ROAD SOURCES

CERC

In this document 'ADMS' refers to ADMS-Roads 5.1, ADMS-Urban 5.1 and ADMS-Airport 5.1. Where information refers to a subset of the listed models, the model name is given in full.

1. INTRODUCTION

In ADMS, roads are modelled as line sources, with modifications to account for:

- traffic-produced turbulence, and
- street canyons (optional).

Details of the way road sources are represented are given in Section 2. A description of traffic-produced turbulence is given in Section 3. The specification for the street canyon module within ADMS is given in the Technical Specification documents P28/01 and P28/02.

2. ROAD SOURCE REPRESENTATION

Road sources are represented as line sources with no plume rise. The concentration C from a finite crosswind line source of length L_s is given by

$$C(x,y,z) = \frac{Q_s}{2\sqrt{2\pi}\sigma_z(x)U}\exp\left(-\frac{(z-z_p)^2}{2\sigma_z^2}\right)\times$$
$$\left[\mathrm{erf}\left(\frac{y+L_s/2}{\sqrt{2}\sigma_y}\right)-\mathrm{erf}\left(\frac{y-L_s/2}{\sqrt{2}\sigma_y}\right)\right]+\text{reflection terms}$$

where Q_s is the source strength (g/m/s), z is the height above the ground (m), y is the lateral distance from the plume centreline (m), z_p is the height of the plume above the ground (m), U is the wind speed at the plume height (m/s), σ_y is the horizontal plume spread (m) and σ_z is the vertical plume spread (m).

For a road, the height of the plume above the ground is set to be $z_p = z_{s\_road}$ where

$$z_{s\_road} = z_s + h_0 .$$

Here, h_0 is usually referred to as the initial mixing height, and is set to 1m, and z_s is the road height as entered by the user.

If chemistry is modelled, the source-receptor travel time used in the calculation of the reaction time (see P18/03 for further details) is adjusted for road sources to account for the time taken for the pollution to become well mixed within the road. This is done by adding an 'initial mixing time', given by

$$\frac{h_0}{\sigma_w(h_0)}$$

where σ_w is the vertical component of turbulence.

3. TRAFFIC-PRODUCED TURBULENCE

For busy roads, extra turbulence will be induced by the traffic. To model the effect on the vertical turbulence, the vertical plume spread parameter, $\sigma_{z_{\mathrm{road}}}$, is increased:

$$\sigma_{z_{\mathrm{road}}}^2 = \sigma_z^2 + h_0^2$$

To model the effect on the lateral turbulence, an extra component is included in the lateral plume spread parameter σ_y. (Note that this extra component is not included when modelling street canyons. The street canyon module includes a separate treatment of traffic-produced turbulence.) The formulation of this extra component, $\sigma_{y_{\mathrm{road}}}$, is as follows (formulation by D. J. Carruthers):

$$\sigma_{y_{\mathrm{road}}} = \sigma_{v_{\mathrm{road}}} t \left\{1 + \left(\frac{t}{t_d}\right)^2\right\}^{-1/2}$$

where

$$\sigma_{v_{\mathrm{road}}} = b \cdot \left(\frac{\sum_i^{n_c} N_i U_i A_i}{W}\right)^{1/2}$$

and the turbulence decay time, t_d, is given by

$$t_d = \left(\frac{W}{\tau}\right) / \sigma_{v_{\mathrm{road}}}$$

In the above definitions,

- t = time to travel from source to this point(s)
- b = constant (0.3) [from OSPM street canyon model]
- τ = constant (0.1) [chosen by CERC after testing]

- n_c = number of vehicle categories
- N_i = number of vehicles per second for that vehicle category
- U_i = speed of vehicles (m/s) for that vehicle category
- A_i = area covered by a vehicle (m^2) for that vehicle category
- W = road width (m)

The formulation implies that $\sigma_{y_{\text{road}}}/\sigma_{v_{\text{road}}} \rightarrow 0$ as $t \rightarrow 0$ and $\sigma_{y_{\text{road}}}/\sigma_{v_{\text{road}}} \rightarrow t_d$ as $t \rightarrow \infty$.

If traffic counts are unknown, they are back-calculated by the model from the user-defined emission rate of NO_X, NO_2, PM_{10}, $PM_{2.5}$ or VOC (in that order of preference). For this calculation, it is assumed that the speed of the traffic is 30 km/hr and that the traffic is 95% light duty vehicles, and 5% heavy duty vehicles; the vehicle split between light and heavy categories can be altered by the user. If no emissions are defined for any of these pollutants, no traffic-produced turbulence is modelled.

4. FLYOVERS

When an elevated road is modelled as a flyover, the downward part of the vertical plume spread, σ_z, is held constant at h_0 until the plume is advected past the downwind edge of the elevated road surface (see **Figure 1(b)**). It then proceeds to grow as it would have done from the source for a standard elevated road.

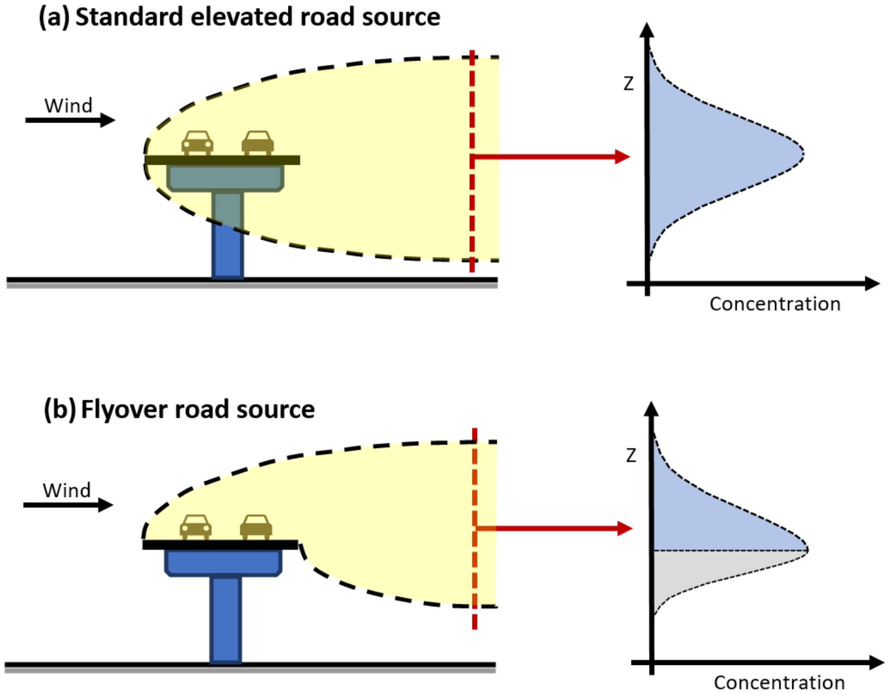

***Figure 1** – Schematic of modelling approach for (a) a standard elevated road source and (b) a flyover road source.*

We split the vertical concentration distribution function, $f(z)$, into two piecewise continuous functions, $f_-(z)$ and $f_+(z)$, above and below the plume centreline height z_p:

$$f(z) = \begin{cases} f_-(z), & \text{for } z < z_p \\ f_+(z), & \text{for } z \geq z_p \end{cases},$$

subject to the following two constraints:

$$\int_{z=-\infty}^{z=z_p} f_-(z)\,dz + \int_{z=z_p}^{z=+\infty} f_+(z)\,dz = 1,$$

$$f_-(z_p) = f_+(z_p).$$

Using the Heaviside function, $f(z)$ can be written as:

$$f(z) = f_-(z)\left(1 - \mathrm{H}(z - z_p)\right) + f_+(z)\mathrm{H}(z - z_p).$$

While the above is suitable for an isolated source (without reflections), a road source in ADMS has reflections off the ground, and the above equation is thus modified to:

$$f(z) = f_-(z)\left(1 - \mathrm{H}(z - z_p)\right) + f_+(z)\mathrm{H}(z - z_p) + f_-(-z).$$

Note that in the presence of an inversion at the top of the boundary layer, three further reflection terms are modelled in ADMS (off the boundary layer, off the ground then the inversion and off the inversion then the ground), but these have been omitted for brevity. No Heaviside function is applied to the reflection terms because each reflection is from only one side of the plume.

We use half Gaussian functions for $f_-(z)$ and $f_+(z)$, which have the same amplitude (in order to satisfy the second constraint above), but different standard deviations (i.e. vertical spreads), $\sigma_{z_{f-}}$ and $\sigma_{z_{f+}}$, which are taken to be:

$$\left.\sigma_{z_{f+}}\right|_x = \left.\sigma_z\right|_x$$

$$\left.\sigma_{z_{f-}}\right|_x = \begin{cases} h_0, & x \leq x_r \\ \left.\sigma_z\right|_{x-x_r}, & x > x_r \end{cases}$$

where $\sigma_z(x)$ is the vertical spread (at a downwind distance of x from the upwind edge of the road) used by ADMS in its standard configuration and x_r is the distance to the downwind edge of the road. The amplitude, a, of $f_-(z)$ and $f_+(z)$ is obtained by solving the first constraint above:

$$a\left(\int_{z=-\infty}^{z=z_p} \exp\left(\frac{-\left(z-z_p\right)^2}{2\sigma_{z_{f-}}^2}\right)dz + \int_{z=z_p}^{z=+\infty} \exp\left(\frac{-\left(z-z_p\right)^2}{2\sigma_{z_{f+}}^2}\right)dz\right) = 1$$

$$\Rightarrow a = \frac{2}{\sqrt{2\pi}(\sigma_{z_{f-}} + \sigma_{z_{f+}})}$$

The equation for $f(z)$ with reflections off the ground only thus becomes:

$$f(z) = \frac{2}{\sqrt{2\pi}(\sigma_{z_{f-}} + \sigma_{z_{f+}})}\Bigg[\exp\left(\frac{-(z-z_p)^2}{2\sigma_{z_{f-}}^2}\right)\left(1-\mathrm{H}\left(z-z_p\right)\right) + \exp\left(\frac{-(z-z_p)^2}{2\sigma_{z_{f+}}^2}\right)\mathrm{H}\left(z-z_p\right) + \exp\left(\frac{-(z+z_p)^2}{2\sigma_{z_{f-}}^2}\right)\Bigg].$$

In stable/neutral conditions, $z_p = z_{s\_road}$. In convective conditions, the standard vertical concentration distribution function is itself two piecewise continuous half Gaussian functions with $z_p = z_{s\_road} + \hat{w}t$ and standard deviations above and below this height of $\sigma_{z_+}(x) = \frac{\sigma_{w+}\sigma_z}{\sigma_w}$ and $\sigma_{z_-}(x) = \frac{\sigma_{w-}\sigma_z}{\sigma_w}$, respectively, where $\hat{w}$, σ_{w_+} and σ_{w_-} are as defined in the ADMS Plume/Puff Spread and Mean Concentration Module Technical Specification document (P10/01). The expressions for $\sigma_{z_{f-}}$ and $\sigma_{z_{f+}}$ thus become:

$$\sigma_{z_{f+}}\Big|_x = \frac{\sigma_{w_+}\sigma_z}{\sigma_w}\Big|_x$$

$$\sigma_{z_{f-}}\Big|_x = \begin{cases} h_0 \dfrac{\sigma_{w_-}}{\sigma_w}\Big|_0, & x \le x_r \\ \dfrac{\sigma_{w_-}\sigma_z}{\sigma_w}\Big|_{x-x_r}, & x > x_r \end{cases}$$