FAA EDMS Airport Air Quality Model Development

Paper # 69574

Clifford T. Hall and Theodore G. Thrasher
CSSI, Inc.
400 Virginia Avenue SW, Suite 710
Washington, DC 20024

Julie A. Draper and Curtis A. Holsclaw
Federal Aviation Administration
Office of Environment and Energy
800 Independence Avenue SW
Washington, DC 20591

Roger L. Wayson, Brian Y. Kim and Gregg G. Fleming
Volpe National Transportation Systems Center
55 Broadway
Cambridge, MA 02142

ABSTRACT

The Federal Aviation Administration (FAA) requires the use of the Emissions and Dispersion Modeling System (EDMS) for air quality analyses of aviation emission sources from proposed airport projects. This analysis may include an emissions inventory or a dispersion analysis for both aviation and non-aviation sources. The FAA considers aviation sources to include aircraft, auxiliary power units, and ground support equipment. EDMS also offers the capability to model other airport emission sources that are not aviation-specific, such as power plants, fuel storage tanks, and ground access vehicles.

This paper presents recent model development activities and those planned in the near future. The current model version, EDMS 4.1, incorporates substantial model enhancements such as: the first phase of enhancements to the aircraft ground support equipment component, results from the recent aircraft plume characterization LIDAR study, use of composite area sources for modeling aircraft dispersion, the ability to import airport "wallpaper", and an expanded import and export utility. The FAA has adopted the dispersion methodology developed by the Environmental Protection Agency for modeling concentrations from both aviation and non-aviation sources. Model development activities planned in the near future include the second phase of enhancements to the GSE component, improved stationary source modeling, and improved dispersion modeling fidelity.

INTRODUCTION

The Emissions and Dispersion Modeling System (EDMS) is required by the Federal Aviation Administration (FAA) for air quality analysis involving aviation sources, which include aircraft, auxiliary power units (APU), and ground support equipment (GSE)[1]. EDMS also offers the capability to model other airport emission sources that are not aviation-specific, such as power plants, fuel storage tanks, and ground access vehicles. As its name implies, EDMS can be used to model both emissions as well as atmospheric concentrations resulting from dispersion. The current major release of EDMS, version 4.1, includes substantial enhancements.

EDMS was originally developed in the mid-1980s as a complex source model capable of assessing air quality impacts due to airport development and has been an Environmental Protection Agency (EPA) “Preferred Guideline” model since 1993. In 1997, it was completely re-engineered to meet both scientific and policy-related needs, and benefit from data and methodology advances. In 1998, the FAA elevated the status of EDMS to a required model when conducting air quality analysis for aviation sources. This was done to ensure consistency and quality in aviation-related air quality analyses. The aviation emission algorithms and data used in EDMS are well established and are EPA developed and/or recommended.

EDMS includes emission factors for the various airport sources. For example, it incorporates all aircraft engine emissions data contained in the internationally accepted International Civil Aviation Organization (ICAO) Engine Exhaust Emissions Data Bank[2], representing nearly two-thirds of EDMS’s aircraft engine emissions data. The remaining third of EDMS’s aircraft engine emission data originate from other sources, such as EPA and manufacturers. EDMS also includes vehicle emission factors from EPA’s on-road model, MOBILE5A[3]. Version 4.1 marked the first phase of migration towards EPA’s draft NONROAD model for GSE, incorporating draft NONROAD derived emission factors.

EDMS can be used to create an emissions inventory for any individual airport emission source, or combination of emission sources. To create an aircraft emissions inventory, the modeler inputs the aircraft fleet present at an airport and the annual number of landing and takeoff (LTO) cycles for each aircraft. The modeler can specify each aircraft’s taxi and queue time, as well as the takeoff weight and approach glide slope angle, which are used to determine the takeoff, climb out, and approach time-in-mode (TIM) values. The takeoff, climb out, and approach TIM values in EDMS’s internal database originate from methodology presented in the Society of Automotive Engineers (SAE) Aerospace Information Report (AIR) 1845 and account for aircraft-engine specific performance. Similar to aircraft, the modeler has the ability to define and include the supporting APU and GSE activity, roadway traffic, parking lot throughput, and stationary source and training fire operations.

For dispersion analyses, EDMS generates input files to be processed by EPA’s AERMOD[4], which has been bundled with EDMS since version 4.0. The manner in which AERMOD is used in EDMS is based on guidance from the American Meteorological Society/EPA Regulatory Model Improvement Committee (AERMIC), which is responsible for developing AERMOD and introducing state-of-the-art modeling concepts into the EPA's local-scale air quality models. AERMOD is soon to be promulgated by EPA to replace the current EPA de facto standard dispersion model for stationary sources, ISCST3. Like its predecessor, AERMOD is a steadystate plume model, but has many state-of-the-art improvements. AERMOD has better characterization of the planetary boundary layer (PBL) and allows dispersion to be accomplished using continuous functions rather than with discrete stability classes that do not change with height. Instead of a Gaussian distribution for both the horizontal and vertical directions, AERMOD uses a bi-Gaussian probability density function (PDF) to characterize the dispersion in the vertical direction. AERMOD also incorporates a new, simple method to model airflow and dispersion in complex terrain. The AERMOD dispersion calculations may be run from within EDMS as noted above, or the user may choose to run AERMOD with the input files generated by EDMS on a different computer.

Because AERMOD requires both surface and upper air meteorological data, AERMET is also bundled with EDMS. AERMET is EPA's meteorological pre-processor and can transform many different formats of "raw" data into an AERMOD-ready format. Similar to AERMOD, AERMET also runs externally to EDMS. Once the dispersion analysis is initiated within EDMS, the execution and control of AERMET and AERMOD is entirely transparent to the user.

RECENT DEVELOPMENTS

EDMS 4.1 incorporates substantial model enhancements to improve the accuracy of the model and user flexibility. These include results from the recent aircraft plume characterization LIDAR study, use of composite area sources for modeling aircraft dispersion, the first phase of enhancements to the aircraft ground support equipment component, the ability to import airport diagram "wallpaper", and an expanded import and export utility.

Improved Aircraft Plume Characterization

As with any dispersion model, the initial properties of a plume are important to properly model its growth and position. Two variables that need to be accurately quantified are the initial release height and the initial sigma (σ_0) values. Results from a LIDAR (LIght Detection And Ranging) study[5] that dissected jet plumes from aircraft on takeoff provided, for the first time, a basis for the initial dispersion parameter values for aircraft sources (e.g. taxiways, queues, runways, and ascending and descending flight paths). It is on this basis that EDMS version 4.1 incorporates these values, and a more accurate characterization of the plume is achieved.

In Version 4.0, the effective release height of runways, taxiways, and queues was based on best available information: a weighted average of the modeled aircraft fleet's engine height. Using the results of the aircraft plume characterization LIDAR study and to account for the buoyancy of hot jet plumes, the release height in version 4.1 is set to 12 meters. This is meant to compensate for plume rise in buoyant jet and turboprop exhaust, since the LIDAR study concluded that significant plume rise occurs and was not being accounted for in previous versions of EDMS.

Version 4.0 uses an initial sigma-z value of 3 meters for all aircraft sources. This value is a measure of how dispersed exhaust is at its point of origin. Based on results of the LIDAR analysis, this coefficient is revised to 4.1 meters in version 4.1.

Due to the lengthy numerical integration involved in dispersion from area sources, EDMS 4.1 models an entire aircraft fleet of various aircraft types with a single set of composite area sources. For every segment of taxiway, queue and runway and flight path, the aircraft release heights are weighted by the total emission of the aircraft in the segment and averaged. Since the release height is 12 meters for each aircraft, the release height of the area sources on the ground is simply 12 meters. But for the elevated segments which model aircraft in flight, each aircraft's mean height while passing through the segment is weighted and averaged.

Likewise, the initial variances (the squares of the initial sigmas) are weighted and averaged. Again, because all aircraft have the same the initial sigma value, the ground area sources also have the same initial sigma value, 4.1 meters. The elevated segments' initial sigma values, however, can vary greatly due to the multitude of aircraft flight paths. Each segment's initial variance is the sum of the initial variance for each aircraft, 16.81 m^2 (4.1 meters x 4.1 meters), and the variance in the heights of the aircraft paths. The paths of two aircraft could pass through the same segment at different heights, and hence increase the initial sigma-z.

Incorporation of NONROAD GSE EFs

EPA's draft NONROAD[6] model attempts to inventory emissions not originating from an on-road vehicle, locomotive, watercraft or aircraft. The various types of equipment and vehicles NONROAD includes is quite extensive. From this exhaustive list, EDMS 4.1 incorporates fleet average emission factors (grams of pollutant per hour per horsepower) that were provided by EPA to FAA as applicable to aircraft GSE for four fuel types: gasoline, diesel, CNG and LPG. NONROAD determines emission factors from the fuel burned, engine technology and equipment deterioration. Technology is phased in according to the year of operation. Because EDMS users already supply the year being studied as an input and as a first phase of EDMS migration towards NONROAD, emission factors were incorporated as a function of year, equipment type, and fuel. EDMS users can modify these inputs as appropriate to best characterize the study airport. Equipment deterioration was excluded from the EDMS interface, but default assumptions were used by EPA in developing the emission factors. FAA expects that a future version of EDMS will allow the user to modify deterioration inputs as well.

NONROAD's emission factors must be multiplied by the brake horsepower and load factor to obtain the emission rates. Expert review of NONROAD data found many of its default values for these parameters to be inappropriate for realistic GSE application. EDMS 4.1 provides in its internal database more appropriate GSE default values to the user.

GSE Populations

In EDMS 4.1, users can model GSE emissions by basing GSE operations on aircraft LTO cycles *or* by specifying the airport GSE population independent of aircraft. This second option provides a new alternative to GSE modeling in EDMS, and is similar in approach to the aircraft emissions calculation approach. In previous EDMS versions, all GSE activity is tied to aircraft operations. With each aircraft added to a study, users assign the necessary supporting equipment and the operating time for each piece. When GSE LTO data are not available, users have the option of modeling a population of GSE. In addition, this option of modeling GSE emissions based on population is more similar to EPA's draft NONROAD model, which also utilizes a population basis.

Gates as Area Sources

Gate activity (GSE and APUs) is often modeled by simplifying the typically large numbers of individual gates to just a few groups of gates. In previous versions of EDMS, gates were only modeled as point or volume sources; this resulted in an entire airport's gate operations being concentrated into a few relatively very "hot" spots. Over-conservatively high concentrations would appear in proximity to these gates. EDMS version 4.1 allows for the methodology of gate simplification to continue, but provides users with the ability to better define the region of gate activity by letting groups of gates also be modeled as area sources. Therefore, gate emissions are evenly spread out over a larger area, increasing the accuracy in the modeled concentrations.

Graphic Interface "Wallpaper"

EDMS 4.1 provides users with the ability to load an airport diagram "wallpaper" file to be displayed under their airport views. Although EDMS ships with the airport layout diagrams for over 400 tower-controller airports in the United States, any standard Windows™ bitmap can be used. The user scales the diagram to match the study coordinates, based on a source of a known length that appears on the diagram – usually a runway. The airport wallpaper makes the presentation of the study easier to interpret for average reviewer. It also provides a means for checking the input data. The airport view also now allows sources to be graphically manipulated on the screen, thus making it easier to correct errors that may be discovered when a wallpaper file is loaded. In previous EDMS versions, this wallpaper capability did not exist.

Import & Export Utilities

Two of the most powerful additions to EDMS 4.1 are the import and export utilities. In 4.1, EDMS is enhanced to allow all EDMS inputs to be entered via a comma-delimited text file. The user has the option to only import the desired portions of the file. This marks the first time that EDMS can read in all required input from a single data file. Previously, only user-created aircraft and ground support equipment, operational profiles, stationary sources and weather data could be provided in this manner. This allows for large studies to be created more efficiently and large-scale changes to be made more quickly. As an example, the fleet mix and corresponding aircraft operations data can now be loaded into EDMS directly from a spreadsheet saved in the proper format. In prior versions of EDMS, these inputs would have been entered manually.

The export utility allows all or part of a study to be exported into a single file whose format can be read in any text editor or spreadsheet application and can be used to transport studies to other users. This innovation allows teams of EDMS users to collaborate on their projects without having to copy entire directories of files at once. The exported file is also a good way to see all of the study inputs in a consolidated format, which can be reviewed quickly for errors. Exporting a study saves all of the inputs as well as a copy of any user-created aircraft that are used by the study. Because user-created aircraft are stored along side the internal system data in EDMS to make them usable in multiple studies, it is no longer necessary to provide a copy of the EDMS software with the study directory when presenting a model run for review.

FUTURE DEVELOPMENTS

FAA is continuously conducting research to better understand aviation emissions, and working to improve the modeling capability of EDMS. Model developments planned in the near future include a second phase of enhancements to the GSE component, improved stationary source modeling, and improved dispersion modeling fidelity.

Continued Migration Toward NONROAD

The next phase of EDMS migration toward NONROAD will likely involve incorporation of deterioration factors and a breakout of GSE technology types. Modeling equipment deterioration should increase the accuracy with which an aging GSE population is modeled. As engines age, they naturally function less efficiently and their emission rates increase. EDMS will include a default age distribution, which the user could override to better reflect the scenario. For each GSE type and operating year, NONROAD includes a distribution of engine technology. Allowing users to modify the technology distribution should also enhance the model's accuracy.

Stationary Sources

The next major release of EDMS (version 4.2) will introduce a transition from how stationary sources are modeled and will provide increased accuracy and flexibility for users. Previously, EDMS made assumptions regarding stationary sources that were intended to simplify the data requirements and reduce the overall burden on the analyst conducting a less rigorous analysis of stationary sources; refined stationary source analysis is intended to be conducted using stationary source-specific dispersion models. However, this left the EDMS methodology inconsistent with the guidance contained in the Air Quality Procedures For Civilian Airports and Air Force Bases, also known as The Air Quality Handbook[7]. EDMS 4.2 will resolve these inconsistencies, while maintaining an ease of use for the novice or less rigorous analyses through the use of default values.

Each stationary source type will include the same parameters listed in the Air Quality Handbook. For example, the parameters for boilers and space heaters will include the fuel sulfur and ash content, which are used to determine emission factors. Currently, the only emissions parameters used are the emission factors and the annual throughput. For all sources it will be possible to account for the effects of pollution control equipment that may be installed. Currently, users must enter their own emission factors to achieve the same results.

In addition to the new emissions parameters, source representations for dispersion will also change. Combustion sources will continue to be modeled as point sources; however, the remaining source types will be more appropriately considered as volume or area sources. The previous dispersion model used by EDMS did not offer the other source types as an option.

Terrain Effects, Plume Rise and Building Downwash

The incorporation of terrain effects in EDMS 4.2 will involve the use of AERMOD's terrain pre-processor, AERMAP. The implementation of AERMAP will be similar to how AERMET is currently incorporated in EDMS. The use of AERMAP will require significantly more data and analysis, however the incorporation of these features within EDMS will not necessarily place additional burdens on the user since the features will be optional. Much of the topological data required by AERMAP can be obtained free of charge.

EPA's current beta version of AERMOD provides the ability to model building downwash by incorporating PRIME (Plume RIse Model Enhancements), a building downwash algorithm developed by the Electric Power Research Institute (EPRI). When this beta version of AERMOD becomes finalized, it will replace the version of AERMOD currently bundled with EDMS. A new interface in EDMS should allow users to take advantage of the added features in the new version of AERMOD. The use of downwash algorithms in PRIME would be preferred since they have been shown to be more accurate than the Schulman-Scire algorithms currently in AERMOD[8].

CONCLUSIONS

In 2002, the FAA released EDMS 4.1 which incorporated many significant enhancements including measured aircraft plume characteristics, the first phase of enhancements to the aircraft ground support equipment component, an import/export utility and many other new features into EDMS. These enhancements have improved the accuracy of the model and user flexibility. FAA is continuously conducting research to better understand aviation emissions, and working to improve the EDMS modeling capability. Model developments planned in the near future are intended to further refine the fidelity and flexibility of EDMS.

REFERENCES

[1] *Emissions and Dispersion Modeling System (EDMS) Reference Manual*. Federal Aviation Administration, Office of Environment and Energy. FAA-AEE-01-01. May 2001.

[2] *ICAO Engine Exhaust Emissions Data Bank, First Edition 1995*. International Civil Aviation Organization. Doc 9646-AN/943. 1995.

[3] *User's Guide to MOBILE5 (Mobile Source Emission Factor Model).* U.S. Environmental Protection Agency, Office of Air and Radiation, Office of Mobile Sources, Emission Planning and Strategies Division, Air Quality Analysis Branch. EPA-AA-TEB-94-01. May 1994.

[4] Cimorelli, Alan J., et al. *AERMOD Description of Model Formulation*. Draft Document. AERMOD Version 98314.

[5] Wayson, R.L., et al. *Preliminary Report: The Use Of LIDAR To Characterize Aircraft Initial Plume Characteristics.* Federal Aviation Administration. DTS-34-FA24T-LR1. June 2002.

[6] *User's Guide For The National Nonroad Emissions Model*, Draft Version. http://www.epa.gov/otaq/nonrdmdl.htm. U.S. Environmental Protection Agency. June 1998.

[7] *Air Quality Procedures For Civilian Airports & Air Force Bases*. Federal Aviation Administration, U.S. Air Force. FAA-AEE-97-03. AL/EQ-TR-1996-0017. April 1997.

[8] Schulman, Lloyd L., David G. Strimaitis, and Joseph S. Scire. *Development and Evaluation of the Prime Plume Rise and Building Downwash Model*. Journal of the Air & Waste Management Association. 50: 378-390. March 2000.