ROAD TUNNEL SPECIFICATION

CERC

In this document 'ADMS' refers to ADMS-Roads 4.1, ADMS-Urban 4.1 and ADMS-Airport 4.1. Where information refers to a subset of the listed models, the model name is given in full.

1. Introduction

This paper contains the technical specification for the road tunnel module in ADMS. This module modifies the standard dispersion of emissions from a road source, as described in the 'Road sources in ADMS-Urban' specification document (P31/01), to reflect dispersion from the ends of the tunnel and any associated vent sources.

The enclosure of a road within a tunnel traps pollutant emissions within the tunnel, which can lead to a build-up of concentrations within the tunnel in the direction of traffic flow and high in-tunnel concentrations. These trapped emissions are then released from the end(s) of the tunnel where traffic leaves the tunnel, referred to as an 'outflow end', with the initial dispersion of pollution tending to follow the traffic movement along an outflow road. The dispersion characteristics of emissions from the portal may be altered by depressed or elevated outflow roads.

A twin bore tunnel, with neighbouring tunnels for traffic in each direction, can show recirculation of pollutants from the exit of one bore to the inlet of the other. Design features such as dividing walls extending beyond the end of the tunnel are often used to reduce this effect. Tunnels with traffic flow in both directions within a single bore will have emissions from both ends.

Additional along-tunnel or transverse ventilation systems may be implemented in road tunnels to improve the air quality within the tunnel and reduce the impact of the tunnel portals on surrounding local air quality. These ventilation systems may include outlets which can be modelled as tunnel vents.

The ADMS road tunnel module models the effect of the road tunnel emissions on concentrations in the surrounding area. It does not calculate pollutant concentrations within the tunnel. Plume depletion due to deposition and chemical transformations within the tunnel are not included in the modelling, nor is recirculation between bores of a twin-bore tunnel calculated. The user can modify the road source emissions to include these effects if required.

Section 2 lists the data used in the road tunnel module to define road tunnel portals and vents. Section 3 describes the modelling of emissions from tunnel portals and Section 4 from tunnel vents.

2. Data used in the road tunnel module

2.1 Road tunnel inputs

The input numerical data for each road tunnel in the road tunnel module are defined below. Each variable except the vertex coordinates and number of outflow ends is defined for each outflow portal i. The traffic direction in the tunnel is defined by the order in which the end vertex coordinates are specified. The definitions of the bore depth, portal base elevation and outflow width are illustrated in Figure 1. In addition to the numerical data, whether an anti-recirculation wall is present and (optionally) the name of an associated outflow road are specified for each outflow portal.

x_1, y_1	Coordinates of the first vertex
x_2, y_2	Coordinates of the last vertex
n_P	Number of traffic directions and hence outflow portals (1 or 2)
Z_B	Bore depth: vertical extent of the tunnel bore (m)
Z_{PE}	Portal base elevation relative to local average ground level (m)
g_O	Ground level outflow width (m)

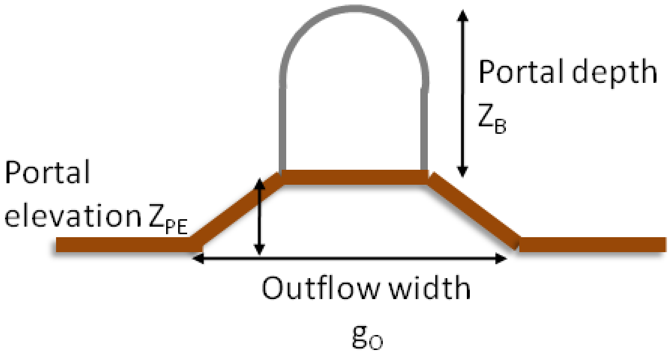

Figure 1 Illustration of the parameters Z_B, Z_{PE} and g_O for a schematic tunnel portal

The traffic speed within the tunnel affects the tunnel portal dispersion definitions. If the road tunnel emissions are user-defined and the traffic speed is not available to the model, an assumed value of 30 km/hr is used, consistent with the traffic-induced turbulence calculations.

2.2 Road tunnel vent inputs

The main source properties for road tunnel vents are defined in the usual way for point or area sources. Additional information required for their use as tunnel vents is the name of the associated road tunnel and the fraction of tunnel emissions (f_{Vj}) extracted by vent j. Any time-varying factor applied to the vent source (t_{Vj}) is applied to the vent emission fraction.

3. Dispersion from road tunnel portals

Emissions from the end of a road tunnel are commonly described as a 'portal jet', as they can follow the path of the traffic leaving the tunnel due to entrainment in vehicle wakes. The modelling approach for tunnel portal jets outlined by Ginzburg and Schattanek [1], based on an earlier wind tunnel modelling study, has been adopted for use in ADMS. This approach uses three volume sources at each outflow end of the tunnel. The total length of the volume sources depends on wind speed, traffic speed and whether an anti-recirculation wall is present. The emissions weighting for each volume source depends on the traffic speed and whether an anti-recirculation wall is present. The shape of the volume sources can be determined by the path of a specified outflow road.

Section 3.1 describes how the source geometry of the tunnel portal volume sources is determined. Section 3.2 gives the emission rates for the tunnel portal volume sources and Section 3.3 describes the tunnel portal dispersion calculations.

3.1 Volume source geometry

The depth of the portal volume sources is calculated as $Z_B + Z_{PE}$, with a minimum value of 2 m. The volume sources are considered to extend upwards from the ground, so the central source height is calculated as half the source depth.

If the portal base elevation Z_{PE} is greater than or equal to zero, the volume source width is calculated as equal to the outflow road width (if an outflow road is specified) or the tunnel road width. If the portal base elevation is less than zero and the slope of the sides of the outflow area is steeper than 30° from horizontal, the volume source width is calculated as the mean of the ground-level outflow width and the outflow road width.

The total volume source length is interpolated from the values given by Ginzburg and Schattanek, reproduced in Table 1, based on the value of wind speed at 10 m above ground for the current modelling hour, the traffic flow speed in the tunnel and whether an anti-recirculation wall is present. The minimum length values from the ranges given in [1] are used to allow the model to represent the dependence of initial dispersion on wind-direction. Note that the entrainment of pollutants in vehicle wakes, leading to longer volume source lengths, is most significant at low wind speeds, and in general the presence of anti-recirculation walls also leads to longer volume source lengths.

Table 1 Total volume source lengths used in ADMS based on [1] table 1

Traffic speed (km/hr)	Portal configuration	Wind speed (m/s)		
		1	3	6
		Total volume source length (m)		
8	Wall	110	45	40
	No wall	90	40	30
24	Wall	250	110	50
	No wall	230	130	40
48	Wall	235	150	60
	No wall	225	90	60

The volume source width and length are combined to create footprint vertices for each of the portal volume sources according to the following options in order of preference: following the trajectory of an outflow road; creating a simplified volume source with some reference to the outflow road trajectory; or creating a projected volume source. The final volume source shapes must fulfil the following requirements: describing a convex outline; occupying an area of at least 1 m^2; and having adjacent vertices separated by at least 1 m. The following sections give more details about each approach to creating the volume source footprint vertices.

Volume source following outflow road

The procedure for creating volume source footprint vertices following the trajectory of a specified outflow road is as follows:

- Create initial vertices at the tunnel portal, each half the volume source width from the tunnel centreline end vertex along vectors perpendicular to the final tunnel segment;
- Move along the outflow road centreline for the required volume source length, at each junction between outflow road segments add two side vertices on the outer side of the junction, each half the volume source width from the outflow road centreline along vectors perpendicular to the segments before and after the junction; and
- When the required volume source length has been obtained, add two final vertices, each half the volume source width from the outflow road centreline, along vectors perpendicular to the current outflow road segment. These final vertices become the initial vertices for a subsequent volume source, if required.

This procedure is illustrated for an example outflow road geometry in Figure 2. If the outflow road is shorter than the total required volume source length, the volume source(s) which extend beyond the end of the outflow road will be projected in the same direction as the final outflow road segment. If adjacent volume source side vertices are separated by less than 1 m they will be replaced by an averaged vertex position. The convexity of each side of each volume source is checked and any vertices which create a non-convex junction are removed.

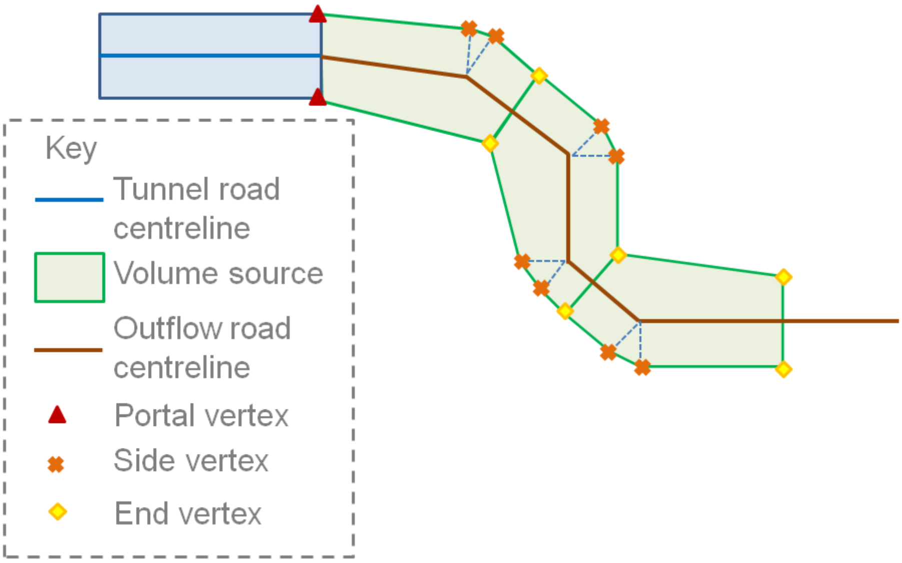

Figure 2 Diagram of the creation of portal volume sources following an example outflow road

Simple volume source

If the overall volume source geometry created by following the outflow road trajectory is non-convex, a ‘simple’ quadrilateral volume source is created by using the initial and final vertices from the initial attempt, which is re-checked for convexity. If this is still non-convex, the final left and right vertices are swapped and the source is checked again. An example outflow road geometry where this approach is used is illustrated in Figure 3.

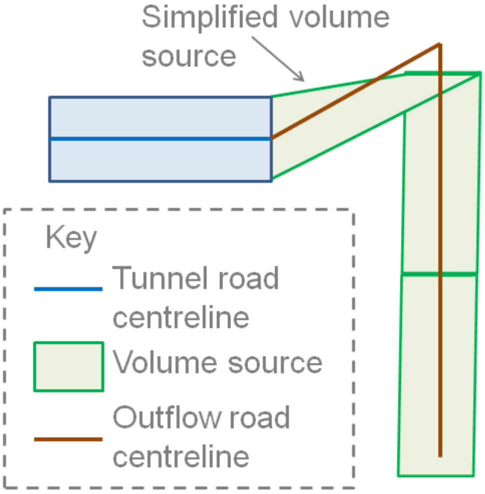

Figure 3 Diagram of the creation of a simplified portal volume source where following the example outflow road would create a non-convex shape

Projected volume source

If an outflow road is specified and the previous two approaches have failed to create convex volume sources, or if no outflow road was specified, projected volume sources will be created instead. These use a rectangular footprint created by adding vertices at the end of the tunnel or beginning of the outflow road and projecting them along the direction of the last segment of the tunnel or the first segment of the outflow road. Examples of projected volume source geometries are illustrated in Figure 4.

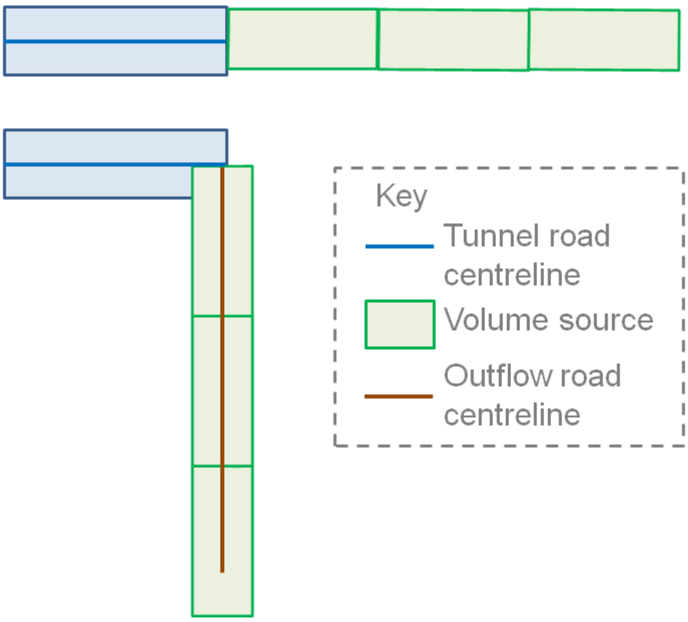

Figure 4 Diagram of projected tunnel portal volume sources for tunnels with and without outflow roads.

3.2 Volume source emissions

The proportion of the road tunnel emissions assigned to each of the three volume sources at a single outflow end is interpolated from the values given in Table 2, based on the tunnel traffic flow speed. If the tunnel has two-directional traffic flow such that there are emissions from both ends of the tunnel, the total emissions are divided equally between the two ends, so the values in the table should be halved.

If tunnel vent sources are modelled, the portal emissions are reduced by the total vent fraction at each modelling hour. This may lead to zero portal emissions at some or all hours.

Table 2 Volume source emission proportions used in ADMS based on [1] table 2

Traffic speed (km/hr)	Emission proportion for each volume source (%)		
	Source 1 (nearest portal)	Source 2	Source 3 (furthest from portal)
8	48	40	12
24	55	33	12
48	57	31	12

3.3 Volume source dispersion

The standard ADMS volume source dispersion calculations are used for road tunnel portal volume sources, as described in the Technical Specification document P25/03. The source temperature is assumed to be equal to ambient conditions, neglecting any buoyancy effects from temperature differences between in-tunnel and atmospheric air.

4. Dispersion from road tunnel vents

The road tunnels module includes an option to model emissions from a road tunnel via point or area vent sources. A vent source may extract emissions from more than one tunnel, for example from both bores of a twin-bore tunnel, and/or a tunnel may have more than one associated vent source. The proportion of tunnel emissions extracted by each vent may be time-varying, for example if active ventilation systems are only used at peak times.

Section 4.1 describes the calculation of vent source emission rates while Section 4.2 describes the calculation of dispersion from vent sources.

4.1 Vent source emission rate

The emission rate from a tunnel vent source, Q_{Vj} in g/s, is calculated for each modelling hour according to:

$$Q_{Vj} = t_T Q_T f_{Vj} t_{Vj}$$

where t_T is the road tunnel source time-varying emission factor for the current hour, Q_T is the total emission rate from all segments of the tunnel road in g/s, f_{Vj} is the tunnel vent fraction for the current tunnel-vent combination and t_{Vj} is the vent source time-varying emission factor for the current hour.

For each tunnel, the total vent fraction including time-variation effects, $F_V = \sum_{j=1}^{n_V} f_{Vj} t_{Vj}$, is limited to a maximum of 1, where n_V is the number of vent sources associated with this tunnel. If F_V is greater than 1, the individual vent emission fractions are scaled down proportionally by modifying the time-varying factors to t_{Vj}/F_V.

4.1 Vent source dispersion

The standard ADMS point or area source dispersion calculations are performed for road tunnel vent sources, as described in the Technical specification documents P10/01 and P12/01 (point sources) and P25/03 (area sources). Only the emission rates for the vent sources are modified by the road tunnel module.

5. References

[1] Ginzburg, H. and Schattanek, G. (1997) Analytical Approach to Estimate Pollutant Concentrations from a Tunnel Portal Exit Plume. Presented at A&WMA 90th Annual Meeting, Toronto, Canada.