# Appendix B: Programmatic Agreement Template

**NCHRP 25-25, Task 104**

**Streamlining Carbon Monoxide Project-Level Air Quality Analyses with Programmatic Agreements**

**Programmatic Agreement Template**

*Prepared for:*

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March 2020

The information contained in this report was prepared as part of NCHRP Project 25-25, Task 104, National Cooperative Highway Research Program.

**SPECIAL NOTE:** This report **IS NOT** an official publication of the National Cooperative Highway Research Program, Transportation Research Board, National Research Council, or The National Academies.

Programmatic Agreement Template

The coloring scheme in the draft programmatic agreement (PA) template, and its associated technical support document (TSD), is as follows:

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

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

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

STATE DOT LETTERHEAD

Date

From: Chief Engineer (or other appropriate Executive such as the Environmental Division Administrator or Manager), State Department of Transportation

To: FHWA Division Administrator, State Division

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

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

Historically, at the national level, work began on the development of a template PA and TSD with a National Cooperative Highway Research Project (NCHRP) (“Task 78”) study*[[1]](#footnote-1)* initiated in 2012 to build upon successful state experiences[[2]](#footnote-2) in streamlining project-level air quality clearances for purposes of NEPA with state-specific PAs. The intent was to create a national template PA and associated TSD that state DOTs could customize and implement for their respective jurisdictions, relieving the state DOTs of the burden of modeling and providing consistency nationally in how projects may be screened for CO. Completed in 2015, the NCHRP Task 78 study examined a variety of project types and conditions in order and identified multiple highway facility types and configurations that would not reasonably be expected to result in violation of the CO NAAQS. It tested even the remote possibility of CO ambient air quality standard violations using worst-case modeling (following FHWA guidance on worst-case assumptions) and maintaining consistency as appropriate with EPA guidance for CO hot-spot analyses.[[3]](#footnote-3) It applied EPA-approved emission and dispersion models, namely MOVES2010b as the emission model and CAL3QHC (version 04244) as the dispersion model.

Subsequently, the PA and TSD templates developed in the NCHRP Task 78 study were updated in a second NCHRP study ( “Task 104”).[[4]](#footnote-4) The NCHRP Task 104 study, which was completed in 2020, covered a greater range of road grades compared to the original Task 78 Templates and also added coverage of a range of intersection skew angles. As with the NCHRP Task 78 study, the modeling for the NCHRP Task 104 update was conducted using EPA-approved emission and dispersion models for project-level CO screening analyses. MOVES2014a was applied as the emission model (which was updated by EPA in the interim period since the original NCHRP Task 78 study was completed), and CAL3QHC (version 04244) was again applied as the dispersion model. This PA and TSD are based on the updated templates developed in the NCHRP Task 104 study.

In a parallel effort conducted following the initiation of the NCHRP Task 78 study, the FHWA developed a categorical finding (CF) that could be implemented in areas subject to EPA conformity requirements for CO, i.e., in areas in which a PA designed for NEPA applications typically would not be applicable but the functionally-equivalent CF could be applied. State DOTs could then use the NCHRP PA for NEPA and the FHWA CF for conformity. Completed in 2014, the FHWA CF[[5]](#footnote-5) documented conditions for a single facility type (i.e., urban intersections) in areas subject to conformity requirements for CO that would not require project-specific emission and dispersion modeling. The FHWA CF was based on a set of worst-case assumptions similar in concept to those applied in the NCHRP PAs. In 2017, FHWA published a revision[[6]](#footnote-6) to its original 2014 CF based on updated emission modeling (with MOVES2014a) and the CAL3QHC dispersion model. However, the FHWA CF large remained limited to large urban intersections; it coverage was not expanded to include the additional highway facility types and configurations covered by this PA. The 2017 FHWA CF is applicable to all states and territories (except California) that are subject to conformity requirements for CO[[7]](#footnote-7).

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

1. If the project meets the minimum technical criteria for the PA to be applied without change, namely:
   1. The CO NAAQS have not changed from what was in effect at the time when this agreement was implemented and upon which the modeling was based (35 ppm for the one-hour and 9 ppm for the eight-hour).
   2. Background concentration not more than the default of 2.4 ppm (eight-hour standard) that was taken for this PA. If not, proceed to Step 3 to calculate state-specific concentrations.
   3. Persistence factor not greater than the EPA default of 0.7 that was taken for this PA. If not, proceed to Step 3 to calculate state-specific concentrations.

FOR USING THE TEMPLATE TABLES WITHOUT CHANGE (WITH NO STATE-SPECIFIC BACKGROUND CONCNTRATIONS, PERSISTENCE FACTOR OR MODELING)

1. If, for the project configuration and conditions of interest (road grade, speed, etc.), a one-hour concentration value is listed in the appropriate attached table (**Table B-1** for freeways and arterials; **Table B-2** for intersections; Table B-3 for interchanges). If it is listed, then the project is covered by the PA, provided that the minimum criteria specified above are also met.

FOR STATE-SPECIFIC BACKGROUND CONCENTRATIONS AND/OR PERSISTENCE FACTOR, BUT NOT STATE-SPECIFIC MODELING

1. For the project type and condition of interest, determine from the appropriate table (**Table B-1** for freeways and arterials; **Table B-2** for intersections; Table B-3 for interchanges)**Error! Reference source not found.** whether a one-hour concentration value is listed.
   1. If a one-hour concentration is not listed, project-specific modeling is needed.
   2. If a one-hour concentration is listed, then proceed to the next step.
2. The one-hour concentration listed in the tables is for the project contribution only. Therefore:
   1. To determine the one-hour concentration for comparison to the NAAQS use the following equation:

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

+ Local Background Concentration (One-Hour)

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

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

Persistence Factor + Local Background Concentration (Eight-Hour)

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

**FOR STATE-SPECIFIC MODELING (**State specific emissions modeling to account for local vehicle mix, inspection and maintenance (I/M) program, fuel type, etc.)

1. For the project type and condition of interest, determine from the appropriate table (**Table B-1** for freeways and arterials; **Table B-2** for intersections; Table B-3 for interchanges)**Error! Reference source not found.** whether a one-hour concentration value is listed.
   1. If a one-hour concentration is not listed, project-specific modeling is needed.
   2. If a one-hour concentration is listed, then proceed to the next step.
2. The one-hour concentration listed in the tables is for the project contribution only. Therefore:
   1. In this case, to determine the one-hour concentration for comparison to the NAAQS:

One-hour concentration (ppm)

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

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

Eight-hour concentration (ppm)

= One-Hour concentration from above x Local Persistence Factor

+ Local Background Concentration (Eight-Hour)

1. Compare the calculated one- and eight-hour concentrations to the applicable NAAQS. If both concentrations are less than the applicable NAAQS, then the project is covered by the PA. Note the eight-hour NAAQS is typically the limiting value.
2. If the project is covered by the PA based on state-specific modeling, the qualitative text provided at the end of the PA should be included (modified if needed for the project) in the project record and environmental documents.

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

##### Freeways and Arterials

**Table B-1**, attached, shows the conditions for urban and rural arterials and freeways that would meet the one- and eight-hour NAAQS and would be covered by this PA[[8]](#footnote-8). The table shows one-hour concentrations, not including background concentrations. The populated cells of the table correspond to the lane and grade combinations for arterials and freeways which, even under worst-case conditions, would not result in exceedances of the 8-hour NAAQS for CO. Where the table entries are *strikethrough*, the corresponding configuration would *not* meet the NAAQS based on worst-case modeling and would *not* be covered by this PA. Project-specific modeling would typically need to be conducted to show compliance with the NAAQS in these cases.

For example, for a transportation improvement project for an urban freeway for which the build scenario has 10 total lanes, average road grades of 3% or less, and a posted speed of 50 mph, **Table B-1** shows a maximum contribution of 8.0 ppm for the one-hour CO standard. Since a CO concentration is shown in the table for this project type and configuration, the project is covered by this PA and does not require project-specific modeling for CO. Conversely, the same freeway with 14-lanes would *not* be covered by this PA, as the table entry is *strikethrough* for that configuration.

Note: this PA covers lanes widths of 12 feet or more for freeway and arterial project types.

##### Intersections

**Table B-2**,[[9]](#footnote-9) attached, shows the maximum 1-hour CO concentrations for urban and rural intersections that, with the applied, conservative 8-hour national CO background level of 2.4 ppm and persistence factor of 0.7, do not produce modeled CO concentrations that could result in exceedances of the 8-hour CO NAAQS.

All of the reported values in Table B-2 correspond with an intersection that with a given grade (or less), six approach lanes or less, and posted approach speeds in the 15-45 mph range (not less than 15 mph) would not produce modeled concentrations that would result in exceedances of the 8-hour CO NAAQS. Any such project would be covered by this PA and would not require project-specific CO modeling to demonstrate compliance with the CO NAAQS. Conversely, for example, a project with no reported value, say seven approach lanes, an 8% grade and/or a 10-mph posted approach speed would *not* be covered by this PA.

For reference, and as documented in the TSD, the intersection analysis assumes four approach lanes in each direction, four departure lanes in each direction, and two left turn lanes for each approach. Additionally, after testing a variety of configurations, the worst-case configuration for the intersection was determined to be one on the side of a hill, angled (at 45°) so that the northbound approach and westbound approaches are both uphill. Road grades were modeled for a range of zero to seven percent. The angle between the approach and departure lanes were modeled at a standard 90-degree angle, as well as skew angles of 60°, 45°, 30°, and 15° angles. The analysis placed the skew at the intersection with the highest emission rates which is associated with the upgrade links. The right lanes in each direction were modeled as including both through and right turn movements and included left-turn queue idling. The same MOVES model inputs and assumptions were used for both the freeway and arterial analyses. Similar CAL3QHC model inputs and assumptions were also used, although intersections were modeled with lanes 11 feet wide in all cases[[10]](#footnote-10).

##### Interchanges with Adjacent Intersections

Table B-3 shows 1-hour CO concentrations for various interchange scenarios that, with the applied 8-hour CO background level and persistence factor, do not produce modeled concentrations that could result in exceedances of the 8-hour NAAQS for CO. Where the table entries are *strikethrough*, the corresponding configuration would *not* meet the NAAQS based on worst-case modeling and would *not* be covered by this PA. Project-specific modeling would typically need to be conducted to show compliance with the NAAQS in these cases. Although intersections were considered on either side of the freeway, Table B-3 only reports the higher of these. The same speed limitations for freeways and arterials from above also apply here.

For example, for a 2-lane freeway with an adjacent intersection with a grade of 3% in a rural location that is located not less than 20 feet from the nearest edge of the freeway lanes, and connected with a 45 degree angled road segment has a one-hour concentration listed of 8.1 ppm, as shown in Table B-3(a). Since a concentration is listed for this project configuration, the project would be covered by this PA and not require project-specific modeling. Conversely, the table entry is *strikethrough* for the same interchange with an intersection that has a 6% road grade, which therefore would *not* be covered by this PA.

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

For reference, and as documented in the TSD, interchanges were analyzed using the MOVES and CALQHC models, with a combination of the grade separated intersection and freeway separated at various distances. The intersection and freeway analyses geometry and traffic inputs are as described in the preceding cases, other than for a simplified receptor set. Interchange scenarios were modeled with the freeway at a 0% grade and intersection (the non-freeway portion) at a 0, 1, 3, 4, 5, 6 and 7% grade. Both rural and urban locations were considered. The total number of freeway lanes analyzed ranged from 2 to 12 lanes, in 2 lane increments. As above, intersection remains a signalized six lane intersection. A variety of assumed distances between the edge of the nearest freeway travel lane to the edge of the nearest travel lane on the intersection were analyzed. These included distances of 20, 30, 60, 80, 100, 125, 150, 175, 300, 500 and 1,000 feet. The roadway link connecting the freeway to the intersection was modeled at skew angles of 90, 60, and 45-degree angles. Intersections were considered on either side of the freeway.

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

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

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

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

**Years of Analysis:** This PA covers projects of the types and conditions listed above whose opening year (year of completion) is 2020 or later.

**Technical Approach:** The modeling and the assumptions used in the modeling to support this PA are described in detail in the accompanying Technical Support Document (TSD). In general, a worst-case modeling approach was applied following EPA guidance. In all cases EPA’s MOVES2014a emission model was used to generate emission estimates and CAL3QHC (version 04244) was used for the dispersion analysis. EPA’s current guidance for modeling CO Hot-Spots (*Guideline for Modeling Carbon Monoxide from Roadway Intersections*, U. S. EPA, EPA-454/R-92-005, November 1992) was also applied. The assumptions and inputs used in the model were worst-case or highly conservative, leading to higher emission estimates and less dispersion (that is, greater forecast ambient concentrations) than would be expected under real-world conditions. Consequently, if a project does not cause a modeled exceedance of the NAAQS with these worst-case or conservative inputs and assumptions, then it may be stated with high confidence that an exceedance under real-world conditions would not be expected. Finally, STATE DOT consulted with the STATE AIR AGENCY to determine appropriate values for CO background concentrations and persistence factor. These values were used to arrive at an 8-hour total CO concentration for comparison with the 8-hour CO ambient air quality standard.

**Safety Margin from Worst-Case Modeling Assumptions:** The safety margin for the modeling for this agreement is substantial, as documented in the TSD. It includes: 1) the differences in modeling results based on worst-case modeling assumptions as applied for this PA relative to what they would have been using typical or representative inputs, and 2) wide margins between the NAAQS and typical near-road concentrations, as observed in long-term trend data from EPA monitoring stations. Note the use of multiple worst-case modeling assumptions versus just one or a few has a cumulative effect that markedly increases modeled air concentrations over what might be expected.

For emission modeling, worst-case modeling assumptions include:

1. emission factors for 2020 were used for all future years, despite that emission factors are projected to decline over time with continued fleet turnover from vehicles built to meet more stringent EPA Tier 3 emission standards,
2. exclusion of emission inspection and maintenance program benefits as applicable,
3. single unit gasoline truck percentages, and
4. high ambient temperature.

For dispersion modeling, worst-case modeling assumptions include:

1. maximum capacity traffic volumes,
2. receptor locations on the edge of the roadway right-of-way,
3. geometric assumptions that serve to concentrate traffic, emissions and concentrations to the greatest extent possible, including:
   1. a “hillside” configuration for intersection modeling,
   2. zero vertical separation for the interchange and mainline roadway, and
   3. zero median widths for arterial streets and minimum distance for highways,
4. interchange ramps with more lanes than would typically be expected,
5. low 1.0 m/s wind speeds, and
6. background concentrations are assumed the same in the future, whereas they are expected to decline given continued fleet turnover nationally to vehicles constructed to more stringent EPA Tier 3 emission standards.

Each of these conservative choices for the emission estimate and dispersion modeling assumptions is discuss in the technical support document.

A State DOT may add one or more of following optional terms in a state-specific PA:

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

**Mutual Applicability of the PA and FHWA Categorical Finding for CO for NEPA Applications**: The STATE DOT at its discretion may apply the PA and the currently-available FHWA categorical finding for CO either individually or together (without one limiting the utility of the other in clearing projects) for air quality clearances for purposes of NEPA.

**Locally Administered Projects**: This PA may also be applied for locally administered projects, i.e., those implemented by cities, towns and counties within STATE. For the project’s environmental document or record, the local agency will include a statement that the project under review meets the project types and conditions covered in the PA (including data and information as necessary to support that determination) and will conclude with one of the statements (or a similar statement, as appropriate to the project) provided in the Administrative Record section below.

**Interpolation or Proration**: As the modeling results presented in this PA are for specific roadway configurations (number of lanes, skew angle, road grade etc.), interpolation or proration of the data presented in the tables may be necessary for application of this PA and may be conducted as appropriate at the discretion of the STATE DOT, in consultation and coordination with the FHWA Division office as appropriate.

**Substantive Difference**: A “substantive” difference, change or variance is defined here as one that would significantly affect the modeling results and/or the analysis to the degree that it would reasonably be expected to change a finding, determination or conclusion that all applicable requirements for the air quality analysis for the project would be met and the project cleared, with the determination to be made by the STATE DOT (in consultation with the FHWA Division office as appropriate) consistent with the general terms of this PA.

**Enduring Applicability of the PA in the Absence of Substantive Changes to the Models or Guidance**: This PA may continue to be applied by the STATE DOT if EPA updates its official emission and/or dispersion models and/or associated guidance for CO screening analyses from the ones applied for this PA (MOVES2014a and CAL3QHC version 04244, respectively) if there is a reasonable expectation or it can otherwise be shown or concluded that the update(s) to the model(s) and/or associated guidance would not substantively change the modeled CO emission rates and/or ambient concentrations and hence not on the underlying modeling, criteria or conclusions for this PA.

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

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

Or

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

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

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

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

## Attachment to the Programmatic Agreement

Tables of results are presented in this Attachment. In each case, scenarios that lead to project level exceedances with the modeling described in the Technical Support Document are shown in red with the values crossed through.

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table B-1. One-hour CO Concentrations (ppm) for Freeways and Arterials\* in Urban and Rural Locations of Varying Lane and Grade Configuration (not including background concentrations).** | | | | | | | | | | |
| **Facility Type** | **Location** | **Number of Lanes** | **Grade (percent)** | | | | | | | |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| Arterials | Rural | 2 | 3 | 3 | 3.3 | 3.4 | 3.7 | 4 | 4.4 | 4.8 |
| Arterials | Rural | 4 | 6.5 | 6.9 | 7.3 | 7.7 | 8.4 | 9 | ~~9.9~~ | ~~10.5~~ |
| Arterials | Rural | 6 | 8.7 | 9.3 | ~~9.9~~ | ~~10.5~~ | ~~11.4~~ | ~~12.3~~ | ~~13.4~~ | ~~14.6~~ |
| Arterials | Rural | 8 | ~~10.7~~ | ~~11.3~~ | ~~12.1~~ | ~~12.8~~ | ~~14~~ | ~~15.1~~ | ~~16.5~~ | ~~17.9~~ |
| Arterials | Rural | 10 | ~~12.3~~ | ~~13.1~~ | ~~14.1~~ | ~~15~~ | ~~16.2~~ | ~~17.6~~ | ~~19.2~~ | ~~20.8~~ |
| Arterials | Rural | 12 | ~~13.6~~ | ~~14.6~~ | ~~15.8~~ | ~~16.7~~ | ~~18.2~~ | ~~19.7~~ | ~~21.6~~ | ~~23.4~~ |
| Arterials | Urban | 2 | 1.8 | 1.9 | 2.1 | 2.1 | 2.3 | 2.4 | 2.7 | 2.8 |
| Arterials | Urban | 4 | 4 | 4.3 | 4.6 | 4.9 | 5.2 | 5.7 | 6.2 | 6.7 |
| Arterials | Urban | 6 | 5.5 | 5.7 | 6.2 | 6.7 | 7.2 | 7.7 | 8.5 | 9.2 |
| Arterials | Urban | 8 | 6.6 | 7.1 | 7.6 | 8.1 | 8.8 | ~~9.6~~ | ~~10.5~~ | ~~11.4~~ |
| Arterials | Urban | 10 | 7.5 | 8.2 | 8.8 | 9.4 | ~~10.3~~ | ~~11.1~~ | ~~12.3~~ | ~~13.3~~ |
| Arterials | Urban | 12 | 8.4 | 9.1 | ~~9.8~~ | ~~10.5~~ | ~~11.5~~ | ~~12.5~~ | ~~13.8~~ | ~~15~~ |
| Freeways | Rural | 2 | 1.4 | 1.7 | 1.9 | 2.1 | 2.4 | 2.8 | 3 | 3.2 |
| Freeways | Rural | 4 | 3.7 | 4.2 | 5 | 5.7 | 6.6 | 7.5 | 8.2 | 8.6 |
| Freeways | Rural | 6 | 5.3 | 6.1 | 7.1 | 8.2 | ~~9.5~~ | ~~10.8~~ | ~~11.8~~ | ~~12.4~~ |
| Freeways | Rural | 8 | 6.6 | 7.6 | 9.2 | ~~10.6~~ | ~~12.2~~ | ~~13.9~~ | ~~15.2~~ | ~~16.1~~ |
| Freeways | Rural | 10 | 7.8 | 9.1 | ~~10.9~~ | ~~12.6~~ | ~~14.7~~ | ~~16.7~~ | ~~18.3~~ | ~~19.3~~ |
| Freeways | Rural | 12 | 8.9 | ~~10.4~~ | ~~12.5~~ | ~~14.6~~ | ~~16.9~~ | ~~19.3~~ | ~~21.1~~ | ~~22.4~~ |
| Freeways | Rural | 14 | ~~9.8~~ | ~~11.5~~ | ~~13.9~~ | ~~16.3~~ | ~~18.9~~ | ~~21.6~~ | ~~23.7~~ | ~~25~~ |
| Freeways | Rural | 16 | ~~10.7~~ | ~~12.6~~ | ~~15.2~~ | ~~17.8~~ | ~~20.7~~ | ~~23.6~~ | ~~25.9~~ | ~~27.4~~ |
| Freeways | Rural | 18 | ~~11.3~~ | ~~13.6~~ | ~~16.4~~ | ~~19.1~~ | ~~22.3~~ | ~~25.6~~ | ~~28~~ | ~~29.6~~ |
| Freeways | Rural | 20 | ~~12~~ | ~~14.3~~ | ~~17.5~~ | ~~20.4~~ | ~~23.7~~ | ~~27.2~~ | ~~29.8~~ | ~~31.6~~ |
| Freeways | Rural | 22 | ~~12.5~~ | ~~15.1~~ | ~~18.4~~ | ~~21.5~~ | ~~25.1~~ | ~~28.7~~ | ~~31.6~~ | ~~33.5~~ |
| Freeways | Urban | 2 | 0.9 | 1 | 1.1 | 1.3 | 1.5 | 1.7 | 1.9 | 1.9 |
| Freeways | Urban | 4 | 2.3 | 2.6 | 3.1 | 3.6 | 4.1 | 4.7 | 5.2 | 5.5 |
| Freeways | Urban | 6 | 3.2 | 3.7 | 4.5 | 5.2 | 6 | 6.9 | 7.6 | 8 |
| Freeways | Urban | 8 | 4 | 4.8 | 5.8 | 6.7 | 7.8 | 8.9 | ~~9.7~~ | ~~10.4~~ |
| Freeways | Urban | 10 | 4.8 | 5.7 | 6.8 | 8 | 9.3 | ~~10.7~~ | ~~11.8~~ | ~~12.4~~ |
| Freeways | Urban | 12 | 5.4 | 6.5 | 7.8 | 9.2 | ~~10.7~~ | ~~12.3~~ | ~~13.5~~ | ~~14.3~~ |
| Freeways | Urban | 14 | 5.9 | 7.2 | 8.8 | ~~10.3~~ | ~~11.9~~ | ~~13.8~~ | ~~15.1~~ | ~~16~~ |
| Freeways | Urban | 16 | 6.4 | 7.8 | ~~9.5~~ | ~~11.2~~ | ~~13.1~~ | ~~15~~ | ~~16.5~~ | ~~17.5~~ |
| Freeways | Urban | 18 | 6.9 | 8.4 | ~~10.3~~ | ~~12.1~~ | ~~14.1~~ | ~~16.2~~ | ~~17.8~~ | ~~18.9~~ |
| Freeways | Urban | 20 | 7.2 | 8.9 | ~~10.9~~ | ~~12.9~~ | ~~15~~ | ~~17.2~~ | ~~19~~ | ~~20.1~~ |
| Freeways | Urban | 22 | 7.5 | 9.3 | ~~11.5~~ | ~~13.5~~ | ~~15.8~~ | ~~18.2~~ | ~~20~~ | ~~21.2~~ |

Notes: Red strikethrough values indicated exceedances of the standard.

\* These findings apply to scenarios with average speed ranging from 15 to 56 mph for arterials and 19 to 75 mph for freeways, for which posted speeds in those ranges may be applied as reasonable proxies.

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Table B-2. One-hour CO concentrations (not including background concentrations) for Rural and Urban Intersections\* at Varying Skew Angles and Intersection Grades for a Six Approach Lane Intersection** | | | | | | | | | |
| **Location** | **Skew Angle** | **Grade (Percent)** | | | | | | | |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| Rural | 15 | 8.6 | 9.1 | ~~9.8~~ | ~~10.2~~ | ~~11.1~~ | ~~11.9~~ | ~~13~~ | ~~13.9~~ |
| Rural | 30 | 6.3 | 6.7 | 7.1 | 7.5 | 8.2 | 8.8 | 9.4 | ~~10.1~~ |
| Rural | 45 | 6.2 | 6.4 | 6.9 | 7.2 | 7.8 | 8.4 | 9 | ~~9.9~~ |
| Rural | 60 | 5.6 | 5.9 | 6.2 | 6.5 | 7 | 7.5 | 8 | 8.7 |
| Rural | 90 | 5.4 | 5.6 | 6 | 6.3 | 6.8 | 7.3 | 7.8 | 8.4 |
| Urban | 15 | 4.7 | 4.9 | 5.3 | 5.6 | 6.1 | 6.7 | 7.1 | 7.7 |
| Urban | 30 | 4.5 | 4.8 | 5 | 5.5 | 6.1 | 6.4 | 6.7 | 7.2 |
| Urban | 45 | 4.1 | 4.4 | 4.6 | 4.8 | 5.2 | 5.7 | 6.2 | 6.5 |
| Urban | 60 | 3.8 | 4.1 | 4.3 | 4.5 | 5 | 5.3 | 5.9 | 6.3 |
| Urban | 90 | 3.6 | 3.9 | 4.1 | 4.3 | 4.5 | 5 | 5.4 | 5.9 |

Notes: Red strikethrough values indicated exceedances of the standard.

\* These findings apply to scenarios with average speed ranging from 15 to 45 mph for intersections, for which posted speeds in that range may be applied as a reasonable proxy.

| Table B-3 (a). One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 45o Skew Angle (not including background concentrations)\* | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Location** | **Number of Lanes** | **Intersection Grade** | **Distance between Freeway and Intersection (ft)** | | | | | | | | | | |
| **20** | **30** | **60** | **80** | **100** | **125** | **150** | **175** | **300** | **500** | **1000** |
| Rural | 2 | 0% | 6.9 | 6.4 | 6.4 | 6.4 | 6.4 | 6.4 | 6.4 | 6.4 | 6.4 | 6.4 | 6.2 |
| Rural | 2 | 1% | 7.3 | 6.7 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 | 6.5 |
| Rural | 2 | 2% | 7.7 | 7.3 | 7.1 | 7.1 | 7.1 | 7.1 | 7.1 | 7.1 | 7.1 | 7.1 | 7.1 |
| Rural | 2 | 3% | 8.1 | 7.6 | 7.4 | 7.4 | 7.4 | 7.4 | 7.4 | 7.4 | 7.4 | 7.4 | 7.4 |
| Rural | 2 | 4% | 8.5 | 8.1 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 8 | 7.9 |
| Rural | 2 | 5% | 8.9 | 8.8 | 8.6 | 8.6 | 8.6 | 8.6 | 8.6 | 8.6 | 8.6 | 8.6 | 8.6 |
| Rural | 2 | 6% | ~~9.7~~ | 9.4 | 9.2 | 9.2 | 9.2 | 9.2 | 9.2 | 9.2 | 9.2 | 9.2 | 9.2 |
| Rural | 2 | 7% | ~~10.3~~ | ~~10.3~~ | ~~10.1~~ | ~~10.1~~ | ~~10.1~~ | ~~10.1~~ | ~~10.1~~ | ~~10.1~~ | ~~10.1~~ | ~~10.1~~ | ~~10.1~~ |
| Rural | 4 | 0% | 9.4 | 7.9 | 7.1 | 7 | 6.9 | 6.8 | 6.8 | 6.8 | 6.6 | 6.6 | 6.4 |
| Rural | 4 | 1% | ~~9.8~~ | 8.3 | 7.3 | 7.2 | 7.1 | 7 | 7 | 7 | 6.9 | 6.8 | 6.7 |
| Rural | 4 | 2% | ~~10.2~~ | 8.7 | 7.7 | 7.7 | 7.7 | 7.6 | 7.5 | 7.5 | 7.5 | 7.3 | 7.3 |
| Rural | 4 | 3% | ~~10.6~~ | 9.1 | 8 | 8 | 8 | 7.9 | 7.8 | 7.8 | 7.8 | 7.6 | 7.6 |
| Rural | 4 | 4% | ~~11~~ | ~~9.5~~ | 8.5 | 8.5 | 8.5 | 8.4 | 8.4 | 8.4 | 8.3 | 8.2 | 8.1 |
| Rural | 4 | 5% | ~~11.4~~ | ~~9.9~~ | 9.2 | 9.2 | 9.2 | 9.1 | 9 | 9 | 9 | 8.8 | 8.8 |
| Rural | 4 | 6% | ~~12.2~~ | ~~10.7~~ | ~~9.8~~ | ~~9.8~~ | ~~9.8~~ | ~~9.7~~ | ~~9.6~~ | ~~9.6~~ | ~~9.6~~ | 9.4 | 9.4 |
| Rural | 4 | 7% | ~~12.7~~ | ~~11.2~~ | ~~10.7~~ | ~~10.7~~ | ~~10.7~~ | ~~10.6~~ | ~~10.5~~ | ~~10.5~~ | ~~10.5~~ | ~~10.3~~ | ~~10.3~~ |
| Rural | 6 | 0% | ~~10.5~~ | 8.7 | 7.7 | 7.6 | 7.5 | 7.3 | 7.2 | 7.2 | 6.9 | 6.8 | 6.6 |
| Rural | 6 | 1% | ~~10.9~~ | 9.1 | 7.9 | 7.8 | 7.7 | 7.5 | 7.4 | 7.4 | 7.1 | 7 | 6.8 |
| Rural | 6 | 2% | ~~11.3~~ | ~~9.5~~ | 8.3 | 8.2 | 8.1 | 7.9 | 7.9 | 7.9 | 7.7 | 7.5 | 7.3 |
| Rural | 6 | 3% | ~~11.7~~ | ~~9.9~~ | 8.6 | 8.5 | 8.4 | 8.2 | 8.2 | 8.2 | 8 | 7.8 | 7.6 |
| Rural | 6 | 4% | ~~12.1~~ | ~~10.3~~ | 9.1 | 9 | 8.9 | 8.8 | 8.8 | 8.8 | 8.5 | 8.4 | 8.2 |
| Rural | 6 | 5% | ~~12.5~~ | ~~10.7~~ | ~~9.7~~ | ~~9.5~~ | ~~9.5~~ | 9.4 | 9.4 | 9.4 | 9.2 | 9 | 8.8 |
| Rural | 6 | 6% | ~~13.3~~ | ~~11.5~~ | ~~10.3~~ | ~~10.1~~ | ~~10.1~~ | ~~10~~ | ~~10~~ | ~~10~~ | ~~9.8~~ | ~~9.6~~ | 9.4 |
| Rural | 6 | 7% | ~~13.8~~ | ~~12~~ | ~~11.2~~ | ~~11~~ | ~~11~~ | ~~10.9~~ | ~~10.9~~ | ~~10.9~~ | ~~10.7~~ | ~~10.5~~ | ~~10.3~~ |
| Rural | 8 | 0% | ~~11.4~~ | 9.4 | 8.3 | 8.1 | 8 | 7.8 | 7.6 | 7.4 | 7.3 | 7 | 6.8 |
| Rural | 8 | 1% | ~~11.8~~ | ~~9.8~~ | 8.5 | 8.3 | 8.2 | 8 | 7.8 | 7.6 | 7.5 | 7.2 | 7 |
| Rural | 8 | 2% | ~~12.2~~ | ~~10.2~~ | 8.9 | 8.7 | 8.6 | 8.4 | 8.2 | 8.1 | 8 | 7.8 | 7.5 |
| Rural | 8 | 3% | ~~12.6~~ | ~~10.6~~ | 9.2 | 9 | 8.9 | 8.7 | 8.5 | 8.4 | 8.3 | 8.1 | 7.8 |
| Rural | 8 | 4% | ~~13~~ | ~~11~~ | ~~9.7~~ | ~~9.5~~ | 9.4 | 9.2 | 9 | 9 | 8.9 | 8.6 | 8.4 |
| Rural | 8 | 5% | ~~13.4~~ | ~~11.4~~ | ~~10.2~~ | ~~10~~ | ~~9.9~~ | ~~9.7~~ | ~~9.7~~ | ~~9.6~~ | ~~9.5~~ | 9.3 | 9 |
| Rural | 8 | 6% | ~~14.2~~ | ~~12.2~~ | ~~10.8~~ | ~~10.6~~ | ~~10.5~~ | ~~10.3~~ | ~~10.3~~ | ~~10.2~~ | ~~10.1~~ | ~~9.9~~ | ~~9.6~~ |
| Rural | 8 | 7% | ~~14.7~~ | ~~12.7~~ | ~~11.6~~ | ~~11.5~~ | ~~11.4~~ | ~~11.2~~ | ~~11.2~~ | ~~11.1~~ | ~~11~~ | ~~10.8~~ | ~~10.5~~ |
| Rural | 10 | 0% | ~~12~~ | ~~9.9~~ | 8.8 | 8.6 | 8.4 | 8.1 | 7.9 | 7.7 | 7.4 | 7.2 | 7 |
| Rural | 10 | 1% | ~~12.4~~ | ~~10.3~~ | 9 | 8.8 | 8.6 | 8.3 | 8.1 | 7.9 | 7.7 | 7.4 | 7.2 |
| Rural | 10 | 2% | ~~12.8~~ | ~~10.7~~ | 9.4 | 9.2 | 9 | 8.7 | 8.6 | 8.4 | 8.3 | 7.9 | 7.7 |
| Rural | 10 | 3% | ~~13.2~~ | ~~11.1~~ | ~~9.7~~ | ~~9.5~~ | 9.3 | 9 | 8.9 | 8.7 | 8.6 | 8.2 | 8 |
| Rural | 10 | 4% | ~~13.6~~ | ~~11.5~~ | ~~10.2~~ | ~~10~~ | ~~9.8~~ | ~~9.5~~ | 9.4 | 9.2 | 9.1 | 8.8 | 8.6 |
| Rural | 10 | 5% | ~~14~~ | ~~11.9~~ | ~~10.7~~ | ~~10.5~~ | ~~10.3~~ | ~~10.2~~ | ~~10.1~~ | ~~9.9~~ | ~~9.8~~ | 9.4 | 9.2 |
| Rural | 10 | 6% | ~~14.8~~ | ~~12.7~~ | ~~11.3~~ | ~~11.1~~ | ~~10.9~~ | ~~10.8~~ | ~~10.7~~ | ~~10.5~~ | ~~10.4~~ | ~~10~~ | ~~9.8~~ |
| Rural | 10 | 7% | ~~15.3~~ | ~~13.2~~ | ~~12~~ | ~~11.8~~ | ~~11.8~~ | ~~11.7~~ | ~~11.6~~ | ~~11.4~~ | ~~11.3~~ | ~~10.9~~ | ~~10.7~~ |
| Rural | 12 | 0% | ~~12.6~~ | ~~11~~ | 9.3 | 9.1 | 8.8 | 8.5 | 8.2 | 8 | 7.6 | 7.5 | 7.1 |
| Rural | 12 | 1% | ~~13~~ | ~~11.1~~ | ~~9.5~~ | 9.3 | 9 | 8.7 | 8.4 | 8.3 | 7.9 | 7.7 | 7.3 |
| Rural | 12 | 2% | ~~13.4~~ | ~~11.1~~ | ~~9.9~~ | ~~9.7~~ | 9.4 | 9.1 | 8.9 | 8.9 | 8.5 | 8.2 | 7.9 |
| Rural | 12 | 3% | ~~13.8~~ | ~~11.4~~ | ~~10.2~~ | ~~10~~ | ~~9.7~~ | 9.4 | 9.2 | 9.2 | 8.8 | 8.5 | 8.2 |
| Rural | 12 | 4% | ~~14.2~~ | ~~11.8~~ | ~~10.7~~ | ~~10.5~~ | ~~10.2~~ | ~~9.9~~ | ~~9.7~~ | ~~9.7~~ | 9.3 | 9.1 | 8.7 |
| Rural | 12 | 5% | ~~14.6~~ | ~~12.2~~ | ~~11.2~~ | ~~11~~ | ~~10.7~~ | ~~10.5~~ | ~~10.4~~ | ~~10.4~~ | ~~10~~ | ~~9.7~~ | 9.4 |
| Rural | 12 | 6% | ~~15.4~~ | ~~13~~ | ~~11.8~~ | ~~11.6~~ | ~~11.3~~ | ~~11.1~~ | ~~11~~ | ~~11~~ | ~~10.6~~ | ~~10.3~~ | ~~10~~ |
| Rural | 12 | 7% | ~~15.9~~ | ~~13.5~~ | ~~12.5~~ | ~~12.3~~ | ~~12.2~~ | ~~12~~ | ~~11.9~~ | ~~11.9~~ | ~~11.5~~ | ~~11.2~~ | ~~10.9~~ |
| Urban | 2 | 0% | 4.6 | 4.4 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.2 | 4.1 | 4.1 |
| Urban | 2 | 1% | 4.8 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.6 | 4.4 | 4.4 |
| Urban | 2 | 2% | 5.1 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.8 | 4.6 | 4.6 |
| Urban | 2 | 3% | 5.3 | 5.1 | 5 | 5 | 5 | 5 | 5 | 5 | 4.9 | 4.8 | 4.8 |
| Urban | 2 | 4% | 5.7 | 5.5 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.4 | 5.3 | 5.2 | 5.2 |
| Urban | 2 | 5% | 6.2 | 6 | 5.9 | 5.9 | 5.9 | 5.9 | 5.9 | 5.9 | 5.8 | 5.7 | 5.7 |
| Urban | 2 | 6% | 6.7 | 6.5 | 6.4 | 6.4 | 6.4 | 6.4 | 6.4 | 6.4 | 6.3 | 6.2 | 6.2 |
| Urban | 2 | 7% | 7 | 6.8 | 6.7 | 6.7 | 6.7 | 6.7 | 6.7 | 6.7 | 6.7 | 6.5 | 6.5 |
| Urban | 4 | 0% | 5.9 | 5.2 | 4.7 | 4.7 | 4.6 | 4.6 | 4.5 | 4.5 | 4.4 | 4.3 | 4.2 |
| Urban | 4 | 1% | 6.2 | 5.5 | 5 | 5 | 5 | 5 | 4.9 | 4.8 | 4.8 | 4.6 | 4.6 |
| Urban | 4 | 2% | 6.5 | 5.8 | 5.2 | 5.2 | 5.2 | 5.2 | 5.1 | 5 | 5 | 4.8 | 4.8 |
| Urban | 4 | 3% | 6.7 | 6 | 5.4 | 5.4 | 5.3 | 5.3 | 5.2 | 5.2 | 5.1 | 5 | 4.9 |
| Urban | 4 | 4% | 6.9 | 6.2 | 5.8 | 5.8 | 5.7 | 5.7 | 5.6 | 5.6 | 5.5 | 5.4 | 5.3 |
| Urban | 4 | 5% | 7.3 | 6.6 | 6.3 | 6.3 | 6.2 | 6.2 | 6.1 | 6.1 | 6 | 5.9 | 5.8 |
| Urban | 4 | 6% | 7.8 | 7.1 | 6.8 | 6.8 | 6.7 | 6.7 | 6.6 | 6.6 | 6.5 | 6.4 | 6.3 |
| Urban | 4 | 7% | 8.2 | 7.5 | 7.1 | 7.1 | 7.1 | 7.1 | 7 | 6.9 | 6.9 | 6.7 | 6.7 |
| Urban | 6 | 0% | 6.8 | 5.9 | 5 | 5 | 4.9 | 4.8 | 4.8 | 4.7 | 4.6 | 4.4 | 4.2 |
| Urban | 6 | 1% | 7.1 | 6.2 | 5.3 | 5.3 | 5.2 | 5.2 | 5.2 | 5.1 | 5 | 4.8 | 4.6 |
| Urban | 6 | 2% | 7.4 | 6.5 | 5.5 | 5.5 | 5.4 | 5.4 | 5.4 | 5.3 | 5.2 | 5 | 4.8 |
| Urban | 6 | 3% | 7.6 | 6.7 | 5.7 | 5.7 | 5.6 | 5.5 | 5.5 | 5.5 | 5.3 | 5.1 | 4.9 |
| Urban | 6 | 4% | 7.8 | 6.9 | 6.1 | 6.1 | 6 | 5.9 | 5.9 | 5.8 | 5.7 | 5.5 | 5.3 |
| Urban | 6 | 5% | 8.2 | 7.3 | 6.6 | 6.6 | 6.5 | 6.4 | 6.4 | 6.3 | 6.2 | 6 | 5.8 |
| Urban | 6 | 6% | 8.7 | 7.8 | 7.1 | 7.1 | 7 | 6.9 | 6.9 | 6.8 | 6.7 | 6.5 | 6.3 |
| Urban | 6 | 7% | 9.1 | 8.2 | 7.4 | 7.4 | 7.3 | 7.3 | 7.3 | 7.2 | 7.1 | 6.9 | 6.7 |
| Urban | 8 | 0% | 7.4 | 6.4 | 5.3 | 5.3 | 5.2 | 5.1 | 5 | 5 | 4.8 | 4.6 | 4.4 |
| Urban | 8 | 1% | 7.7 | 6.7 | 5.7 | 5.7 | 5.5 | 5.5 | 5.4 | 5.4 | 5.2 | 5 | 4.8 |
| Urban | 8 | 2% | 8 | 7 | 5.9 | 5.9 | 5.7 | 5.7 | 5.6 | 5.6 | 5.4 | 5.2 | 5 |
| Urban | 8 | 3% | 8.2 | 7.2 | 6 | 6 | 5.9 | 5.8 | 5.8 | 5.7 | 5.5 | 5.3 | 5.1 |
| Urban | 8 | 4% | 8.4 | 7.4 | 6.4 | 6.4 | 6.3 | 6.2 | 6.1 | 6.1 | 5.9 | 5.7 | 5.5 |
| Urban | 8 | 5% | 8.8 | 7.8 | 6.9 | 6.9 | 6.8 | 6.7 | 6.6 | 6.6 | 6.4 | 6.2 | 6 |
| Urban | 8 | 6% | 9.3 | 8.3 | 7.4 | 7.4 | 7.3 | 7.2 | 7.1 | 7.1 | 6.9 | 6.7 | 6.5 |
| Urban | 8 | 7% | ~~9.7~~ | 8.7 | 7.8 | 7.8 | 7.6 | 7.6 | 7.5 | 7.5 | 7.3 | 7.1 | 6.9 |
| Urban | 10 | 0% | 7.9 | 7.2 | 5.6 | 5.5 | 5.5 | 5.3 | 5.3 | 5.2 | 5 | 4.7 | 4.4 |
| Urban | 10 | 1% | 8.2 | 7.4 | 6 | 5.9 | 5.9 | 5.7 | 5.7 | 5.6 | 5.4 | 5.1 | 4.8 |
| Urban | 10 | 2% | 8.5 | 7.5 | 6.2 | 6.1 | 6.1 | 5.9 | 5.9 | 5.8 | 5.6 | 5.3 | 5 |
| Urban | 10 | 3% | 8.7 | 7.7 | 6.4 | 6.3 | 6.2 | 6.1 | 6 | 6 | 5.7 | 5.4 | 5.1 |
| Urban | 10 | 4% | 8.9 | 7.9 | 6.7 | 6.6 | 6.6 | 6.4 | 6.4 | 6.3 | 6.1 | 5.8 | 5.5 |
| Urban | 10 | 5% | 9.3 | 8.2 | 7.2 | 7.1 | 7.1 | 6.9 | 6.9 | 6.8 | 6.6 | 6.3 | 6 |
| Urban | 10 | 6% | ~~9.8~~ | 8.7 | 7.7 | 7.6 | 7.6 | 7.4 | 7.4 | 7.3 | 7.1 | 6.8 | 6.5 |
| Urban | 10 | 7% | ~~10.2~~ | 9.1 | 8.1 | 8 | 8 | 7.8 | 7.8 | 7.7 | 7.5 | 7.2 | 6.9 |
| Urban | 12 | 0% | 8.6 | 7.8 | 6 | 5.8 | 5.7 | 5.6 | 5.5 | 5.5 | 5.1 | 4.9 | 4.4 |
| Urban | 12 | 1% | 8.8 | 8 | 6.4 | 6.2 | 6.1 | 6 | 5.9 | 5.9 | 5.5 | 5.3 | 4.8 |
| Urban | 12 | 2% | 9 | 8.1 | 6.6 | 6.4 | 6.3 | 6.2 | 6.1 | 6.1 | 5.7 | 5.5 | 5 |
| Urban | 12 | 3% | 9.2 | 8.3 | 6.7 | 6.6 | 6.5 | 6.4 | 6.3 | 6.2 | 5.8 | 5.6 | 5.1 |
| Urban | 12 | 4% | 9.4 | 8.5 | 7.1 | 6.9 | 6.8 | 6.7 | 6.6 | 6.6 | 6.2 | 6 | 5.5 |
| Urban | 12 | 5% | ~~9.8~~ | 8.8 | 7.6 | 7.4 | 7.3 | 7.2 | 7.1 | 7.1 | 6.7 | 6.5 | 6 |
| Urban | 12 | 6% | ~~10.3~~ | 9.2 | 8.1 | 7.9 | 7.8 | 7.7 | 7.6 | 7.6 | 7.2 | 7 | 6.5 |
| Urban | 12 | 7% | ~~10.7~~ | ~~9.6~~ | 8.5 | 8.3 | 8.2 | 8.1 | 8 | 8 | 7.6 | 7.4 | 6.9 |

Notes: Red strikethrough values indicated exceedances of the standard.

\* These findings apply to scenarios with the intersection average speed ranging from 15 to 45 mph and the freeway average speed ranging from 19 to 75 mph, for which posted speeds in those ranges may be applied as reasonable proxies.

| Table B-4 (b). One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 60o Skew Angle (not including background concentrations)\* | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Location** | **Number of Lanes** | **Intersection Grade** | **Distance between Freeway and Intersection (ft)** | | | | | | | | | | |
| **20** | **30** | **60** | **80** | **100** | **125** | **150** | **175** | **300** | **500** | **1000** |
| Rural | 2 | 0% | 6.7 | 6.2 | 6 | 6 | 6 | 6 | 6 | 5.9 | 5.8 | 5.6 | 5.6 |
| Rural | 2 | 1% | 7 | 6.5 | 6.3 | 6.3 | 6.3 | 6.3 | 6.3 | 6.2 | 6.1 | 5.9 | 5.9 |
| Rural | 2 | 2% | 7.4 | 6.8 | 6.6 | 6.6 | 6.6 | 6.6 | 6.6 | 6.5 | 6.4 | 6.2 | 6.2 |
| Rural | 2 | 3% | 7.8 | 7.1 | 6.9 | 6.9 | 6.9 | 6.9 | 6.9 | 6.8 | 6.7 | 6.5 | 6.5 |
| Rural | 2 | 4% | 8.2 | 7.6 | 7.4 | 7.4 | 7.4 | 7.4 | 7.4 | 7.3 | 7.2 | 7 | 7 |
| Rural | 2 | 5% | 8.8 | 8.1 | 7.9 | 7.9 | 7.9 | 7.9 | 7.9 | 7.8 | 7.7 | 7.5 | 7.5 |
| Rural | 2 | 6% | 9.4 | 8.7 | 8.4 | 8.4 | 8.4 | 8.4 | 8.4 | 8.3 | 8.2 | 8 | 8 |
| Rural | 2 | 7% | ~~9.9~~ | 9.3 | 9.1 | 9.1 | 9.1 | 9.1 | 9.1 | 9 | 8.9 | 8.7 | 8.7 |
| Rural | 4 | 0% | 9.1 | 7.6 | 6.9 | 6.8 | 6.7 | 6.6 | 6.5 | 6.4 | 6 | 5.8 | 5.6 |
| Rural | 4 | 1% | 9.4 | 7.9 | 7.2 | 7.1 | 7 | 6.9 | 6.8 | 6.7 | 6.3 | 6.1 | 5.9 |
| Rural | 4 | 2% | ~~9.8~~ | 8.3 | 7.5 | 7.4 | 7.3 | 7.2 | 7.1 | 7 | 6.6 | 6.4 | 6.2 |
| Rural | 4 | 3% | ~~10.2~~ | 8.7 | 7.8 | 7.7 | 7.6 | 7.5 | 7.4 | 7.3 | 6.9 | 6.7 | 6.5 |
| Rural | 4 | 4% | ~~10.6~~ | 9.1 | 8.3 | 8.2 | 8.1 | 8 | 7.9 | 7.8 | 7.4 | 7.2 | 7 |
| Rural | 4 | 5% | ~~11.2~~ | ~~9.7~~ | 8.8 | 8.7 | 8.6 | 8.5 | 8.4 | 8.3 | 7.9 | 7.7 | 7.5 |
| Rural | 4 | 6% | ~~11.8~~ | ~~10.3~~ | 9.3 | 9.2 | 9.1 | 9 | 8.9 | 8.8 | 8.4 | 8.2 | 8 |
| Rural | 4 | 7% | ~~12.3~~ | ~~10.8~~ | ~~10~~ | ~~9.9~~ | ~~9.8~~ | ~~9.7~~ | ~~9.6~~ | ~~9.5~~ | 9.1 | 8.9 | 8.7 |
| Rural | 6 | 0% | ~~10.3~~ | 8.5 | 7.5 | 7.4 | 7.3 | 7.1 | 6.9 | 6.7 | 6.3 | 6 | 5.8 |
| Rural | 6 | 1% | ~~10.6~~ | 8.8 | 7.8 | 7.7 | 7.6 | 7.4 | 7.2 | 7 | 6.6 | 6.3 | 6.1 |
| Rural | 6 | 2% | ~~11~~ | 9.2 | 8.1 | 8 | 7.9 | 7.7 | 7.5 | 7.3 | 6.9 | 6.6 | 6.4 |
| Rural | 6 | 3% | ~~11.4~~ | ~~9.6~~ | 8.4 | 8.3 | 8.2 | 8 | 7.8 | 7.6 | 7.2 | 6.9 | 6.7 |
| Rural | 6 | 4% | ~~11.8~~ | ~~10~~ | 8.9 | 8.8 | 8.7 | 8.5 | 8.3 | 8.1 | 7.7 | 7.4 | 7.2 |
| Rural | 6 | 5% | ~~12.4~~ | ~~10.6~~ | 9.4 | 9.3 | 9.2 | 9 | 8.8 | 8.6 | 8.2 | 7.9 | 7.7 |
| Rural | 6 | 6% | ~~13~~ | ~~11.2~~ | ~~9.9~~ | ~~9.8~~ | ~~9.7~~ | ~~9.5~~ | 9.3 | 9.1 | 8.7 | 8.4 | 8.2 |
| Rural | 6 | 7% | ~~13.5~~ | ~~11.7~~ | ~~10.6~~ | ~~10.5~~ | ~~10.4~~ | ~~10.2~~ | ~~10~~ | ~~9.8~~ | 9.4 | 9.1 | 8.9 |
| Rural | 8 | 0% | ~~11.1~~ | 9.2 | 8.1 | 7.9 | 7.8 | 7.6 | 7.4 | 7.2 | 6.5 | 6.2 | 6 |
| Rural | 8 | 1% | ~~11.4~~ | ~~9.5~~ | 8.4 | 8.2 | 8.1 | 7.9 | 7.7 | 7.5 | 6.8 | 6.5 | 6.3 |
| Rural | 8 | 2% | ~~11.8~~ | ~~9.9~~ | 8.7 | 8.5 | 8.4 | 8.2 | 8 | 7.8 | 7.1 | 6.8 | 6.6 |
| Rural | 8 | 3% | ~~12.2~~ | ~~10.3~~ | 9 | 8.8 | 8.7 | 8.5 | 8.3 | 8.1 | 7.4 | 7.1 | 6.9 |
| Rural | 8 | 4% | ~~12.6~~ | ~~10.7~~ | ~~9.5~~ | 9.3 | 9.2 | 9 | 8.8 | 8.6 | 7.9 | 7.6 | 7.4 |
| Rural | 8 | 5% | ~~13.2~~ | ~~11.3~~ | ~~10~~ | ~~9.8~~ | ~~9.7~~ | ~~9.5~~ | 9.3 | 9.1 | 8.4 | 8.1 | 7.9 |
| Rural | 8 | 6% | ~~13.8~~ | ~~11.9~~ | ~~10.5~~ | ~~10.3~~ | ~~10.2~~ | ~~10~~ | ~~9.8~~ | ~~9.6~~ | 8.9 | 8.6 | 8.4 |
| Rural | 8 | 7% | ~~14.3~~ | ~~12.4~~ | ~~11.2~~ | ~~11~~ | ~~10.9~~ | ~~10.7~~ | ~~10.5~~ | ~~10.3~~ | ~~9.6~~ | 9.3 | 9.1 |
| Rural | 10 | 0% | ~~11.8~~ | ~~9.7~~ | 8.6 | 8.4 | 8.1 | 7.9 | 7.7 | 7.5 | 6.6 | 6.4 | 6.2 |
| Rural | 10 | 1% | ~~12.1~~ | ~~10~~ | 8.9 | 8.7 | 8.4 | 8.2 | 8 | 7.8 | 6.9 | 6.7 | 6.5 |
| Rural | 10 | 2% | ~~12.5~~ | ~~10.4~~ | 9.2 | 9 | 8.7 | 8.5 | 8.3 | 8.1 | 7.2 | 7 | 6.8 |
| Rural | 10 | 3% | ~~12.9~~ | ~~10.8~~ | ~~9.5~~ | 9.3 | 9 | 8.8 | 8.6 | 8.4 | 7.5 | 7.3 | 7.1 |
| Rural | 10 | 4% | ~~13.3~~ | ~~11.2~~ | ~~10~~ | ~~9.8~~ | ~~9.5~~ | 9.3 | 9.1 | 8.9 | 8 | 7.8 | 7.6 |
| Rural | 10 | 5% | ~~13.9~~ | ~~11.8~~ | ~~10.5~~ | ~~10.3~~ | ~~10~~ | ~~9.8~~ | ~~9.6~~ | 9.4 | 8.5 | 8.3 | 8.1 |
| Rural | 10 | 6% | ~~14.5~~ | ~~12.4~~ | ~~11~~ | ~~10.8~~ | ~~10.5~~ | ~~10.3~~ | ~~10.1~~ | ~~9.9~~ | 9 | 8.8 | 8.6 |
| Rural | 10 | 7% | ~~15~~ | ~~12.9~~ | ~~11.7~~ | ~~11.5~~ | ~~11.2~~ | ~~11~~ | ~~10.8~~ | ~~10.6~~ | ~~9.7~~ | ~~9.5~~ | 9.3 |
| Rural | 12 | 0% | ~~12.3~~ | ~~10.7~~ | 9.1 | 8.9 | 8.6 | 8.2 | 8 | 7.8 | 6.8 | 6.7 | 6.4 |
| Rural | 12 | 1% | ~~12.6~~ | ~~10.8~~ | 9.4 | 9.2 | 8.9 | 8.5 | 8.3 | 8.1 | 7.1 | 7 | 6.7 |
| Rural | 12 | 2% | ~~13~~ | ~~10.9~~ | ~~9.7~~ | ~~9.5~~ | 9.2 | 8.8 | 8.6 | 8.4 | 7.4 | 7.3 | 7 |
| Rural | 12 | 3% | ~~13.4~~ | ~~11.1~~ | ~~10~~ | ~~9.8~~ | ~~9.5~~ | 9.1 | 8.9 | 8.7 | 7.7 | 7.6 | 7.3 |
| Rural | 12 | 4% | ~~13.8~~ | ~~11.5~~ | ~~10.5~~ | ~~10.3~~ | ~~10~~ | ~~9.6~~ | 9.4 | 9.2 | 8.2 | 8.1 | 7.8 |
| Rural | 12 | 5% | ~~14.4~~ | ~~12.1~~ | ~~11~~ | ~~10.8~~ | ~~10.5~~ | ~~10.1~~ | ~~9.9~~ | ~~9.7~~ | 8.7 | 8.6 | 8.3 |
| Rural | 12 | 6% | ~~15~~ | ~~12.7~~ | ~~11.5~~ | ~~11.3~~ | ~~11~~ | ~~10.6~~ | ~~10.4~~ | ~~10.2~~ | 9.2 | 9.1 | 8.8 |
| Rural | 12 | 7% | ~~15.5~~ | ~~13.2~~ | ~~12.2~~ | ~~12~~ | ~~11.7~~ | ~~11.3~~ | ~~11.1~~ | ~~10.9~~ | ~~9.9~~ | ~~9.8~~ | ~~9.5~~ |
| Urban | 2 | 0% | 4.4 | 4.1 | 4 | 4 | 4 | 4 | 4 | 4 | 3.8 | 3.8 | 3.8 |
| Urban | 2 | 1% | 4.6 | 4.4 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.1 | 4.1 | 4.1 |
| Urban | 2 | 2% | 4.8 | 4.6 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.3 | 4.3 | 4.3 |
| Urban | 2 | 3% | 5.1 | 4.8 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.5 | 4.5 | 4.5 |
| Urban | 2 | 4% | 5.5 | 5.3 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 5 | 5 | 5 |
| Urban | 2 | 5% | 5.8 | 5.6 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.5 | 5.3 | 5.3 | 5.3 |
| Urban | 2 | 6% | 6.4 | 6.2 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | 5.9 | 5.9 | 5.9 |
| Urban | 2 | 7% | 6.8 | 6.6 | 6.5 | 6.5 | 6.5 | 6.5 | 6.5 | 6.5 | 6.3 | 6.3 | 6.3 |
| Urban | 4 | 0% | 5.8 | 5.1 | 4.4 | 4.4 | 4.3 | 4.2 | 4.2 | 4.2 | 4 | 4 | 3.8 |
| Urban | 4 | 1% | 5.9 | 5.2 | 4.7 | 4.7 | 4.6 | 4.5 | 4.5 | 4.5 | 4.3 | 4.3 | 4.1 |
| Urban | 4 | 2% | 6.2 | 5.5 | 4.9 | 4.9 | 4.8 | 4.7 | 4.7 | 4.7 | 4.5 | 4.5 | 4.3 |
| Urban | 4 | 3% | 6.5 | 5.8 | 5.1 | 5.1 | 5 | 4.9 | 4.9 | 4.9 | 4.7 | 4.7 | 4.5 |
| Urban | 4 | 4% | 6.8 | 6.1 | 5.6 | 5.6 | 5.5 | 5.4 | 5.4 | 5.4 | 5.2 | 5.2 | 5 |
| Urban | 4 | 5% | 7.1 | 6.4 | 5.9 | 5.9 | 5.8 | 5.7 | 5.7 | 5.7 | 5.5 | 5.5 | 5.3 |
| Urban | 4 | 6% | 7.6 | 6.9 | 6.5 | 6.5 | 6.4 | 6.3 | 6.3 | 6.3 | 6.1 | 6.1 | 5.9 |
| Urban | 4 | 7% | 7.9 | 7.2 | 6.9 | 6.9 | 6.8 | 6.7 | 6.7 | 6.7 | 6.5 | 6.5 | 6.3 |
| Urban | 6 | 0% | 6.7 | 5.8 | 4.8 | 4.7 | 4.6 | 4.5 | 4.4 | 4.4 | 4.2 | 4 | 3.8 |
| Urban | 6 | 1% | 6.8 | 5.9 | 5 | 5 | 4.9 | 4.8 | 4.7 | 4.7 | 4.5 | 4.3 | 4.1 |
| Urban | 6 | 2% | 7.1 | 6.2 | 5.2 | 5.2 | 5.1 | 5 | 4.9 | 4.9 | 4.7 | 4.5 | 4.3 |
| Urban | 6 | 3% | 7.4 | 6.5 | 5.5 | 5.4 | 5.3 | 5.2 | 5.1 | 5.1 | 4.9 | 4.7 | 4.5 |
| Urban | 6 | 4% | 7.7 | 6.8 | 5.9 | 5.9 | 5.8 | 5.7 | 5.6 | 5.6 | 5.4 | 5.2 | 5 |
| Urban | 6 | 5% | 8 | 7.1 | 6.2 | 6.2 | 6.1 | 6 | 5.9 | 5.9 | 5.7 | 5.5 | 5.3 |
| Urban | 6 | 6% | 8.5 | 7.6 | 6.8 | 6.8 | 6.7 | 6.6 | 6.5 | 6.5 | 6.3 | 6.1 | 5.9 |
| Urban | 6 | 7% | 8.8 | 7.9 | 7.2 | 7.2 | 7.1 | 7 | 6.9 | 6.9 | 6.7 | 6.5 | 6.3 |
| Urban | 8 | 0% | 7.3 | 6.4 | 5.1 | 4.9 | 4.9 | 4.7 | 4.7 | 4.6 | 4.4 | 4.2 | 4 |
| Urban | 8 | 1% | 7.4 | 6.4 | 5.3 | 5.2 | 5.2 | 5 | 5 | 4.9 | 4.7 | 4.5 | 4.3 |
| Urban | 8 | 2% | 7.7 | 6.7 | 5.5 | 5.4 | 5.4 | 5.2 | 5.2 | 5.1 | 4.9 | 4.7 | 4.5 |
| Urban | 8 | 3% | 8 | 7 | 5.8 | 5.6 | 5.6 | 5.4 | 5.4 | 5.3 | 5.1 | 4.9 | 4.7 |
| Urban | 8 | 4% | 8.3 | 7.3 | 6.2 | 6.1 | 6.1 | 5.9 | 5.9 | 5.7 | 5.5 | 5.4 | 5.2 |
| Urban | 8 | 5% | 8.6 | 7.6 | 6.5 | 6.4 | 6.4 | 6.2 | 6.2 | 6 | 5.8 | 5.7 | 5.5 |
| Urban | 8 | 6% | 9.1 | 8.1 | 7.1 | 7 | 7 | 6.8 | 6.8 | 6.6 | 6.4 | 6.3 | 6.1 |
| Urban | 8 | 7% | 9.4 | 8.4 | 7.5 | 7.4 | 7.4 | 7.2 | 7.2 | 7 | 6.8 | 6.7 | 6.5 |
| Urban | 10 | 0% | 7.9 | 7.2 | 5.6 | 5.2 | 5.1 | 5 | 4.9 | 4.9 | 4.5 | 4.3 | 4 |
| Urban | 10 | 1% | 7.9 | 7.2 | 5.6 | 5.5 | 5.4 | 5.3 | 5.2 | 5.2 | 4.8 | 4.6 | 4.3 |
| Urban | 10 | 2% | 8.2 | 7.5 | 5.9 | 5.7 | 5.6 | 5.5 | 5.4 | 5.4 | 5 | 4.8 | 4.5 |
| Urban | 10 | 3% | 8.5 | 7.6 | 6.2 | 5.9 | 5.8 | 5.7 | 5.6 | 5.6 | 5.3 | 5 | 4.7 |
| Urban | 10 | 4% | 8.8 | 7.9 | 6.5 | 6.4 | 6.2 | 6.1 | 6.1 | 5.9 | 5.7 | 5.4 | 5.2 |
| Urban | 10 | 5% | 9.1 | 8 | 6.8 | 6.7 | 6.5 | 6.4 | 6.4 | 6.2 | 6 | 5.7 | 5.5 |
| Urban | 10 | 6% | ~~9.6~~ | 8.5 | 7.3 | 7.3 | 7.1 | 7 | 7 | 6.8 | 6.6 | 6.3 | 6.1 |
| Urban | 10 | 7% | ~~9.9~~ | 8.8 | 7.7 | 7.7 | 7.5 | 7.4 | 7.4 | 7.2 | 7 | 6.7 | 6.5 |
| Urban | 12 | 0% | 8.6 | 7.8 | 6 | 5.6 | 5.4 | 5.3 | 5.2 | 5.1 | 4.7 | 4.4 | 4.2 |
| Urban | 12 | 1% | 8.6 | 7.8 | 6 | 5.8 | 5.7 | 5.6 | 5.5 | 5.4 | 5 | 4.7 | 4.5 |
| Urban | 12 | 2% | 8.9 | 8.1 | 6.3 | 6 | 5.9 | 5.8 | 5.7 | 5.6 | 5.2 | 4.9 | 4.7 |
| Urban | 12 | 3% | 9 | 8.2 | 6.4 | 6.2 | 6.1 | 6 | 5.9 | 5.8 | 5.4 | 5.2 | 4.9 |
| Urban | 12 | 4% | 9.3 | 8.5 | 6.7 | 6.6 | 6.4 | 6.4 | 6.2 | 6.1 | 5.8 | 5.6 | 5.4 |
| Urban | 12 | 5% | ~~9.6~~ | 8.6 | 7 | 6.9 | 6.7 | 6.7 | 6.5 | 6.4 | 6.1 | 5.9 | 5.7 |
| Urban | 12 | 6% | ~~10.1~~ | 9 | 7.6 | 7.5 | 7.3 | 7.3 | 7.1 | 7 | 6.7 | 6.5 | 6.3 |
| Urban | 12 | 7% | ~~10.4~~ | 9.3 | 8 | 7.9 | 7.7 | 7.7 | 7.5 | 7.4 | 7.1 | 6.9 | 6.7 |

Notes: Red strikethrough values indicated exceedances of the standard

\* These findings apply to scenarios with average speed ranging from 15 to 56 mph for arterials and 19 to 75 mph for freeways, for which posted speeds in those ranges may be applied as reasonable proxies.

| Table B-5 (c). One-hour CO Concentrations at Varying Intersection-Freeway Distances, Intersection Grade, and Lane Configurations for 90o Skew Angle (not including background concentrations)\* | | | | | | | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Location** | **Number of Lanes** | **Intersection Grade** | **Distance between Freeway and Intersection (ft)** | | | | | | | | | | |
| **20** | **30** | **60** | **80** | **100** | **125** | **150** | **175** | **300** | **500** | **1000** |
| Rural | 2 | 0% | 6.7 | 6 | 5.8 | 5.8 | 5.8 | 5.8 | 5.8 | 5.6 | 5.6 | 5.6 | 5.4 |
| Rural | 2 | 1% | 7 | 6.3 | 6 | 6 | 6 | 6 | 6 | 5.8 | 5.8 | 5.7 | 5.6 |
| Rural | 2 | 2% | 7.4 | 6.7 | 6.4 | 6.4 | 6.4 | 6.4 | 6.4 | 6.2 | 6.2 | 6.2 | 6 |
| Rural | 2 | 3% | 7.8 | 7.1 | 6.7 | 6.7 | 6.7 | 6.7 | 6.7 | 6.5 | 6.5 | 6.3 | 6.3 |
| Rural | 2 | 4% | 8.1 | 7.4 | 7.2 | 7.2 | 7.2 | 7.2 | 7.2 | 7 | 7 | 6.8 | 6.8 |
| Rural | 2 | 5% | 8.8 | 8.1 | 7.7 | 7.7 | 7.7 | 7.7 | 7.7 | 7.5 | 7.5 | 7.3 | 7.3 |
| Rural | 2 | 6% | 9.4 | 8.7 | 8.2 | 8.2 | 8.2 | 8.2 | 8.2 | 8 | 8 | 7.8 | 7.8 |
| Rural | 2 | 7% | ~~9.9~~ | 9.2 | 8.8 | 8.8 | 8.8 | 8.8 | 8.8 | 8.6 | 8.6 | 8.4 | 8.4 |
| Rural | 4 | 0% | 9 | 7.6 | 6.7 | 6.6 | 6.5 | 6.4 | 6.3 | 6.2 | 5.8 | 5.8 | 5.6 |
| Rural | 4 | 1% | 9.3 | 7.9 | 6.9 | 6.8 | 6.7 | 6.6 | 6.5 | 6.4 | 6 | 5.9 | 5.7 |
| Rural | 4 | 2% | ~~9.7~~ | 8.3 | 7.3 | 7.2 | 7.1 | 7 | 6.9 | 6.8 | 6.4 | 6.4 | 6.2 |
| Rural | 4 | 3% | ~~10.1~~ | 8.7 | 7.6 | 7.5 | 7.4 | 7.3 | 7.2 | 7.1 | 6.7 | 6.5 | 6.3 |
| Rural | 4 | 4% | ~~10.4~~ | 9 | 8.1 | 8 | 7.9 | 7.8 | 7.7 | 7.6 | 7.2 | 6.9 | 6.8 |
| Rural | 4 | 5% | ~~11.1~~ | ~~9.7~~ | 8.6 | 8.5 | 8.4 | 8.3 | 8.2 | 8.1 | 7.7 | 7.4 | 7.3 |
| Rural | 4 | 6% | ~~11.7~~ | ~~10.3~~ | 9.1 | 9 | 8.9 | 8.8 | 8.7 | 8.6 | 8.2 | 7.9 | 7.8 |
| Rural | 4 | 7% | ~~12.2~~ | ~~10.8~~ | ~~9.7~~ | ~~9.6~~ | ~~9.5~~ | 9.4 | 9.3 | 9.2 | 8.8 | 8.5 | 8.4 |
| Rural | 6 | 0% | ~~10.3~~ | 8.5 | 7.3 | 7.1 | 7 | 6.9 | 6.7 | 6.5 | 6 | 6 | 5.8 |
| Rural | 6 | 1% | ~~10.6~~ | 8.8 | 7.5 | 7.3 | 7.2 | 7.1 | 6.9 | 6.7 | 6.2 | 6.1 | 5.9 |
| Rural | 6 | 2% | ~~11~~ | 9.2 | 7.9 | 7.7 | 7.6 | 7.5 | 7.3 | 7.1 | 6.6 | 6.6 | 6.4 |
| Rural | 6 | 3% | ~~11.4~~ | ~~9.6~~ | 8.2 | 8 | 7.9 | 7.8 | 7.6 | 7.4 | 6.9 | 6.7 | 6.5 |
| Rural | 6 | 4% | ~~11.7~~ | ~~9.9~~ | 8.7 | 8.5 | 8.4 | 8.3 | 8.1 | 7.9 | 7.4 | 7.1 | 6.9 |
| Rural | 6 | 5% | ~~12.4~~ | ~~10.6~~ | 9.2 | 9 | 8.9 | 8.8 | 8.6 | 8.4 | 7.9 | 7.5 | 7.3 |
| Rural | 6 | 6% | ~~13~~ | ~~11.2~~ | ~~9.7~~ | ~~9.5~~ | 9.4 | 9.3 | 9.1 | 8.9 | 8.4 | 8 | 7.8 |
| Rural | 6 | 7% | ~~13.5~~ | ~~11.7~~ | ~~10.3~~ | ~~10.1~~ | ~~10~~ | ~~9.9~~ | ~~9.7~~ | ~~9.5~~ | 9 | 8.6 | 8.4 |
| Rural | 8 | 0% | ~~11.1~~ | 9 | 7.9 | 7.7 | 7.5 | 7.2 | 7.1 | 6.9 | 6.3 | 6.2 | 6 |
| Rural | 8 | 1% | ~~11.4~~ | 9.3 | 8.1 | 7.9 | 7.7 | 7.4 | 7.3 | 7.1 | 6.4 | 6.3 | 6.1 |
| Rural | 8 | 2% | ~~11.8~~ | ~~9.7~~ | 8.5 | 8.3 | 8.1 | 7.8 | 7.7 | 7.5 | 6.9 | 6.8 | 6.6 |
| Rural | 8 | 3% | ~~12.2~~ | ~~10.1~~ | 8.8 | 8.6 | 8.4 | 8.1 | 8 | 7.8 | 7.1 | 6.9 | 6.7 |
| Rural | 8 | 4% | ~~12.5~~ | ~~10.4~~ | 9.3 | 9.1 | 8.9 | 8.6 | 8.5 | 8.3 | 7.6 | 7.3 | 7.1 |
| Rural | 8 | 5% | ~~13.2~~ | ~~11.1~~ | ~~9.8~~ | ~~9.6~~ | 9.4 | 9.1 | 9 | 8.8 | 8.1 | 7.7 | 7.5 |
| Rural | 8 | 6% | ~~13.8~~ | ~~11.7~~ | ~~10.3~~ | ~~10.1~~ | ~~9.9~~ | ~~9.6~~ | ~~9.5~~ | 9.3 | 8.6 | 8.2 | 8 |
| Rural | 8 | 7% | ~~14.3~~ | ~~12.2~~ | ~~10.9~~ | ~~10.7~~ | ~~10.5~~ | ~~10.2~~ | ~~10.1~~ | ~~9.9~~ | 9.2 | 8.8 | 8.6 |
| Rural | 10 | 0% | ~~11.8~~ | ~~9.5~~ | 8.4 | 8.2 | 7.9 | 7.7 | 7.5 | 7.2 | 6.5 | 6.3 | 6 |
| Rural | 10 | 1% | ~~12.1~~ | ~~9.8~~ | 8.6 | 8.4 | 8.1 | 7.9 | 7.7 | 7.4 | 6.6 | 6.4 | 6.1 |
| Rural | 10 | 2% | ~~12.5~~ | ~~10.2~~ | 9 | 8.8 | 8.5 | 8.3 | 8.1 | 7.8 | 7.1 | 6.9 | 6.6 |
| Rural | 10 | 3% | ~~12.9~~ | ~~10.6~~ | 9.3 | 9.1 | 8.8 | 8.6 | 8.4 | 8.1 | 7.3 | 7 | 6.7 |
| Rural | 10 | 4% | ~~13.2~~ | ~~10.9~~ | ~~9.8~~ | ~~9.6~~ | 9.3 | 9.1 | 8.9 | 8.6 | 7.8 | 7.4 | 7.1 |
| Rural | 10 | 5% | ~~13.9~~ | ~~11.6~~ | ~~10.3~~ | ~~10.1~~ | ~~9.8~~ | ~~9.6~~ | 9.4 | 9.1 | 8.3 | 7.8 | 7.5 |
| Rural | 10 | 6% | ~~14.5~~ | ~~12.2~~ | ~~10.8~~ | ~~10.6~~ | ~~10.3~~ | ~~10.1~~ | ~~9.9~~ | ~~9.6~~ | 8.8 | 8.3 | 8 |
| Rural | 10 | 7% | ~~15~~ | ~~12.7~~ | ~~11.4~~ | ~~11.2~~ | ~~10.9~~ | ~~10.7~~ | ~~10.5~~ | ~~10.2~~ | 9.4 | 8.9 | 8.6 |
| Rural | 12 | 0% | ~~12.3~~ | ~~10.6~~ | 8.9 | 8.5 | 8.3 | 8 | 7.8 | 7.5 | 6.7 | 6.5 | 6.2 |
| Rural | 12 | 1% | ~~12.6~~ | ~~10.7~~ | 9.1 | 8.7 | 8.5 | 8.2 | 8 | 7.7 | 6.8 | 6.6 | 6.3 |
| Rural | 12 | 2% | ~~13~~ | ~~10.7~~ | ~~9.5~~ | 9.1 | 8.9 | 8.6 | 8.4 | 8.1 | 7.3 | 7.1 | 6.8 |
| Rural | 12 | 3% | ~~13.4~~ | ~~11~~ | ~~9.8~~ | 9.4 | 9.2 | 8.9 | 8.7 | 8.4 | 7.4 | 7.2 | 6.9 |
| Rural | 12 | 4% | ~~13.7~~ | ~~11.3~~ | ~~10.3~~ | ~~9.9~~ | ~~9.7~~ | 9.4 | 9.2 | 8.9 | 7.9 | 7.6 | 7.3 |
| Rural | 12 | 5% | ~~14.4~~ | ~~12~~ | ~~10.8~~ | ~~10.4~~ | ~~10.2~~ | ~~9.9~~ | ~~9.7~~ | 9.4 | 8.4 | 8 | 7.7 |
| Rural | 12 | 6% | ~~15~~ | ~~12.6~~ | ~~11.3~~ | ~~10.9~~ | ~~10.7~~ | ~~10.4~~ | ~~10.2~~ | ~~9.9~~ | 8.9 | 8.5 | 8.2 |
| Rural | 12 | 7% | ~~15.5~~ | ~~13.1~~ | ~~11.9~~ | ~~11.5~~ | ~~11.3~~ | ~~11~~ | ~~10.8~~ | ~~10.5~~ | ~~9.5~~ | 9.1 | 8.8 |
| Urban | 2 | 0% | 4.5 | 4.2 | 3.9 | 3.8 | 3.8 | 3.8 | 3.8 | 3.8 | 3.7 | 3.6 | 3.6 |
| Urban | 2 | 1% | 4.6 | 4.3 | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 | 4.1 | 3.9 | 3.9 | 3.9 |
| Urban | 2 | 2% | 4.9 | 4.6 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.3 | 4.1 | 4.1 | 4.1 |
| Urban | 2 | 3% | 5.2 | 4.9 | 4.6 | 4.5 | 4.5 | 4.5 | 4.5 | 4.5 | 4.3 | 4.3 | 4.3 |
| Urban | 2 | 4% | 5.4 | 5.1 | 4.8 | 4.7 | 4.7 | 4.7 | 4.7 | 4.7 | 4.5 | 4.5 | 4.5 |
| Urban | 2 | 5% | 5.8 | 5.5 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 5.2 | 5 | 5 | 5 |
| Urban | 2 | 6% | 6.3 | 6 | 5.7 | 5.6 | 5.6 | 5.6 | 5.6 | 5.6 | 5.4 | 5.4 | 5.4 |
| Urban | 2 | 7% | 6.7 | 6.4 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | 6.1 | 5.9 | 5.9 | 5.9 |
| Urban | 4 | 0% | 5.9 | 5.2 | 4.5 | 4.2 | 4.2 | 4 | 4 | 4 | 3.9 | 3.8 | 3.8 |
| Urban | 4 | 1% | 6 | 5.3 | 4.6 | 4.5 | 4.4 | 4.3 | 4.3 | 4.3 | 4.1 | 4.1 | 4 |
| Urban | 4 | 2% | 6.3 | 5.6 | 4.9 | 4.7 | 4.6 | 4.5 | 4.5 | 4.5 | 4.3 | 4.3 | 4.1 |
| Urban | 4 | 3% | 6.6 | 5.9 | 5.2 | 4.9 | 4.9 | 4.7 | 4.7 | 4.7 | 4.5 | 4.5 | 4.3 |
| Urban | 4 | 4% | 6.8 | 6.1 | 5.4 | 5.1 | 5.1 | 4.9 | 4.9 | 4.9 | 4.7 | 4.7 | 4.5 |
| Urban | 4 | 5% | 7.2 | 6.5 | 5.8 | 5.6 | 5.5 | 5.4 | 5.4 | 5.4 | 5.2 | 5.2 | 5 |
| Urban | 4 | 6% | 7.7 | 7 | 6.3 | 6 | 6 | 5.8 | 5.8 | 5.8 | 5.6 | 5.6 | 5.4 |
| Urban | 4 | 7% | 8.1 | 7.4 | 6.7 | 6.5 | 6.4 | 6.3 | 6.3 | 6.3 | 6.1 | 6.1 | 5.9 |
| Urban | 6 | 0% | 6.8 | 5.9 | 4.9 | 4.6 | 4.4 | 4.3 | 4.2 | 4.2 | 4 | 4 | 3.8 |
| Urban | 6 | 1% | 6.9 | 6 | 5 | 4.8 | 4.7 | 4.6 | 4.5 | 4.5 | 4.3 | 4.2 | 4 |
| Urban | 6 | 2% | 7.2 | 6.3 | 5.3 | 5 | 4.9 | 4.8 | 4.7 | 4.7 | 4.5 | 4.3 | 4.1 |
| Urban | 6 | 3% | 7.5 | 6.6 | 5.6 | 5.3 | 5.1 | 5 | 4.9 | 4.9 | 4.7 | 4.5 | 4.3 |
| Urban | 6 | 4% | 7.7 | 6.8 | 5.8 | 5.5 | 5.3 | 5.2 | 5.1 | 5.1 | 4.9 | 4.7 | 4.5 |
| Urban | 6 | 5% | 8.1 | 7.2 | 6.2 | 5.9 | 5.8 | 5.7 | 5.6 | 5.6 | 5.4 | 5.2 | 5 |
| Urban | 6 | 6% | 8.6 | 7.7 | 6.7 | 6.4 | 6.2 | 6.1 | 6 | 6 | 5.8 | 5.6 | 5.4 |
| Urban | 6 | 7% | 9 | 8.1 | 7.1 | 6.8 | 6.7 | 6.6 | 6.5 | 6.5 | 6.3 | 6.1 | 5.9 |
| Urban | 8 | 0% | 7.4 | 6.4 | 5.2 | 4.9 | 4.7 | 4.5 | 4.5 | 4.4 | 4.2 | 4.1 | 4 |
| Urban | 8 | 1% | 7.5 | 6.5 | 5.3 | 5 | 5 | 4.8 | 4.8 | 4.6 | 4.4 | 4.3 | 4.2 |
| Urban | 8 | 2% | 7.8 | 6.8 | 5.6 | 5.3 | 5.2 | 5 | 5 | 4.8 | 4.6 | 4.4 | 4.3 |
| Urban | 8 | 3% | 8.1 | 7.1 | 5.9 | 5.6 | 5.4 | 5.2 | 5.2 | 5 | 4.8 | 4.6 | 4.5 |
| Urban | 8 | 4% | 8.3 | 7.3 | 6.1 | 5.8 | 5.6 | 5.4 | 5.4 | 5.2 | 5 | 4.8 | 4.7 |
| Urban | 8 | 5% | 8.7 | 7.7 | 6.5 | 6.2 | 6.1 | 5.9 | 5.9 | 5.7 | 5.5 | 5.3 | 5.2 |
| Urban | 8 | 6% | 9.2 | 8.2 | 7 | 6.7 | 6.5 | 6.3 | 6.3 | 6.1 | 5.9 | 5.7 | 5.6 |
| Urban | 8 | 7% | ~~9.6~~ | 8.6 | 7.4 | 7.1 | 7 | 6.8 | 6.8 | 6.6 | 6.4 | 6.2 | 6.1 |
| Urban | 10 | 0% | 7.9 | 7.1 | 5.6 | 5.2 | 4.9 | 4.7 | 4.7 | 4.6 | 4.4 | 4.2 | 4 |
| Urban | 10 | 1% | 8 | 7.2 | 5.7 | 5.3 | 5.1 | 5 | 4.9 | 4.8 | 4.6 | 4.4 | 4.2 |
| Urban | 10 | 2% | 8.3 | 7.5 | 6 | 5.6 | 5.3 | 5.2 | 5.1 | 5 | 4.7 | 4.5 | 4.3 |
| Urban | 10 | 3% | 8.6 | 7.6 | 6.3 | 5.9 | 5.6 | 5.4 | 5.3 | 5.2 | 4.9 | 4.7 | 4.5 |
| Urban | 10 | 4% | 8.8 | 7.8 | 6.5 | 6.1 | 5.8 | 5.6 | 5.5 | 5.4 | 5.1 | 4.9 | 4.7 |
| Urban | 10 | 5% | 9.2 | 8.1 | 6.9 | 6.5 | 6.2 | 6.1 | 6 | 5.9 | 5.6 | 5.4 | 5.2 |
| Urban | 10 | 6% | ~~9.7~~ | 8.6 | 7.4 | 7 | 6.7 | 6.5 | 6.4 | 6.3 | 6 | 5.8 | 5.6 |
| Urban | 10 | 7% | ~~10.1~~ | 9 | 7.8 | 7.4 | 7.1 | 7 | 6.9 | 6.8 | 6.5 | 6.3 | 6.1 |
| Urban | 12 | 0% | 8.5 | 7.7 | 5.9 | 5.4 | 5.1 | 5 | 4.9 | 4.8 | 4.6 | 4.4 | 4.2 |
| Urban | 12 | 1% | 8.6 | 7.8 | 6 | 5.5 | 5.3 | 5.3 | 5.1 | 5 | 4.8 | 4.6 | 4.4 |
| Urban | 12 | 2% | 8.9 | 8.1 | 6.3 | 5.8 | 5.5 | 5.5 | 5.3 | 5.2 | 4.9 | 4.7 | 4.5 |
| Urban | 12 | 3% | 9.1 | 8.2 | 6.5 | 6 | 5.7 | 5.7 | 5.5 | 5.4 | 5.1 | 4.9 | 4.7 |
| Urban | 12 | 4% | 9.3 | 8.4 | 6.7 | 6.2 | 5.9 | 5.9 | 5.7 | 5.6 | 5.3 | 5.1 | 4.9 |
| Urban | 12 | 5% | ~~9.7~~ | 8.7 | 7.1 | 6.6 | 6.4 | 6.4 | 6.2 | 6.1 | 5.8 | 5.6 | 5.4 |
| Urban | 12 | 6% | ~~10.2~~ | 9.1 | 7.6 | 7.1 | 6.8 | 6.8 | 6.6 | 6.5 | 6.2 | 6 | 5.8 |
| Urban | 12 | 7% | ~~10.6~~ | ~~9.5~~ | 8 | 7.5 | 7.3 | 7.3 | 7.1 | 7 | 6.7 | 6.5 | 6.3 |

\* These findings apply to scenarios with average speed ranging from 15 to 56 mph for arterials and 19 to 75 mph for freeways, for which posted speeds in those ranges may be applied as reasonable proxies.

1. ICF, Zamurs and Associates, and Volpe Transportation Center, NCHRP 25-25/Task 78, “*Programmatic Agreements for Project-Level Air Quality Analyses*”, 2015.

   See: <http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=3311> [↑](#footnote-ref-1)
2. As noted in the 2015 NCHRP 25-25 Task 78 report, following a review of state agreements in place at that time, the 2009 Virginia DOT PA and TSD were selected as the model for the new national template. Due to limited funding, however, the 2015 NCHRP Task 78 templates did not include skew angles, which had been included in the Virginia DOT version. This update to the 2015 NCHRP templates includes both skew angles and road grades. [↑](#footnote-ref-2)
3. US EPA, *Guideline for Modeling Carbon Monoxide from Roadway Intersections*, EPA-454/R-92-005, Nov. 1992; and *Using MOVES in Project-Level Carbon Monoxide Analyses*, EPA-420-C-10-041 December 2010 [↑](#footnote-ref-3)
4. E. Carr, S. Hartley, G. Noel & A. Eilbert, NCHRP 25-25 Task 104, “*Streamlining Carbon Monoxide Project-Level Air Quality Analyses with Programmatic Agreements*”, 2020. <http://apps.trb.org/cmsfeed/TRBNetProjectDisplay.asp?ProjectID=4100> [↑](#footnote-ref-4)
5. FHWA Carbon Monoxide Categorical Hot-Spot Finding *(Superseded)*, February 2014. Available at: <http://www.fhwa.dot.gov/environment/air_quality/conformity/policy_and_guidance/cmcf/> [↑](#footnote-ref-5)
6. FHWA Carbon Monoxide Categorical Hot-Spot Finding, 2017. Available at: <https://www.fhwa.dot.gov/environment/air_quality/conformity/policy_and_guidance/cmcf_2017/index.cfm> [↑](#footnote-ref-6)
7. State DOTs have encouraged FHWA to explore options for expanding its CF, e.g., by incorporating the project types and configurations covered by this template PA. [↑](#footnote-ref-7)
8. These findings apply to scenarios with average speed ranging from 15 to 56 mph for arterials and 19 to 75 mph for freeways. For application of the PA, posted speeds may be assumed in place of forecast speeds. [↑](#footnote-ref-8)
9. These findings apply to scenarios with average speed ranging from 15 to 45 mph for intersections. For application of the PA, posted speeds may be assumed in place of forecast speeds. [↑](#footnote-ref-9)
10. As part of NCHRP 25-25, Task 78 sensitivity testing showed that only a few percentage points higher CO concentration was found when using 11-foot lane widths rather than standard 12-foot width. [↑](#footnote-ref-10)