Technical Note for Modelling Vehicular Emissions Using AERMOD

Contents

1 Introduction

The Technical Note (TN) present the principles and requirements for modelling vehicular emissions using AERMOD for projects in Hong Kong. AERMOD, developed and maintained by the USEPA, is the state-of-the-science air dispersion model for regulatory applications. USEPA has documented their detailed study on the replacement of CALINE to AERMOD for vehicular emission applications in the Technical Support Document for Replacement of CALINE3 with AERMOD for Transportation Related Air Quality Analyses (Ref 1). It is also the intention of the EPD to use a single model for modelling all Tier 1 and Tier 2 sources for consistency and to minimise preparation efforts for separate models.

The technical note has the following aims:

- To provide a best practice guide and a consistent methodology for air modellers to conduct assessment;
- To ensure that modelling studies are undertaken with satisfactory accuracy and reliability and that the report details the methodology and results clearly; and
- To ensure there is a sound scientific basis to the methodology

This TN is not intended to be a guideline for AERMOD model. Please refer to USEPA's guidelines on AERMOD for full details related to this model (Ref 2).

Ref 1. USEPA, Technical Support Document (TSD) for Replacement of CALINE3 with AERMOD for Transportation Related Air Quality Analyses, December 2016.

Ref 2. USEPA, Support Center for Regulatory Atmospheric Modelling, https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models#aermod

2 Source Characterization

This section describes the recommended source characterisation for the vehicular emissions on open roads using AERMOD.

2.1 Source types

When modelling the dispersion of vehicular emissions from an open road, line sources are preferred over other source types such as area sources, volume and point sources considering the linear geometry of roads and the similar configuration of this source type in the previous model used for open roads (i.e. CALINE).

2.2 Source parameters

When setting up a line source in AERMOD, the following parameters are required in the source card and are described in the following sections.

- Source location
    - Source type: LINE
    - The coordinates of road segment (X1, Y1, X2, Y2)
    - The base elevation of the ground surface beneath the road link (mPD)
- Road parameters
    - The emission rate is input in units of gram per second per square meter (g/s-m^2)
    - The release height above ground in meters (mAG)
    - The width of the line source in meters (m)
    - The initial vertical dimension coefficient (Szinit) of the source in meters (m)
- Emission profile
    - Use EMISFACT to specify variable emission factors

In AERMOD, the source keywords and parameters for LINE source type in an input file are summarised below:

SO LOCATION	SrcID Srctyp Xs1 Ys1 Xs2 Ys2 Zs
SO SRCPARAM	SrcID Lnemis Relhgt Width (Szinit)
where	SrcID: Source ID Srctyp: Source type, LINE for open road emissions Xs1 Ys1 Xs2 Ys2: X and Y coordinates of the midpoint of the start and end of the line source Zs: base elevation of the source in mPD

	Lnemis: emission rate Relhgt: release height Width: width of the source Szinit: initial vertical dimension of the line source.

2.2.1 Source Location: Coordinates and base elevation

Enter the coordinates of the midpoint of the ends of the road links in the SO LOCATION card.

The base elevation is the elevation of the ground surface underneath the road link in meter above Principal Datum (mPD). Do not include the height of the road surface above ground level into the base elevation.

<u>Sample Source Location card:</u>

	Road link ID	Source Type	Starting x y	Ending x y	Base Elevation
SO LOCATION	RD_001_2	LINE	821001.5 821253.4	821001.2 821253.0	13
SO LOCATION	RD_001_3	LINE	821001.2 821253.0	820997.0 821249.0	10

2.2.2 Emission rates

Source Parameters (Lnemis Relhgt Width Szinit)
① "Lnemis" -- The emission rate per unit area (mass per unit area per unit time)

For estimating the vehicular emission rates, the latest version of EMFAC-HK model should be adopted and the corresponding guideline should be followed [LINK].

The units of emission rates in CALINE model (gram per mile per vehicle) were different from the metric units in AERMOD (gram per second per square meter). The emission rates in AERMOD are expressed in mass per time and area, which also differ from that in CALINE (mass per distance and vehicle per time). The formula for converting emission rate from CALINE to AERMOD is as follows:

$$\mathrm{E_{AER}} = \frac{E_{CAL} \times TF}{1609.34 \times 3600 \times W_{road}}$$

where

E_AER: emission factor in grams per second per square meter (g/s-m^2)

E_Cal: emission factor in grams per mile per vehicle (g/mil-veh) per hour

TF: traffic flow for the road link in number of vehicles per hour

W_road: the road width of the modelled road link in meters. Add 3 meters to both sides of the travelling lanes for roads without noise barriers for the mixing zone.

Conversion from miles to meters: 1 mile = 1609.34 meter

Conversion from hour to seconds: 1 hour = 3600 seconds

Variable Emission Rates

The composite emission factors (g/s-m^2), taking into account the traffic mix, traffic volume, speed, starting emissions, and temperature and relative humidity for each road link can be specified in the SO EMISFACT card or the SO HOUREMIS card. Figures below show examples of the SO EMISFACT and SO HOUREMIS cards.

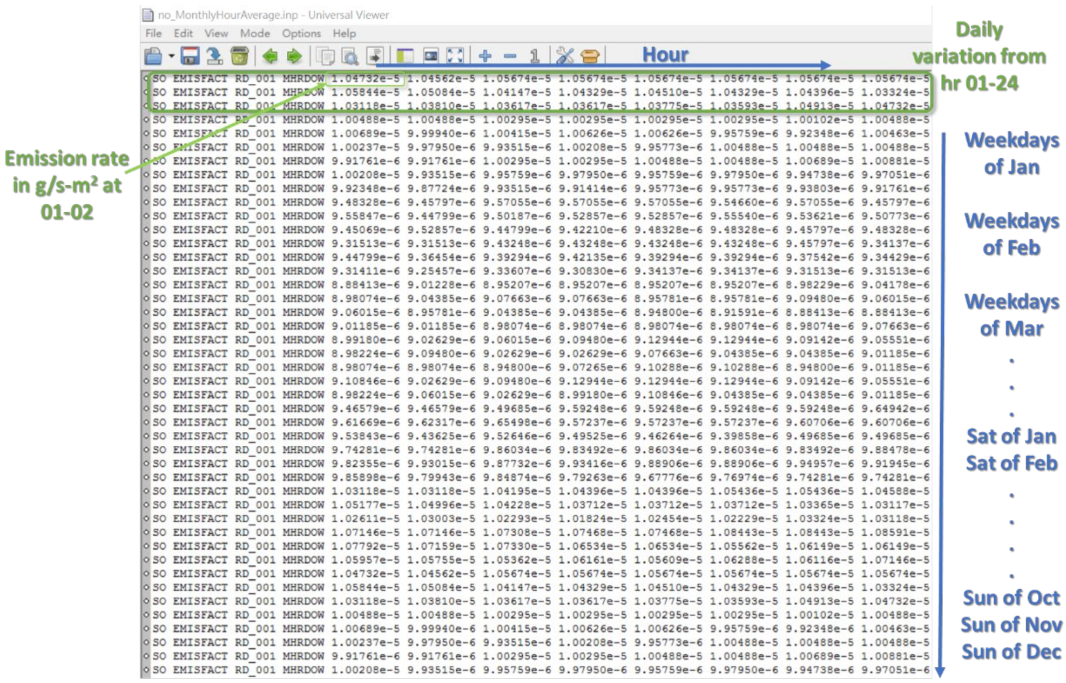


Figure 1. Example of the SO EMISFACT card for a road link with varying emission rate. The entries for MHRDOW are 24-hour values for weekdays of each month, then Saturdays of each month and Sundays of each month. The total number of values for one road link is 864.

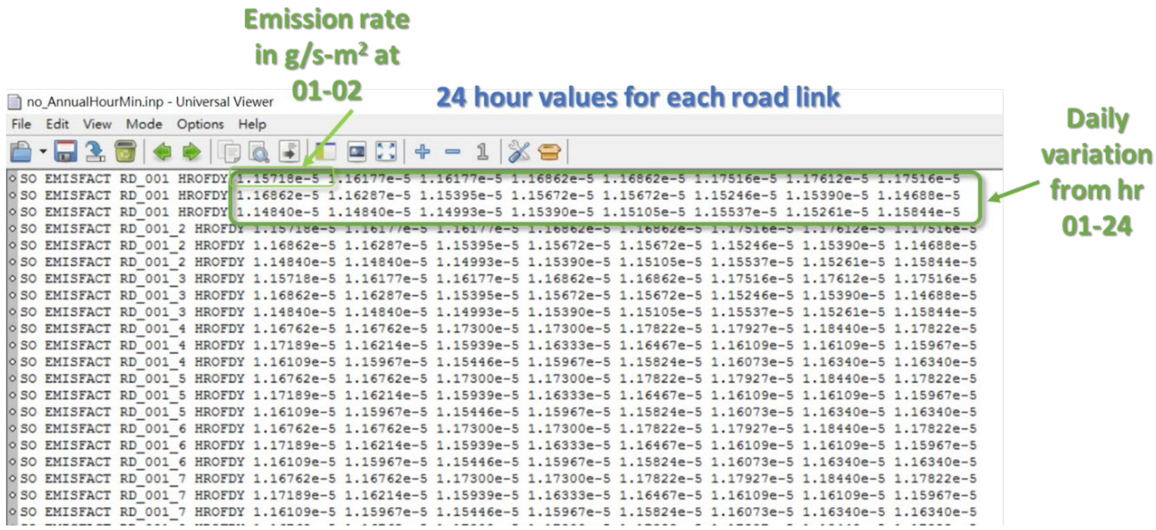


Figure 2. Example of the SO EMISFACT card for road links with varying emission rates for 24 hours in a day using HROFDY. Twenty-four values are required for each road link.

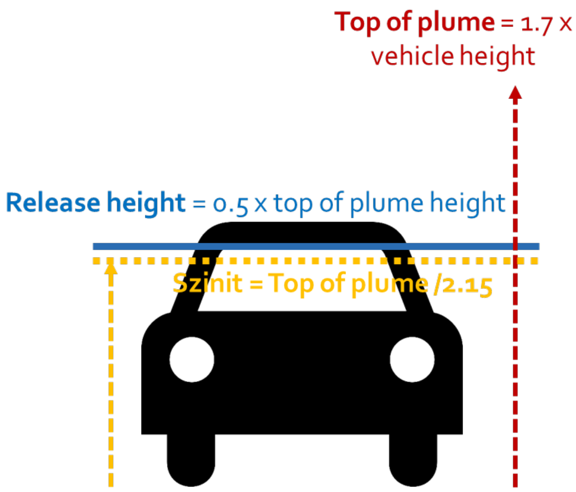
```
SO HOUREMIS 15 1 1 8 R1 5.7472e-07 2.125 1.9767
SO HOUREMIS 15 1 1 8 R2 3.2123e-07 2.125 1.9767
SO HOUREMIS 15 1 1 9 R1 4.3312e-07 2.125 1.9767
SO HOUREMIS 15 1 1 9 R2 4.5854e-07 2.125 1.9767
SO HOUREMIS 15 1 1 10 R1 3.4298e-07 2.125 1.9767
SO HOUREMIS 15 1 1 10 R2 3.9855e-07 2.125 1.9767
```

Figure 3. Example of the SO HOUREMIS card for road links (Line sources) with varying emissions for each hour in a year.

2.2.3 Release height, plume height, and initial vertical dimension

Source Parameters (Lnemis Relhgt Width Szinit)
② "Relhgt" -- The source release height (m) above ground
③ "Szinit" -- Initial vertical dimension of plume (m)

Unlike CALINE4 which computes a mixing zone based on wind speed, road width and wind angle to road link, inputs are required to simulate the mixing zone in AERMOD. The turbulence caused by moving vehicles is assumed as the initial plume, with the top of plume height defined as 1.7 times the average height of vehicles. To estimate a weighted average vehicle height for each road link, the total daily traffic volume for each vehicle class should be considered and a traffic volume-weighted average vehicle height can be computed.



Traffic volume-weighted average vehicle height for a road link =

$$\frac{\sum_{Vehicle\ Class} Number\ of\ vechicle * Vehicle\ Height}{\sum_{Vehicle\ Class} Number\ of\ vechicle}$$

where number of vehicles = total daily traffic volume for each vehicle class

The suggested average vehicle heights for the 18 vehicle classes are provided in Table 1.

Table 1. Suggested Average Vehicle Heights for Each Vehicle Class

Index	**VehicleClassDescription**	**Notation**	**Suggested Vehicle Height (m)**
1	PrivateCars	PC	1.6
2	Taxi	TAXI	1.4
3	LightGoodsVehicles (<=2.5t)	LGV3	1.98
4	LightGoodsVehicles (2.5-3.5t)	LGV4	2
5	LightGoodsVehicles (3.5-5.5t)	LGV6	3
6	MediumGoodsVehicles (5.5-15t)	HGV7	3.6
7	MediumGoodsVehicles (15-24t)	HGV8	3.8
8	PublicLightBuses	PLB	3
9	PrivateLightBuses (<=3.5t)	PV4	3
10	PrivateLightBuses (>3.5t)	PV5	3
11	Non-franchisedBuses (<6.4t)	NFB6	3.8
12	Non-franchisedBuses (6.4-15t)	NFB7	3.8
13	Non-franchisedBuses (15-24t)	NFB8	3.8
14	SingleDeckFranchisedBuses	FBSD	3.4
15	DoubleDeckFranchisedBuses	FBDD	4.4
16	MotorCycles	MC	0.65
17	HeavyGoodsVehicles (>24t)	HGV9	3.89
18	Non-franchisedBuses (>24t)	NFB9	3.8

Sample calculations for traffic volume-weighted average vehicle height for a road link

% traffic	**Vehicle Class**	**Vehicle Height (m)**
70	Private Cars	1.6
30	Double deck Franchised Buses	4.4

$$Weighted\ average\ vehicle\ height\ for\ a\ road\ link =$$

$$70\%\ \times 1.6\,m + 30\%\ \times 4.4\,m\ = 2.44\,m$$

The release height of the line source above the road surface, **Relhgt**, is defined as half of the plume height. If a road link is not at-grade (i.e. it is elevated above the ground level), the road surface height (in mAG) needs to be added into the modelled release height.

The initial vertical dimension coefficient, **Szinit**, is estimated by dividing the top of plume height by 2.15, which is equivalent to 0.79 times the weighted-average vehicle height.

2.2.4 Road height for elevated roads and flyovers

While the road height in CALINE4 is limited to 10 meters, there is no such limitation in AERMOD. The height of the road surface above ground (in mAG) should be added to the release height.

Example of Road Parameters Calculation

- ✧ Base elevation of road link A, (RdA) is 5 mPD.
- ✧ Emission rate: 1 g/s-m^2
- ✧ Height of RdA above ground level is 12 mAG.
- ✧ Weighted average vehicle height is 2 m.
- ✧ Modelled release height = 2 m *1.7 / 2 + 12 m = 13.7 m
- ✧ Road width: 10 m. Modelled road width = 10 m + 6 m = 16m
- ✧ Szinit = top of plume / 2.15 = 2 m *1.7 / 2.15 = 1.58 m

The source card in AERMOD for RdA would be:

```
SO LOCATION  RdA LINE      835750 815660      835780 815760        5

SO SRCPARAM RdA         1.00E+00       13.7      16       1.58
```

2.2.5 Road width

Source Parameters (Lnemis Relhgt **Width** Szinit**)**
④ "Width" -- The width of source (m)

The road width input into AERMOD model would equal to the physical road width plus three meters on both sides of the roads without the presence of physical barriers or obstructions. The additional width accounts for the mechanical turbulence from travelling vehicles. For the side of road with barrier, the addition of three meters is not necessary. Figure 6 and Figure 7 show the model setup in the horizontal plane.

2.2.6 Adjustment to the modelled road with noise barriers

- Vertical / cantilevered barriers: Raise the line source to the level of the vertical barrier for the release height of the road link with barriers.
- Cantilevered barriers: shift the line source horizontally to account for the cantilever.
- Road width: no adding the 3 meters to the side of the road with the barrier.
- Location of the road link: the centerline of the road link should be shifted horizontally considering the presence of the barrier and the revised road width.

Figures below illustrate how the barriers are shifted vertically and horizontally.

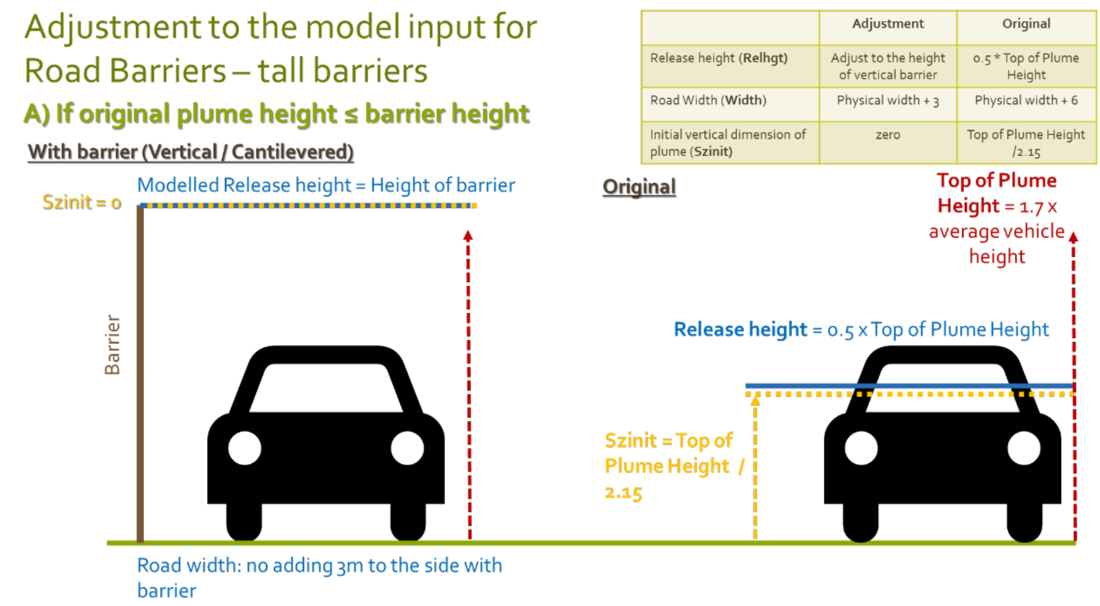


Figure 4 Vertical adjustment for barriers taller than plume heights

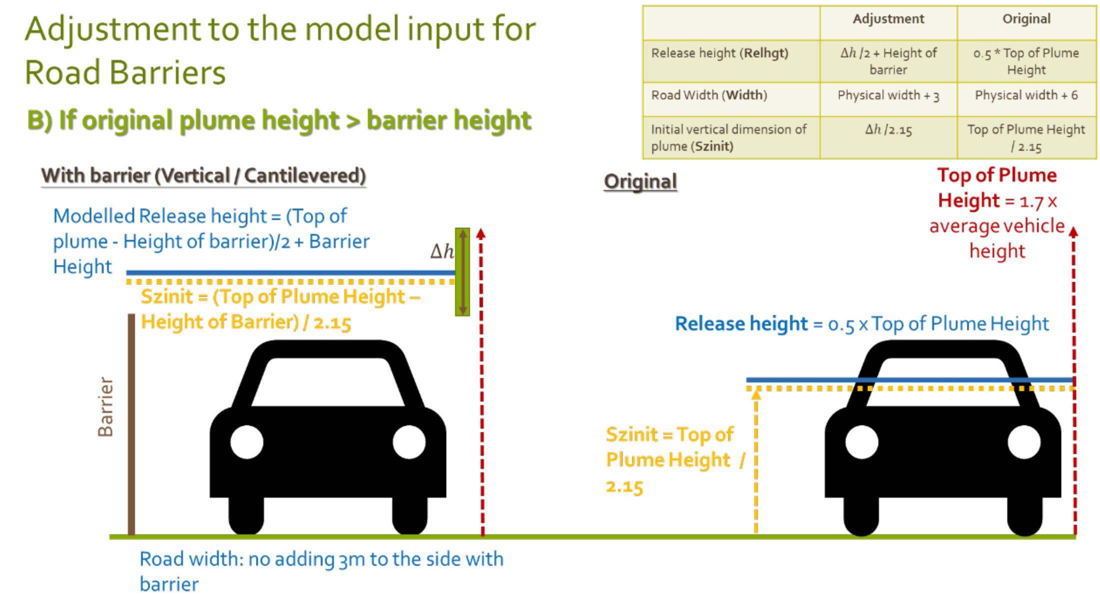


Figure 5 Vertical adjustment for barriers shorter than the plume height.

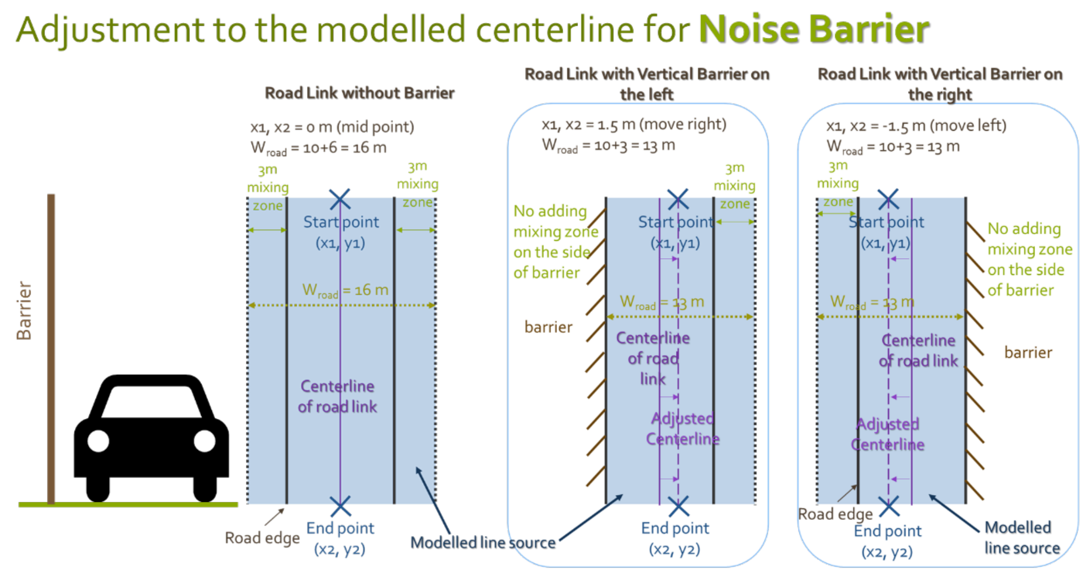


Figure 6 Source centreline adjustment for vertical barriers.

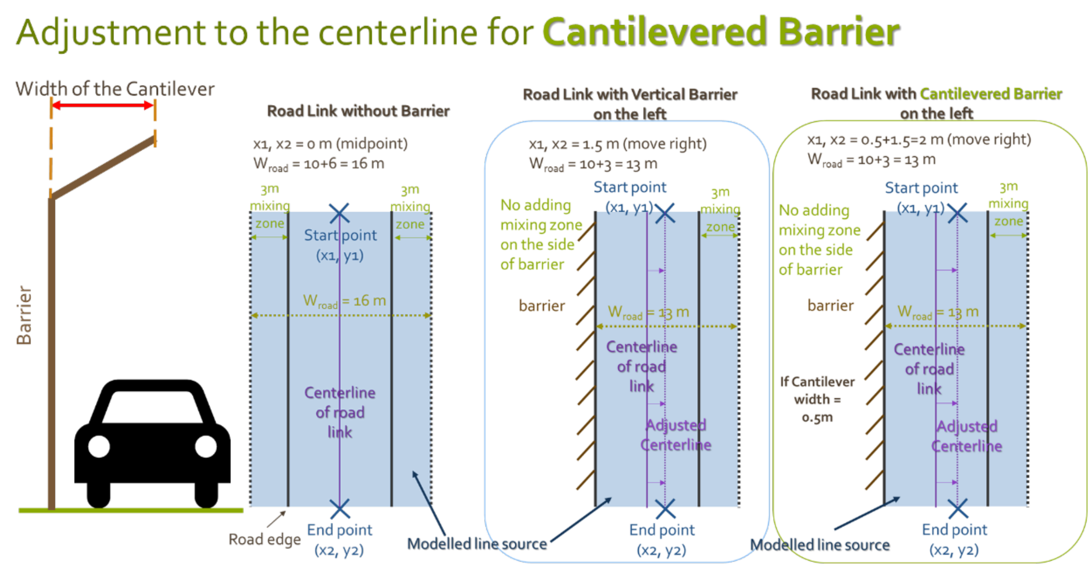


Figure 7 Source centreline adjustment for cantilevered barriers.

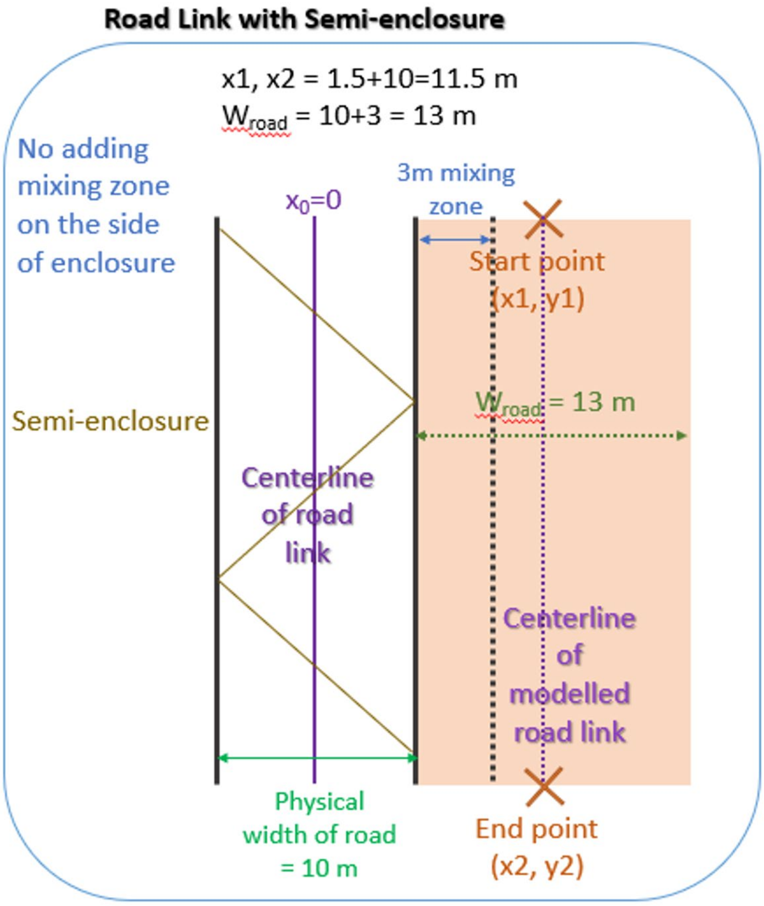


Figure 8 Illustration of shifting of centreline of modelled road link for links with a semi-enclosure.

3 Portal Emissions

These include traffic emissions from tunnel portals and any other similar openings and are generally modelled as volume sources to simulate the portal jet. The length of the portal jet depends on various factors, including vehicle speed and wind speed, and cannot be easily represented in a Gaussian model. Consultants may assume 2/3 and 1/3 of the portal emissions to distribute in the first half and the second half of the portal emission source, respectively, with a length of 100 m. For emissions arising from underpasses or other horizontal openings, these are treated as volume and area sources with appropriate physical dimensions.

4 Tool for converting road information to AERMOD input.

To facilitate consultants in the transition from CALINE to AERMOD, a tool is developed to input traffic information and road parameters for each road link and convert them into AERMOD input files for the road links. This tool can be found on the Air Modelling Platform (VIA) [LINK].

Useful references

Santa Barbara County USA (2020), Modeling Guidelines for Air Quality Impact Assessments

USEPA (2011). Haul Road Workgroup Final Report Submission to EPA-OAQPS. https://www.epa.gov/sites/default/files/2020-10/documents/haul_road_workgroup-final_report_package-20120302.pdf

USEPA (2016), Technical Support Document (TSD) for Replacement of CALINE3 with AERMOD for Transportation Related Air Quality Analyses.

USEPA (2023), Quick reference for AERMOD – Version 23132

USEPA (2021). Appendix J in "Transportation Conformity Guidance for Quantitative Hot-spot Analyses in PM2.5 and PM10 Nonattainment and Maintenance Areas", EPA-420-B-21-037

USEPA, Support Center for Regulatory Atmospheric Modeling, https://www.epa.gov/scram/air-quality-dispersion-modeling-preferred-and-recommended-models#aermod

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