicles accessing the road, and precipitation data. Values for average vehicle weight were derived from the fleet information in MOVES and EMFAC, so road dust emissions vary slightly between the models. Additional details on all emissions estimation methods are provided in **Appendix B**.

3.1.1 Results for 2006 Baseline: 125,000 AADT, 8% Trucks

For PM_{10}, total 2006 MOVES- and EMFAC-based emissions estimates for the hypothetical project were nearly identical, totaling 20.0 and 19.1 kg/day, respectively. For both sets of emissions, tire wear and re-entrained road dust emissions are about equal, with approximately half of the total PM_{10} emissions being associated with road dust, as shown in **Figure 1**. However, MOVES exhaust emissions estimates for 2006 are about 70% higher than the EMFAC-based estimates,[3] while EMFAC brake wear estimates are 2.5 times higher than the MOVES-based estimates.[4]

[3] For exhaust emissions, MOVES inputs may not reflect diesel truck fleets and emission control programs in California as accurately as EMFAC.

[4] For brake wear emissions, both MOVES and EMFAC rely on two published studies (Garg et al., 2000; Sanders et al., 2003) that measured brake wear emissions from light-duty vehicles under various conditions, such as driving cycles, brake types, and brake pad materials. MOVES specifies brake wear emissions by operating bin, such that emission rates vary by vehicle speed. EMFAC relies on per-mile emission rates for brake wear that vary by vehicle type and depend on assumed braking attributes such as brake applications per mile of travel. Additional information on brake wear and tire wear emissions can be found in Appendix B.

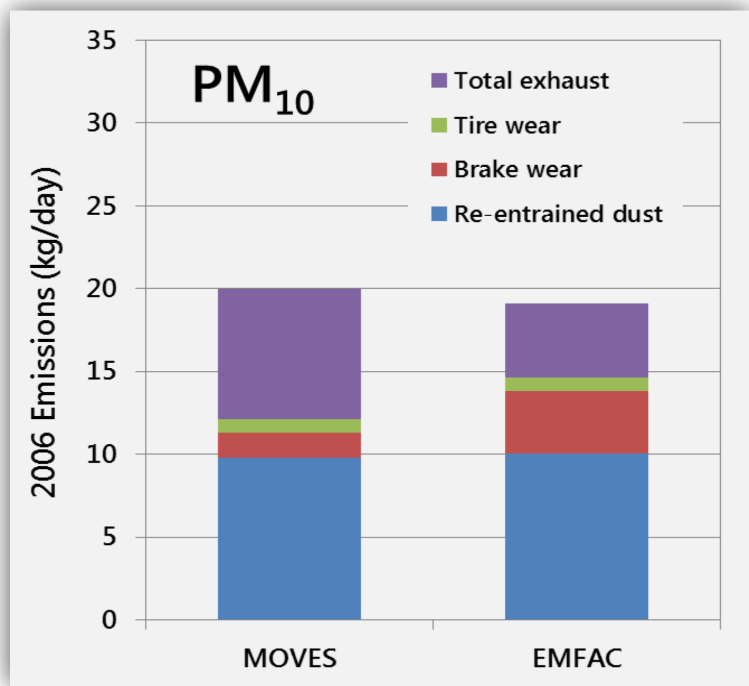

Figure 1. Baseline PM_{10} emissions for a hypothetical 2006 freeway project with an AADT of 125,000 vehicles, 8% of which are diesel trucks.

For $PM_{2.5}$, total MOVES- and EMFAC-based emissions (including re-entrained road dust) for the 2006 hypothetical project are 8.9 and 7.6 kg/day, respectively. Because MOVES and EMFAC do not calculate re-entrained road dust emissions directly, the AP-42 method referenced above was used to calculate emissions from this process, which were then added to MOVES and EMFAC emissions estimates for exhaust, tire wear, and brake wear (see the left-hand chart in Figure 2). Road dust emissions would typically not be considered for a $PM_{2.5}$ hot-spot analysis unless road dust represented a significant $PM_{2.5}$ source in the project region. MOVES- and EMFAC-based $PM_{2.5}$ emissions without road dust total 7.5 and 6.1 kg/day, respectively, as shown in the right-hand chart in Figure 2. For subsequent analyses shown in this report, $PM_{2.5}$ emissions will include only exhaust, brake wear, and tire wear components.

For $PM_{2.5}$, MOVES again produces higher exhaust emissions than EMFAC, while EMFAC produces higher brake wear emissions. In fact, for $PM_{2.5}$, the EMFAC-based brake wear emissions estimate is eight times higher than the MOVES-based estimate, which reflects different assumptions in the two models for the $PM_{10}/PM_{2.5}$ ratio for brake wear. In MOVES, a $PM_{10}/PM_{2.5}$ ratio of 8 is assumed, while EMFAC uses a $PM_{10}/PM_{2.5}$ ratio of 2.3.

Figure 2. Baseline $PM_{2.5}$ emissions for a hypothetical 2006 freeway project with an AADT of 125,000 vehicles, 8% of which are diesel trucks. The chart on the left includes re-entrained road dust emissions, which were calculated using a method from AP-42.

The re-entrained road dust emission levels shown in Figures 1 and 2 can vary by region, even if projects have similar traffic activity, because silt loading values are region-specific.[5] However, these 2006 emission levels provide a useful baseline illustration for understanding impacts associated with the EPA's sample highway project with 125,000 AADT and 10,000 diesel trucks, as well as evaluating traffic activity levels required to produce similar project-level emissions in other years.

3.1.2 Results for 2010 Through 2035: Activity Needed to Reproduce 2006 Baseline Emissions

Beyond 2006, vehicle exhaust emissions decrease significantly as a result of federal and California emissions standards. Therefore, to produce the baseline emission levels for 2006 shown in Figures 1 and 2 would require higher traffic volumes in later years. To examine this effect, we held the truck percentage constant at 8% and calculated the overall AADT required to produce emission totals in later years that are equivalent to the 2006 baseline levels.[6]

Figure 3 shows that, by 2020, producing project-level PM_{10} emissions equivalent to those from the 2006 analysis year would require traffic volumes of 180,000 vehicles for MOVES-based analyses and

[5] Appendix B includes a comparison of the silt loading value used in this study with the AP-42 default value.

[6] Note that we also kept vehicle speeds constant for this illustrative analysis, although higher traffic volumes would eventually increase congestion and reduce vehicle speeds.

167,000 vehicles for EMFAC-based analyses. By 2035, traffic volumes of 200,000 for MOVES-based analyses and 175,000 for EMFAC-based analyses would be required to match 2006 emission levels, increases of 60% and 40%, respectively.

For $PM_{2.5}$ emissions, which are dominated by exhaust emissions and, therefore, impacted to a greater extent by fleet turnover, the changes in traffic volumes are even more dramatic. By 2020, MOVES-based $PM_{2.5}$ estimates would require an AADT of 500,000 vehicles to reach 2006 emission levels, while EMFAC-based $PM_{2.5}$ estimates would require an AADT of 360,000 to reach 2006 emission levels (also shown in Figure 3).[7] By 2035, reaching 2006 emission levels requires an AADT of 1.6 million vehicles for MOVES-based analyses; this number is almost 13 times higher than the baseline volume of 125,000 vehicles. For EMFAC-based $PM_{2.5}$ estimates, a 2035 AADT of approximately 420,000 vehicles would be required to reach 2006 emission levels; this number is more than three times higher than the baseline volume. The differences in MOVES- and EMFAC-based traffic volumes are primarily driven by the higher brake wear emissions estimated by EMFAC, as brake wear emissions are not impacted by fleet turnover and change little by analysis year.

[7] This analysis illustrates traffic volumes required to produce emissions equivalent to the 2006 baseline scenario, holding travel speeds constant. Actual project analyses would adjust traffic speeds to appropriately reflect roadway capacity and traffic volume changes specific to the project's characteristics.

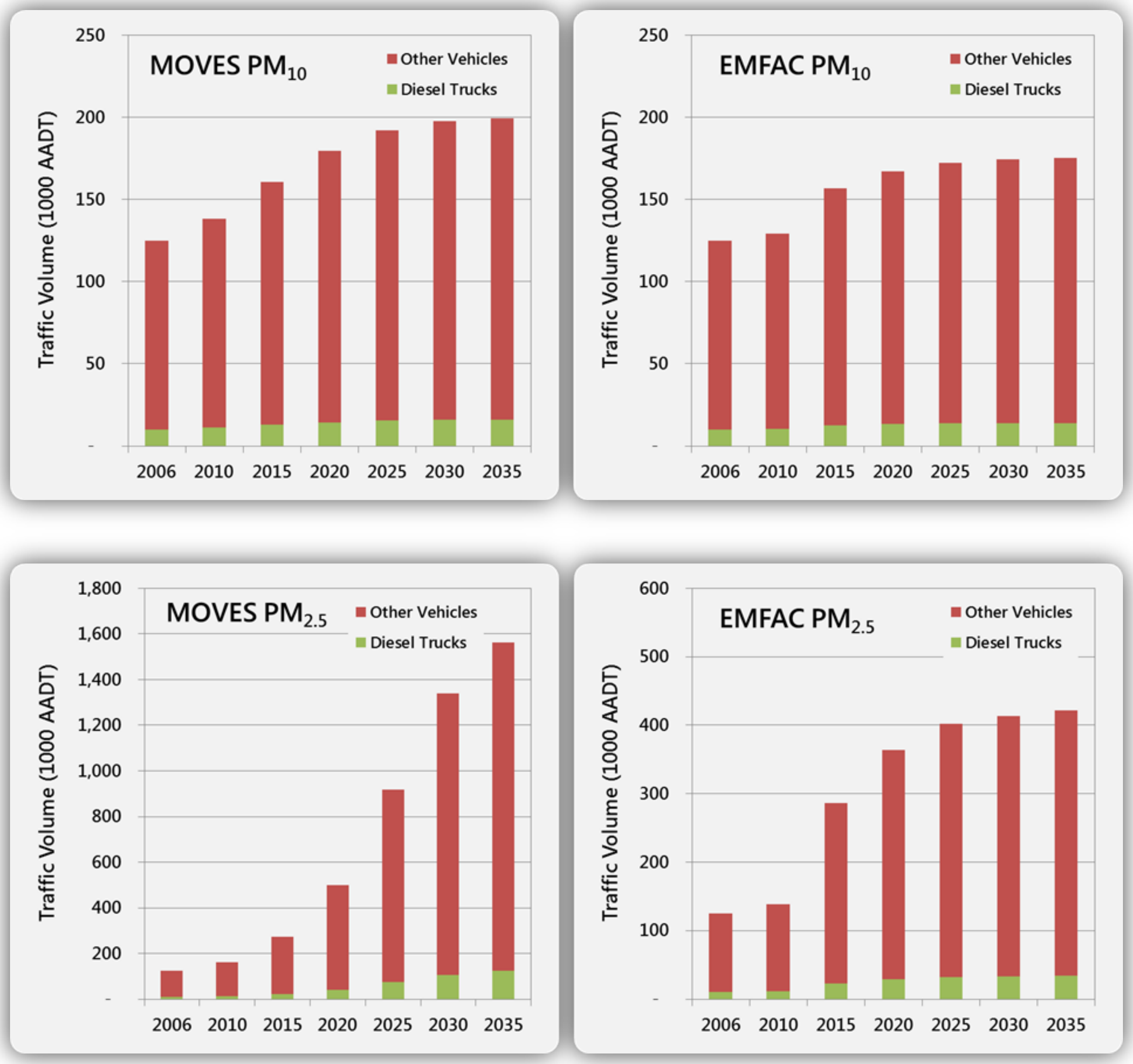

Figure 3. Projected (2010–2035) traffic volumes needed to produce 2006-equivalent emissions. (Scales are different for MOVES- and EMFAC-estimated $PM_{2.5}$ emissions.)

3.2 Additional Emissions Scenarios

To identify project types and characteristics that can be reasonably excluded from consideration as POAQCs, we developed additional project scenarios and estimated their emissions for comparison with the baseline values previously shown in Figures 1 and 2. The scenarios, summarized in Table 1, account for impacts of fleet turnover, as well as changes in total traffic volumes and diesel truck volumes. We used MOVES and EMFAC to estimate PM emissions and summarized the results here. In addition, Appendix A provides a lookup table of emissions associated with all the scenarios evaluated.

Table 1. Summary of emissions modeling scenarios.

Scenarios	Description
Fleet turnover	125,000 AADT with 8% trucks in 2006, 2010, 2015, 2020, 2025, 2030, 2035
Increased AADT	20, 40, 60, 80, 100% increases in the overall AADT of 125,000 vehicles in 2006, 2010, 2015, 2020, 2025, 2030, 2035 (8% trucks for each scenario)
Increased truck volume	125,000 AADT with 20 and 40% trucks in 2006, 2015, 2025, 2035

3.2.1 Fleet Turnover Scenarios

To further examine the impacts of fleet turnover, we estimated PM_{10} and $PM_{2.5}$ emissions for several analysis years from 2010 to 2035; to do so, we used the EPA significance levels of 125,000 AADT and 8% diesel trucks. For PM_{10}, MOVES-based emissions estimates for the hypothetical project decrease from 20.0 kg/day in 2006 to 12.5 kg/day in 2035, a reduction of about 37%. Similarly, EMFAC-based PM_{10} estimates decrease from 19.1 kg/day to 13.6 kg/day, a reduction of about 29%. **Figure 4** shows that PM_{10} emissions reductions are associated with the exhaust portion of the emissions inventory, with emissions for tire wear, brake wear, and re-entrained road dust remaining nearly constant across all analysis years. For both the MOVES and EMFAC models, tire wear and brake wear emission rates change little over time, so the emissions from these processes do not decrease with fleet turnover, as is the case with exhaust emissions. Tire wear and brake wear emissions are discussed further in Appendix B.

As a result of these trends, the contribution of the non-exhaust processes increases sharply over time, rising from 61% in 2006 to 97% in 2035 for MOVES-based estimates. Notably, the contribution of re-entrained road dust alone rises from 49% in 2006 to 79% in 2035. For EMFAC-based estimates, a sharp decrease in exhaust emissions occurs between 2010 and 2015 due to the impact of California diesel regulations. After 2015, further fleet turnover benefits are minimal, and project-level emissions remain nearly constant. For the MOVES-based estimates, decreases in exhaust emissions are more gradual over time; however, project-level PM_{10} emissions change little beyond 2020. These findings suggest that, for PM_{10}, fleet turnover benefits are largely limited to near-term years, and project-level emissions are increasingly dominated by non-exhaust processes (especially re-entrained road dust) over time.

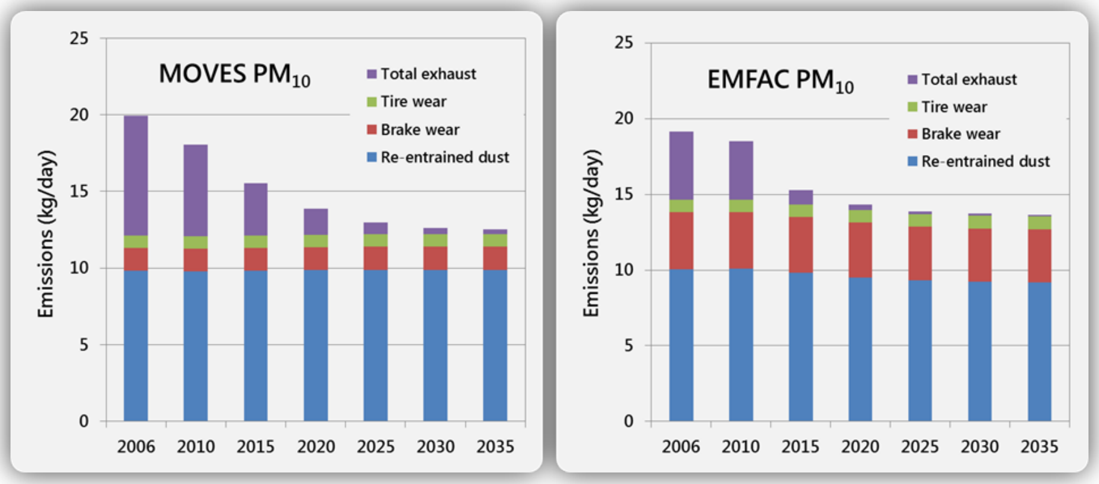

Figure 4. PM_{10} emissions for the hypothetical project for selected analysis years.

For $PM_{2.5}$, re-entrained road dust is typically not considered, and project-level emissions are more influenced by exhaust emissions than is the case with PM_{10}. MOVES-based $PM_{2.5}$ emissions estimates for the hypothetical project are cut approximately in half between 2006 and 2015 and are reduced by 92% between 2006 and 2035 (decreasing from 7.5 kg/day to 0.6 kg/day). EMFAC-based $PM_{2.5}$ estimates are also cut approximately in half between 2006 and 2015 and are reduced by about 70% between 2006 and 2035 (decreasing from 6.1 kg/day to 1.8 kg/day). Figure 5 shows that EMFAC-based brake wear $PM_{2.5}$ emission estimates are consistently about 8 times higher than MOVES-based estimates, limiting the overall reduction in project-level emissions. In addition, the contribution of brake wear and tire wear to the overall EMFAC-based $PM_{2.5}$ inventory rises from 30% in 2006 to 95% in 2035. For MOVES, the increase in the contribution of these processes to the overall inventory is less pronounced but also significant, rising from 4% in 2006 to 52% in 2035.

As was the case for PM_{10}, EMFAC-based exhaust $PM_{2.5}$ emissions decrease sharply between 2010 and 2015, resulting in project-level emissions that remain nearly constant after 2015. For the MOVES-based estimates, decreases in exhaust emissions are more gradual over time, and significant fleet turnover benefits are observed in 2020 and 2025. These findings suggest that, for projects outside California, fleet turnover results in sharp $PM_{2.5}$ reductions over time for the hypothetical project with 125,000 AADT and 8% trucks. However, these fleet turnover benefits are somewhat limited for California projects due to the high brake wear emissions estimates produced by EMFAC and the modest decreases in exhaust emissions that occur after 2015.

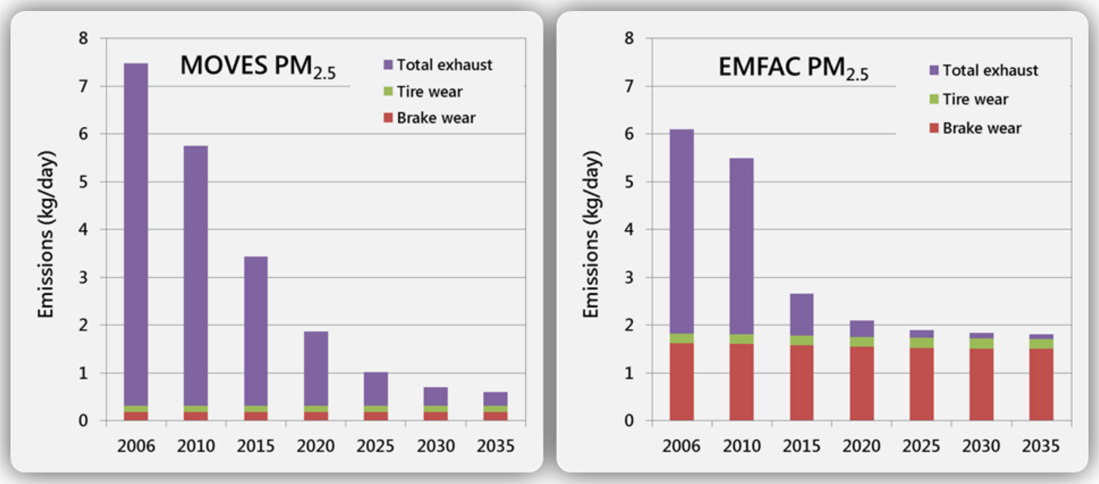

Figure 5. $PM_{2.5}$ emissions for the hypothetical project for selected analysis years.

Another important finding related to these PM_{10} and $PM_{2.5}$ emissions results is that the most uncertain aspects of the emissions inventories are becoming more important over time. Although exhaust emissions have been researched extensively over time through engine-testing programs, relatively little research has focused on PM emissions from re-entrained road dust, tire wear, and brake wear. The large differences in emissions estimates for brake wear between the MOVES and EMFAC models highlight the uncertainty associated with these estimates.

3.2.2 Increased AADT Scenarios, Constant Truck Percent

The next set of scenarios modeled increases in overall AADT while holding the truck percentage constant at 8%. For analysis years from 2006 to 2035, we evaluated emissions for overall traffic volumes ranging from 125,000 to 250,000 AADT, with truck volumes ranging from 10,000 (8% of 125,000) to 20,000 (8% of 250,000). For each scenario evaluated, PM_{10} emissions calculations include re-entrained road dust emissions, while $PM_{2.5}$ emissions did not include road dust. For a given fleet mix and analysis year, and constant travel speeds, a linear relationship exists between traffic volumes and emissions, as illustrated in Figure 6. For example, modeling the 2006 sample project with MOVES using an AADT of 150,000 vehicles (a 20% increase over the 125,000 baseline) results in a PM_{10} emissions estimate of 24 kg/day, which is a 20% increase over the baseline value of 20 kg/day.

Figure 6 also shows a substantial decrease in emissions across all traffic volumes for years beyond 2006, though the changes become minimal from 2025 to 2035. In addition, Figure 6 shows that, for both MOVES and EMFAC, a traffic volume of 250,000 AADT in 2015 produces $PM_{2.5}$ emissions that are lower than the $PM_{2.5}$ emissions produced by a volume of 125,000 AADT in 2006. This further illustrates the fleet turnover benefit of $PM_{2.5}$ estimates, as was previously seen in Figures 3 and 5. However, for PM_{10} (where re-entrained road dust is a key emissions source), doubling traffic volumes produces emissions estimates that are higher than the 2006 baseline across all analysis years.

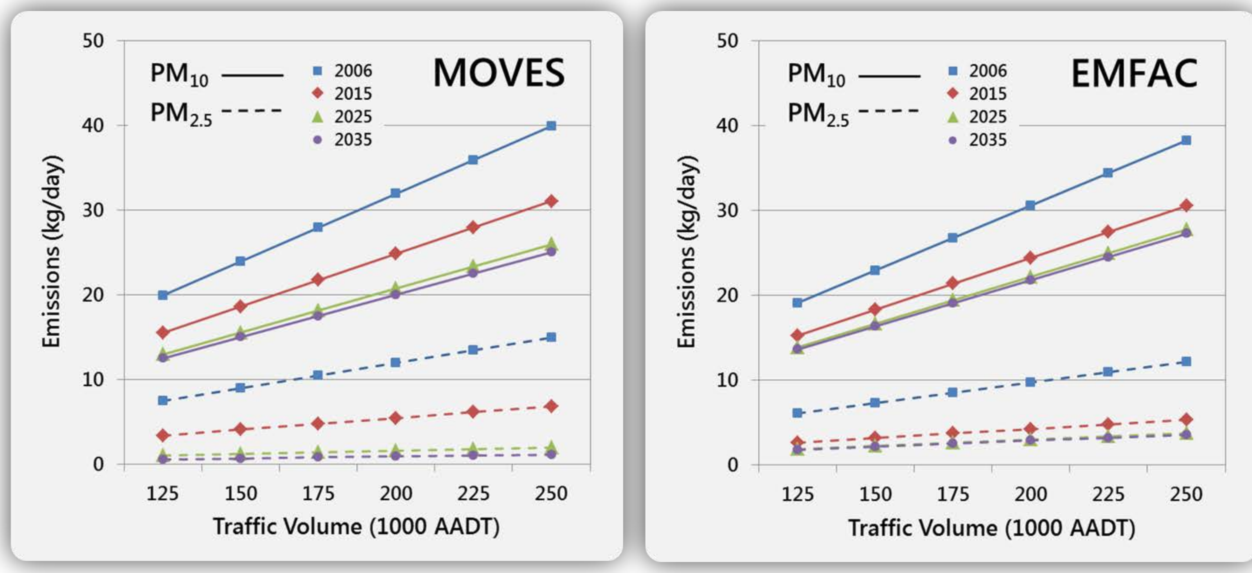

Figure 6. PM emissions estimates by AADT and analysis year for MOVES and EMFAC. PM_{10} emissions include re-entrained road dust, while $PM_{2.5}$ emissions do not.

3.2.3 Increased Truck Volumes

The final set of scenarios modeled increases in truck percentage for the baseline traffic volume of 125,000 vehicles. For selected analysis years (2006, 2015, 2025, 2035), we evaluated emissions for truck percentages of 8%, 20%, and 40%. For PM_{10}, MOVES- and EMFAC-based results are shown in Figures 7 and 8, respectively. Because increased truck volumes have a significant impact on both exhaust and re-entrained road dust emissions,[8] the overall PM_{10} emissions inventories increase sharply as the truck percentage increases. For example, increasing the truck percentage from 8% to 40% increases MOVES-based PM_{10} emissions by a factor of approximately 3 across all analysis years, as shown in Figure 7. Also, for both MOVES and EMFAC, modeling a truck percentage of even 20% results in total PM_{10} emissions across all analysis years that are higher than the 2006 baseline of 20 kg/day (based on 8% trucks in 2006).

[8] Re-entrained road dust emissions are a function of average vehicle weight, which increases as the truck percentage increases.

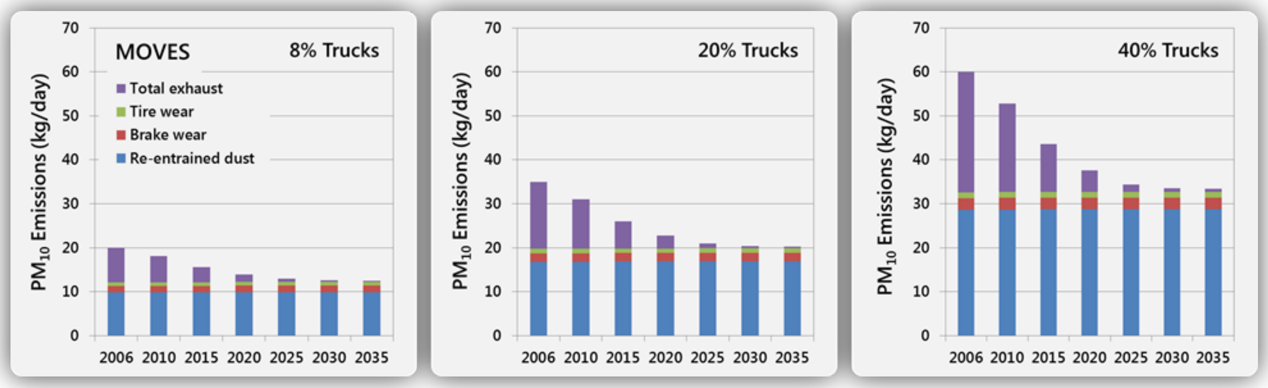

Figure 7. MOVES-estimated PM_{10} emissions changes associated with increased truck volume for selected years.

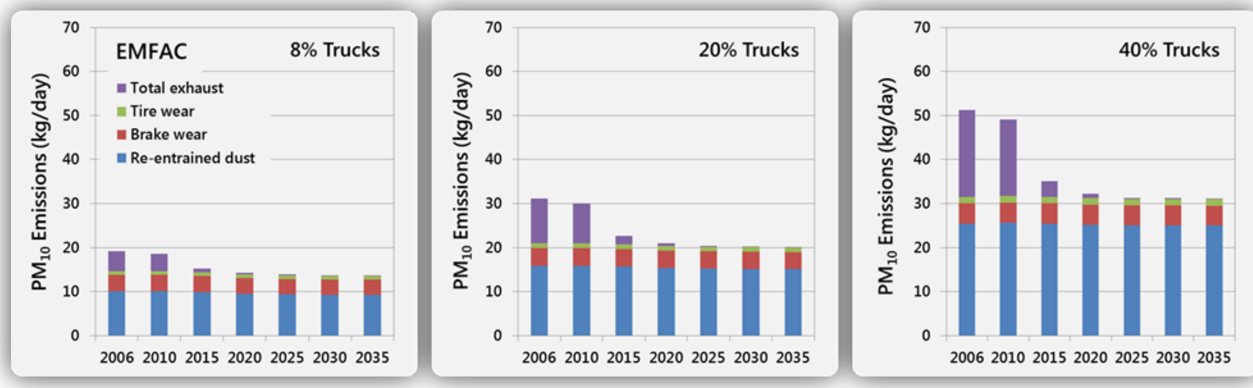

Figure 8. EMFAC-estimated PM_{10} emissions changes associated with increased truck volume for selected years.

For $PM_{2.5}$, in contrast, the absence of re-entrained road dust emissions and the considerable decrease in exhaust emissions over time offsets the impact of increased truck traffic volumes. For example, in 2015, total MOVES-based $PM_{2.5}$ emissions for the 20% truck scenario are less than the 2006 baseline $PM_{2.5}$ emissions with 8% trucks. For the 40% truck scenario, by 2020, total MOVES-based $PM_{2.5}$ emissions are less than the 2006 baseline emissions (see the red ovals in Figure 9). Similarly, for the EMFAC-based $PM_{2.5}$ results, by 2015, emissions for both the 20% and 40% truck scenarios are less than the 2006 baseline. These findings indicate that a current-year (2015) California transportation project with 125,000 AADT and 40% trucks has lower PM impacts than EPA's sample 2006 POAQC with 125,000 AADT and 8% trucks (see the red ovals in Figure 10).

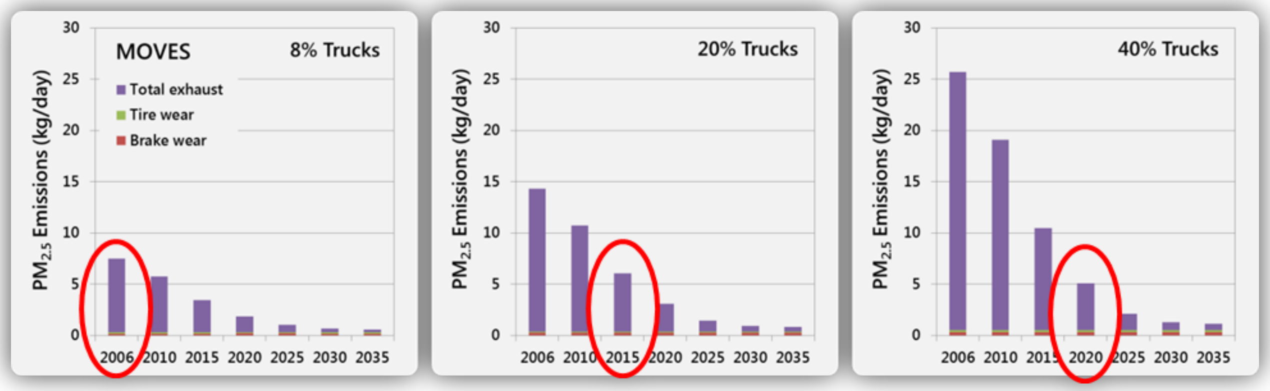

Figure 9. MOVES-estimated $PM_{2.5}$ emissions changes associated with increased truck volume for selected years. Red ovals highlight comparisons between the 2006 baseline and future years.

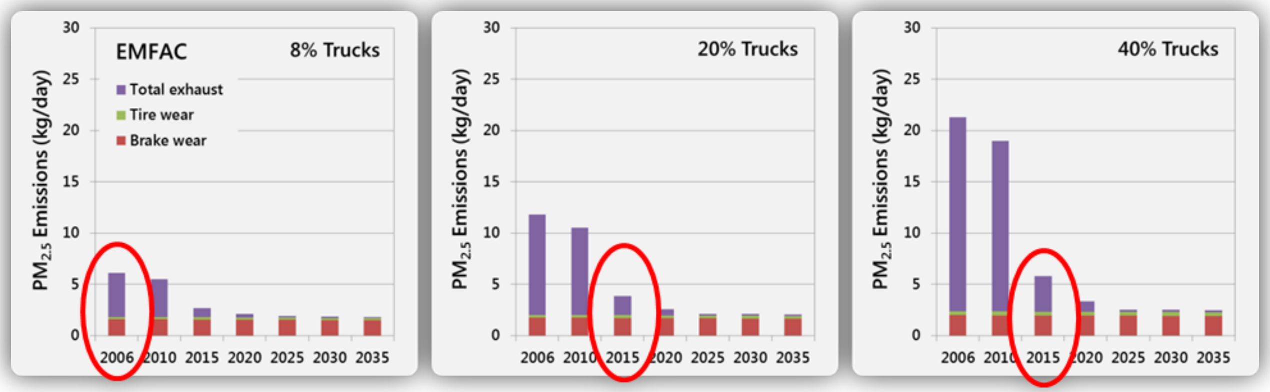

Figure 10. EMFAC-estimated $PM_{2.5}$ emissions changes associated with increased truck volume for selected years. Red ovals highlight comparisons between the 2006 baseline and future years.

4. Conclusions and Recommendations

4.1 Summary of Results

This study involved emissions modeling analyses designed to evaluate the relationship between transportation project characteristics (e.g., traffic volumes, truck percentages, and design year) and PM emissions. The results of these analyses provide information that can be used in the interagency consultation process to start to identify project types and project characteristics that, when combined in a project, can reasonably exclude the project from consideration as a POAQC.

The starting point for these analyses was a POAQC sample project described in the final PM hot-spot rule issued by the EPA in March 2006. The sample projects included in the preamble of this rule involve a new highway project that serves a significant volume of diesel traffic; specifically, a facility with AADT of 125,000 and at least 8% diesel truck traffic. The project team assessed PM emissions associated with this type of project, as well as changes in emissions across various analysis years and project activity scenarios. Key analysis findings are as follows:

- For $PM_{2.5}$, both the MOVES and EMFAC models predict that impacts from a hypothetical highway project with 125,000 AADT and 8% trucks are cut in half between 2006 and 2015.
- Both the MOVES and EMFAC models predict that, by 2020, $PM_{2.5}$ impacts from a highway project with 125,000 AADT and 40% trucks (i.e., 50,000 trucks) are less than impacts from a 2006 project with 125,000 AADT and 8% trucks (i.e., 10,000 trucks). These results imply that a five-fold increase in truck traffic is offset by fleet turnover benefits during that time span.
- For a constant truck percentage of 8%, an overall AADT of approximately 360,000 (EMFAC) to 500,000 (MOVES) vehicles in 2020 would have $PM_{2.5}$ impacts similar to 125,000 vehicles in 2006.
- For a constant truck percentage of 8%, an overall AADT of approximately 420,000 (EMFAC) to 1.6 million (MOVES) vehicles in 2035 would have $PM_{2.5}$ impacts similar to 125,000 vehicles in 2006.
- For PM_{10}, fleet turnover benefits are largely limited to near-term years (e.g., 2020 and earlier), and over time, project-level emissions are increasingly dominated by non-exhaust processes (especially re-entrained road dust) that are not impacted by fleet turnover.
- EMFAC brake wear emissions estimates are significantly higher than MOVES-based brake wear estimates, particularly for $PM_{2.5}$ emissions.
- For both PM_{10} and $PM_{2.5}$, emissions processes with the highest degree of uncertainty (e.g., re-entrained dust and brake wear) are becoming an increasingly important part of project-level emissions inventories.

- For a given vehicle fleet and analysis year, a linear relationship exists between overall traffic volumes and project-level PM emissions.

These findings have important implications for POAQC determinations, as described in the following section.

4.2 Insights on POAQC Determinations

The results of this study yield a number of key insights that may be helpful in POAQC determinations. First, the results highlight the importance of project location and relevant NAAQS standards on POAQC determinations. For projects in PM_{10} nonattainment areas, re-entrained road dust emissions (and, to a lesser extent, tire wear and brake wear emissions) increasingly dominate project-level inventories over time, and these emissions vary little by analysis year. Therefore, fleet turnover effects and congestion relief will neither provide significant emissions reductions over time, nor allow build scenarios to compare favorably with no-build scenarios.

However, for projects in $PM_{2.5}$ nonattainment areas, the picture is very different. Exhaust emissions dominate the project-level inventory (especially for MOVES-based analyses), and for the year 2015, impacts from a highway project with 125,000 AADT and 8% trucks are already approximately 50% less than impacts from such a project in 2006. In addition, even for projects with 125,000 AADT and 40% (50,000) diesel trucks, fleet turnover means that, by 2020 and beyond, those projects are likely to produce $PM_{2.5}$ emissions equivalent to or less than the emissions from the 2006 baseline project with 10,000 trucks.

Another important insight is the linear relationship between traffic activity and PM emissions, given a consistent vehicle fleet (e.g., truck percentage). This linear relationship, combined with the various scenarios analyzed for this study, may allow project analysts to quickly estimate PM impacts associated with their project and compare those impacts with the 2006 EPA sample project. For example, suppose an analyst is reviewing a highway project with a 2025 analysis year in a $PM_{2.5}$ nonattainment area. Further assume that the project has an estimated truck AADT of 14,000, which is well above the 10,000 trucks in the EPA's sample project. Emissions for this project would likely be similar to the 175,000 AADT, 8% truck case we evaluated (which has a truck AADT of 14,000). The lookup table in Appendix A shows that, for the year 2025, MOVES-based $PM_{2.5}$ emissions estimates for this project total 1.4 kg/day, which is significantly less than the 7.5 kg/day of $PM_{2.5}$ emissions estimated for the 2006 baseline project. This information could help an interagency consultation workgroup to determine whether the project should be considered a POAQC.

Another important insight for POAQC determinations is that current emissions modeling techniques have limitations with regard to estimates of emissions from re-entrained road dust, tire wear, and brake wear; with time, these processes will become increasingly important at the project level. Therefore, additional research is needed to refine emissions estimation techniques for these processes.

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Appendix A. Emissions Lookup Table

Table A-1. Lookup table of project-level PM emissions by scenario.

Scenario[a]	Description	MOVES-Based Emissions (kg/day)		EMFAC2014-Based Emissions (kg/day)	
		PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Emissions change by year (fleet turnover) (125,000 AADT; 8% trucks for all scenarios)	**2006 fleet turnover**	**19.96**	**7.47**	19.13	6.09
	2010 fleet turnover	18.04	5.75	18.51	5.49
	2015 fleet turnover	**15.54**	**3.43**	15.27	2.66
	2020 fleet turnover	13.89	1.87	14.32	2.09
	2025 fleet turnover	**12.98**	**1.02**	13.88	1.89
	2030 fleet turnover	12.63	0.70	13.71	1.84
	2035 fleet turnover	**12.52**	**0.60**	13.63	1.81
Emissions change by volume (8% trucks for all scenarios)	2006 fleet with 125,000 AADT	19.96	7.47	19.13	6.09
	2006 fleet with 150,000 AADT	23.95	8.97	22.95	7.31
	2006 fleet with 175,000 AADT	27.95	10.46	26.78	8.53
	2006 fleet with 200,000 AADT	31.94	11.96	30.61	9.75
	2006 fleet with 225,000 AADT	35.93	13.45	34.43	10.97
	2006 fleet with 250,000 AADT	39.92	14.95	38.26	12.19
	2010 fleet with 125,000 AADT	18.04	5.75	18.51	5.49
	2010 fleet with 150,000 AADT	21.65	6.90	22.22	6.59
	2010 fleet with 175,000 AADT	25.25	8.05	25.92	7.69
	2010 fleet with 200,000 AADT	28.86	9.20	29.62	8.78
	2010 fleet with 225,000 AADT	32.47	10.35	33.33	9.88
	2010 fleet with 250,000 AADT	36.08	11.50	37.03	10.98
	2015 fleet with 125,000 AADT	15.54	3.43	15.27	2.66
	2015 fleet with 150,000 AADT	18.65	4.11	18.32	3.19
	2015 fleet with 175,000 AADT	21.76	4.80	21.38	3.73
	2015 fleet with 200,000 AADT	24.87	5.49	24.43	4.26
	2015 fleet with 225,000 AADT	27.97	6.17	27.48	4.79
	2015 fleet with 250,000 AADT	31.08	6.86	30.54	5.32
	2020 fleet with 125,000 AADT	13.89	1.87	14.32	2.09
	2020 fleet with 150,000 AADT	16.66	2.25	17.18	2.51

Scenario[a]	Description	MOVES-Based Emissions (kg/day)		EMFAC2014-Based Emissions (kg/day)	
		PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Emissions change by volume (8% trucks for all scenarios) *(continued)*	2020 fleet with 175,000 AADT	19.44	2.62	20.05	2.93
	2020 fleet with 200,000 AADT	22.22	2.99	22.91	3.35
	2020 fleet with 225,000 AADT	24.99	3.37	25.77	3.77
	2020 fleet with 250,000 AADT	27.77	3.74	28.64	4.19
	2025 fleet with 125,000 AADT	12.98	1.02	13.88	1.89
	2025 fleet with 150,000 AADT	15.58	1.22	16.65	2.27
	2025 fleet with 175,000 AADT	18.17	1.42	19.43	2.65
	2025 fleet with 200,000 AADT	20.77	1.63	22.21	3.03
	2025 fleet with 225,000 AADT	23.37	1.83	24.98	3.41
	2025 fleet with 250,000 AADT	25.96	2.03	27.76	3.79
	2030 fleet with 125,000 AADT	12.63	0.70	13.71	1.84
	2030 fleet with 150,000 AADT	15.16	0.84	16.46	2.21
	2030 fleet with 175,000 AADT	17.69	0.98	19.20	2.58
	2030 fleet with 200,000 AADT	20.21	1.12	21.94	2.95
	2030 fleet with 225,000 AADT	22.74	1.26	24.68	3.32
	2030 fleet with 250,000 AADT	25.26	1.40	27.43	3.68
	2035 fleet with 125,000 AADT	12.52	0.60	13.63	1.81
	2035 fleet with 150,000 AADT	15.03	0.72	16.36	2.17
	2035 fleet with 175,000 AADT	17.53	0.84	19.08	2.53
	2035 fleet with 200,000 AADT	20.03	0.96	21.81	2.89
	2035 fleet with 225,000 AADT	22.54	1.08	24.54	3.25
	2035 fleet with 250,000 AADT	25.04	1.20	27.26	3.61
Emissions change by truck percentage (fleet mix)[b] (125,000 AADT all scenarios)	2006 fleet with 8% diesel trucks	19.96	7.47	19.13	6.09
	2006 fleet with 20% diesel trucks	34.93	14.31	31.15	11.79
	2006 fleet with 40% diesel trucks	60.00	25.71	51.28	21.27
	2010 fleet with 8% diesel trucks	18.04	5.75	18.51	5.49
	2010 fleet with 20% diesel trucks	31.05	10.75	29.94	10.55
	2010 fleet with 40% diesel trucks	52.86	19.09	49.07	18.98
	2015 fleet with 8% diesel trucks	**15.54**	**3.43**	15.27	2.66
	2015 fleet with 20% diesel trucks	**25.99**	**6.08**	22.67	3.83
	2015 fleet with 40% diesel trucks	**43.53**	**10.49**	35.09	5.78
	2020 fleet with 8% diesel trucks	13.89	1.87	14.32	2.09
	2020 fleet with 20% diesel trucks	22.75	3.08	22.67	3.83

Scenario[a]	Description	MOVES-Based Emissions (kg/day)		EMFAC2014-Based Emissions (kg/day)	
		PM_{10}	$PM_{2.5}$	PM_{10}	$PM_{2.5}$
Emissions change by truck percentage (fleet mix)[b] (125,000 AADT all scenarios) *(continued)*	2020 fleet with 40% diesel trucks	37.64	5.09	35.09	5.78
	2025 fleet with 8% diesel trucks	12.98	1.02	13.88	1.89
	2025 fleet with 20% diesel trucks	20.97	1.43	22.67	3.83
	2025 fleet with 40% diesel trucks	34.42	2.13	35.09	5.78
	2030 fleet with 8% diesel trucks	12.63	0.70	13.71	1.84
	2030 fleet with 20% diesel trucks	20.43	0.93	22.67	3.83
	2030 fleet with 40% diesel trucks	33.54	1.32	35.09	5.78
	2035 fleet with 8% diesel trucks	12.52	0.60	13.63	1.81
	2035 fleet with 20% diesel trucks	20.29	0.81	20.17	2.06
	2035 fleet with 40% diesel trucks	33.36	1.15	31.16	2.47

[a] Several scenarios are presented under all three scenario groups; these emissions scenarios are identical, but are shown separately for ease of comparison.
[b] For a given truck percentage, “trucks” refers to combination short-haul and long-haul trucks in MOVES and to medium heavy-duty and heavy heavy-duty trucks in EMFAC.

Appendix B. Emissions Modeling Methods

Overview

This appendix documents the methods used to estimate PM_{10} and $PM_{2.5}$ emissions for each modeling scenario analyzed for the hypothetical transportation project. The EPA's MOVES2014 model and the CARB's EMFAC2014 model (referred to as "MOVES" and "EMFAC," respectively, hereafter) were used to estimate emissions from motor vehicles. Both models support project-level emissions assessments.

MOVES can be configured to produce two types of output data: emissions inventories or emission rates (ER). The former option represents emission quantities (e.g., kg of PM_{10}) for a given project with predefined activity, while the latter option produces an ER lookup table (e.g., grams of PM_{10} per mile driven) that covers a wide range of conditions (e.g., variations in speed, vehicle miles traveled [VMT], fleet mix). To estimate emissions, the ER must be combined with project-level activity data outside of MOVES. For this study, we selected the ER method to reduce model run times, provide flexibility for making adjustments to scenario designs, and maintain consistency with the EMFAC model runs (as described below).

The EMFAC model includes a Project-Level (PL) assessment module for project analysis. The PL tool is similar in concept to the MOVES ER mode, producing emission rates that must be combined with project-level activity data to estimate emissions. The general work flow for configuring MOVES and EMFAC, running the models, and using output emission rates by process (i.e., vehicle exhaust, tire wear, and brake wear) to estimate project-level emissions is shown in **Figure B-1.** Emission rates and project-level activity data were combined in a database environment to estimate emissions. Neither MOVES nor EMFAC generates emissions for re-entrained road dust (i.e., the suspension or resuspension of roadway dust by vehicle movement).

Because neither MOVES nor EMFAC models emissions of re-entrained dust (i.e., suspension or resuspension dust) from vehicle movement, emissions from this process were estimated using a method from the EPA's AP-42 emission factors handbook that CARB has adopted for developing the annual statewide PM emissions inventory (California Air Resources Board, 1997). Additional details on MOVES and EMFAC modeling and on estimating re-entrained road dust emissions are provided in the remainder of this appendix.

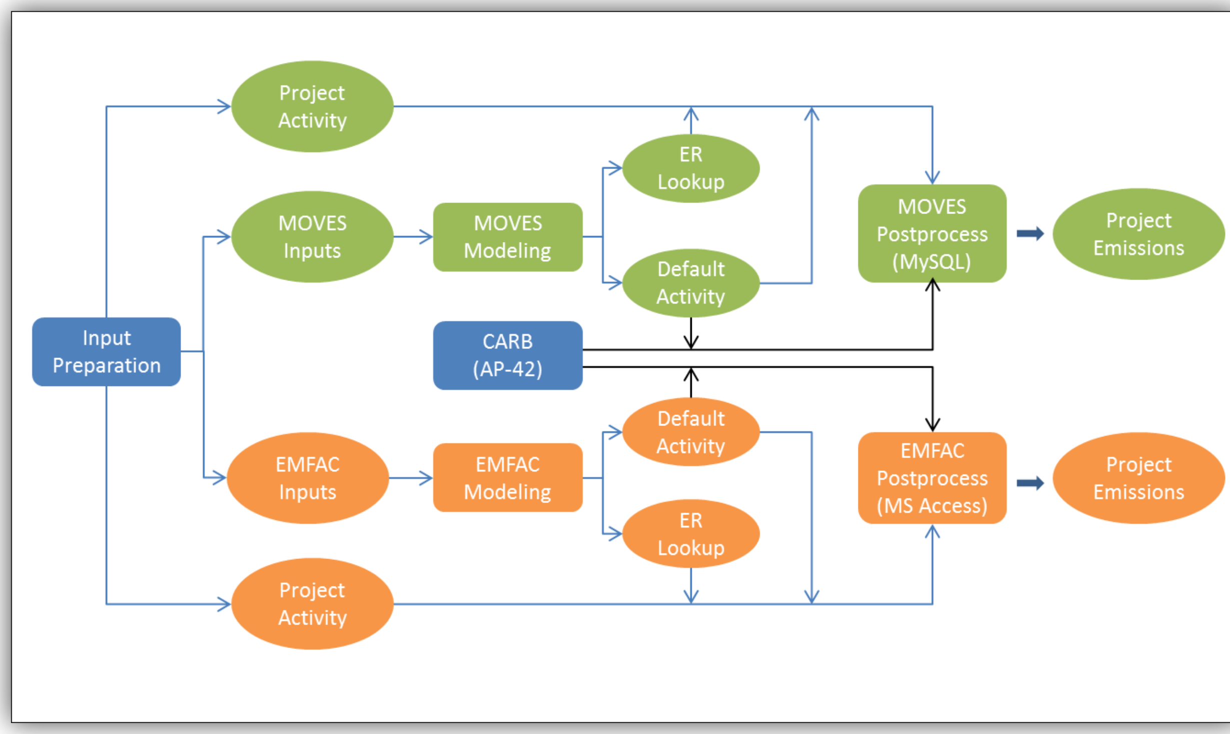

Figure B-1. Workflow of project-level emissions modeling (box = procedures; oval = data files; blue background = applicable to both MOVES and EMFAC approaches; green background = only applicable to MOVES; orange background = only applicable to EMFAC; blue arrow = work flow for exhaust, tire wear, and brake wear emissions estimates; black arrow = work flow for re-entrained dust emissions estimates).

MOVES and EMFAC Modeling

The hypothetical project is based on a sample project developed by the EPA for a three-day PM hot-spot training class, and it includes a freeway with HOV lanes in both directions, interchanges, and major connecting arterial roadways. These roadways are divided into 51 segments that are treated as link-level emissions sources. For each link source, the link length, road type, and average speeds for peak and off-peak hours,[9] originally defined by the EPA, were adopted in this study. Hourly traffic volumes were adjusted to match the EPA's sample POAQC project with an AADT of 125,000 vehicles, 8% of which are treated as diesel trucks.

Using the project configuration discussed above as a starting point, we made the following assumptions in support of MOVES and EMFAC modeling approaches.

- **Location** of project is Fresno, California.

[9] Peak hours were defined as 6:00–9:00 a.m. and 4:00–7:00 p.m.; all remaining hours were defined as off-peak hours.

- **Analysis years** are 2006, 2010, 2015, 2020, 2025, 2030, and 2035.
- **Analysis month** is January, which represents the worst-case condition for PM emissions.
- **Weekday** modeling was selected to represent worst-case conditions.
- **Meteorological** data (i.e., hourly temperature and relative humidity for the month of January for Fresno County) was obtained from the MOVES default database and used as inputs to both the MOVES and EMFAC modeling.
- **Diesel trucks** were defined as the "diesel combination truck" vehicle category in MOVES and as the "Truck 2" vehicle category in EMFAC.
- **Fleet mix** information was based on scenario-specific diesel truck percentages (i.e., 8%, 20%, and 40%) and detailed VMT outputs by vehicle type from MOVES and EMFAC default runs for Fresno County.
- **Hourly traffic volumes** were estimated based on the EPA-defined traffic volumes for peak and off-peak hours and the hourly traffic volume distributions derived from VMT outputs from the MOVES and EMFAC default runs for Fresno County.
- **Age distribution.** For MOVES, age distribution data submitted by the State of California to the EPA's 2011 National Emissions Inventory (NEI) were adopted for "combination trucks," while MOVES default date were used for all other vehicles. For EMFAC, the default age distribution data for Fresno County were used.
- **Fuel supply** data for Fresno County from the MOVES default database were used. This information is only required for MOVES modeling.
- **Speed.** The average speed values by roadway link for peak and off-peak hours from the EPA's original sample project were used. For freeway links, average speeds of 60 mph and 55 mph were used for off-peak and peak hours, respectively. We also assumed that all vehicles travel at the same speed on each link (i.e., there is no variation in speed among different vehicle types).

MOVES Modeling

As mentioned above, MOVES was run in ER mode to generate lookup tables for exhaust, tire wear, and brake wear ERs. Because MOVES can only model one hour of the day at a time in ER mode, to populate the complete ER lookup table covering 24 hours and 7 analysis years, we performed 168 ER-mode MOVES runs in batch mode. A set of Python scripts was developed to automate the configuration of each MOVES run. MOVES ER outputs are stored in a MySQL database that contains ERs by year, month, day, hour, link, pollutant, process, source type, and fuel type.

These ERs were combined with project-level activity data in a MySQL environment to estimate PM_{10} and $PM_{2.5}$ emissions for each analysis scenario. This post-processing was performed using a series of MySQL scripts that matched hourly ERs by vehicle type, fuel type, and speed, with corresponding link-level activity data.

EMFAC Modeling

Similarly, EMFAC was run in PL mode to populate the lookup table for exhaust, tire wear, and brake wear ERs. Additional EMFAC runs were also conducted to produce the default activity outputs (e.g., VMT by vehicle type) that were used to configure project activity data for subsequent emissions calculations.

User-defined inputs for EMFAC PL include geographic area (e.g., county), calendar year and month, vehicle categorization, and meteorological data (temperature and relative humidity combinations representing every hour of the day). EMFAC PL was run using the "Truck1-Truck2-NonTruck" vehicle classification scheme, which allowed EMFAC-PL outputs to be applied to diesel trucks directly (i.e., by using the Truck2 ERs). The ER lookup output table from EMFAC contains gram-per-mile emission rates by year, month, average speed bin, pollutant, process, vehicle category, and fuel type.

For post-processing, the EMFAC PL ER lookup tables were imported into a Microsoft Access database, along with link-level activity data for the project. The ERs and activity data were combined using a series of queries and macros to estimate PM_{10} and $PM_{2.5}$ emissions for each analysis scenario. As was the case for MOVES post-processing, EMFAC PL hourly ERs were matched by vehicle type, fuel type, and speed, with corresponding link-level activity data.

Tire Wear and Brake Wear Emissions

As noted in Section 3.2.1 of this report, the relative contributions of tire wear and brake wear emissions to project-level emissions inventories are increasing over time, as both the MOVES and EMFAC models show exhaust emission rates decreasing sharply in future years, while tire wear and brake wear emission rates remain essentially constant. As discussed below, these non-exhaust portions of the inventory are also highly uncertain, as limited data are available on brake wear and tire wear emissions.

For brake wear emissions, both MOVES and EMFAC rely on two published studies (Garg et al., 2000; Sanders et al., 2003) that provide data on brake wear emissions from light duty vehicles across a range of driving conditions, brake types, and brake pad materials. MOVES specifies brake wear emission rates for $PM_{2.5}$ by operating bin (e.g., low speed coasting, cruising) and then applies a constant PM_{10}-to-$PM_{2.5}$ ratio of 8 to estimate PM_{10} emissions. In addition, heavy-duty vehicle $PM_{2.5}$ emission rates are assumed to be three times higher than light-duty vehicle $PM_{2.5}$ emission rates. EMFAC, on the other hand, specifies per-mile emission rates by vehicle type that vary according to the number of brakes per vehicle. In addition, EMFAC generates PM_{30} emission rates for brake wear and then applies a set of ratios that represent the fraction of PM_{30} that is PM_{10} (0.98) and $PM_{2.5}$ (0.42). Therefore, the effective PM_{10}-to-$PM_{2.5}$ ratio is 2.3 (0.98/0.42). Overall, these differences between MOVES and EMFAC result in higher brake wear emission estimates from EMFAC, particularly for $PM_{2.5}$, as discussed in Section 3.1.1 of this report.

For tire wear, MOVES again starts with $PM_{2.5}$ emission rates for light-duty vehicles, and then assumes that emission rates for other vehicle classes vary only by the number of tires per vehicle. To estimate PM_{10} emissions, MOVES applies a PM_{10}-to-$PM_{2.5}$ ratio of 6.7. In addition, per-mile tire wear emission rates in MOVES decrease with increasing speed (U.S. Environmental Protection Agency, 2014). In EMFAC, tire wear emission rates are represented by a constant per-wheel PM emission rate of 0.002 g/mile/wheel, meaning that per-vehicle emission rates vary with the average number of wheels per vehicle class (California Air Resources Board, 2000). EMFAC also assumes a PM_{10}-to-$PM_{2.5}$ ratio of 4. In general, tire wear PM_{10} emissions estimates from the two models are similar, and tire wear $PM_{2.5}$ emissions estimates from EMFAC are somewhat higher due to the PM_{10}-to-$PM_{2.5}$ ratio used in that model.

Re-Entrained Dust ER

Neither MOVES nor EMFAC models re-entrained road dust emissions. Therefore, we used an AP-42-based method (Equation B-1) that CARB adopted for developing the annual statewide PM emissions inventory (California Air Resources Board, 1997). The AP-42 equation used to derive daily re-entrained road dust emission rates is shown below (U.S. Environmental Protection Agency, 2003).

$$E = [k(sL)^{0.91} \times W^{1.02}] \times (1 - \frac{P}{4N}) \qquad \text{Equation B-1}$$

where

E = PM emission factor, lb/mile

sL = the roadway-specific silt loading in g/m^2 (see Table B-1)

k = particle size multiplier (see Table B-2)

W = the average weight of vehicles traveling the road

P = number of "wet" days, assumed zero to represent the worst condition

N = the number of days in the annual averaging period (default = 365)

AP-42 provides default values for each of these input parameters; however, we applied California-specific values from CARB for the silt loading and particle size multiplier values. In addition, the fleet average vehicle weight was derived from default vehicle weights by vehicle class from MOVES and EMFAC, as well as scenario-specific fleet mix information (i.e., truck percentage) for the hypothetical project. The fleet mix information in MOVES and EMFAC varies somewhat by analysis year, leading to small changes in average vehicle weight for each analysis year modeled.

Because the silt loading and particle size multiplier values used for these analyses were specific to California, these values might be different for projects in other states, leading to different estimates for re-entrained road dust emissions. To provide context for how these emissions estimates could vary, Tables B-1 and B-2 compare the California-specific silt loading and particle size multiplier with the default values from AP-42.

Table B-1. Silt loading default values (g/m^2): California vs. AP-42.

Road Type	CA	AP-42
Freeway	0.02	0.015
Major arterial	0.032	0.06[a]

[a] AADT ranges from 5,000 to 10,000.

Table B-2. Particle size multiplier default values (lbs/VMT): California vs. AP-42.

Particle Size	CA	AP-42
PM_{10}	0.0022	
$PM_{2.5}$	0.00033	0.00054

Silt loading is highly dependent on road type and whether anti-skid abrasives are applied to the roadway. For example, the silt loading for unlimited access roads (e.g., arterials and collectors) increases substantially when anti-skid abrasives are applied during the winter months (U.S. Environmental Protection Agency, 2003).

Appendix B References

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