

Air Quality and Emission Control Strategy Evaluation Software BRIDGE PROGRAM

大気質と排気ガス低減戦略評価ソフトウェア「ブリッジプログラム」

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ABSTRACT

An original software tool, BRIDGE PROGRAM, has been developed to simplify the evaluation of emission control strategies for improving air quality. It is particularly effective for in-house evaluation of emission inventory reductions and air quality impacts as a result of introducing innovative, low emission technologies. The software uses a Relational Database Management System (RDBMS) to manage and modify the large emission data sets that characterize specific regions. Mobile, stationary, and biogenic emission rates can be scaled up or down, individually or by groups of source categories. The software automatically generates compatible files of gridded emissions for photochemical models used by regulatory agencies. This software has been used to modify emission inventories in regions of the United States and Japan. This paper describes the methodology and utility of the new software.

要 旨

大気質を改善するための排気ガス低減戦略の評価を簡素化するソフトウェア(BRIDGE PROGRAM)を開発した。このツールは、画期的な低公害技術がどのように大気質改善に貢献するかを評価する手法として特に有効である。本ソフトウェアでは「リレーショナルデータベースマネジメントシステム」(RDBMS)によって特定地域の膨大なエミッションデータを管理し、調整する。このソフトウェアにより、移動発生源、固定発生源や生物起源のエミッションを発生源別に、または、発生源区分ごとに影響度合いを変化させることが可能となる。また、規制当局が採用している互換性のある光化学反応グリッドモデルへの入力データに自動的に変換することが可能である。本ソフトウェアは、アメリカや日本のエミッションインベントリの評価に使用されている。

1. Introduction

There is a growing interest around the world for regions with poor air quality to search for pollution control strategies that will reduce emission inventories and achieve healthful air. These regions, typically urban or influenced by nearby urban emissions, have emission inventories that are dominated by mobile sources. As a result, strict regulations have been directed toward the drastic reduction of mobile emissions, particularly light-duty vehicles (LDV). Using the emission inventory of California's South Coast Air Basin (SCAB) as an example, reductions of roughly 80% total organics gases and 60% oxides of nitrogen are required to attain the National Ambient Air Quality Standard (NAAQS) for ozone. These are enormous reductions that will require implementing a host of clean technology solutions across all industries, not just from the mobile sector.

Honda has responded to the strict regulations by researching and developing many clean technologies, including clean gasoline powered vehicles, alternative fueled vehicles such as natural gas and pure electric vehicles, as well as fuel cell vehicles. Until now, Honda has lacked the internal capability to evaluate the air quality impacts of the most promising clean technologies introductions. It would be advantageous to have the in-house ability to evaluate the emission and air quality benefits of these vehicles before or during the early research phase. This capability would provide insight for determining the most effective direction for development or future research. This type of early indication of emission benefit could also be valuable for scientific discussions with regulatory agencies or other interested groups.

Mathematical models are commonly used to describe

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the chemical and physical processes within the atmosphere during the assessment of emission reductions on regional air quality⁽¹⁾. These models require comprehensive meteorological and emissions data that are spatially and temporally allocated. To accurately represent an emission control strategy, baseline emission data should be modified at the disaggregate level.

An effective software system, BRIDGE PROGRAM, has been established to “bridge” the gaps between agency-supplied emissions data, emission control strategies, and advanced photochemical air quality models. The methodology is based on applying control factors to the baseline emission contributions of carbon monoxide (CO), oxides of nitrogen (NO_x), sulfur oxides (SO_x), total organic gases (TOG), and particulate matter (PM). The emission rates from individual or groups of emitting source classes can be scaled up or down to represent the target emission rates. The hourly gridded emission files required for photochemical models are automatically generated.

The system described in this paper has the structure to activate a sophisticated mechanism for designing emission control strategies for not only the transportation industry but for other industries as well. This software tool can assist in finding the technology combinations to clean our air.

2. Description of the Evaluation Model System

The system design for applying a relational database management system (RDBMS) to evaluate air quality emission control strategies is shown in Fig. 1. All of the input and output data flow is conducted through the RDBMS. Air quality data, chemical mechanisms, and baseline emissions of mobile, stationary, and biogenic sources are loaded into the database. Tables are created to store the data and links are established to form relationships. A control strategy Graphical User Interface (GUI) allows novice users to communicate with the database and easily modify any emission source type.

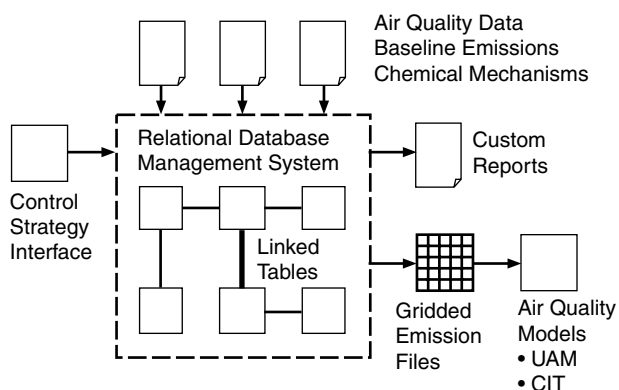


Fig.1 The system design and data flow

The database can be interrogated directly with Structured Query Language (SQL) scripts to extract information and return custom reports for inventory analysis⁽²⁾. The hourly gridded emission files required by regulatory and research photochemical models, specifically the Urban Airshed Model⁽³⁾ (UAM CB-IV) and the California Institute of Technology Model^{(4), (5)} (CIT), are automatically generated.

It was important to select a commercially available RDBMS that could be easily adapted and widely used⁽⁶⁾. Oracle8 was selected although early development was concurrently performed in Microsoft SQL Server. The RDBMS has the capability to easily manipulate, display, and analyze large and diverse data sets.

3. Mechanism to Identify Source Types

Reflecting the introduction of a new technology or a proposed regulatory standard into an emission inventory requires the ability to identify the appropriate source types for modification. The Source Classification Code (SCC) was selected as the mechanism to identify source types. The U.S. Environmental Protection Agency, California Air Resources Board (CARB), and the South Coast Air Quality Management District (SCAQMD) support the SCC usage. Many countries interested in improving air quality look to these agencies for guidance. The SCC is an 8-digit code divided into four parts (X-XX-XXX-XX), which correspond to the four hierarchical levels of source description as illustrated in Fig. 2. Specifying a full 8-digit code uses all four levels and completely describes a particular source type. Not specifying the deeper levels will lead to increased groupings of industries and eventually will describe the most general categories.

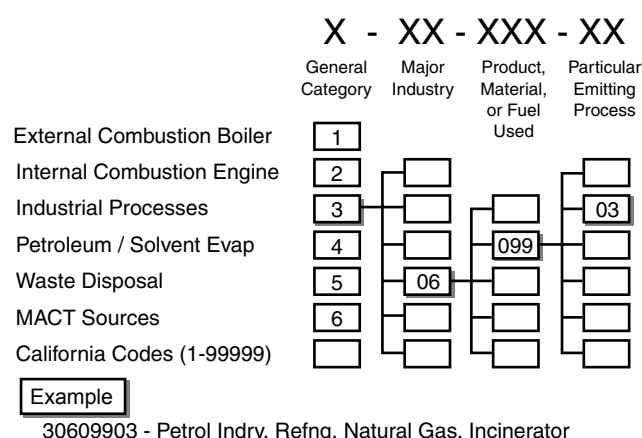


Fig.2 The structure and tree diagram representation of the eight-digit, four-tier Source Classification Code

All of the emission entries in the database are obtained from local and government agencies and contain key fields for values of SCC, CO, NO_x, SO_x,

TOG, and PM⁽⁷⁾. The SCC provided a logical means to apply control factors across entire industries or specific processes, which realistically simulates the implementation of a new regulation or technology. Several of the tables created in the RDBMS include a common column, like the SCC column. These types of recurring columns weave relationships throughout the RDBMS⁽⁸⁾. Countries or regions that have not yet assembled or are beginning to assemble an emission inventory can adopt the SCC or design a suitable source identification scheme^{(9), (10)}. Consultants or “think tank” groups may be utilized as an alternative means of generating emission inventory estimates in countries where this type of data is not publicly disclosed.

4. Designing an Emission Control Strategy

An emission control strategy is a plan to reduce the emissions from targeted source types in order to attain a desired emission inventory level, typically described in units of tons/day. Usually the inventory goals are set to achieve air quality standards, like ozone attainment. Designing an effective control strategy typically requires an understanding of the relative emission contributions from the various active sources within a region. The powerful tools accompanying a relational database allow the user to query the enormous emission data files. Ad hoc queries can be rapidly scripted and refined for successive interrogation of the database. Information can be extracted to expose leading candidate sources for emission reduction. Knowledge of reactivity and ozone forming potential are insightful for choosing some sources over others but is not mandatory because this information is incorporated into the photochemical models. These mathematical models describe the chemical and physical processes within the atmosphere and predict the pollutant concentrations, which can be plotted and animated for easier comprehension.

A GUI was created to simplify the most common tasks during the process of modifying an emission inventory. GUIs are valuable tools to facilitate communication between the database and non-expert users. Experts can always communicate with the database directly by using SQL. Fig. 3 shows the general GUI for selecting an episode date, defining the spatial and temporal range, and choosing the appropriate format for the gridded emission files as required by air quality models.

The domain size can be customized to represent the region of interest as shown by the GUI in Fig. 4. Offsets are available to align the corner of the inventory data so it coincides with the domain representation of the ensuing photochemical air quality model. This is a particularly useful feature when studying new regions.

The SCC button in Fig. 3 will launch the SCC GUI shown in Fig. 5. The left-hand column of Fig. 5 contains the entire list of over 2000 unique SCCs. This

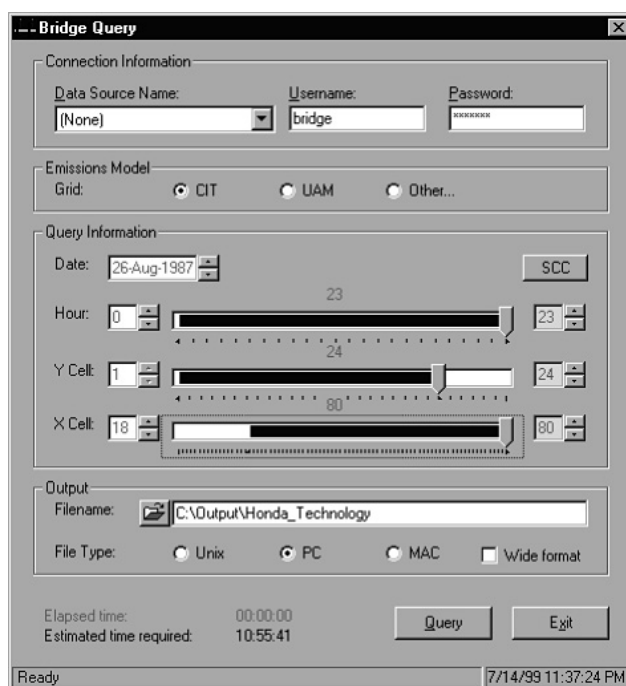


Fig.3 The general GUI simplifies common tasks

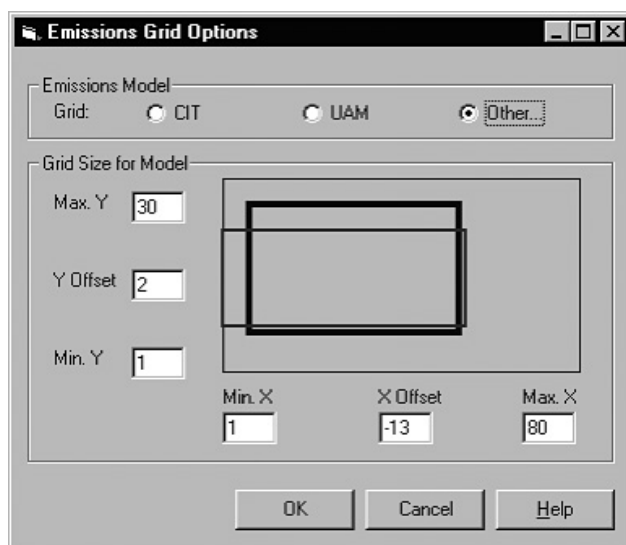


Fig.4 Flexible domain sizing and inventory offsets

tree diagram can be expanded or collapsed to expose any specific source type. An entire branch of sources within the tree diagram can be selected by marking the box at the most general level. Any source can be deselected by marking it again.

Once a source type has been selected, it is added to a summarized list on the right-hand side of Fig. 5. The sources in this list are available for emission modification. Control factors can be applied to CO, NOx, SOx, TOG, and PM emissions. A unity factor represents no change to the baseline emission rate. A factor less than unity represents an emission reduction

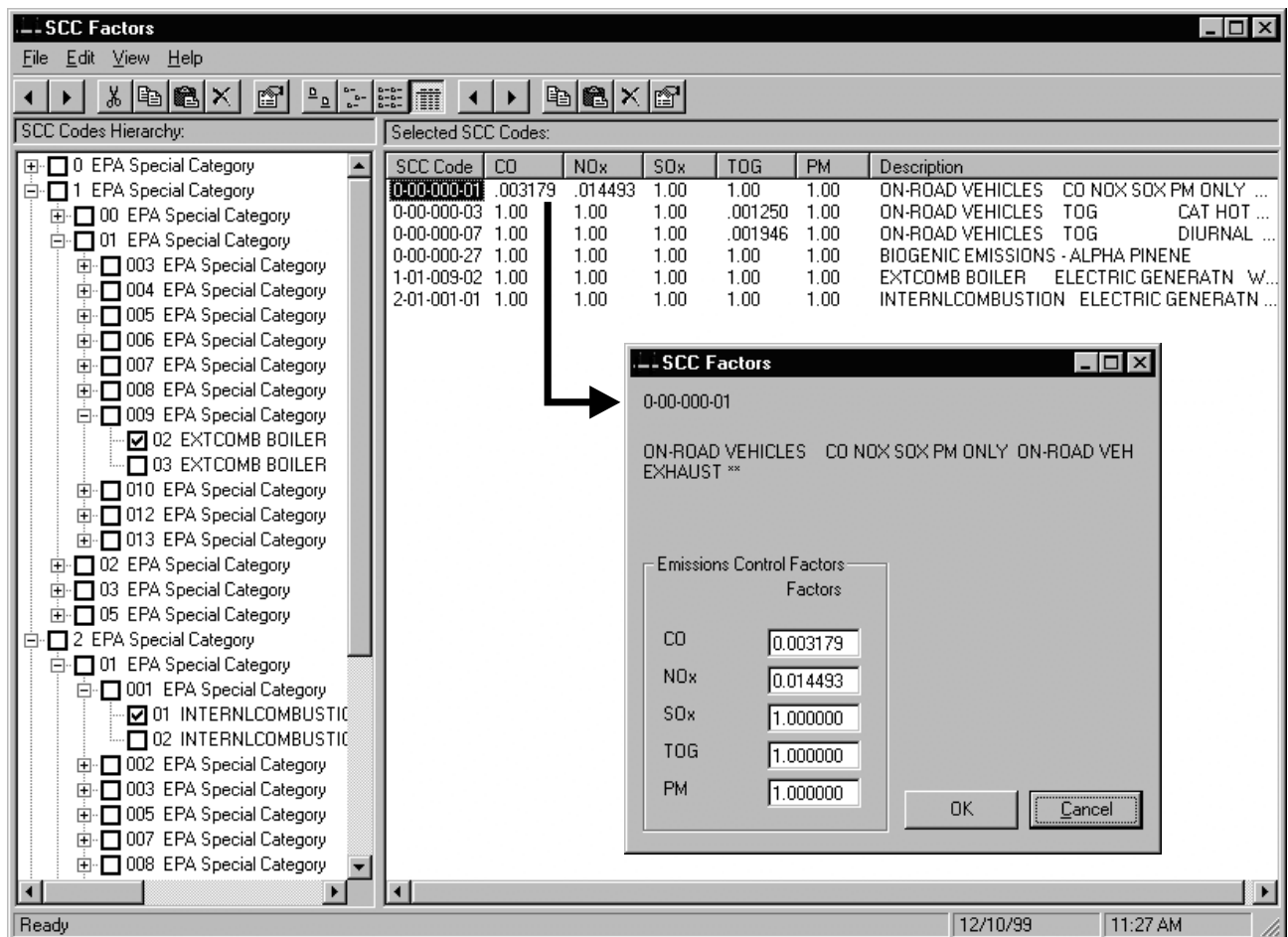


Fig.5 The SCC GUI allows the user to select individual or groups of SCCs and apply control factors

while factors greater than unity represent emission increases.

The example in the summary list of Fig. 5 shows three different SCCs will be used to reduce emissions from ON-ROAD VEHICLES. Emission rates for CO, NOx, and TOG will be significantly reduced to reflect a clean fleet technology. This is evident because the emission control factors, or coefficients, have been set to values much less than unity. The control factor values are determined by the relative contribution of the new emission rates compared to the existing baseline fleet emission rates that are stored in the database⁽¹¹⁾⁻⁽¹³⁾. The user must also consider the number of vehicles or market penetration when modifying emissions from ON-ROAD VEHICLES.

After applying control factors to the selected sources the user returns to the general GUI, Fig. 3, and executes the data manipulation with the query button. The database applies the new emission rates to each spatial location where that specific source type is active within the region. Emission files are automatically gridded into cells as a function of time and space for use in regulatory or research air quality models. Fig. 6 shows emission inventories for Japan's Kanto region and the United States' South Coast Air Basin. Because most of the

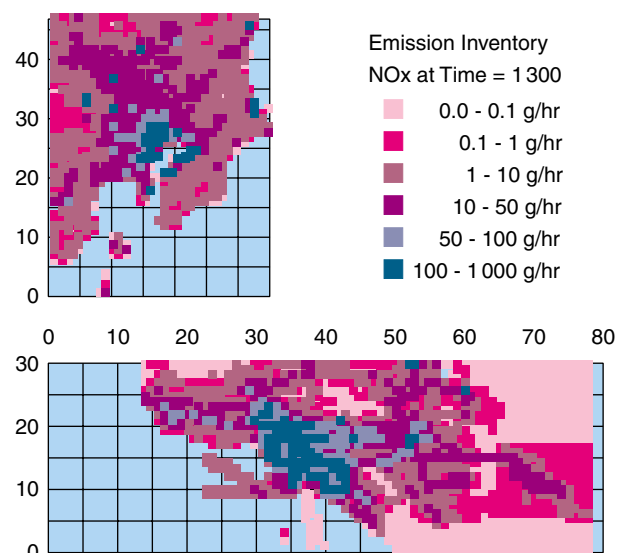


Fig.6 An example of hourly emission inventories for Japan's Kanto region and U.S. SCAB

steps in the process of designing an emission control strategy have been automated, the influence of human error has been minimized. This process of creating control strategies would continue until the results of the emission reductions and air quality simulation successfully met a predetermined criteria.

5. Conclusion

An original and effective software tool has been developed to simplify the evaluation of emission control strategies for improving air quality. Mobile, stationary, and biogenic emission inventories are quickly modified to reflect the introduction of innovative, low emission technologies. Control factors are applied to an emitting source class to alter emission contributions of CO, NO_x, SO_x, TOG and PM. The hourly gridded emission files required for photochemical models are automatically generated. The tool gives Honda the in-house capability to evaluate the emission and air quality benefits of vehicle technologies before or during the early research phase, which can provide insight for determining the most effective direction for research and development.

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