AIR POLLUTION LINE SOURCE

M9 Motorway, Stirlingshire, Scotland: example of a line source. @ C.Michael Hogan

An **air pollution line source** is an idealized geometric emitter, which can be represented by an emission source consisting simply of a straight line, which may be of finite or infinite length.The utility of this model is the ability to serve as a proxy for roadway, railway or aircraft air pollution sources. Since widespread use of this type of model began in the USA in the early 1970s, world-wide application is presently being used by transportation engineers and urban planners for the purpose of highway corridor alignments, highway design and analysis of aircraft takeoff patterns.

Early line source models

Initial theory of line source modeling was based upon finite summation of point source modeling technology as articulated by Turner, Beychok and many others. The first models were crude box model summations or other numerical approaches.

A roadway air dispersion model was developed starting in the late 1950s and early 1960s in response to requirements of the National Environmental Policy Act and the U.S. Department of Transportation to understand impacts of proposed new highways upon air quality, especially in urban areas. The first models were simple box model representations.

Several research groups were active in the first intensive phase of more sophisticated model development, among which were: the Environmental Research and Technology group in Massachusetts, the ESL Inc. group in Californiaand the California Air Resources Board group in

California. The ESL researchers were the first to develop a closed form integral solution of the Turner equations, making calculations straightforward and without the errors associated with summation of a finite number of segment intervals.

Theory of the line source model

The theory discussed here is that of the first closed form solution of integrating the Turner equations.

The resulting solution for an infinite line source is:

$$\chi = \int_0^\infty \frac{q}{\pi\,(ucdx^2)\,(cos\alpha\ )} \left(\exp \frac{y^2}{2c^2x^2}\right) dx$$

where:

- "x" is the distance from the observer to the roadway
- "y" is the height of the observer "u" is the mean wind speed
- "α" is the angle of tilt of the line source relative to the reference frame
- "c" and "d" are the standard deviation of horizontal and vertical wind directions (measured in radians) respectively.

This equation was integrated into a closed form solution using the error function (erf), and variations in geometry can be performed to include the full infinite line, line segment, elevated line, or arc made from segments. Three dimensional air pollutant contours are then calculated using this model to study alternative roadway designs, various assumptions of meteorology and traffic conditions (e.g. truck mix, fleet emission controls and vehicle speeds). The ESL research group also extended their model by introducing the area source concept of a vertical strip to simulate the mixing zone on the highway produced by vehicle turbulence.

Calibration of line source models

First calibration research of line source models occurred in the early 1970s in Santa Clara County, California under a grant from the United States Environmental Protection Agency.The ESL group received a contract from the EPA to validate a line source model using sulfur hexafluoride as a tracer gas. Motor vehicles were specially fitted with devices designed to emit sulfur hexafluoride gas at a uniform rate. This gas was chosen since its natural occurrence is so

low that background interference can be neglected. Sulfur hexafluoride levels were measured at numerous locations along U.S.Highway 101 and at two different elevations above ground level.

Early applications of the line source model


Interstate 66, Arlington, Virginia. @ A.Fagan

Some of the earliest uses of the model were in legal cases involving highway air pollution at the Arlington, Virginia portion of Interstate 66 and the New Jersey Turnpike widening project through East Brunswick, New Jersey. Area source models were developed in 1971 through 1974 by the same groups pioneering the line source models. Pollutants analyzed included oxides of nitrogen, carbon monoxide and reactive hydrocarbons.
The I66 case involved the Virginia Highway Commission, who lost a lawsuit in the U.S. district court to a citizens group Arlington Coalition on Transportation (ACT), who contracted to ESL for use of the air pollution line source mode. ACT won this case after a decision by the United States Court of Appeals for the Fourth Circuit, Arlington Coalition on Transportation v. Volpe . The court strongly relied upon ACT's expert's calculations and testimony projecting that air quality levels would violate Federal ambient air quality standards as set forth in the Clean Air Act

Typical sources modeled

Aircraft flight pattern suitable for line source model.

Heathrow, UK. Source: Adrian Pingstone

The principal real world sources that are commonly modeled using line source techniques are: urban roadways, trains using non-electrified engine technology and aircraft take-offs. Some industrial sources are also represented in the range of applications, but those instances are less common.

Urban roadways are by far the most frequent application for line sources. Most typically the line source model is utilized in the planning stage or in the design stage, but occasionally when there are alternative strategies for traffic management (e.g. speed limit prescription, use of one way couplets, time of day traffic management decisions or synchronization of traffic signal issues) For example in the Boston Transportation Planning Review work of the 1970s all major existing and potential roadways in the Boston metropolitan area were analyzed using the ESL model. (ESL. 1973) In this way the air pollutant dosage to nearby residents and schools could be forecast for a host of scenarios of lane widths, demand forecasts and speed limits.

Caltrain Faribanks Morse engine, San Francisco Peninsula.

Source: R.Pierce

Urban train systems are often analyzed for impacts to residential and other sensitive receptors. An example application has been the Caltrain system serving the San Francisco Peninsula and the city of San Francisco. Before a major service expansion in the mid-1980s the Joint Powers Board included line source modeling as part of a comprehensive Environmental Impact Report. (Hogan et al. 1985)

The U.S.Federal Aviation Administration was the first agency to utilize an advanced line source model to analyze hydrocarbon, carbon monoxide and oxides of nitrogen dispersion from taxiing as well as take-off patterns. In 1973 that agency developed a line source model that could be used in any U.S. airport that could accept arbitrary meteorological input (wind speed, wind direction, turbulence class, etc) along with time varying emissions and any quasi-linear flight path.

Source : http://www.eoearth.org/view/article/51cbf1fb7896bb431f6a76d7/?topic=51cbfc78f702fc2ba8129e6f