

Using MOVES3 in Project-Level Carbon Monoxide Analyses

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1 Introduction

1.1 PURPOSE OF THIS GUIDANCE

1.1.1 General

The purpose of this guidance is to describe how to use the MOVES3 emissions model to estimate carbon monoxide (CO) emissions from transportation projects, including roadway intersections, highways, transit projects, parking lots and intermodal terminals. This guidance can be applied when using MOVES3 to complete project-level quantitative CO analysis, including hot-spot analyses for transportation conformity determinations, modeling project-level emissions for state implementation plan (SIP) development, and completing analyses pursuant to the National Environmental Policy Act (NEPA). This guidance applies in all states other than California, where the most recently approved version of the EMFAC model is used. EPA has coordinated with the Federal Highway Administration (FHWA) and Federal Transit Administration (FTA) in developing this guidance.

MOVES is a computer model designed by EPA to estimate emissions from cars, trucks, and other mobile sources.¹ MOVES is designed to allow users to analyze motor vehicle emissions at multiple geographic scales, from national to county to project-level, using different levels of input data. For project-level analyses, MOVES allows users to enter specific details of vehicle activity for each link in a highway or transit project.

MOVES3 is the newest MOVES model, and it is a major revision to the previous versions of MOVES2014. MOVES3 is based on analyses of millions of emission test results and considerable advances in EPA's understanding of vehicle emissions. MOVES3 incorporates new regulations, features, and significant new data, as detailed in the MOVES3 technical reports.

This guidance covers the use of MOVES3, and all references to "MOVES" in this guidance apply to MOVES3 and future versions of the MOVES model, unless otherwise noted at the time those versions are announced.

Note that this guidance covers only how to use MOVES in estimating CO project-level emissions; there are other existing resources that support CO project-level analyses. For example, EPA's regulatory recommendations for CO air quality modeling can be found in Appendix W to 40 CFR Part 51. Users should continue to consult the *Guideline for Modeling Carbon Monoxide from Roadway Intersections* (1992 Guideline) for screening analyses of intersection projects for all issues not related to the calculation of vehicle

¹ The latest MOVES model and supporting documentation are available online at: <https://www.epa.gov/moves/latest-version-motor-vehicle-emission-simulator-moves>. The latest policy guidance on using MOVES for transportation conformity and other purposes are also available at: <https://www.epa.gov/state-and-local-transportation/policy-and-technical-guidance-state-and-local-transportation>.

emission rates (including intersection scope and selection, receptor site selection, and air quality modeling procedures).² However, today's MOVES guidance supersedes the emission factor sections from the 1992 Guideline to reflect the use of MOVES for project-level CO analyses. See Section 1.2.1 for further background on the 1992 Guideline. Finally, users should consult EPA's *PM Hot-spot Guidance: Transportation Conformity Guidance for Quantitative Hot-spot Analyses in PM_{2.5} and PM₁₀ Nonattainment and Maintenance Areas* for how to use MOVES to conduct quantitative PM hot-spot analyses.³

1.1.2 Using this Guidance for Transportation Conformity Hot-Spot Analyses

When using this guidance to complete quantitative CO hot-spot analyses for transportation conformity purposes, certain specific requirements apply; these are summarized here.

Transportation conformity is required under Clean Air Act section 176(c) (42 U.S.C. 7506(c)) to ensure that federally supported highway and transit project activities are consistent with ("conform to") the purpose of a SIP. EPA's transportation conformity rule (40 CFR 51.390 and Part 93) establishes the criteria and procedures for determining whether transportation activities conform to the SIP in CO nonattainment and maintenance areas. The list of areas currently designated nonattainment and maintenance for CO can be found on EPA's "Green Book" website at <https://www.epa.gov/green-book>.⁴ This guidance applies for transportation conformity purposes in areas designated under the current CO NAAQS.⁵

Table 1 in 40 CFR 93.109(b) of the conformity rule outlines the requirements for project-level conformity determinations. For example, CO hot-spot analyses must be based on the latest planning assumptions available at the time the analysis begins (40 CFR 93.110) and the design concept and scope of the project must be consistent with that included in the conforming transportation plan and transportation improvement program (TIP) or regional emissions analysis (40 CFR 93.115). In addition, interagency consultation must be used to develop a process to evaluate and choose models and associated methods and assumptions to be used in CO hot-spot analyses (40 CFR 93.105(c)(1)(i)). The agencies that may be involved in the interagency consultation process include the project sponsor, state and local transportation and air quality agencies, EPA, and DOT. The roles and

² *Guideline for Modeling Carbon Monoxide from Roadway Intersections*, EPA-454/R-92-005, November 1992; available online at: <https://www.epa.gov/state-and-local-transportation/project-level-conformity-and-hot-spot-analyses#guidance>.

³ The latest version of this guidance is available online at: <https://www.epa.gov/state-and-local-transportation/project-level-conformity-and-hot-spot-analyses#pmguidance>.

⁴ At this time there are no nonattainment areas for the current CO NAAQS. All areas have been redesignated to attainment and are therefore maintenance areas. Only about a third of the 77 CO maintenance areas are currently required to conduct CO hot-spot analyses for transportation conformity purposes because they have not yet completed their 20-year maintenance period. See EPA's *Transportation Conformity Guidance for Areas Reaching the End of the Maintenance Period*, EPA-420-B-14-093, October 2014, available online at: <https://www.epa.gov/state-and-local-transportation/policy-and-technical-guidance-state-and-local-transportation#state>.

⁵ This guidance is applicable to current and future CO NAAQS revisions, unless EPA notes otherwise.

responsibilities of various agencies for meeting the transportation conformity requirements are addressed in 40 CFR 93.105 or in a state's approved conformity SIP. Refer to the conformity rule for a complete listing of all project-level conformity requirements.

EPA has approved MOVES3 for use in CO hot-spot analyses for project-level conformity determinations, with a two-year grace period that ends January 9, 2023. Refer to the *Federal Register* notice for more information on EPA's approval of MOVES3 for CO hot-spot analyses.⁶ EPA has also issued additional policy guidance on when MOVES3 will be required for hot-spot analyses and other purposes.⁷

1.1.3 Other Purposes for this Guidance

This guidance addresses using MOVES3 for conducting a CO hot-spot analysis for transportation conformity purposes and is the only EPA guidance that covers how to use MOVES3 to estimate CO emissions for a transportation project. This technical guidance may also apply when completing analyses of transportation projects for other purposes, such as general conformity determinations or assessing near-road air quality in communities with environmental justice concerns.

1.2 TYPES OF PROJECT-LEVEL CO ANALYSES

This MOVES guidance is part of the overall process of completing project-level CO analyses. Project-level CO analyses consist of both emissions and air quality modeling and can be completed using either a screening or a refined analysis. Screening analyses estimate the maximum likely impacts of emissions from a given source, generally at the receptor with the highest concentrations, based on worst-case traffic and meteorological data. Such analyses can save effort in cases where requirements are met. In contrast, refined analyses use detailed local information and simulate detailed atmospheric processes to provide more specialized and accurate estimates of how nearby sources affect air quality at downwind locations.

Unless otherwise noted, the guidance in this document can be used to estimate highway and transit project emissions for all project-level CO analyses, both screening and refined. The following sections further describe the relationship of this MOVES guidance to particular types of screening and refined CO analyses.

⁶ See *Federal Register Notice of Availability: Official Release of the MOVES3 Motor Vehicle Emissions Model for SIPs and Transportation Conformity (PDF)*; available online at: <https://www.epa.gov/state-and-local-transportation/policy-and-technical-guidance-state-and-local-transportation#emission>.

⁷ *Policy Guidance on the Use of MOVES3 for State Implementation Plan Development, Transportation Conformity, General Conformity, and Other Purposes*, EPA-420-B-20-052, November 2020; available online at: <https://www.epa.gov/state-and-local-transportation/policy-and-technical-guidance-state-and-local-transportation#emission>.

1.2.1 Screening Analyses of Roadway Intersections

The 1992 Guideline provides guidance on completing CO screening analyses of roadway intersections. As noted above, this document only supersedes the 1992 Guideline's emission rate calculation procedures to reflect the use of MOVES; the 1992 Guideline otherwise remains in effect, and users should continue to consult that guidance for all issues not related to the calculation of vehicle emission rates (including intersection scope and selection, receptor site selection, and air quality modeling procedures).

1.2.2 All Other Screening Analyses

This guidance also covers how to use MOVES for CO screening analyses of projects that are not explicitly covered by the 1992 Guideline. This would include projects such as:

- A mainline highway segment not containing an intersection;
- An intersection project that includes start or hotelling activity on an off-network link (such as a truck stop, parking lot, or terminal facility);
- Any other project that includes off-network activity;
- Transit and other terminal projects.

The guidance will note when different procedures are appropriate when using MOVES to complete a CO screening analysis for such projects. In some cases, the procedures for using MOVES for these types of screening analyses will be the same as using MOVES for a CO refined analysis (see Section 1.2.3). When this is the case, this guidance covers these situations in a single section for brevity.

1.2.3 Refined Analyses of Any Project

In certain situations, project sponsors may want or need to complete a CO refined analysis. Although a refined analysis requires significantly more data and effort, this option may be convenient for transportation projects that require both a PM and CO quantitative hot-spot analysis. This guidance gives additional guidance on using MOVES for refined analyses to explain how the full capabilities of the model can be employed in these situations.

1.3 CONTACTS

For specific transportation conformity questions concerning a particular nonattainment or maintenance area, please contact the transportation conformity staff person responsible for your state at the appropriate EPA Regional Office. Contact information for EPA Regional Offices can be found at: <https://www.epa.gov/state-and-local-transportation/epa-regional-contacts-regarding-state-and-local-transportation>.

General questions on using MOVES for CO project-level analysis can be directed to the MOVES in-box at mobile@epa.gov.

Technical questions about this guidance can be directed to Laura Berry, at berry.laura@epa.gov.

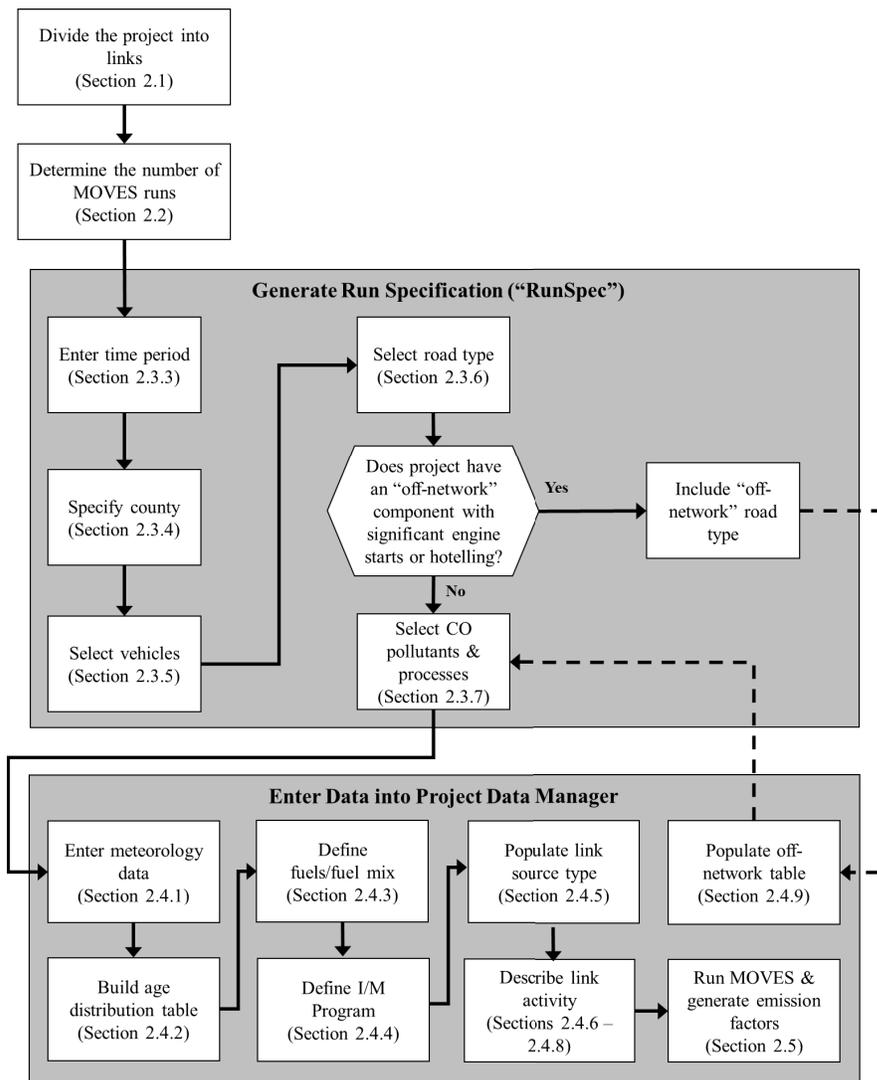
1.4 GUIDANCE AND EXISTING REQUIREMENTS

This guidance does not create any new requirements. The Clean Air Act and the regulations described in this document contain legally binding requirements. This guidance is not a substitute for those provisions or regulations, nor is it a regulation in itself. Thus, it does not impose legally binding requirements on EPA, DOT, states, or the regulated community, and may not apply to a particular situation based upon the circumstances. EPA retains the discretion to adopt approaches on a case-by-case basis that may differ from this guidance but still comply with the statute and applicable regulations. This guidance may be revised periodically without public notice.

2 Estimating Project-Level CO Emissions Using MOVES

This guidance addresses the necessary steps to run MOVES to estimate a project’s emissions for a project-level CO analysis. The guidance describes how to provide the appropriate inputs to MOVES to generate the emission factors necessary to complete the air quality analysis. This section presumes users already have a basic understanding of how to run MOVES.⁸ Figure 1 describes the general process for estimating the CO emissions at the project level using MOVES.

Figure 1. Steps for Using MOVES in Project-Level CO Analyses



MOVES includes a default database of meteorology, fleet, activity, fuel, and control program data for the entire United States. The data included in this database come from a

⁸ See EPA’s MOVES training resources available at: <https://www.epa.gov/moves/moves-training-sessions>.

variety of sources and are not necessarily the most accurate or up-to-date information available at the local level for a particular project. This guidance will describe when the use of that default database is appropriate for a project-level CO analysis.

2.1 CHARACTERIZING A PROJECT IN TERMS OF LINKS

The first step in completing a project-level CO analysis using MOVES is to define a project's links. Within MOVES, a link represents a segment of road (or an "off-network" location as described below) where a certain type of vehicle activity occurs. The goal of defining a project's links is to accurately estimate emissions from a specific type of activity where that activity occurs. Generally, the links specified for a project should include segments with similar traffic/activity conditions and characteristics. For example, a free-flow highway segment with a relatively stable average speed might be modeled as a single link, whereas an intersection will involve several types of links, as described further below. From the link-specific activity and other inputs, MOVES calculates emissions from every link of a project for a specific hour chosen by the modeler for the MOVES run. In MOVES, running emissions, including periods of idling at traffic signals, are defined in the Links Importer (see Section 2.4.6).

This section gives different guidance on how to characterize links in MOVES, depending on the type of project and CO analysis involved, as follows:

- For a screening analysis of a roadway intersection being completed in accordance with the 1992 Guideline, see Section 2.1.1;
- For all other screening analyses, including intersection projects that include off-network activity, see Section 2.1.2;
- For a refined analysis of any project, see Section 2.1.2.

2.1.1 Screening Analyses of Roadway Intersections

According to EPA's *Guideline on Air Quality Models* regulation, CO screening analyses of intersection projects can continue to use the CAL3QHC dispersion model.⁹

Performing such an analysis for an intersection using the CAL3QHC dispersion model requires emission rates for both free-flow traffic (determined by defining "free flow" links) and idling traffic (determined from "queue links").¹⁰ Free-flow links can be used

⁹ Appendix W of 40 CFR Part 51 is the regulation known as *The Guideline on Air Quality Models*. The most recent update to this regulation is the final rule published January 17, 2017, (82 FR 5182), found on EPA's website at: https://www.epa.gov/sites/default/files/2020-09/documents/appw_17.pdf. The updated regulation allows the use of CAL3QHC for CO screening analyses. See footnote 2 in Section 1.1.1 of this guidance for 1992 CO Guideline reference information.

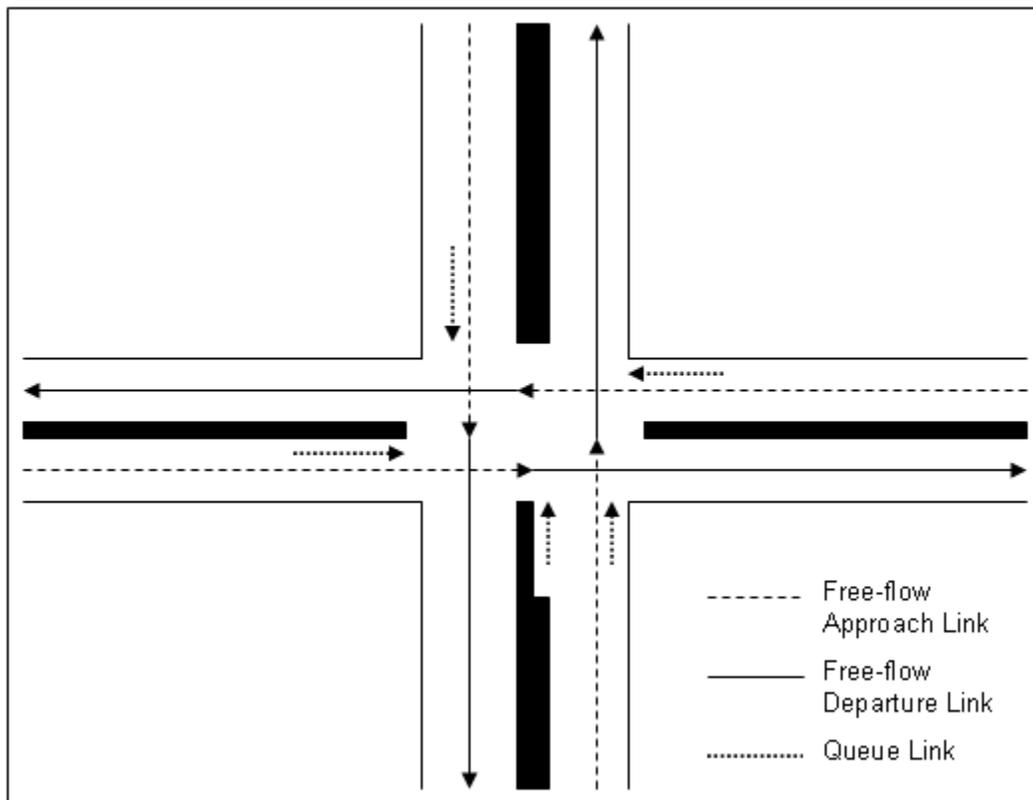
¹⁰ The 1992 Guideline describes how to use CAL3QHC when performing dispersion modeling for intersections (see 1992 Guideline, page 1-5). To be consistent with the 1992 Guideline, this guidance recommends use of the CAL3QHC queuing algorithm for intersection idle queues when completing a CO screening analysis of an intersection. This differs from the recommendation for refined analyses, where idling should be explicitly included in the link activity entered into MOVES, rather than determined by the CAL3QHC queuing algorithm. Since the purpose of a screening analysis is inherently different from that of a refined analysis, the separate methods still serve the respective goals of each approach.

to represent traffic approaching and departing an intersection. See Section 3 of this guidance for an example of how to use MOVES for a CO screening analysis of an intersection.

Note that the 1992 Guideline does not cover screening analyses of intersections that include off-network activity. For those situations, refer to Section 2.1.2.

Figure 2 is an example of a simple intersection showing free-flow approach, free-flow departure, and queue links. The following sections provide more information on how to define these links in MOVES.

Figure 2. Diagram of Suggested Links for a Simple Intersection



Free-flow Approach and Departure Links

Free-flow links are used to represent vehicle activity on intersection approach and departure links. The intersection in Figure 2, for example, shows four free-flow approach and four free-flow departure links. Free-flow links are described by the average speeds experienced by drivers travelling along the link in the absence of the delay caused by an intersection traffic signal. Users should define a free-flow link as the center-to-center distance from the intersection of interest to the next intersection. As described in Section

4.7.4 of the 1992 Guideline, a maximum of 300 meters for this distance is sufficient, but users may specify a longer distance for completeness.¹¹

Queue Links

A queue link is used to represent vehicles idling at an intersection. The intersection in Figure 2, for example, shows five queue links. Since MOVES is calculating a gram per vehicle-hour emission factor in this case, the length of the queue link in MOVES can be indicated as zero.¹² As opposed to free-flow and departure links, which use grams/vehicle-mile, queue links require a gram/veh-hour emission rate.

2.1.2 All Other Screening Analyses and Refined Analyses of Any Project

When completing screening analyses of projects not covered by the 1992 Guideline, or any refined analysis, there are several options for characterizing link activity for project-level CO emissions. The following text describes how different types of links can be characterized in MOVES.

General

In MOVES, activity on free-flow highway links can be defined by an average speed, link drive schedule, or operating mode (“Op-Mode”) distribution (discussed in Section 2.4.8). For analyses with MOVES, average speed and traffic volume is required, at a minimum, for each link. If no other information is available, MOVES uses default assumptions of vehicle activity patterns (called drive cycles) for average speed and type of roadway to estimate emissions. Default drive cycles use different combinations of vehicle activity (acceleration, deceleration, cruise, and/or idle) depending on the speed and road type. For example, if the link average speed is 30 mph and it is an urban arterial (Urban Unrestricted Road Type), MOVES uses a default drive cycle that includes a high proportion of acceleration, deceleration, and idle activity as would be expected on an urban arterial with frequent stops. If the average speed is 60 mph and it is a rural freeway (Rural Restricted Road Type), MOVES uses a default drive cycle that assumes a higher proportion of cruise activity, smaller proportions of acceleration and deceleration activity, and little or no idle activity.

Project sponsors should determine average congested speeds by using appropriate methods based on best practices used for highway analysis.¹³ Some resources are

¹¹ Since the goal of the MOVES run is to produce a grams/vehicle-mile emission rate for running links, the exact length or volume of each link is not important for running MOVES results because in the post-processing script that creates these rates, total emissions will be divided by vehicle volume and link length. However, exact link lengths and volumes are important for subsequent CAL3QHC dispersion modeling.

¹² The link length of a queue link in MOVES is not used by the post-processing script that calculates emission rates, and therefore could be any number.

¹³ When completing screening analyses of projects not covered by the 1992 Guideline, or any refined analysis, idling vehicles should be represented in combination with decelerating, accelerating, and free-flow traffic on an approach segment of an intersection. Note that this is in contrast to the guidance given

available through FHWA's Travel Model Improvement Program (TMIP).¹⁴ Methodologies for computing intersection control delay are provided in the *Highway Capacity Manual*.¹⁵

As described further in Section 2.4.8, for refined analyses, users are encouraged to take advantage of the full capabilities of MOVES for estimating emissions on different highway and intersection project links when completing CO refined analyses. Although average speeds and travel volumes are typically available for most transportation projects, users can develop and use more precise data through the MOVES Link Drive Schedule Importer or Operating Mode Distribution Importer, as described further in Section 2.4.9. When more detailed data are available to describe the pattern of changes in vehicle activity (proportion of time in acceleration, deceleration, cruise, or idle activity) over a length of road, MOVES is capable of calculating these specific emission impacts. EPA encourages users to consider these options for CO refined analyses of highway and intersection projects.

Free-flow Highway Links

The links defined in MOVES should capture the expected physical layout of a project and representative variations in vehicle activity. A simple example would be a single, one directional, four-lane highway that could be characterized as just one link. More sophisticated analyses may break up traffic flow on that single link into multiple links of varying operating modes or drive cycles that may have different emission factors depending on the relative acceleration, cruise, or deceleration activity on each segment of that link. In general, the definition of a link will depend on how much the type of vehicle activity (acceleration, deceleration, cruise or idle) changes over a length of roadway, the level of detail of available data, and the modeling approach used with MOVES. For a highway lane where vehicle behavior is fairly constant, the length of the link could be longer and the use of detailed activity data will have a smaller impact on results.

Intersection Links

If the project analysis is a CO refined analysis involving intersections, the intersections need to be treated separately from the free-flow links that connect to those intersections. Although road segments between intersections may experience free-flow traffic operations, the approaches and departures from the intersections will likely involve acceleration, deceleration, and idling activity not present on the free-flow link. For intersection modeling, the definition of link length will depend on the geometry of the intersection, how that geometry affects vehicle activity, and the level of detail of available activity information. Guidance for defining intersection links for a CO refined

when completing a CO screening analysis of an intersection, when the CAL3QHC queuing algorithm is recommended in order to be consistent with the 1992 Guideline (see Section 2.1.1).

¹⁴ See FHWA's Travel Model Improvement Program website: <http://tmip.fhwa.dot.gov/>.

¹⁵ Users should consult the most recent version of the Highway Capacity Manual. As of the release of this guidance, the latest version is the *Highway Capacity Manual, Sixth Edition: A Guide for Multimodal Mobility Analysis*, released September 2016 by the Transportation Research Board (see <https://www.trb.org/publications/hcm6e.aspx> for details).

analysis is given in the appendix, but the definition of links used for a particular project will depend on the specific details of that project and the amount of available activity information.

Note: For both free-flow highway and intersection links, users may directly enter output from traffic simulation models in the form of second-by-second individual vehicle trajectories. More information on using vehicle trajectories from traffic microsimulation models for CO refined analyses can be found in the appendix.

Off-Network Links

If the analysis involves an area that is not part of the road network, such as a terminal or a parking area, such an area can be modeled using an off-network link defined in the Off-Network Importer and one or more links in the Links Importer:

- Start and hotelling activity would be defined in the Off-Network Importer. Section 2.4.9 describes the inputs needed.
- Running and idling activity at this area would be defined the way other road links are defined, (e.g., in the Links Importer, using on-network road types).

Start Activity: For off-network sources such as a parking lot or transit terminal, the user should have information on starts per hour (or peak hour starts). Additionally, it is necessary to provide an estimate of the duration that vehicles are parked before starting (soak-time distribution). If there are multiple areas of start activity within a project with roughly the same soak time distributions, these areas can be modeled with one off-network link using an appropriately weighted distribution of soak times.¹⁶

Hotelling: In MOVES, hotelling applies only to long haul combination trucks, source type ID 62. Hotelling activity includes long duration idling (classified in MOVES as OpModeID 200), and use of auxiliary power units (APUs, classified in MOVES as OpModeID 201). Additionally, hotelling operation using electric power (no emissions) can be modeled using OpMode 203. This type of activity is defined on an off-network link and would not likely be occurring at transit or other terminals. Shorter periods of idling for long-haul combination trucks should be modeled as a running link via the Links Importer.

Idling Activity: Idling for other vehicles and shorter periods of idling for long-haul combination trucks should be modeled as one or more project links with an operating mode distribution that consists only of idle operation (OpModeID 1). This can be specified in the Links table by inputting the vehicle population, i.e., the number of vehicles idling during the hour (or idling during peak hour) and specifying an average speed of “0” mph. The links for idling activity should be associated with an on-network road type such as “Urban Unrestricted.” There is no limit to the number of links that can have this type of idling activity. Multiple links can be defined for the same off-network area to capture idling activity of various vehicle types.

¹⁶ In the event that a project has multiple areas of start activity in different locations that have different soak time distributions, please consult with your EPA Region before modeling.

Running Activity: Some transit and other terminal projects may have significant running emissions similar to free-flow highway projects (such as buses and trucks coming to and from an intermodal terminal). These emissions can be calculated by defining one or more unique running links as described above and the appendix (that is, define links for this activity using an on-network road type in addition to any other roadway links associated with the project). These running link emissions can then be aggregated with the emissions from the other activities happening on the off-network link (e.g., starts and idling from non-running activity on the transit or other terminal link) outside of the MOVES model to generate the necessary air quality model inputs.

Note: The user may choose to exclude sources such as a separate service drive, separate small employee parking lot, or other minor sources that are determined to be insignificant to project emissions.

2.2 DETERMINING THE NUMBER OF MOVES RUNS

The following section describes the number of MOVES runs that may be needed for project-level CO analyses.¹⁷ When MOVES is run at the Project Scale, it estimates emissions for only one hour, as specified by the modeler.

2.2.1 Screening Analyses of Roadway Intersections

For a CO screening analysis of an intersection project, only one MOVES scenario (run) is necessary for each analysis year. To remain consistent with the 1992 Guideline for such analyses, this guidance describes how to use “worst-case” conditions.¹⁸ To capture anticipated worst-case conditions, users should define the MOVES run specification (“RunSpec”) using the peak hourly traffic volume expected for the intersection project. As stated in the 1992 Guideline, the peak hour traffic conditions are defined as the average or typical values during the hour of the day which usually records the peak hour traffic, rather than the worst case traffic conditions for the entire year.¹⁹ Average speeds, vehicle mix, and idle times should reflect conditions at the peak period. Project sponsors should use the appropriate methods based on best practices used for highway analysis in the area for determining peak period traffic conditions. Some resources for determining traffic characteristics are available through FHWA’s Travel Model Improvement Program (TMIP).²⁰ Guidance on how to enter these individual inputs into MOVES is discussed in Section 2.4.

¹⁷ If completing a CO quantitative hot-spot analysis for transportation conformity purposes, users should refer to the conformity rule requirements when selecting travel activity data. See Section 1.1.2 for a summary of these conformity requirements.

¹⁸ See 1992 Guideline, Section 4.

¹⁹ See 1992 Guideline, Section 1.3.

²⁰ FHWA Travel Model Improvement Program website: <http://tmip.fhwa.dot.gov/>.

2.2.2 *All Other Screening Analyses*

The 1992 Guideline does not expressly address what conditions should be captured for a CO screening analysis of a project that is not solely a roadway intersection. Project sponsors are encouraged to employ best professional practices and appropriate methods and use the interagency consultation process or procedures to determine the appropriate number of MOVES runs for these screening analysis situations.

2.2.3 *Refined Analyses of Any Project*

If MOVES is being used to complete a CO refined analysis, more than one MOVES run may be needed to capture any emission rate variation due to changes in temperature, volume, speeds, and fleet mix over the course of the day, season, or year being analyzed. However, the specific number of MOVES runs needed will depend on the situation. For example, where potential CO NAAQS violations are expected to occur in only one quarter of the calendar year (e.g., only a wintertime violation), the user might choose to model only a single day to represent all days within that quarter. However, if CO NAAQS violations are expected in multiple quarters, or if variations in travel activity and/or temperature within a single quarter need to be accounted for, then additional MOVES runs may be necessary.

Project sponsors may have activity data collected at a range of possible temporal resolutions. Depending on the sophistication of the activity data analysis for a given project, these data may range from a daily average-hour and peak-hour value to hourly estimates for all days of the year. The remainder of this section describes how project sponsors can use MOVES for CO refined analyses in cases where they have (1) typical travel activity data, and (2) more detailed travel activity data.

Projects with Typical Travel Activity Data

Traffic forecasts for highway and intersection projects are often completed for annual average daily traffic volumes, with an allocation factor for a daily peak-hour volume. This data can be used to conduct an analysis with MOVES that is representative for all hours of the day, or year being considered. The most reasonable methods in accordance with good practice should be used to obtain the peak-hour allocation factors and diurnal distribution of traffic and the methods must be determined in accordance with interagency consultation procedures (40 CFR 93.105(c)(1)(i)) if the analysis is conducted for transportation conformity purposes. It is important to capture variation in emission rates as activity and ambient temperature change over the period being analyzed.

One option is to represent traffic over four time periods of a day: morning peak (AM), midday (MD), evening peak (PM), and overnight (ON). For example, the peak-hour volume can be used to represent activity conditions over a three-hour morning (AM) and three-hour evening (PM) period. The remaining 18 hours of the day can be represented by the average-hour volume (AADT minus the total volume assigned to the peak period,

divided by the number of off-peak hours). These 18 hours would be divided into a midday (MD) and overnight (ON) period.

The following is one suggested approach for an analysis employing the average-hour/peak-hour traffic scenario:

- Morning peak (AM) emissions based on traffic data and meteorology occurring between 6 a.m. and 9 a.m.;
- Midday (MD) emissions based on data from 9 a.m. to 4 p.m.;
- Evening peak (PM) emissions based on data from 4 p.m. to 7 p.m.; and
- Overnight (ON) emissions based on data from 7 p.m. to 6 a.m.

If there are local or project-specific data to suggest that the AM or PM peak traffic periods will occur in different hours than the default values suggested here, or over a longer or shorter period of time, that information should be documented and the hours representing each time period adjusted accordingly.

Projects with Additional Travel Activity Data

Some project sponsors may have developed traffic or other activity data to show variations in volume and speed across hours, days, or months. Additionally, if users are modeling a transit or other terminal project, traffic volumes, starts, and idling estimates are likely to be readily available for each hour of the day. Under either of these circumstances, users may choose to apply the methodology described above (using average-hour and peak-hour as representative for all hours of the time period being calculated). Alternatively, additional MOVES runs could be generated to produce unique emission factors using these additional activity data and emission factors for each period of time for which specific activity data are available.

2.3 DEVELOPING BASIC RUN SPECIFICATION INPUTS

Once the user has defined the project conceptually in terms of links and determined the number of MOVES runs, the next step in using MOVES for project-level analyses is to develop a run specification (“RunSpec”). The RunSpec is a computer file in XML format that can be edited and executed directly or with the MOVES Graphical User Interface (GUI). MOVES requires the user to set up a RunSpec to define the place and time of the analysis as well as the vehicle types, road types, fuel types, and the emission-producing processes and pollutants that will be included in the analysis. Once selections are made for the RunSpec, the user must create an input database for that RunSpec using the MOVES Project Data Manager, described in Section 2.4.

The headings in this subsection describe each set of input options needed to create the RunSpec as defined in the Navigation Panel of the MOVES GUI. To create a project-level RunSpec, the user would go down the Navigation Panel filling in the appropriate data for each of the items listed. Those panels are:

- Description
- Scale
- Time Spans
- Geographic Bounds
- Onroad Vehicles
- Road Type
- Pollutants and Processes
- General Output
- Output Emissions Detail
- Create Input Database
- Advanced Features

Additional information on each panel can be found in resources for MOVES training available on EPA’s website (<https://www.epa.gov/moves/moves-training-sessions>).

2.3.1 *Description*

This panel allows the user to enter a description of the RunSpec using up to 5,000 characters of text. Entering a complete description of the RunSpec is important for users to keep track of their MOVES runs as well as to provide supporting documentation for the regulatory submission. Users may want to identify the project, the time period being analyzed, and the purpose of the analysis in this field.

2.3.2 *Scale*

The Scale Panel in MOVES allows the user to select different scales or domains for the MOVES analysis. This panel in MOVES also allows users to choose the “Onroad” or “Nonroad” module; “Onroad” is already selected and is the appropriate choice for project-level analyses. All MOVES runs for project-level analyses must be done using the “Project” domain in the “Scale” Panel. The Project domain is necessary to allow MOVES to accept detailed activity input at the link level.²¹

The Scale Panel also requires users to select a calculation type of either Inventory or Emission Rates, which produces output as either grams/hour or grams/vehicle-mile emission rates, respectively.

For screening analyses of intersections, since CAL3QHC requires emission rates in terms of both grams/vehicle-mile for free-flow links and grams/veh-hour for queue links, users performing an analysis for a project which includes vehicle queuing (such as is the case with an intersection) should select Inventory as output. From the Inventory output,

²¹ Running MOVES using the “County” or “Default” domains would not allow for detailed link level input or output that is needed for project-level CO analyses. The Scale Panel also includes options for Onroad or Nonroad models. This guidance applies only to the Onroad model in MOVES.

appropriate emission rates can be calculated through several post-processing steps described in Section 2.5.

When completing screening analyses of projects not covered by the 1992 Guideline, or any refined analysis, users may benefit from choosing either Inventory or Emission Rates, depending on the specifics of the project (including the air quality model being used to complete the analysis):

- When a grams/hour emission factor is needed for air quality modeling, users should select Inventory, which produces results for total emissions on each link; this is equivalent to a grams/hour/link emission factor, which can be thought of as a link-specific grams per hour emissions factor.
- When a gram/vehicle-mile emission factor is needed, the Emission Rates option should be selected to produce link-specific grams/vehicle-mile emission factors.

The selection of calculation type is required early in the RunSpec construction process because this choice affects the available options in later panels. The Emission Rates mode is more complex than the Inventory mode. Successful application of this mode requires careful planning and a clear understanding of the rates calculations in MOVES. Large differences in results between the Inventory and Emission Rates modes usually indicate a mistake in post-processing of the emission rates using the Emission Rates mode. The most common mistakes when using the Emission Rates mode are:

- not including all pollutant processes, and
- multiplying emission rates by the wrong activity.

Even when done correctly, minor differences in post-processing methods can create small differences in results. EPA recommends that the same mode be used in any analysis that compares two or more cases. The interagency consultation process should be used to agree upon a common approach and to share detailed results during reviews of draft CO hot-spot analyses that support project-level conformity determinations.

This guidance explains the steps of post-processing both Inventory and Emission Rates results to produce the desired emission factors in Section 2.5.

2.3.3 Time Spans

At the Project Scale, each MOVES run represents one specific hour. The Time Spans Panel is used to define the specific time period covered in the MOVES run. The Time Spans Panel allows the user to select the year, month, day, and hour that the run will represent. As Project Scale models only one hour at a time, only the start hour needs to be selected on this panel.

The user should enter the desired time period (i.e., the specific year, month, type of day, and hour) in the MOVES Time Spans Panel. The “day” selection should be set to “weekday” or “weekend,” but not both.

To be consistent with the 1992 Guideline, for a CO screening analysis of an intersection, the year, month, and hour should be set to specifically describe the peak traffic scenario, which would most likely be for a weekday. For example, the run describing a peak traffic scenario might be: 2015, January, weekday, 8:00 to 8:59 a.m..

2.3.4 Geographic Bounds

The Geographic Bounds panel allows the user to define the specific county that will be modeled. The MOVES database includes county codes and descriptive information for the more-than-3000 counties in the United States. Specifying a county in MOVES determines certain default information for the analysis. Users should select the specific county where the project is located. Only a single county can be included in a MOVES run at the Project Scale. If a project spans multiple counties, users have two options:

1. If the county-specific local data is the same for all the counties in the project, select the county in which the majority of the project is located;
2. If not, separate the project into multiple parts, each of which is in a separate county, and do a separate MOVES run for each part.

2.3.5 Onroad Vehicles

The Onroad Vehicles Panel is used to specify the vehicle types that are included in the MOVES run. MOVES allows the user to select from among 13 “source use types” (the terminology that MOVES uses to describe vehicle types). Users should generally select all 13 vehicle types to reflect the full range of vehicles that will operate in the project area. The exception may be when modeling projects that contain a captive fleet where only certain types of vehicles are present (e.g., a transit bus terminal).

Selecting a vehicle type will include the relevant fuel types for that vehicle. To change the percentages of vehicles using the different fuel types in the project, use the Fuels Importer of the Project Data Manager (discussed in Section 2.4.3).

2.3.6 Road Type

The Road Type panel is used to define the types of roads that are included in the project. MOVES defines five different road types:

- Off-Network – any location where the predominant activity is vehicle starts and hotelling (parking lots, truck stops, rest areas, freight or bus terminals);
- Rural Restricted Access – a rural highway that can be accessed only by an on-ramp;
- Rural Unrestricted Access – all other rural roads (arterials, connectors, and local streets);
- Urban Restricted Access – an urban highway that can be accessed only by an on-ramp; and
- Urban Unrestricted Access – all other urban roads (arterials, connectors, and local streets)

MOVES uses these road types to determine the default drive cycle on a particular link. For example, MOVES uses drive cycles for unrestricted access road types that assume stop-and-go driving, including multiple accelerations, decelerations, and short periods of idling. For restricted access road types, MOVES uses drive cycles that include a higher fraction of cruise activity with much less time spent accelerating and idling.

Road Type is a necessary input into the RunSpec and users should select one or more of the five road types that correspond to the road types of the project. The determination of rural or urban road types should be based on the Highway Performance Monitoring System (HPMS) functional classification of the road type. Note that driving and idling in a parking lot or similar off-road location should be modeled with one of the on-network road types (such as Urban Unrestricted Access).²² This includes idling for deliveries and pickup and drop-off.

Additionally, any project that includes a significant number of engine starts or significant amounts of hotelling for long-haul combination trucks needs to include the Off-Network Road Type to account for emissions from those activities properly. More details on describing inputs for engine start and hotelling activity are given in Section 2.4.9.

2.3.7 Pollutants and Processes

The Pollutant and Processes Panel is used to select both the types of pollutants and the emission processes that produce them. When completing a CO screening analysis of an intersection project using CAL3QHC, both free-flow and queue links will be characterized. For CO emissions from these links, MOVES calculates emissions for two separate processes:

- Running Exhaust
- Crankcase Running Exhaust

If modeling an intersection, users should select Carbon Monoxide (CO): “Running Exhaust” and “Crankcase Running Exhaust.” Emission rates will be post-processed from the MOVES output to calculate an aggregate of both processes.

MOVES does not automatically sum the appropriate processes to create an aggregate emission factor, although EPA has created MOVES scripts that automate the summing of aggregate emissions when completing project-level analyses. These scripts are available through the post-processing menu of the MOVES GUI and are discussed in Section 2.5

When completing screening analyses of projects not covered by the 1992 Guideline, or any refined analysis, users can similarly sum the processes described above using the MOVES post-processing scripts to calculate aggregate emissions from the MOVES output.

²² In contrast to the County Scale where this type of idling is Off-Network, at the Project Scale, all non-hotelling idling needs to be modeled on a running link with one of the four road types: urban/ rural, restricted/unrestricted.

If the project contains an off-network link, users should select Carbon Monoxide (CO): “Start Exhaust”, “Crankcase Start Exhaust”, “Extended Idle Exhaust”, “Crankcase Extended Idle Exhaust”, and/or “Auxiliary Power Exhaust” depending on the vehicle activity occurring on the off-network link. Emission rates will need to be post-processed from the MOVES output using the MOVES post-processing scripts discussed in Section 2.5.

2.3.8 General Output

In the General Output Panel, users create or identify an output database where MOVES will put the results of the run. It is helpful for the output database name to be related to the name of the project to help both the modeler and future reviewers keep track. EPA also recommends that an output database name end with “_out” to indicate it is an output database and distinguish it from an input database. Only letters, numbers, and underscores can be used for database names.

An output database can hold the results of multiple MOVES runs. EPA recommends that modelers use the same output database for all of the runs associated with a project. More discussion of good data management practices is found in Section 2.3.10.

Units for output of “grams”, “joules, and “miles” are already chosen and the user can change them as needed. Also, “Distance Traveled” and “Population” should be selected under the “Activity” heading to obtain vehicle volume information for each link in the output.

2.3.9 Output Emissions Detail

Output Emissions Detail is used to specify the level of detail desired in the output data. Emissions by hour and link are the default selections and cannot be changed. Road type and “Emission Process” will also be checked if Emission Rates was selected on the Scale Panel. For an Inventory run, EPA recommends that users select the box labeled “Emission Process.” No other boxes should be selected in order to produce fleet aggregate emission rates for each link. Emission rates for each process can be appropriately summed to calculate aggregate CO emission rates for each link (as described previously in Section 2.3.7).

2.3.10 Create Input Database

The Create Input Database Panel becomes available after all the other Navigation Panel items have been completed and have green checks. The user can create the input database by entering a name. (However, it is not necessary to create the database before opening the Project Data Manager, which can be done by clicking the “Enter/Edit Data” button.)

Good data management practices are essential to prevent confusion and errors, particularly when doing a refined analysis with multiple MOVES runs, because each

would need its own input database. Where there are multiple runs, it is helpful for the input database name to be related to the name of the project and the hour selected for the run, to help both the modeler and future reviewers keep track.²³ For example, EPA recommends the following conventions:

- Use a naming protocol for each of the input databases that reflects the purpose of that run, e.g., “ProjectName_PeakHR_in”. EPA recommends that input database names end with “_in” to indicate it is a user input database. Only letters, numbers, and underscores can be used for database names.
- When the RunSpec is complete, save each RunSpec with a name that relates to the input database name, e.g., “ProjectName_PeakHR.mrs”. EPA recommends saving RunSpecs with the extension “.mrs”, short for “MOVES RunSpec”, so that these files can be easily identified.

Section 4.5 describes how to populate an input database using the Project Data Manager. Once a database has been completely populated and the Project Data Manager has been closed, users should ensure that the correct database is selected on the Create Input Database Panel. If it is not auto-populated, users may have to hit the Refresh button to make sure the database they created appears in the dropdown list.

2.3.11 Advanced Features

The Advanced Features Panel is used to invoke features that are used for model diagnostics and other special purposes. In general, the features on this panel are not appropriate for SIP and transportation conformity use, except for states that have adopted California Low Emission Vehicle (LEV) criteria pollutant standards (and such California standards have received a Clean Air Act waiver from EPA) and states in the Ozone Transport Commission (OTC) that received early implementation of National Low Emitting Vehicle (NLEV) standards. In these cases, the “Input Data Sets” feature on this panel should be used in conjunction with the LEV/NLEV tools accessed through the Tools drop-down menu in the MOVES GUI. Specifically:

- OTC states that did not adopt California LEV standards but were subject to the early implementation of NLEV should use the “Build NLEV Input Database” tool.
- OTC states that adopted California LEV standards prior to the 2001 model year should use the “Build LEV Input Database” tool.
- OTC states that were subject to the early implementation of NLEV and adopted California LEV standards beginning with model year 2001 or later should use both the “Build LEV Input Database” and the “Build NLEV Input Database” tools.
- All other states that adopted California LEV standards in any year should use the “Build LEV Input Database” tool.

²³ When creating multiple input databases that are similar, once the first input database is created, it can be copied (e.g., with File Explorer or HeidiSQL) and then modified with the Project Data Manager. This may save time compared to creating each new input database from scratch.

Detailed instructions on how to use both tools are available in the MOVES GUI: after opening the tool via the Tools drop-down menu, click the “Open Instructions” button.

After creating the input database(s) with the appropriate tool, users should include these databases in the RunSpec through the “Input Data Sets” section of the Advanced Features Panel. Select the appropriate input database in the database drop-down menu (users may need to click the Refresh button if the database does not appear in the list), and then click the Add button.

2.4 ENTERING PROJECT DETAILS USING THE PROJECT DATA MANAGER

After completion of all the necessary panels to create the RunSpec, the user would then create the necessary input database to describe the project in detail for the period of time selected in the RunSpec. An input database is a set of tables that describe project-specific data to be used for the run, and the Project Data Manager assists the user in creating and populating this set of tables. The Project Data Manager can be accessed from the Create Input Database Panel of the RunSpec with the Enter/Edit Data button.

For a project-level screening analysis, only one input database will be needed. For a refined analysis that includes more than one MOVES run, an input database will be needed for each run. See Section 2.3.10 above for EPA’s recommendations for good data management practices.

Also, each tab of the Project Data Manager includes a box for entering a “Description of Imported Data.” Modelers should make liberal use of these descriptions to (1) indicate whether default or local data were used, and (2) indicate the source and date of any local data, along with the filename of imported spreadsheets. These descriptions are preserved with the input database so reviewers (or future users of the same runs) will have the documentation of inputs readily at hand.

If an input database was not created (by defining a name for it) in the RunSpec “Create Input Database” Panel, a database must be created on the Database Tab. When the database is created, MOVES records the selections in the RunSpec at that moment and uses this information to populate and evaluate database entries. Users should avoid making changes to the RunSpec after the input database has been created, because this can create inconsistencies between the input database and the rest of the RunSpec.

The Project Data Manager includes multiple tabs that open importers, which are used to enter project-specific data. These tabs and importers are:

- Meteorology Data
- Age Distribution
- Fuel
- I/M ProgramsRetrofit Data
- Links
- Link Source Types

- Link Drive Schedules
- Operating Mode Distribution
- Off-Network
- Hotelling
- Generic

Each of the importers allows the user to create a template file with required data field names and with some key fields populated. The user then edits this template to add project specific local data with a spreadsheet application or other tool and imports the data files into MOVES. In some importers, there is also the option to export default data from the MOVES database in order to review it. Once the user determines that the default data are accurate and applicable to the particular project, or determines that the default data need to be changed and makes those changes, the user then imports that data into MOVES. Details of the mechanics of using the data importers are provided in the MOVES training.²⁴ Guidance for the use of these importers in project-level CO analyses is described below.

To run MOVES, each of the importer tabs must have a green check; MOVES3 will not run if any of them have a red X. The initial status of the tabs depends on the selections made in the RunSpec. For instance, when a project has no off-network links, the Off-Network Road Type would not be selected in the RunSpec. In this case, the Off-Network and Hotelling Importers would not be used and therefore those tabs will display green checks. However, if any hotelling processes are selected in the RunSpec, the Hotelling Importer will begin with a red X to indicate data is needed.

In addition, the status of some tabs depends on data loaded on other tabs. For example, when a project has an off-network link, the Operating Mode Distribution Tab will start with a green check when the database is first created. When the Links Tab is used to import an off-network link, the Operating Mode Distribution Tab will change to show a red X, indicating that data is needed. Once the Operating Mode Distribution Tab is used to import the vehicle soak activity, the tab will update to show a green check. Note that where an input includes “sourceTypeID” (type of vehicle) as a column heading, such as Off-Network and Operating Mode Distribution, MOVES3 requires that all vehicles selected in the RunSpec be included in that table to get a green check on that tab.

Most analyses will not use all of the importers. Some tabs, such as Link Drive Schedules, Retrofit Data, and Generic are optional and always have green checks unless there is an issue with any of the imported data.

2.4.1 Meteorology Data

The Meteorology Data Importer is used to import temperature and humidity data for the month and hour that are defined in the MOVES RunSpec. Default temperature and

²⁴ See the latest version of “Hands-On Training” at: <https://www.epa.gov/moves/moves-training-sessions>.

humidity values are available in MOVES, but are not recommended for use in a project-level CO analysis.

Screening Analyses of Roadway Intersections

The 1992 Guideline recommends the following two options for defining temperature and humidity for screening analyses of intersections:

1. The temperature and humidity corresponding to each of the ten highest non-overlapping 8-hour CO monitoring values for the last three years should be obtained. The average 8-hour temperature and humidity for each event should be calculated and then all ten values should be averaged for use with MOVES.
2. Alternatively, the average temperature and humidity in January may be used.²⁵

Meteorological data may be obtained either from the National Weather Service (NWS) or as part of a site-specific measurement program. Local universities, the Federal Aviation Administration (FAA), military stations, and state and local air agencies may also be sources of such data. The National Oceanic and Atmospheric Administration's National Centers for Environmental Information (NCEI); online at <https://www.ncei.noaa.gov/> is the world's largest active archive of weather data through which years of archived data can be obtained. A data source should be selected that is representative of local meteorological conditions.

All Other Screening Analyses

The 1992 Guideline does not expressly address what conditions should be captured for a CO screening analysis of a project that is not solely a roadway intersection. However, the guidance given in the 1992 Guideline may also be appropriate for any CO screening analysis.

Refined Analyses of Any Project

For refined analyses, users should enter data specific to the project's location and time period modeled, as CO emissions are found to vary depending on temperature. As discussed in Section 2.2.3, in a refined analysis MOVES will typically be run for multiple time periods and specific meteorology data that accurately represents these runs is needed. Within each period of the day, in each quarter selected, temperatures should be used that represent the average temperature within that time period. For example, for January AM peak periods corresponding to 6 a.m. to 9 a.m., the average January temperature based on the meteorological record for those hours should be used in estimating the average January AM peak period temperature for MOVES runs. The user may choose to run additional hours and temperatures beyond the number of traffic periods for which data exist. For example, within an 11-hour overnight (ON) modeling period, temperature data could be used to differentiate hours with significantly different

²⁵ See 1992 Guideline, Section 4.7.1.

temperatures, despite having assumed identical traffic estimates. Humidity estimates should be based on the same hours and data source as the temperature estimates.

2.4.2 Age Distribution

The Age Distribution Importer is used to enter data that provides the distribution of vehicle fractions by age for each calendar year (yearID) and vehicle type (sourceTypeID). These data are required for running MOVES at the project level. The distribution of ageID (the variable for age) fractions must sum to one for each vehicle type and calendar year.

To build a MOVES-compatible age distribution table for project-level CO analyses, there are three possible options.

1. If available, users should use the latest available state or local age distribution assumptions from their SIP or transportation conformity regional emissions analysis. The MOVES3 Technical Guidance covers how this would be created.²⁶
2. If the project is designed to serve a fleet that operates only locally, such as a drayage yard or bus terminal, the user should provide project-specific fleet age distribution data. For most captive fleets, an exact age distribution should be readily available or obtainable. The data should be in a format compatible with MOVES.
3. If no state or local age distribution is available, the MOVES default age distribution can be used by exporting it from the Age Distribution Importer. These fractions are national defaults and could be significantly different than the local project age distribution. Age distribution can have a considerable impact on emission estimates, so the default data should be used only if an alternative state or local dataset cannot be obtained. However, for single unit long-haul and combination long-haul trucks, it is generally more appropriate to use MOVES national default age distributions.

2.4.3 Fuel

The user needs to define in MOVES what fuel(s) and fuel mix will be used in the project area. The four required tables in the Fuel Importer: FuelSupply, FuelFormulation, FuelUsageFraction, and AVFT (Alternative Vehicle and Fuel Technology) are used to enter the necessary information describing fuel mix and fuel type for each MOVES run, including the appropriate fractions of gasoline, diesel, compressed natural gas and electric vehicles.

²⁶ See EPA's *MOVES3 Technical Guidance: Using MOVES to Prepare Emission Inventories for State Implementation Plans and Transportation Conformity*, EPA-420-B-20-052 November 2020, available on EPA's web site at: <https://www.epa.gov/state-and-local-transportation/policy-and-technical-guidance-state-and-local-transportation#emission>.

Users should review the default fuel formulation and fuel supply data in MOVES by exporting it from the Fuel Importer, and make changes only if local volumetric fuel property information is available. Otherwise, EPA strongly recommends that the MOVES default fuel information be used for project-level CO analyses unless a full local fuel property study exists. The exception to this is in the case of Reid Vapor Pressure (RVP), where a user should change the value to reflect the differences between ethanol and non-ethanol blended gasoline not reflected in the default database. Any changes to RVP (or to any other gasoline formulation parameters) should be done using the “Fuel Wizard” tool accessible in the Fuel Importer.

For additional guidance on defining fuel information, consult EPA’s MOVES3 Technical Guidance.²⁷

2.4.4 I/M Programs

Projects within areas covered by an Inspection and Maintenance (I/M) program should define the program in the MOVES I/M Programs Importer. Users should first examine the default I/M program description included in MOVES for the particular county in question. The default I/M data can be reviewed by selecting the Export Default Data button in the I/M tab of the Project Data Manager. Users should review the details of the default I/M program and make any necessary changes to match the actual local program that is planned to be in place in the year being analyzed.

For additional guidance on defining an I/M program in MOVES, consult the MOVES Technical Guidance.²⁸

If the area does not have an I/M program, the box next to “No I/M Program” should be checked to produce a green check for this importer.

2.4.5 Retrofit Data

The Retrofit Data Importer in MOVES allows users to enter heavy-duty diesel retrofit and/or replacement program data that apply adjustments to vehicle emission rates. There are no default retrofit or replacement data in MOVES. However, users are not required to input such data into MOVES; they would only do so if they have a retrofit or replacement program that they want to model. For example, a bus terminal project might include plans to mitigate emissions by either retrofitting the bus fleet that will operate at that terminal with control equipment that reduces CO emissions or replacing some or all of the bus fleet. In that case, the user would specify the details of the retrofit or replacement project using the Retrofit Data Importer. Please refer to EPA’s latest guidance on quantifying emission reductions from retrofit and replacement programs for

²⁷ The MOVES3 Technical Guidance can be found at: <https://www.epa.gov/state-and-local-transportation/policy-and-technical-guidance-state-and-local-transportation#emission>.

²⁸ See footnote 27.

SIP and conformity purposes.²⁹ Strategies that affect vehicle activity, such as implementing a truck idle reduction plan, should be handled in the Off-Network Importer and Links Importer.

2.4.6 Links

The Links Importer is used to define the individual roadway links. All links being modeled should have unique IDs. The Links Importer requires information on each link's length (in miles), traffic volume (units of vehicles per hour), average speed (miles per hour), and road grade (percent; 100 percent equals a 45-degree slope). Users should follow guidance given in Section 2.1 when determining the number of links and the length of each link.

This importer also includes a column to add a link description. Descriptions are helpful to both modelers and reviewers to keep track of what is included in the modeling run.

Note that if the run includes the Off-Network Road Type, the Operating Mode Distribution Importer will not display a green check until the vehicle soak distribution for the off-network link is entered using the Operating Mode Distribution Importer.

2.4.7 Link Source Types

The Link Source Types Importer allows users to enter the fraction of the link traffic volume that is represented by each vehicle type (source type). It is not required if the project contains only an off-network link. For each LinkID, the "SourceTypeHourFractions" must sum to one across all source types. If there is an off-network link, that LinkID should not be included; instead, information for an off-network link will need to be included in the Off-Network and Operating Mode Distribution Importers.³⁰

Additionally, the user must ensure that the source types selected in the MOVES Vehicles/Equipment Panel match the source types defined through the Link Source Types Importer.

There are no defaults that can be exported from the Link Source Types Importer. For any analysis at the project level, the user must provide source type fractions for all vehicles being modeled. There are two options available to populate the Link Source Types input:

²⁹ *Diesel Retrofit and Replacement Projects: Quantifying and Using Their Emission Benefits in SIPs and Conformity - Guidance for State and Local Air and Transportation Agencies*, EPA-420-B-18-017, March 2018. This guidance can be found on EPA's website at: <https://www.epa.gov/state-and-local-transportation/policy-and-technical-guidance-state-and-local-transportation#quantifying>.

³⁰ When using MOVES 3.0.0 or 3.0.1, and the only link in a MOVES run is an off-network link, the Link Source Types Importer will still need a green check. In this case, create a template for the linkSourceTypeHour table. This will create a file with a row for each source type in the run. Fill in linkID as 0 for each row, and provide a sourceTypeHourFraction that sums to 1. This distribution will not be used since there is no linkID 0 defined in the Links Importer, but it will provide a green check for this importer. This workaround is not needed for MOVES3.0.2 or later versions.

1. For projects that will have an entirely different source type distribution than that of the regional fleet, the preferred option is for the user to collect project-specific data. This data could be based on analysis of similar existing projects. For example, for projects such as bus or freight terminals or maintenance facilities that contain links that are primarily used by a specific subset of the regional fleet, users need to develop the fractions of link traffic volume by vehicle type data specific to the project. This could be based on analysis of similar existing projects through the interagency consultation process.
2. If the project traffic data suggests that the source type distribution for the project can be represented by the distribution of the regional fleet for a given road type, the user can provide a source type distribution consistent with the road type used in the latest regional emissions analysis. For example, interstates tend to have a higher fraction of truck traffic than minor arterial roads. Therefore, the interstate source type distribution used in the regional emissions analysis may be appropriate to use for an interstate project.

2.4.8 Describing Vehicle Activity for Screening Analyses of Roadway Intersections

The Links Importer is also where users may describe vehicle activity for intersection links, including the approach/departure free-flow links and queue links.

Consistent with the 1992 Guideline, to produce emission rates for a CO screening analysis of an intersection, users performing such an analysis should calculate emissions based on average speeds and use the CAL3QHC queuing algorithm for intersection idle queues. The average speed defined for each link is internally matched with a MOVES default drive cycle based on that average speed, road grade, and road type and used to calculate emissions. The intersection free-flow links and queue links should be defined as follows:

Free-Flow Approach and Departure Links

An average free-flow speed and traffic volume should be defined for each free-flow link that reflects conditions at peak traffic conditions. A variety of methods are available to estimate average free-flow speed. Project sponsors should use the appropriate method based on best practices used for highway analysis in the area for determining congested average speeds.

Queue Links

Queue links should be assigned an average speed of zero, indicating entirely idle operation, in the Links Importer. The result for such a link would be the emissions from the volume vehicles on that link idling for the entire hour. For screening analysis with CAL3QHC, a grams/vehicle-hour emissions rate is needed. Other inputs to CAL3QHC include signal cycle length and red time length; CAL3QHC has a queuing algorithm that

uses those inputs to determine the amount of time in the hour that vehicles are idling at the signal.

If the analysis is a screening analysis for an intersection, please skip to Section 2.5.

2.4.9 Describing Running Vehicle Activity for All Other Screening Analyses and Refined Analyses of Any Project

When completing screening analyses of projects not covered by the 1992 Guideline, or any refined analysis, modelers may use the average speed input or choose to use one of the optional alternative MOVES activity inputs: Link Drive Schedule or Operating Mode Distribution. For these types of analyses, idling should be explicitly included in the link activity entered into MOVES instead of being determined by the CAL3QHC queuing algorithm. This section describes these options in more detail, as well as describing how to enter off-network activity into MOVES.

Entering Link Activity into MOVES

MOVES determines vehicle emissions based on operating modes, which represent different types of vehicle activity such as acceleration (at different rates), deceleration, idle, and cruise that have distinct emission rates. MOVES handles these data in the form of a distribution of the time vehicles spend in different operating modes.

There are several methods that users may employ to generate an operating mode distribution based on the project design and available traffic information. MOVES currently offers three options that the user can employ to add link activity data, depending on data availability. These are:

1. Provide average speed and road type through the Links Importer:
Using this approach, MOVES will calculate emissions based on a default drive cycle for a given speed, grade, and road type. Input of link drive schedules or operating mode distributions is not needed. For users modeling a free-flow link with only basic information on average speed and volume on a link, this option may be appropriate. This approach accounts for some differences in emissions due to changes in operating modes associated with different average speeds on a specific road type. However, this approach provides the least resolution when analyzing the emission impact of a project because the default drive cycles used by the model may not accurately reflect the specific project. For instance, due to the range of operating modes associated with intersection projects, a single average speed would not spatially capture localized idling and acceleration emissions. Additionally, the default drive schedules may be more appropriate for links on flat terrain.

Average speed is an appropriate input when running MOVES in Inventory mode to model an idle-only link, using a running link with an average speed of 0. The result for such a link would be the emissions from the volume vehicles on that link idling for the entire hour. If vehicles idle for only part of the hour, one approach is to adjust the link volume by the fraction of idling time, i.e., multiply the number of vehicles by (minutes of idling/60 minutes) and use that adjusted vehicle volume for that link in the table. Otherwise, emissions for that link will need to be adjusted by the fraction of idling time in post-processing. When running in Emission Rates mode, an idle-only link must be modeled using an operating mode distribution (see below).

2. Provide a link drive schedule using the Link Drive Schedule Importer:

The Link Drive Schedule Importer allows the user to define the precise speed and grade as a function of time (seconds) on a particular roadway link. The time domain is entered in units of seconds, the speed variable is miles-per-hour and the grade variable in percent grade (vertical distance/lateral distance, 100% grade equals a 45-degree slope).³¹ If this optional importer is used, MOVES will build an operating mode distribution from the information in the Link Drive Schedules table combined with default assumptions regarding vehicle weights and road load coefficients. This MOVES-calculated operating mode distribution will be used to calculate link running emissions instead of using the average speed in the Links table.

Link Drive Schedules are applied to all source types operating on the link. The Link Drive Schedule therefore represents the “tracer” path of an average vehicle on each link. Link drive schedules could be based on observations using methods such as chase (floating) cars on similar types of links, or on expected vehicle activity based an analysis of link geometry. Link drive schedules will only represent average vehicle activity, not the full range of activity that will occur on the link. As described in the appendix, users can overcome this limitation by defining multiple links for the same portion of the project (links that “overlap”) with separate source distributions and drive schedules to model multiple representative vehicles.

3. Provide a detailed operating mode distribution for the link:

The Operating Mode Distribution Importer allows the user to directly import operating mode fraction data for source types, hour/day combinations, roadway links, and pollutant/process combinations that are included in the run specification. Operating mode distributions may be obtained from:

³¹ Note that MOVES does not determine if the vehicle speed trajectory is realistic for assumed vehicle characteristics and the grade input. Users should ensure that vehicle speeds are realistic and appropriate for all characteristics of a link, including grade.

- Op-Mode distribution data from other locations with similar geometric and operational (traffic) characteristics;³² or
- Output from traffic micro-simulation models.³³

If this optional importer is used, MOVES will use these operating mode fractions for calculating link running emissions instead of creating an operating mode distribution from the average speed included in the Links table.

Instructions for the Operating Mode Distribution Input when Using Emission Rates:

When running MOVES in Emission Rates mode, the operating mode distribution input can be used to model an idle-only link on one of the on-network road types:

- With the Links Importer, specify a running link with an average speed of 1 mph.³⁴
- With the Operating Mode Distribution Importer:
 - For all running polProcessIDs (i.e., polProcessIDs with the last two digits of “01”), input a fraction of:
 - 1.0 for opModeID 1
 - 0.0 for opModeIDs 0 and 11 through 40
 - To account for brakewear, input the following fractions for polProcessID 11609 (PM_{2.5}) and 10609 (PM₁₀):
 - 1.0 for opModeID 501
 - 0.0 for opModeIDs 0 through 40
 - To account for tirewear, input the following fractions for polProcessID 11610 (PM_{2.5}) and 10610 (PM₁₀):
 - 1.0 for opModeID 400
 - 0.0 for opModeIDs 401 through 416

Users should consider the discussion in this section when deciding on the appropriate activity input. The MOVES model is capable of using complex activity datasets with high levels of resolution to calculate link-level emissions. EPA encourages the

³² For example, chase (or floating) cars, traffic cameras, and radar guns have been used previously to collect some traffic data for use in intelligent transportation systems and other applications. EPA encourages the development of validated methods for collecting verifiable vehicle operating mode distribution data at specific locations representative of different projects covered by this guidance.

³³ A traffic micro-simulation model can be used to construct link drive schedules or operating mode distributions if prior validation of the model’s predictions of speed and acceleration patterns for roadway links similar to those in the project was conducted. If a user has a micro-simulation model that has been previously demonstrated to adequately predict speed/acceleration patterns for relevant vehicle classes (e.g., heavy-duty), and has a procedure for importing data into MOVES, it may be appropriate to use the micro-simulation model.

³⁴ The units for the running emissions process in Emission Rates mode is “mass per distance,” and no distance is traveled while idling. Therefore, an average speed of 1 mph is used to transform the units for an idling link to “mass per hour.”

development of validated methods for collecting verifiable vehicle Op-Mode distribution data at locations and in traffic conditions representative of different projects covered by this guidance. However, the user should determine the most robust activity dataset that can be reasonably collected while still achieving the goal of determining an accurate assessment of the CO air quality impacts from a given project. The choice of whether to rely on average speed information in the Links Importer, or add more detailed information through the Link Drive Schedules or Op-Mode Distribution Importers should be based on the data available to the user and should reflect the vehicle activity and behavior on each link. Appendix A provides additional detail for using these three options to describe activity at an intersection project.

2.4.10 Describing Starting and Hotelling Vehicle Activity for All Other Screening Analyses and Refined Analyses of Any Project

If the project includes an area where vehicles are starting their engines or in hotelling mode (such as a truck stop, parking lot, or passenger or freight intermodal terminal), additional importers in the Project Data Manager are needed:

- the Off-Network Importer
- the Operating Mode Distribution Importer, and
- if there is hotelling activity, the Hotelling Importer.

Off-Network Importer. This importer is used to describe the off-network link. There are no default values available for any of the off-network inputs, so users will need to populate the Off-Network table with information describing vehicle activity in the off-network area being modeled. The required fields are vehicle population, start fraction, and “extended idle fraction” (which refers to all hotelling activity rather than only extended idling):

- The “vehiclePopulation” column reflects the total number of each source type parked on the off-network area over the course of the hour covered by the MOVES run.³⁵
- The “startFraction” column is the fraction of the total vehicle population that starts during the hour.
- The “extendedIdleFraction” specifies the fraction of time that the vehicle population spends in hotelling operation in the hour. This column should be zero for all vehicles other than long-haul combination trucks, because hotelling is an activity that applies only to long-haul combination trucks. For combination long-haul trucks (SourceTypeID 62), if a non-zero number is entered, the user would also complete the Hotelling Importer.
- The “parkedVehicleFraction” is not required as an input and can be left blank as it is used for evaporative emissions and does not apply to CO modeling.

³⁵ Note that while link volume for the off-network link is required on the Links input, the vehicle population column of the Off-Network table is what MOVES uses to calculate emissions on this link.

The Off-Network Importer allows only one off-network link to be described per run. If more than one off-network link is associated with the project, another MOVES run may be needed to characterize each additional off-network location.³⁶

Operating Mode Distribution Importer. If an off-network link is defined, users need to also define an Op-Mode distribution that describes the soak-time distribution of vehicles on the link; this will affect the start emissions. The soak time is the time a vehicle is stationary with the engine turned off, following the last time it was operated. There are no default soak-time distributions available. Soak times and soak-time distributions should be specific to the type of project being modeled. This information could either be directly collected or obtained from information collected for a similar project. For instance, a park-and-ride lot may have vehicles parked for eight or nine hours prior to starting, while an intermodal freight terminal may have vehicles parked for only one hour before starting. This information should be defined through the appropriate distribution of soak-time Op-Modes (OpModes 101-108) in the Op-Mode Distribution table.³⁷

When a template is created for this importer, operating modes for the running and braking processes (i.e., opModeIDs 0 through 40 and 501) will be present if these processes are selected in the RunSpec. These operating modes should be deleted unless the user is supplying detailed operating mode distributions to describe running activity, as discussed above (in the third option for defining activity on running links using the Operating Mode Distribution Importer).

Hotelling Importer. This importer is needed when the extendedIdleFraction for sourceTypeID 62 (long-haul combination trucks) is non-zero in the Off-Network table. Hotelling operation applies only to long-haul combination trucks and is defined as the operation of the truck in “hotelling” mode, typically at overnight rest areas. In order to heat and cool the cab, as well as to run appliances, an added energy load is necessary. This energy is provided from four possible modes, defined in the Hotelling Importer for each model year:

- Extended idling (OpModeID 200), where the truck engine is operating at a higher RPM than during normal idling to accommodate the extra load from the accessories;
- Diesel auxiliary power unit (OpModeID 201), or APU, where a small, separate diesel engine is used to power accessories;

³⁶ Alternatively, if the off-network links are identical in terms of fleet mix and soak times, one off-network link can be used and the results post-processed so that they can be used to represent parking areas with different numbers of starts per hour. See the MOVES module of EPA’s PM hot-spot training for more information, available on the web site at: <https://www.epa.gov/state-and-local-transportation/project-level-training-quantitative-pm-hot-spot-analyses>. Please consult with EPA if your project includes more than one off-network area.

³⁷ In MOVES3.0.1 or MOVES3.0.0, a template created for this importer may include operating modes for hotelling. These need to be deleted because hotelling operating modes are input through the Hotelling Importer. This is no longer an issue as of MOVES3.0.2. Also note that soak time op-mode definitions are listed in a tab of the spreadsheet. In addition, these definitions can be found on the MOVES Onroad Cheat Sheet available at: https://github.com/USEPA/EPA_MOVES_Model/blob/master/docs/MOVES3CheatsheetOnroad.pdf.

- Battery power (OpModeID 203), where the engine is off and the accessories are being run from battery power; and
- Engine-off (OpModeID 204), where accessories are powered by an external source of electricity available at the truck stop.³⁸

Note that battery power and engine-off both yield zero emissions. Local hotelling activity for a given project will likely be different than the national defaults. Default information is available, but should be used only in the absence of local information. Users should look at the default information and decide whether it is consistent with the expected operating modes in the project's location.

Shorter periods of idling for long-haul combination trucks and all idling for other vehicles should be modeled as a project link with an average speed of "0" mph, as explained above in Section 2.4.9, in the first option for defining activity on running links using average speed in the Links Importer.

Sources of Information and Documentation.

For vehicle population inputs, the user should be able to rely on existing project documentation. The user will also need to estimate the number of starts and hotelling operation of the facility during the peak hour. For example, in a bus terminal project, the user could estimate the number of starts for the peak hour based on expected passenger ridership and proposed operating schedules for the buses using the terminal.

Information on start and hotelling activity should be specific to the project being modeled. However, data from similar projects could be adapted for use in a CO hot-spot analysis, when appropriate. For instance, the ratio of starts to vehicles for a parking lot project being analyzed could be determined by studying a similar parking lot.

The methods and assumptions used to derive off-network inputs (including starts, hotelling activity, and soak-time distributions) should be documented as part of the analysis, including any adjustments based on data from similar projects.

2.5 GENERATING EMISSION RATES FOR USE IN AIR QUALITY MODELING

The MOVES model provides results as either an emission total (if Inventory mode is selected) or an emission rate (if Emission Rates mode is selected). The emission results calculated for each pollutant are in the following terms (assuming grams and miles are selected on the General Output Panel, as described in Section 2.3.8):

- grams/hour for each link in Inventory mode
- grams/vehicle-mile for each link in Emission Rates mode

³⁸ More information is available in the *Population and Activity of Onroad Vehicles in MOVES3*, EPA-420-R021-012, April 2021, available on EPA's website at: <https://www.epa.gov/moves/moves-onroad-technical-reports#moves3> .

Regardless of which mode is used, MOVES will produce emission results at the level of detail selected on the Output Emissions Detail Panel of the RunSpec, as described in Section 2.3.9. For example, if output by “Emission Process” is selected, MOVES will produce separate grams/hour or grams/vehicle-mile results for each emission process modeled.

When run to calculate “Inventory” output (as described in Section 2.3.2), the MOVES model does not explicitly produce the required emission rates. The emission results are calculated by MOVES in terms of absolute grams for each link defined in the “Links” input file. Therefore, the user will need run a MOVES post-processing script to generate the grams/vehicle-mile, grams/vehicle-hour, or other appropriate emission rate. The following sections describe these procedures in more detail for CO screening analyses of intersections as well as other situations.

2.5.1 Screening Analyses of Roadway Intersections

As noted earlier, according to EPA’s regulatory recommendations for air quality modeling (Section 4.2.3.1(b) of Appendix W to 40 CFR Part 51, which references the 1992 Guideline), the CAL3QHC model would be used for CO screening analyses of intersection projects. CAL3QHC calculates air quality estimates based on the defined emission rate, volume of traffic on, and length of a given link in combination with information on signal timing, queue length, and Level-of-Service (LOS). For these analyses, the required information from MOVES is a grams/vehicle-mile emission rate for each free-flow link and a grams/vehicle-hour emission rate for each queue link.

After running MOVES in Inventory Mode, the CO_CAL3QHC_EF script can be run on the output database. Make sure that the correct output database is selected on the General Output Panel, then in the Post Processing menu, select “Run SQL Script on Onroad Output Database.” In the pop-up window, select the CO_CAL3QHC_EF script, and click OK. Then access the script from the MOVES post-processing menu. After running the script, a new table will be created in the MOVES output database called “CO_EmissionFactors.” (Note: the SQL screen may need to be refreshed to display the new table created by the script). The table will contain summary gram/veh-mile rates for running/free-flow links and gram/veh-hour idle rates for queue links. These rates may be used directly in CAL3QHC.

2.5.2 All Other Screening Analyses and Refined Analyses of Any Project

When completing screening analyses of projects not covered by the 1992 Guideline, or any refined analysis, MOVES provides results as either an emission total (if “Inventory” output is selected when developing the RunSpec) or an emission factor (if “Emission Rates” output is selected). The emission results are produced for each pollutant and process and are calculated in terms of grams per link or grams/vehicle-mile per link.

AERMOD requires a single emissions value for each time unit and link being modeled. AERMOD uses a gram/time emission factor for each source and for each hour of the day.

AERMOD sources should be mapped to links modeled by MOVES and the time of day should be mapped based on the time periods analyzed, as described in Section 2.2.3.

MOVES includes post-processing scripts that can calculate a single emissions value for each time unit and link being modeled. After running MOVES, these scripts can be run on the output database. First, make sure that the correct output database is selected on the General Output Panel. Then, in the Post Processing menu, select “Run SQL Script on Onroad Output Database.” In the pop-up window, select the desired script, and click OK. After reading the next informational dialog that pops up, click OK to run the script. Each script will produce a table in the output database, with the table name corresponding to the name of the script. The SQL screen may need to be refreshed to display the new table created by the script.

- If Inventory mode is used, select the “CO_Grams_Per_Hour.sql” script to calculate total emissions in grams/hour for each MOVES run, year, month, hour, and link in the output database. These grams/hour emissions would need to be converted into the appropriate inputs for AERMOD, such as grams/second (volume source type), or grams/second/square meter (line/area source type).
- If Emission Rates mode is used, select the “CO_Grams_Per_Veh_Mile.sql” script to calculate total emissions in grams/vehicle-mile for each MOVES run, year, month, hour, and link in the output database. These grams/vehicle-mile emissions from MOVES would need to be converted into the appropriate inputs for AERMOD. Converting these emissions is more complicated than converting results from Inventory mode, because these rates must be multiplied by the correct hourly volumes and link lengths first, then converted to into the appropriate inputs such as grams/second (volume source type), or grams/second/square meter (line/area source type).

EPA also has a tool, “MOVES2AERMOD,” to convert MOVES results done with Inventory mode into a format that can be included in AERMOD (with the AERMOD keyword EMISFACT). The MOVES2AERMOD script can be found on EPA’s MOVES website.³⁹ The ZIP file contains instructions for using the tool.

This concludes the discussion on how to generate project-level CO emission rates using MOVES. Please refer to the 1992 Guideline and Appendix W to 40 CFR Part 51 for further information on how to incorporate MOVES emission rates into air quality modeling.

³⁹ See EPA’s website at: <https://www.epa.gov/moves/tools-develop-or-convert-moves-inputs#emisfact>. The MOVES2AERMOD tool can be used with any number of MOVES runs. MOVES runs represent emissions at different times. In the MOVES2AERMOD tool, the modeler assigns the runs to the appropriate hours of the day in all four seasons of the year via the “Traffic_Distribution” spreadsheet, one of the three spreadsheets that modelers need to populate to use the tool.

Appendices

Appendix A EXAMPLE: USING MOVES FOR A CO SCREENING ANALYSIS OF AN INTERSECTION

The following is an abbreviated example of using MOVES to calculate CO emission rates for a portion of an intersection project. The example shown is of a single, one-way arterial road through a signalized intersection; while real-world projects would be more complex, this simplified example makes it easier to demonstrate the steps necessary to calculate emission rates using MOVES.

This example does not include the subsequent air quality modeling; project sponsors should refer to the 1992 Guideline for an example of running CAL3QHC for an intersection project using CO emission rates.

Note also that this example includes only an intersection of the type covered by the 1992 Guideline. This example is not relevant for CO refined analyses and may not be relevant for other types of projects. Additionally, all activity will be defined through the average speed function of the Links Importer. It is therefore not necessary to import a Link Drive Schedule, Op-Mode Distribution, or Off-Network table.

The following is some pertinent data about the example project being analyzed:

- The analysis is of a single intersection (see next section for details) located in a county in a state other than California.
- The analysis month and year is January 2025.
- Meteorological data for January at this location is 16.5 degrees Fahrenheit and 84.1% relative humidity.
- All vehicle types are present in the intersection being analyzed; however, no local age distribution is available.
- There is no I/M program for the county where the project is located. This input will not be used.

A.1 CHARACTERIZING THE PROJECT IN TERMS OF LINKS (SECTION 2.1)

A diagram of one road involved in a proposed intersection project is shown in Figure 3. A single free-flow approach link (Link 1) leads to a signalized intersection; vehicles idle at the defined queue link (Link 2), and exit the intersection on the free-flow departure link (Link 3). Vehicle volumes and average speeds are estimated to reflect typical peak hour activity:

Link 1 (Free-flow Approach Link): 1000 vehicles per hour – 45 mph average speed

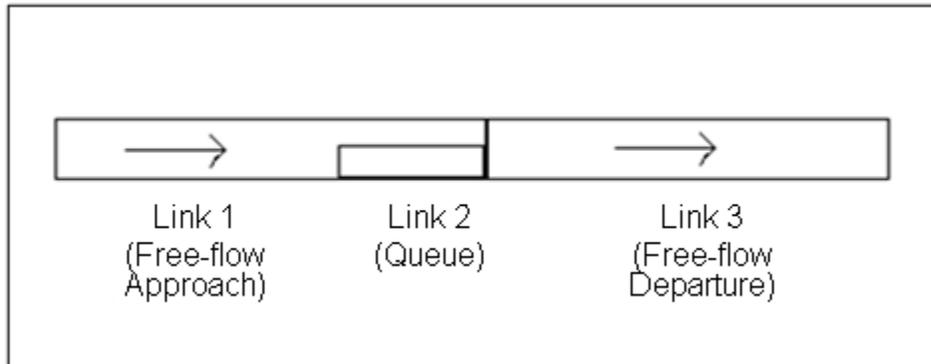
Link 2 (Queue Link): 1000 vehicles per hour – 0 mph speed (idle)

Link 3 (Free-flow Departure Link): 1000 vehicles per hour – 45 mph average speed

All links are at 0% grade. Approach and departure links each have a length of 300 meters. The queue link is assigned a link length of 50 meters.

Note: Since the goal of the MOVES run is to produce a grams/vehicle-mile and/or grams/vehicle-hour emission rate(s), the exact length or volume of each link is not important for running MOVES; in the post-processing script that creates these rates, total emissions will be divided by vehicle volume and for non-queue links, divided by link length as well. Exact length and volume of links are important for subsequent CAL3QHC dispersion modeling.

Figure 3. Links Characterizing the Proposed Intersection



A.2 DETERMINING THE NUMBER OF MOVES RUNS (SECTION 2.2)

This example follows the 1992 Guideline by conservatively using typical peak-hour traffic activity in one MOVES run to generate emission rates.

A.3 DETERMINE BASIC RUN SPECIFICATION INPUTS (SECTION 2.3)

When configuring MOVES for the analysis, a RunSpec is developed following the guidance in Section 2.3:

- Description Panel: though optional, a description of the run is added, including the project name, year being modeled, and the purpose of the run (see Section 2.3.1)
- Scale Panel: “Onroad”, “Project”, and “Inventory” are selected, which will produce total emissions for each link (see Section 2.3.2).
- Time Spans Panel: the appropriate year, month, type of day, and hour is selected (see Section 2.3.3): 2025, January, weekday, 7:00-7:59 am (hourID 8).
- Geographic Bounds Panel: the specific county where the project is located is selected (see Section 2.3.4).
- Onroad Vehicles Panel: all vehicle types are selected (see Section 2.3.5).
- Road Type Panel: the Urban Unrestricted Road Type is selected (see Section 2.3.6).

- Pollutants and Processes Panel: the pollutant/processes CO Running and CO Crankcase Running are selected (see Section 2.3.7). No other CO processes are selected because the project modeled is comprised only of running links: the Off-Network Road Type is not present in this project and therefore no start or hotelling processes need to be selected.
- General Output Panel: an output database is specified, and units of grams and miles are left checked (see Section 2.3.8). Population and Distance Traveled are selected as Activity outputs.
- Output Emissions Detail Panel: no additional boxes are selected.
- Create Input Database Panel: an input database name is chosen, and the “Create Database” button is clicked.

A.4 ENTERING PROJECT DETAILS USING PROJECT DATA MANAGER (SECTION 2.4)

After filling out the appropriate selections in the RunSpec, the project details are entered using the Project Data Manager, which can be accessed from the Create Input Database Panel using the “Enter/Edit Data” button.

A.4.1 Meteorology Data

The meteorology table is populated using the second option in Section 2.4.1 with the average January temperature of 16.5 degrees Fahrenheit and relative humidity of 84.1%. The meteorology input table is shown in Figure 4.

Figure 4. Meteorology Input (Average January Conditions) – Intersection

monthID	zoneID	hourID	temperatu	relHumidity
1	261610	8	16.5	84.1

A.4.2 Age Distribution

For the purposes of this example, no local age distribution is available, so the default MOVES age distribution for 2025 is used. As stated in Section 2.4.2 of the guidance, the default data should be used only if an alternative state or local dataset, e.g., from the area’s latest regional emissions analysis, cannot be obtained. Part of the age distribution table is shown in Figure 5.

Figure 5. Fleet Age Distribution (Partial) – Intersection

sourceTyp	yearID	ageID	ageFraction
11	2025	0	0.058795
11	2025	1	0.05825
11	2025	2	0.056384
11	2025	3	0.052498
11	2025	4	0.050439
11	2025	5	0.047835
11	2025	6	0.045175
11	2025	7	0.042926
11	2025	8	0.031622
11	2025	9	0.029763
11	2025	10	0.028053
11	2025	11	0.026307
11	2025	12	0.022223
11	2025	13	0.023216
11	2025	14	0.016007
11	2025	15	0.012358
11	2025	16	0.027225
11	2025	17	0.033579
11	2025	18	0.04137
11	2025	19	0.040161
11	2025	20	0.036187
11	2025	21	0.029451
11	2025	22	0.031635
11	2025	23	0.025445
11	2025	24	0.021134
11	2025	25	0.01678

A.4.3 Fuel

As recommended in Section 2.4.3 of this guidance, the default MOVES fuel information is used for the analysis (Figures 6, 7, 8, and 9).

Figure 6. Fuel Supply Table – Intersection

fuelRegionID	fuelYearID	monthGroupID	fuelFormulationID	marketShare	marketShareCV
270000000	2025	1	90	1	0.5
270000000	2025	1	9115	1	0.5
270000000	2025	1	25003	1	0.5
270000000	2025	1	27001	1	0.5
270000000	2025	1	28001	1	0.5

Figure 7. Fuel Formulation Table (Partial) – Intersection

fuelFormu	fuelSubtyp	RVP	sulfurLeve	ETOHVolu	MTBEVolu	ETBEVolu	TAMEVolu	aromaticC	olefinCont	benzeneCc	e200	e300
10	10	6.9	30	0	0	0	0	26.1	5.6	1	41.09	83.09
20	20	0	11	0	0	0	0	0	0	0	0	0
30	30	0	7.6	0	0	0	0	0	0	0	0	0
50	51	7.7	11	85	0	0	0	0	0	0	999	999
90	90	0	0	0	0	0	0	0	0	0	0	0
96	10	8.7	338	0	0	0	0	26.4	11.9	1.64	50	83
97	10	6.6	150	0	0	0	0	24	11	0.8	52	84
98	12	8.8	30	10	0	0	0	25.77	8.44	0.65	47.61	84.89
99	12	8.8	30	10	0	0	0	25.77	8.44	0.65	47.61	84.89
9115	12	12.8	10	10	0	0	0	21.7733	8.34953	0.68035	51.5882	85.8947
9415	10	12	10	0	0	0	0	23.4733	6.64953	0.69035	45.1881	85.6947
9715	15	12.65	9.5	15	0	0	0	20.6846	7.93205	0.646333	56.9577	86.572
25003	21	0	6	0	0	0	0	0	0	0	0	0
27001	51	10.5	8	74	0	0	0	0	0	0.16	999	999
28001	30	0	7.6	0	0	0	0	0	0	0	0	0

Figure 8. Fuel Usage Fraction – Intersection

countyID	fuelYearID	modelYear	sourceBin	fuelSupply	usageFraction
26161	2025	0	1	1	1
26161	2025	0	2	2	1
26161	2025	0	3	3	1
26161	2025	0	5	1	0.982134
26161	2025	0	5	5	0.017866
26161	2025	0	9	9	1

Figure 9. Alternative Vehicle and Fuel Technology (Partial) – Intersection

sourceTyp	modelYearID	fuelTypeID	engTechID	fuelEngFraction
11	1960	1	1	1
11	1961	1	1	1
11	1962	1	1	1
11	1963	1	1	1
11	1964	1	1	1
11	1965	1	1	1
11	1966	1	1	1
11	1967	1	1	1
11	1968	1	1	1
11	1969	1	1	1
11	1970	1	1	1
11	1971	1	1	1
11	1972	1	1	1
11	1973	1	1	1
11	1974	1	1	1
11	1975	1	1	1
11	1976	1	1	1
11	1977	1	1	1
11	1978	1	1	1
11	1979	1	1	1
11	1980	1	1	1
11	1981	1	1	1
11	1982	1	1	1
11	1983	1	1	1
11	1984	1	1	1
11	1985	1	1	1
11	1986	1	1	1

A.4.4 I/M Programs

In this example, it is not necessary to input an I/M program since there is no program in the county containing the project. However, the I/M tab needs to have a green check for MOVES to run. Therefore, the Importer is opened and the “No I/M Program” box is checked, which results in a green check on the tab.

A.4.5 Links

The Links table is populated with the parameters of each link (shown in Figure 11). Links 1 and 3 (free-flow approach and departure links) are assigned a link length of 300 meters (0.1875 miles), a link volume of 1000, and an average speed of 45 mph. Link 2 is assigned a link length of 50 meters (0.016 miles), a link volume of 1000, and an average speed of 0 mph. Since no Op-Mode distribution or Link-Drive Schedule is defined for

any of the links, MOVES will calculate emission based on average speed, road type, and grade.

Figure 10. Links Table – Intersection

linkID	countyID	zoneID	roadType	linkLength	linkVolume	linkAvgSpe	linkDescription	linkAvgGrade
1	26161	261610	5	0.1875	1000	45	Approach Link	0
2	26161	261610	5	0.016	1000	0	Queue Link	0
3	26161	261610	5	0.1875	1000	45	Departure Link	0

A.4.6 Link Source Types

The distribution of source types is defined based on the distribution of vehicles on arterial roads used in the latest regional emissions analysis (see Figure 10). The same distribution is used for all three links.

Figure 11. Link Source Types Input Table (Partial) -- Intersection

linkID	sourceTypeID	sourceTypeHourFraction
1	11	0.007727302
1	21	0.701588744
1	31	0.228137367
1	32	0.027312514
1	41	0.00038476
1	42	0.000225036
1	43	0.002638374
1	51	0.000320476
1	52	0.016751713
1	53	0.001927479
1	54	0.003798933
1	61	0.004306703
1	62	0.004880637
2	11	0.007727302
2	21	0.701588744
2	31	0.228137367
2	32	0.027312514
2	41	0.00038476
2	42	0.000225036
2	43	0.002638374
2	51	0.000320476
2	52	0.016751713
2	53	0.001927479
2	54	0.003798933
2	61	0.004306703
2	62	0.004880637
3	11	0.007727302

A.5 GENERATING EMISSION RATES FOR USE IN AIR QUALITY MODELING (SECTION 2.5)

After running MOVES, the MOVES CO_CAL3QHC_EF post-processing script is run. The resulting emission rates (shown in bold in Figure 12) are 2.742 grams/vehicle-mile for the free-flow approach and departure links (Links 1 and 3) and 5.570 grams/vehicle-hour for vehicles idling on the queue link (Link 2). These rates can be now be used in CAL3QHC to complete this CO screening analysis.

Figure 12. Emission Rate Calculations for Each Link – Intersection

movesRun	yearId	monthId	dayId	hourId	linkId	pollutant	GramsPerVehMile	GramsPerVehHour
1	2025	1	5	8	1	CO	2.741874674	
1	2025	1	5	8	2	CO		5.569603027
1	2025	1	5	8	3	CO	2.741874674	

Appendix B EXAMPLE: USING MOVES TO CALCULATE START AND IDLE EMISSION FACTORS AT A PARK AND RIDE LOT

The following is an abbreviated example of using MOVES to calculate CO emission rates for the start and idle activity (gram/vehicle-start and gram/vehicle-hour, respectively) for passenger vehicles associated with a park-and-ride lot serving a transit bus facility. Although this example is for the peak (or worst-case) hour, the methodology described for calculating start and idle emission factors could apply to both screening and refined analyses.

For illustrative purposes, the passenger vehicles are assumed to be entirely passenger cars (source type 21). Additionally, only start and idle emissions are considered in this example to illustrate how to set up MOVES to obtain these emissions. Although a real-world project would likely be more complex, this simplified example makes it easier to demonstrate the steps necessary to calculate emission rates using MOVES.

A more realistic scenario would also include emissions associated with the passenger cars driving as well as transit buses entering and exiting the facility. Users can refer to Section 2 of the guidance, as well as the intersection example in Section 3, for information on how this type of activity – activity on free-flow and queue links – would be defined for such a park-and-ride lot and transit terminal.

The following is some pertinent data about the example project being analyzed:

- The analysis is of a park-and-ride lot serving a transit bus facility (see next section for details) located in a county in a state other than California.
- The analysis month and year is January 2025.
- Meteorological data for January at this location is 25 degrees Fahrenheit and 70% relative humidity.
- An age distribution for passenger cars is available from the latest regional conformity analysis.
- Project engineers have estimated soak times for the cars that will use the lot based on an analysis of similar facilities (see next section for details).
- There is no I/M program active in the county where the project is located.

B.1 CHARACTERIZING THE PROJECT IN TERMS OF LINKS (SECTION 2.1)

To calculate both a start emission factor and idle emission factor for passenger cars, two links are defined. A single idle link (Link 1) is defined to represent idling passenger cars and the road type chosen for this link is “Urban Unrestricted.” The start emission activity from the vehicles is defined through an off-network link (Link 2). The following traffic data is available for the peak hour of activity:

Link 1 (Idle Link): 50 passenger cars idling – 0 mph average speed (idle); road type “Urban Unrestricted”

Link 2 (Off-network Link): 100 starts during the peak hour; road type “Off-Network”

The lengths of the idle link and off-network link are set to 0:

- Idle links can have a link length of zero since there is no distance covered by idling vehicles;
- Off-network links are for estimating emissions when vehicles are parked, started, or hotelling (long-haul combination trucks only), and there is no distance associated with these activities.

Also, both links have a 0% grade.

Based on activity patterns at similar transit park-and-ride lots in the area, project sponsors determine that the hour with the peak emissions will be 5-6 pm (hourID 18) when commuters return to their cars and start them. At that time of day, passenger cars will have been “soaking” for about nine to ten hours. (Soak time is the amount of time a vehicle has not been running before starting again.)

B.2 DETERMINING THE NUMBER OF MOVES RUNS (SECTION 2.2)

Since this is a screening analysis, this example uses peak-hour vehicle activity in one MOVES run to generate “worst-case” emission rates.

B.3 DETERMINE BASIC RUN SPECIFICATION INPUTS (SECTION 2.3)

When configuring MOVES for the analysis, a RunSpec is developed following the guidance in Section 2.3:

- Description Panel: though optional, a description of the run is added, including the project name, year being modeled, and the purpose of the run (see Section 2.3.1)
- Scale Panel: “Onroad,” “Project,” and “Inventory” are selected, which will produce total emissions for each link (see Section 2.3.2).
- Time Spans Panel: the appropriate year, month, type of day, and hour is selected (see Section 2.3.3): 2025, January, weekday, 5:00-5:59 pm (shown on the panel as “17:00-17:59”, which is MOVES hourID 18).
- Geographic Bounds Panel: the specific county where the project is located is selected (see Section 2.3.4).
- Onroad Vehicles Panel: for the purposes of this example, only passenger cars are selected (sourceType 21) (see Section 2.3.5).
- Road Type Panel: the Off-Network and Urban Unrestricted Road Types are selected (see Section 2.3.6).
- Pollutants and Processes Panel: for the pollutant CO, the processes running exhaust, crankcase running exhaust, start exhaust, and crankcase start exhaust, are selected according to the guidance (see Section 2.3.7).
- General Output Panel: an output database is specified, and units of grams and miles are left checked (see Section 2.3.8). Population is selected as an Activity output.

- Output Emissions Detail Panel: No additional boxes are selected.

B.4 ENTERING PROJECT DETAILS USING PROJECT DATA MANAGER (SECTION 2.4)

After filling out the appropriate selections in the RunSpec, the project details were entered using the Project Data Manager.

B.4.1 Meteorology Data

The meteorology table was populated using the second option in Section 2.4.1 with the average January temperature (25 degrees Fahrenheit) and relative humidity (70%). The meteorology input table is shown in Figure 13.

Figure 13. Meteorology Input (Average January Conditions) – Park and Ride

monthID	zoneID	hourID	temperature	relHumidity
1	261610	18	25	70

B.4.2 Age Distribution

An age distribution table was used that reflects the passenger car fleet accessing the park-and-ride lot (see Figure 14). In this example, the age distribution used is based on the latest regional SIP, as discussed in Section 2.4.2 of the guidance.

Figure 14. Fleet Age Distribution (Partial) – Park and Ride

sourceTyp	yearID	ageID	ageFraction
21	2025	0	0.133990
21	2025	1	0.145950
21	2025	2	0.114040
21	2025	3	0.093500
21	2025	4	0.066700
21	2025	5	0.051590
21	2025	6	0.049480
21	2025	7	0.043290
21	2025	8	0.033510
21	2025	9	0.031090
21	2025	10	0.018740
21	2025	11	0.012660
21	2025	12	0.013140
21	2025	13	0.012240
21	2025	14	0.012450
21	2025	15	0.010690
21	2025	16	0.020260
21	2025	17	0.015660
21	2025	18	0.012790
21	2025	19	0.014070
21	2025	20	0.017810
21	2025	21	0.011510
21	2025	22	0.011170
21	2025	23	0.009270
21	2025	24	0.007693
21	2025	25	0.006385
21	2025	26	0.005299

B.4.3 Fuel

As recommended in Section 2.4.3 of this guidance, the default MOVES fuel information was used for the analysis (Figures 15, 16, 17, and 18). However, the AVFT table was changed to model an entirely gasoline fleet (fractions of 1.0 for all gasoline passenger cars).

Figure 15. Fuel Supply Table – Park and Ride

fuelRegionID	fuelYearID	monthGroupID	fuelFormulationID	marketSha	marketShareCV
270000000	2025	1	90	1	0.5
270000000	2025	1	9115	1	0.5
270000000	2025	1	25003	1	0.5
270000000	2025	1	27001	1	0.5

Figure 16. Fuel Formulation Table (Partial) – Park and Ride

fuelFormu	fuelSubtyp	RVP	sulfurLeve	ETOHVolu	MTBEVolu	ETBEVolu	TAMEVolu	aromaticC	olefinCont	benzeneC	e200	e300
10	10	6.9	30	0	0	0	0	26.1	5.6	1	41.09	83.09
20	20	0	11	0	0	0	0	0	0	0	0	0
50	51	7.7	11	85	0	0	0	0	0	0	999	999
90	90	0	0	0	0	0	0	0	0	0	0	0
96	10	8.7	338	0	0	0	0	26.4	11.9	1.64	50	83
97	10	6.6	150	0	0	0	0	24	11	0.8	52	84
98	12	8.8	30	10	0	0	0	25.77	8.44	0.65	47.61	84.89
99	12	8.8	30	10	0	0	0	25.77	8.44	0.65	47.61	84.89
9115	12	12.8	10	10	0	0	0	21.7733	8.34953	0.68035	51.5882	85.8947
9415	10	12	10	0	0	0	0	23.4733	6.64953	0.69035	45.1881	85.6947
9715	15	12.65	9.5	15	0	0	0	20.6846	7.93205	0.646333	56.9577	86.572
25003	21	0	6	0	0	0	0	0	0	0	0	0
27001	51	10.5	8	74	0	0	0	0	0	0.16	999	999

Figure 17. Fuel Usage Fraction – Park and Ride

countyID	fuelYearID	modelYearGro	sourceBinFuel	fuelSupplyFue	usageFraction
26161	2025	0	1	1	1
26161	2025	0	2	2	1
26161	2025	0	5	1	0.982134
26161	2025	0	5	5	0.017866
26161	2025	0	9	9	1

Figure 18. Alternative Vehicle and Fuel Technology (Partial) – Park and Ride

sourceTyp	modelYearID	fuelTypeID	engTechID	fuelEngFraction
21	1960	1	1	1
21	1960	2	1	0
21	1960	5	1	0
21	1960	9	30	0
21	1961	1	1	1
21	1961	2	1	0
21	1961	5	1	0
21	1961	9	30	0
21	1962	1	1	1
21	1962	2	1	0
21	1962	5	1	0
21	1962	9	30	0
21	1963	1	1	1
21	1963	2	1	0
21	1963	5	1	0
21	1963	9	30	0
21	1964	1	1	1
21	1964	2	1	0
21	1964	5	1	0
21	1964	9	30	0
21	1965	1	1	1
21	1965	2	1	0
21	1965	5	1	0
21	1965	9	30	0
21	1966	1	1	1
21	1966	2	1	0
21	1966	5	1	0

B.4.4 Inspection and Maintenance (I/M)

In this example, it is not necessary to input an I/M program since there is no program in the county containing the project. However, the I/M tab needs to have a green check for MOVES to run. Therefore, the Importer is opened and the “No I/M Program” box is checked, which results in a green check on the tab.

B.4.5 Links

The Links table was populated with the parameters of each link (shown in Figure 20). To reflect the previously described peak hour activity:

- Link 1 is defined as the idle link (road type ID 5), with a link length of 0 miles, a link volume of 50, and an average speed of 0 mph.
- Link 2 is defined as the off-network link (road type ID 1), with a link length of 0 miles, a link volume of 100, and an average speed of 0 mph.

Figure 19. Links Table – Park and Ride

linkID	countyID	zoneID	roadTypeID	linkLength	linkVolume	linkAvgSpeed	linkDescription	linkAvgGrade
1	26161	261610	5	0	50	0	Idle link	0
2	26161	261610	1	0	100	0	Off-network link (starts)	0

B.4.6 Link Source Types

A source type distribution was defined for the idle link, Link 1. All activity is from passenger cars (sourceType 21 - see Figure 19). The source type distribution for the starting vehicles on the Off-Network link (Link 2) is defined in the Off-Network Table (see Section 4.4.7).

Figure 20. Link Source Types Input Table – Park and Ride

linkID	sourceTyp	sourceTypeHourFraction
1	21	1

B.4.7 Off-Network and Op-Mode Distribution

Information on start activity is defined through both the Off-Network and Op-Mode Distribution tables. First, the source type and link volume are defined in the Off-Network Table (Figure 21) with a start fraction of 1 (indicating that all 100 vehicles are starting during the hour). The extended idle fraction and parked vehicle fraction are set to 0.⁴⁰

Figure 21. Off-Network Table – Park and Ride

zoneID	sourceTyp	vehiclePopulation	startFraction	extendedIdleFraction	parkedVehicleFraction
261610	21	100	1	0	0

The soak distribution (the time spent parked before starting) is defined in the Op-Mode Distribution Table. As noted in Section 4.1, for this specific project, all passenger cars have been parked for nine to 10 hours prior to starting. As shown in Figure 22, the OpModeID corresponding to this soak time is OpModeID107.⁴¹ Start emissions for CO come from both the start exhaust process (polProcess 202), as well as the crankcase start process (polProcess 216). A fraction of 1 for OpModeID 107 is defined for each pollutant process.

⁴⁰ Note: the “Extended Idle Fraction” field is only relevant for Long-Haul Combination Diesel Trucks. See the MOVES Technical Guidance for more information.

⁴¹ For a list of OpModeIDs, as well IDs for many other MOVES inputs, see EPA’s MOVES3 Onroad Cheat Sheet, available at: https://github.com/USEPA/EPA_MOVES_Model/blob/master/docs/MOVES3CheatsheetOnroad.pdf.

Figure 22. Op-Mode Distribution Table – Park and Ride

sourceTyp	hourDayID	linkID	polProcessID	opModeID	opModeFraction
21	185	2	202	107	1
21	185	2	216	107	1

B.5 GENERATING EMISSION RATES FOR USE IN AIR QUALITY MODELING (SECTION 2.5)

After running MOVES, the post-processing script “CO_Grams_Per_Hour” was run on the output database. The resulting emission rates (shown in Figure 23) are used in air quality modeling.

Figure 23. Emission Rates for Each Link – Park and Ride

movesRun	yearId	monthId	hourId	linkId	pollutant	gramsPerHour
1	2025	1	18	1	Total CO	86.94779205
1	2025	1	18	2	Total CO	1944.270508

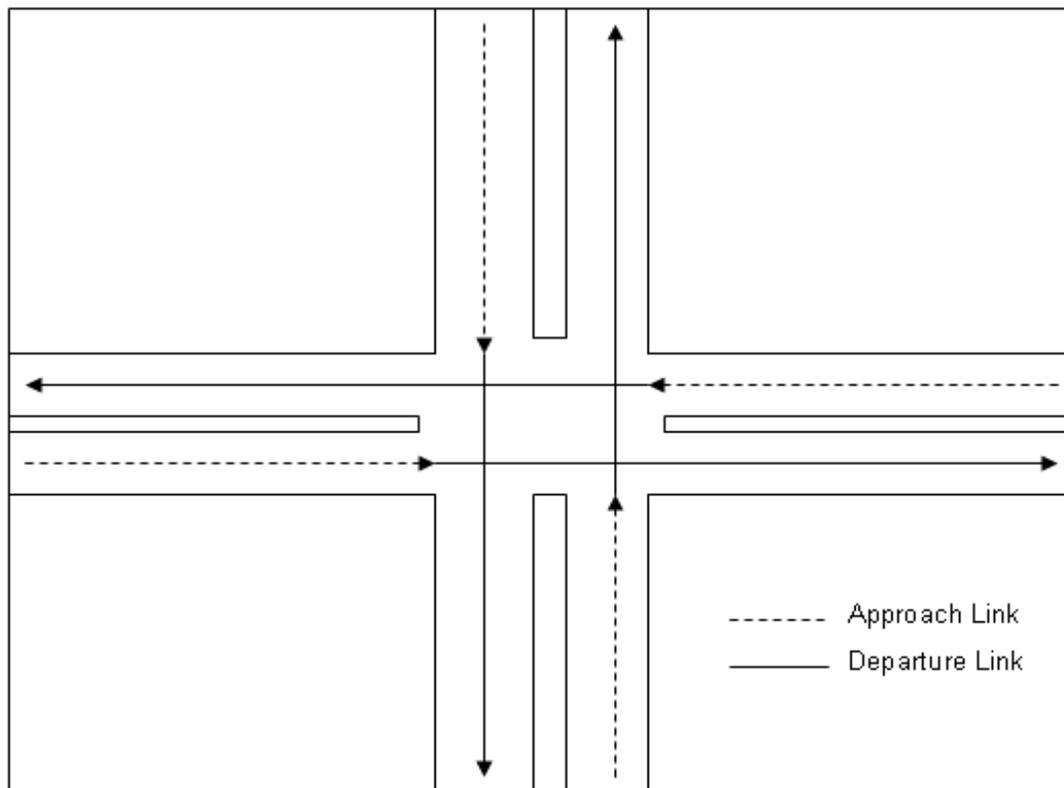
Appendix C CHARACTERIZING INTERSECTION PROJECTS FOR CO REFINED ANALYSES USING MOVES

C.1 INTRODUCTION

This appendix expands upon the discussion in Section 2.1 on how best to characterize links when modeling an intersection project using MOVES. The MOVES emissions model allows users to represent intersection traffic activity with a higher degree of sophistication compared to previous models. This appendix provides several options to describe vehicle activity to take advantage of the capabilities MOVES offers to complete modeling for CO refined analyses of intersection projects.

Figure 24 is an example of a simple signalized intersection showing the intersection divided into areas of approach and departure. The dotted arrows represent where vehicles approach the signal, and the solid arrows represent where vehicles depart from the signal.

Figure 24. Example of a Simple Intersection



When modeling an intersection, each area of approach and departure can be modeled as one or more links in MOVES depending on the option chosen to enter traffic activity.

This guidance suggests three possible options for characterizing activity when CO refined analyses are completed:

- Option 1: Using average speeds
- Option 2: Using link drive schedules
- Option 3: Using Op-Mode distributions

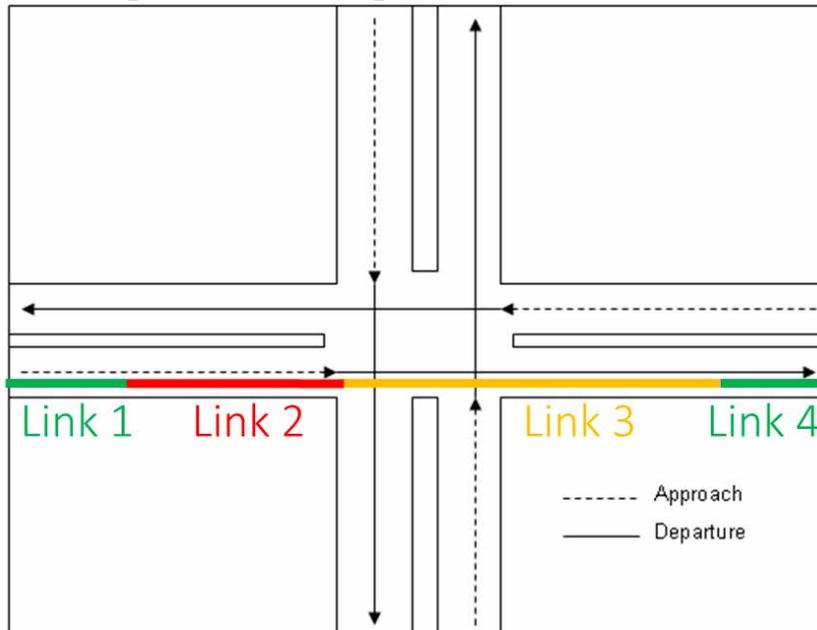
When more detailed data are available to describe vehicle activity, users are encouraged to consider using the Options 2 and 3 to take full advantage of the capabilities of MOVES.

Once a decision has been made on how to characterize links, users should continue to develop the remaining MOVES inputs as discussed in Section 2.4 of the guidance.

C.2 OPTION 1: USING AVERAGE SPEEDS

The first option is for the user to estimate the average speeds for each link in the intersection based on travel time and distance. Travel time should account for the total delay attributable to traffic signal operation, including the portion of travel when the light is green and the portion of travel when the light is red. The effect of a traffic signal cycle on travel time includes deceleration delay, move-up time in a queue, stopped delay, and acceleration delay. Using the intersection example given in Figure 24, one option is to model each direction as a series of links that represent different areas of activity. Each of these links could have a unique average speed based on all the activity occurring on that link.

Figure 25. Example Links at a Simple Intersection



In this example:

- Link 1 represents a “cruise” link where activity is not affected by the traffic signal.
- Link 2 represents a “queue” link that reflects the higher emissions associated with vehicle idling through lower speeds affected by stopped delay. Activity on this link includes deceleration, idle, and acceleration when the signal is red; and cruise activity when the signal is green. (This link includes all of this activity because this is a refined analysis rather than a screening analysis.)
- Link 3 represents an “acceleration” link that reflects the higher emissions associated with vehicle acceleration through lower speeds affected by acceleration delay when the signal is red; and cruise activity when the signal is green.
- Link 4, like Link 1, represents a cruise link where activity is not affected by the traffic signal. Cruise links further away from intersections would not have any delay from the traffic signal.

A variety of methods are available to estimate average speed. Project sponsors determine congested speeds by using appropriate methods based on best practices for highway analyses. Some resources are available through FHWA’s Travel Model Improvement Program (TMIP).⁴² Methodologies for computing intersection control delay are provided in the Highway Capacity Manual.⁴³

C.3 OPTION 2: USING LINK DRIVE SCHEDULES

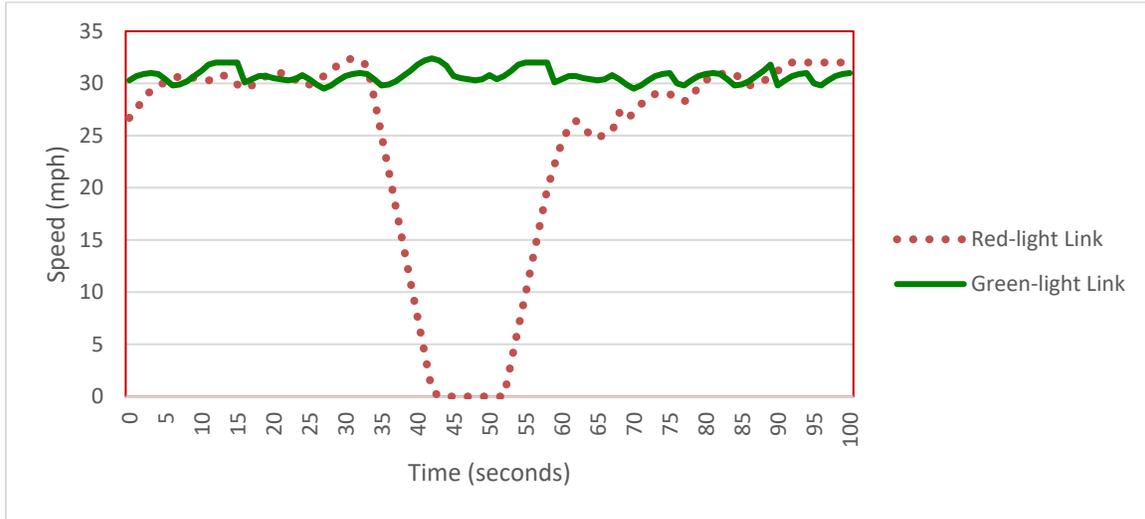
A more refined approach is to enter vehicle activity into MOVES as one or more link drive schedules to represent cruise, deceleration, idle, and acceleration activity of a congested intersection. A link drive schedule defines a speed trajectory to represent the entire vehicle fleet via second-by-second changes in speed and highway grade. Unique link drive schedules can be defined to describe types of vehicle activity that have distinct emission rates, including cruise, deceleration, idle, and acceleration. By defining a link drive schedule, all of these activity types can be included in the link.

Figure 26 illustrates why using this more refined approach can result in a more detailed emissions analysis. This figure shows the trajectories of two vehicles approaching and progressing through an intersection: one vehicle that stops because of the red phase of a traffic light cycle (the red-light link, shown as the red dotted line), and a second vehicle that does not stop because the light is green (the green-light link, shown as the solid green line).

⁴² See FHWA’s TMIP website: <http://tmip.fhwa.dot.gov/>.

⁴³ Users should consult the most recent version of the Highway Capacity Manual. As of the release of this guidance, the latest version is the *Highway Capacity Manual, Sixth Edition* (2016) which can be obtained from the Transportation Research Board (see <https://www.trb.org/publications/hcm6e.aspx> for details).

Figure 26. Example Link Drive Schedules for Links Representing a Signalized Intersection



For the example intersection in Figure 24, two links could be used to represent each direction of travel. (If the vehicle mix and drive schedules are the same for each direction of travel, then two links could be used for all four directions and the two links would be modeled with the total volume representing all four directions of travel. If the streets have different speed limits or have different percentages of light- and heavy-duty vehicles, then two links would be needed for each of the four directions.)

The two links would have distinct drive schedules that represent either the vehicles encountering the red light or vehicles encountering the green light, as shown in Figure 26:

- Red-light link: The red-light link is characterized by several distinct phases: a steady cruise speed, decelerating to a stop for the red light, idling during the red signal phase, and accelerating when the light turns green. Each vehicle approaching the intersection when the light is red (or yellow) would have a similar speed trace except for the duration of idle time, which would vary depending on whether the vehicle was stopped at the beginning, middle, or end of the red light phase. Therefore, the red-light link drive schedule can be input with the average idle time of vehicles that stop at that signal.
- Green-light link: In contrast, vehicles progressing through an intersection during the green signal phase of a traffic light cycle can be characterized by a more or less steady cruise speed through the intersection. These vehicles can be represented with a separate link with a link drive schedule reflecting this steady cruise activity.
- Vehicle volumes for the red-light link and the green-light link should total the number of vehicles proceeding through the intersection in the hour. (The vehicle volumes may or may not be equal; it depends on the percent of time that the light is red vs. green.)
- The link lengths of these two links should be the same.

There are other considerations with numerous vehicles stopping and starting at an intersection over many signal cycles during an hour. Modelers should use additional links if necessary to capture the differences in vehicle types. For instance, heavy trucks decelerate and accelerate at slower rates than passenger cars. These could be defined with additional links that have unique link drive schedules. In this case, the links need to reflect the appropriate vehicle types (done through the Link Source Type Input).

Drivers tend not to decelerate at a constant rate, but through a combination of coasting and light and heavy braking. Acceleration rates are initially higher when starting from a complete stop at an intersection, becoming progressively lower to make a smooth transition to cruise speed.

In the case of an uncongested intersection, the rates of vehicles approaching and departing the intersection are in equilibrium. Some vehicles may slow, and then speed up to join the dissipating queue without having to come to a full stop. Once the queue clears, approaching vehicles during the remainder of the green phase of the cycle will cruise through the intersection virtually unimpeded.

In the case of a congested intersection, the rate of vehicles approaching the intersection is greater than the rate of departure, with the result that no vehicle can travel through without stopping; vehicles approaching the traffic signal, whether it is red or green, will have to come to a full stop and idle for one or more cycles before departing the intersection. The latest Highway Capacity Manual is a good source of information for vehicle operation through signalized intersections. All assumptions, methods, and data underlying the development of link drive schedules should be documented as part of the CO project-level analysis.

For both free-flow highway and intersection links, users may directly enter output from traffic simulation models in the form of second-by-second individual vehicle trajectories. These vehicle trajectories for each road segment can be input into MOVES using the Link Drive Schedule Importer and defined as unique LinkIDs. There are no limits in MOVES as to how many links can be defined; however, model run times increase as the user defines more links. A representative sampling of vehicles can be used to model higher volume segments by adjusting the resulting sum of emissions to account for the higher traffic volume. For example, if a sampling of 5,000 vehicles (5,000 links) was used to represent the driving patterns of 150,000 vehicles, then the sum of emissions would be multiplied by a factor of 30 to account for the higher traffic volume (i.e., 150,000 vehicles/5,000 vehicles). Since the vehicle trajectories include idling, acceleration, deceleration, and cruise, separate roadway links do not have to be explicitly defined to show changes in driving patterns (i.e., both the red light and green light driving cycles are going to be represented in these 5000 links). The sum of emissions from each vehicle trajectory (LinkID) represents the total emission contribution of a given road segment.

The emission factors obtained from MOVES for each segment of vehicle activity obtained via individual link drive schedules are readily transferable to air quality models.

C.4 OPTION 3: USING OP-MODE DISTRIBUTIONS

A third option is for a user to generate representative Op-Mode distributions for approach and departure links by calculating the fraction of fleet travel times spent in each mode of operation. For any given signalized intersection, vehicles are cruising, decelerating, idling, and accelerating. Op-Mode distributions can be calculated from the ratios of individual mode travel times to total travel times on approach links and departure links. This type of information could be obtained from Op-Mode distribution data from:

- 1) existing intersections with similar geometric and operational (traffic) characteristics, or
- 2) output from traffic simulation models for the proposed project or similar projects.

Acceleration and deceleration assumptions, methods, and data underlying the activity-to-Op-Mode calculations should be documented as part of the CO project-level analysis.

The following methodology describes a series of equations to assist in calculating vehicle travel times on approach and departure links. Note that a single approach and single departure link should be defined to characterize vehicles approaching, idling at, and departing an intersection (e.g., there is no need for an “idling link,” as vehicle idling is captured as part of the approach link).

C.4.1 Approach Links

When modeling each approach link, the fraction of fleet travel times in seconds (s) in each mode of operation should be determined based on the fraction of time spent cruising, decelerating, accelerating, and idling:

$$\text{Total Fleet Travel Time (s)} = \text{Cruise Time} + \text{Decel Time} + \text{Accel Time} + \text{Idle Time}$$

The cruise travel time can be represented by the number of vehicles cruising multiplied by the length of approach divided by the average cruise speed.

$$\text{Cruise Time (s)} = \text{Number of Cruising Vehicles} * (\text{Length of Approach (mi)} \div \text{Average Cruise Speed (mi/hr)}) * 3600 \text{ s/hr}$$

The deceleration travel time can be represented by the number of vehicles decelerating multiplied by the average cruise speed divided by the average deceleration rate:

$$\text{Decel Time (s)} = \text{Number of Decelerating Vehicles} * (\text{Average Cruise Speed (mi/hr)} \div \text{Average Decel Rate (mi/hr/s)})$$

The acceleration travel time occurring on an approach link can be similarly represented. However, to avoid double counting acceleration activity that occurs on the departure link, users should multiply the acceleration time by the proportion of acceleration that occurs on the approach link (Accel Length Fraction on Approach):

$$\text{Accel Time (s)} = \text{Number of Accelerating Vehicles} * (\text{Average Cruise Speed (mi/hr)} \div \text{Average Accel Rate (mi/hr/s)}) * \text{Accel Length Fraction on Approach}$$

The idle travel time can be represented by the number of vehicles idling multiplied by the average stopped delay (average time spent stopped at an intersection):

$$\text{Idle Time (s)} = \text{Number of Idling Vehicles} * \text{Average Stopped Delay (s)}$$

Control delay (total delay caused by an intersection) may be used in lieu of average stopped delay, but control delay includes decelerating and accelerating travel times, which should be subtracted out (leaving only idle time).

After calculating the fraction of time spent in each mode of approach activity, users should select the appropriate MOVES Op-Mode corresponding to each particular type of activity (see Section 2.4.8 for more information). The operating modes in MOVES typifying approach links include:

- Cruise/acceleration (OpModeID 11-16, 22-25, 27-30, 33, 35, 37-40);
- Low and moderate speed coasting (OpModeID 11, 21); and
- Deceleration/braking (OpModeID 0) and Idling (OpModeID 1).

The relative fleet travel time fractions can be allocated to the appropriate Op-Modes in MOVES. The resulting single Op-Mode distribution accounts for relative times spent in the different driving modes (cruise, deceleration, acceleration, and idle) for the approach link.

C.4.2 Departure Links

When modeling each departure link, the fraction of fleet travel times spent in each mode of operation should be determined based on the fraction of time spent cruising and accelerating:

$$\text{Total Fleet Travel Time (s)} = \text{Cruise Time} + \text{Accel Time}$$

The cruise travel time can be represented by the number of vehicles cruising multiplied by the travel distance divided by the average cruise speed:

$$\text{Cruise Time (s)} = \text{Number of Cruising Vehicles} * (\text{Length of Departure (mi)}) / (\text{Average Cruise Speed (mi/hr)}) * 3600 \text{ s/hr}$$

The acceleration travel time occurring during the departure link can be represented by the number of vehicles accelerating multiplied by the average cruise speed divided by the average acceleration rate. However, to avoid double-counting acceleration activity that occurs on the approach link, users should multiply the resulting acceleration time by the

proportion of acceleration that occurs on the departure link (Accel Length Fraction on Departure):

$$\text{Accel Time (s)} = \text{Number of Accelerating Vehicles} * (\text{Average Cruise Speed (mi/hr)} \div \text{Average Accel Rate (mi/hr/s)}) * \text{Accel Length Fraction on Departure}$$

After calculating fraction of time spent in each mode of departure activity, users should select the appropriate MOVES Op-Mode corresponding to each particular type of activity (see Section 2.4.8 for more information). The operating modes typifying departure links include:

- Cruise/acceleration (OpModeID 11-16, 22-25, 27-30, 33, 35, 37-40)

The relative fleet travel time fractions can be allocated to the appropriate Op-Modes. The resulting single Op-Mode distribution accounts for relative times spent in the different driving modes (cruise and acceleration) for the departure link.