DEVELOPMENT OF AN AIR QUALITY MANAGEMENT DECISION SUPPORT SYSTEM FOR BEIJING, CHINA

Jo Ellen Brandmeyer,* Eric Solano, and Robert A. Zerbonia
RTI International, Research Triangle Park, NC
George Gao
PA Consulting Group, Washington, DC
Li Xin, Chen Tian, and Jiang Jiawen
Beijing Municipal Environmental Protection Bureau, Beijing, China
e-mail: **brandmeyer@rti.org**
Web address: **http://www.rti.org**
Voice (919) 541-5961 Fax (919) 541-7155

1.0 INTRODUCTION

RTI is collaborating with PA Consulting Group and experts in China to construct an integrated air quality management decision support system (AQMDSS) to help the Beijing Municipal Environmental Protection Bureau (BMEPB) improve air quality in Beijing for the 2008 Olympics and beyond. Because the Beijing region experiences poor air quality from multiple pollutants of concern, the CMAQ[i]/Models-3 one-atmosphere approach to modeling is required. This AQMDSS will integrate existing tools for emissions inventory development and processing, industrial-scale air dispersion modeling, regional-scale photochemical modeling, and geospatial data analysis.

This document discusses the system architecture of the AQMDSS, its connectivity, and its multilingual user interface.

2.0 AQMDSS ARCHITECTURE

Figure 1 shows the conceptual diagram for the overall AQMDSS at BMEPB. The system is designed to use state-of-the-science models with shared databases.

The three large boxes represent the three types of computer systems that will be networked and the applicable software applications on each type of system. The top box represents an Oracle server and databases that will supply historical data for use with the AQMDSS models.

The middle box represents a large number of personal computers that run applications using the Microsoft Windows operating system. These computers will continue to run their existing applications, and some will also provide access to new software. For example, the Chemical Mass Balance model (CMB 8.2) is a Windows-based model that will not be ported to the Linux environment.

The bottom box represents Linux-based computers, software, and databases. The remainder of this section presents the models that will be included in the AQMDSS and discusses the database design.

* *Corresponding author address*: Jo Ellen Brandmeyer, RTI International, 3040 Cornwallis Rd, PO Box 12194, Research Triangle Park, NC 27709-2194

2.1 Models

A wide variety of emission sources contribute to the air quality problems of Beijing, which is a large metropolitan area that is experiencing rapid economic growth. These sources include industrial facilities and mining operations, electrical utilities and heating plants, mobile sources, and Asian dust storms. Therefore, the AQMDSS has two primary purposes: (1) identify emission sources and their relative contribution to Beijing's air quality problems and (2) investigate control strategies to cost-effectively improve the air quality.

The U.S. Environmental Protection Agency's (EPA's) Multimedia Integrated Modeling System (MIMS) is the framework for the AQMDSS. Instead of working directly with shell scripts to run the models, users will specify parameters and execute models using MIMS tools.

CMAQ/Models-3 is the regional photochemical model chosen for the AQMDSS. Beijing has multiple pollutants of concern, including particulate matter (PM_{10} and $PM_{2.5}$), tropospheric ozone, and SO_2. The one-atmosphere modeling approach will allow the BMEPB to investigate control strategies for all of these pollutants in the same simulations.

AERMOD[ii], which will soon replace the Industrial Source Complex (ISC) model, was chosen as the industrial-scale air dispersion model and will be used to estimate areas of influence for existing and proposed facilities. Some of the facility data will be shared between AERMOD and CMAQ.

The Sparse Matrix Operator Kernel Emissions (SMOKE) processing system will be the primary emissions processing tool. The initial design of the AQMDSS included the Consolidated Community Emissions Processing Tool (CONCEPT). However, it may not be released in time to include it. Because both SMOKE and CONCEPT expect the emissions inventory to already exist, the AQMDSS will include tools for building a bottom-up emissions inventory and storing it in the emissions inventory database.

The BMEPB is concerned about improving air quality while not stifling economic growth. Therefore, a cost-effectiveness tool will be included in the AQMDSS. This tool will compare the cost of various control strategies with the effectiveness of each. Effectiveness will be measured as improvement in air quality.

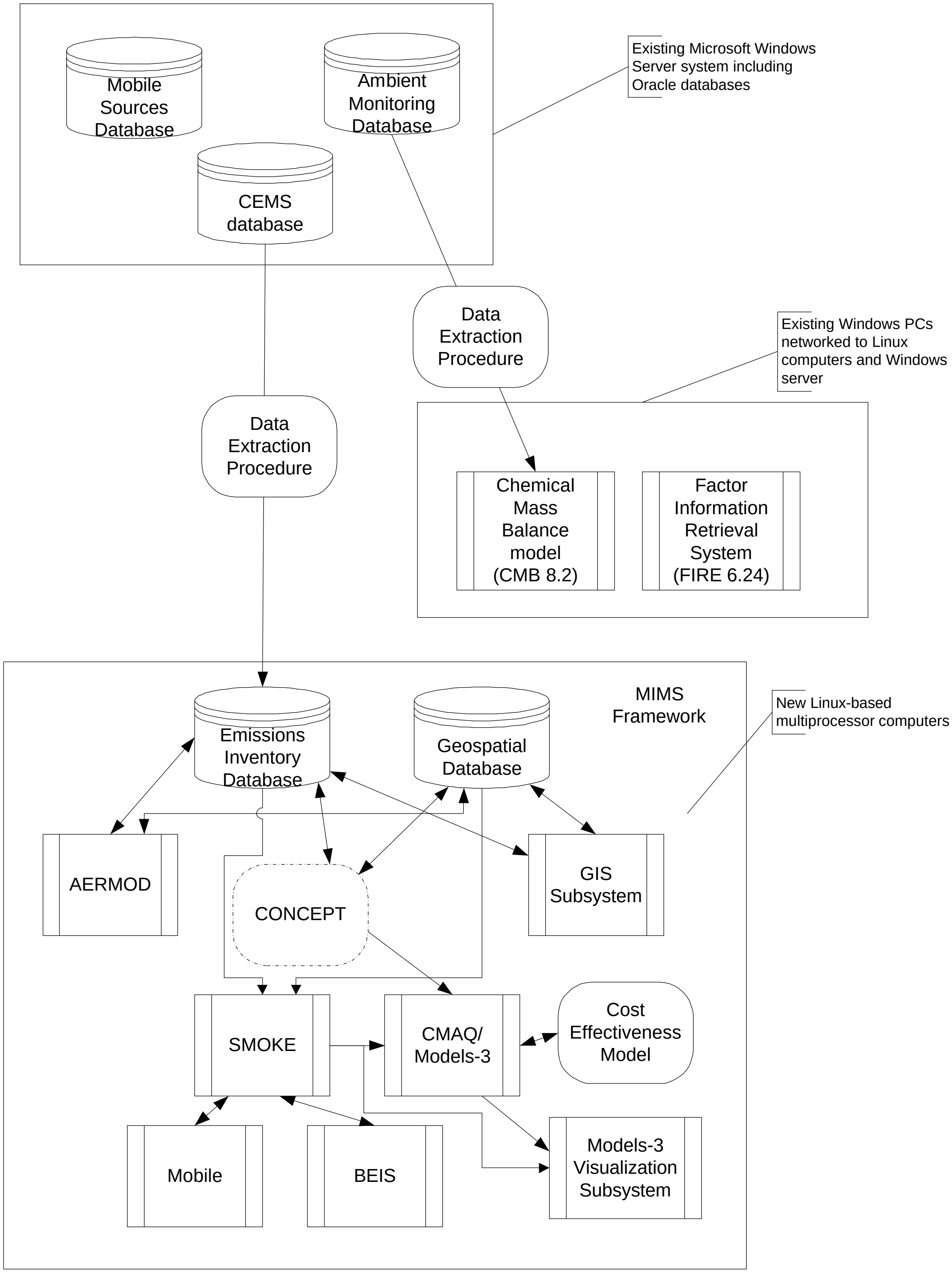

Figure 1. Conceptual diagram for overall AQMDSS at BMEPB.

Finally, the CMB 8.2 model was selected for source apportionment. This model will help estimate how much the various types of particulate matter sources contribute to values recorded at monitoring station locations in Beijing.

2.2 Database Design

The database is designed to support the building and processing of the emissions inventory, geographic information systems (GIS) functionality, and other modeling needs. The structure is implemented using a relational database management system. When practical, foreign keys and range constraints are included both to maintain referential integrity and to reduce potential emissions inventory processing error messages.

The database layout was constructed from a needs analysis of the models and processors that will use it. The National Emissions Inventory (NEI) Input Format (NIF) version 3 was the starting point for the design. Some fields (e.g., country code) and tables (e.g., temporal factors, cross-reference tables) were added to support SMOKE, CONCEPT, and other models.

To simplify data storage and retrieval, some data files are loaded into the database as blobs (i.e., binary large objects). This design reduces data storage and retrieval time by eliminating parsing and reconstruction of a complex file structure. A GIS-compatible modeling grid for AERMOD results associated with a facility is an example of a blob.

3.0 CONNECTIVITY

The MIMS framework provides tools for connecting executable programs, launching programs in sequence, and transferring data between those programs. The AQMDSS uses those tools. This section discusses the additional connectivity between the central databases and the various models and processors provided in the AQMDSS.

When designing the AQMDSS, the design team was aware that the models and processors are not static. That is, the models and framework are still being actively maintained and improved. To allow the AQMDSS to use state-of-the-science models, models must be able to be removed and replaced with new versions with minimal effort. Therefore, the models were left unchanged, so they will not directly read from and write to the database.

Instead of modifying the models, the AQMDSS includes connectivity tools that transfer data between the models and the database. For simplification, Figure 1 does not show these tools, which are written in Java. Each tool provides one well-defined function. The remainder of this section describes the two types of connectivity tools included in the AQMDSS.

3.1 Extractors

The first type of tool extracts data from the database and puts them into a file formatted specifically for a model or processor. Depending on the needs of the particular model, the extractor can create either a comma-separated value (csv) or a fixed format text file.

Parameters are exposed to the extractors because they are included in MIMS scenarios. For example, the extractor can obtain the directory and name of the data file from scenario parameters. Also, the user can specify parameters for multiple extractors and then allow MIMS to execute them unattended.

3.2 Inserters

The second type of connectivity tool inserts data into the database. Because of the size of most CMAQ files, the files will not be stored in the database. However, other programs may use some output data. Inserters will add these selected data to the database.

Each inserter is a Java program that does one specific task. An appropriate user interface allows the user to select the data to insert into the database. We plan to use the NetCDF Java Library from the University Corporation for Atmospheric Research (UCAR) to extract selected data from NetCDF-formatted data files and insert them into the database.

4.0 USER INTERFACE

The MIMS framework provides the primary user interface for the AQMDSS. To make the AQMDSS most useful to the BMEPB, the design team addressed two additional requirements related to reducing data entry errors and developing a multilingual design. These are discussed in the remainder of this section.

4.1 Data Entry

In the United States, state and local agencies have been constructing emission inventories for more than a decade and have the requisite data for the air quality models. As a result, EPA no longer provides tools for creating a new emissions inventory. Beijing, however, is just beginning to construct a similar type of emissions inventory. The AQMDSS includes Java programs to help the BMEPB load their raw emissions data in the proper formats for the models.

These graphical user interfaces (GUIs) are designed to reduce data entry errors. As discussed in Section 2.2, the database design includes referential integrity and range checks where appropriate. The data entry GUIs go further by reducing the amount of typing required for the user to enter and update data.

The first programming technique uses drop-down selection boxes for code entry. For example, emission processors require specific pollutant codes. Instead of typing the code in a text box, the user selects the code from a drop-down box. If a required code is not in the database, a user with appropriate permission can add the code using the appropriate maintenance GUI.

The second programming technique uses parent-child relationships among related records. For example, a facility (i.e., point source) has a record in a facility table. This record contains information applicable to the entire facility. Then, each emission source has a record in a facility-source emissions table. Further, each pollutant emitted from each source has a record in a facility-source-pollutant table. In this example, the facility record is the parent of the facility-source records, each of which is the parent of the facility-source-pollutant records. Instead of accessing the facility-source-pollutant record directly, the user chooses first the facility, then the appropriate source for that facility, and finally the pollutant to edit for that source.

4.2 Multilingual Design

One requirement of the AQMDSS is that the user interface be in Chinese. The team developing the AQMDSS includes Chinese programmers in Beijing who can perform the requisite translations. However, simply translating the existing user interface does not allow the framework and the models to be easily upgraded to new versions in the future. Also, U.S. members of the project team are not fluent in Chinese but must be able to provide support to the BMEPB. Therefore, the AQMDSS includes a multilingual design.

Java includes tools to support the software development process internationalization/localization. In this process, literal strings that are displayed in the user interface, such as frame titles and button text, are removed from the source code and placed in external resource files. The old strings are replaced by functions that look up the information from the appropriate place in a resource file and display it.

Although internationalization/localization requires more effort than traditional programming, it provides a huge benefit for multilingual user environments. When software that was produced using this method needs to support an additional language, the software itself does not need to be edited or recompiled. Instead, only a new copy of the resource files must be created to contain the translated strings.

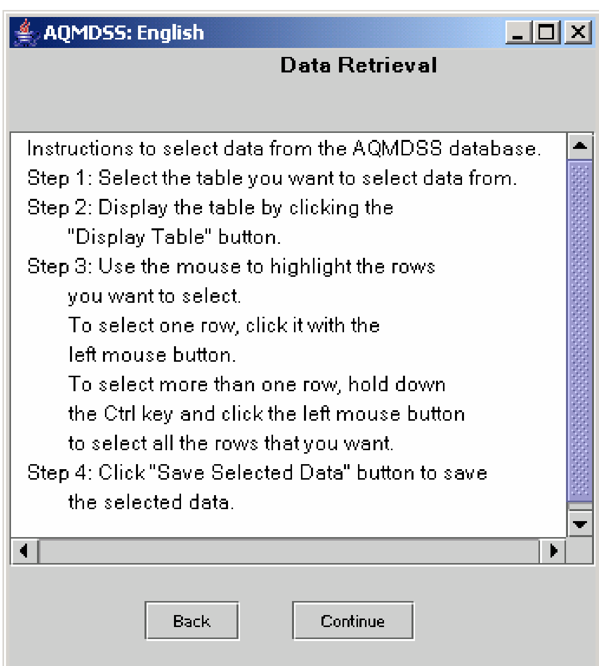

Figure 2. English version of sample frame.

Figures 2 and 3 illustrate the results of this internationalization/localization work on a sample frame. In this example, the labels, button text, and text box contents have been translated, but not the frame title.

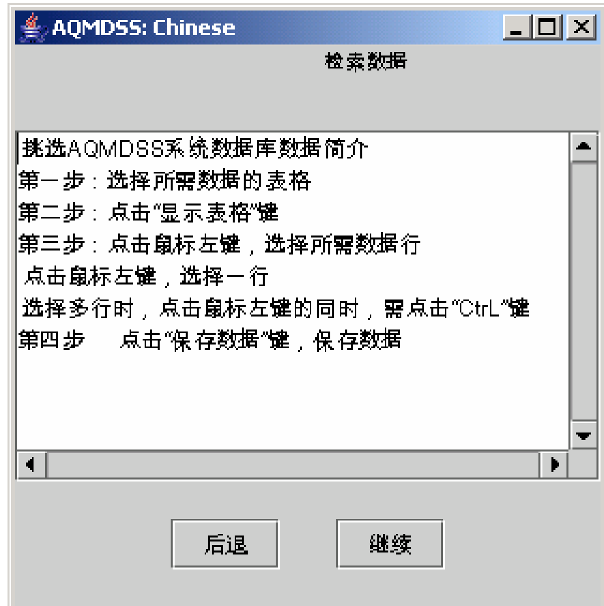

Figure 3. Chinese version of sample frame.

5.0 CONCLUSIONS

The new AQMDSS is being built using a flexible, extensible design. Scheduled for testing and implementation in 2005, it will be an effective tool to support the BMEPB's goal of improving air quality in Beijing. Its design will also allow updates to the models with minimal software changes, as well as the addition of more models in the future.

This project is funded by the BMEPB. The design team also acknowledges the assistance of numerous U.S. EPA personnel, as well as the developers of the many open source models and tools that are being used in the AQMDSS.

---

[i] Community Multiscale Air Quality (CMAQ)

[ii] American Meteorological Society/U.S. Environmental Protection Agency Regulatory Model Improvement Committee (AERMIC) Model (AERMOD)