Regional Emission Analysis using Travel Demand Models and MOVES-Matrix

Xiaodan Xu, Graduate Research Assistant*
School of Civil and Environmental Engineering, Georgia Institute of Technology
790 Atlantic Drive, Atlanta, GA 30332
TEL: 404/502-0794
Email: xxu312@gatech.edu

Haobing Liu, Graduate Research Assistant
School of Civil and Environmental Engineering, Georgia Institute of Technology
790 Atlantic Drive, Atlanta, GA 30332
TEL: 404/426-1678
Email: haobing.liu@gatech.edu

Yanzhi “Ann” Xu, Ph.D.
Research Engineer II
School of Civil and Environmental Engineering, Georgia Institute of Technology
790 Atlantic Drive, Atlanta, GA 30332
TEL: 404/723-0543
Email: yanzhi.xu@ce.gatech.edu

Michael O. Rodgers, Ph.D.
Principal Research Scientist and Adjunct Professor
School of Civil and Environmental Engineering, Georgia Institute of Technology
790 Atlantic Drive, Atlanta, GA 30332
TEL: 404/385-0569
Email: michael.rodgers@ce.gatech.edu

Randall L. Guensler, Ph.D.
Professor
School of Civil and Environmental Engineering, Georgia Institute of Technology
790 Atlantic Drive, Atlanta, GA 30332
TEL: 404/894-0405
Email: randall.guensler@ce.gatech.edu

*Corresponding author

Abstract
Transportation conformity is required by the Clean Air Act section 176(c) to ensure that federal funding and approval are given to highway and transit projects that are consistent with (“conform to”) the air quality goals established by a state air quality implementation plan (SIP). Transportation activities may not cause new air quality violations, worsen existing violations, or delay timely attainment of the national ambient air quality standards (USEPA, 2012). The regulations establish the link between air quality planning and transportation planning. Each MPO must make a positive conformity determination for regional transportation plans (RTPs) and transportation improvement plans (TIPs) under this regulation. In this case, it is necessary to develop an approach for environmental assessment on those transportation plans, and the linkage between regional travel demand model (TDM) and emission estimation tool can be a viable
option for achieving this goal. Currently, establishing such a linkage is a resource-intensive process, which often requires that agencies hire outside consultants to script ad hoc software to translate TDM outputs into MOVES inputs, often known as air quality pre- or post-processors. Existing pre- or post-processors are designed for county (regional) level analysis, limiting the capability to further apply emissions results to hot spot or environmental justice analysis. In this paper, we present a new tool establishing linkage between a comprehensive MOVES emissions rate lookup table, referred to as MOVES-Matrix, and an activity-based TDM. This new tool allows for rapid assessment of transportation scenarios and related emissions impacts on a link-by-link basis, enabling further linkage to dispersion models and spatial analysis.

1. Literature Review

The final paper will provide a comprehensive literature review of regional SIP emissions modeling and conformity modeling, beginning with Chatterjee, et al., 1997 and covering a number of case studies by type. The literature review will identify the various approaches employed, limitations and shortcomings, and the historic push for use of local data rather than regional default data. The literature review will set the stage for the case study analyses and MOVES-Matrix applications that follow.

2. MOVES-Matrix

The USEPA created MOVES to estimate emissions from on-road vehicles in the United States. The MOVES model is the regulatory emission analysis tool that must be applied to all recent transportation conformity analysis (unless a project-level conformity screening tool has been approved for use in the region). In regional-level analysis, MOVES works with traffic flow information provided by travel demand model and applicable model post-processors. However, for every transportation scenario that is assessed, a new set of MOVES inputs usually needs to be developed. The MOVES interface is complex and input file preparation is time consuming, which makes MOVES difficult to use in assessing large-scale transportation networks that experience dynamic changes in on-road fleet composition and operating conditions.

MOVES-Matrix was created by running MOVES a tremendous number of times (Guensler, et al. 2016). The researchers iterated MOVES across all variables that affect output emission rates (except for fuel composition and inspection and maintenance program which were static for each region). Each iteration yielded an emission rate applicable to all MOVES pollutants, where each emission rate represents a source type, by model year (age group), for specific vehicle fuel type (gasoline, diesel, CNG, etc.), for a specific operation (average speed & road type, or on-road VSP/STP operating mode bin), for a specific calendar year, and applicable regional regulatory parameters (fuels properties, I/M), for specific temperature and humidity conditions. Because MOVES has been run for every iteration, the user can call for the applicable MOVES emission rate in MOVES-Matrix from other operations and obtain the exactly the same emission output that MOVES provides without ever having to launch MOVES again or transfer MOVES outputs into the analyses. Figure below is an overview of MOVES-Matrix approach. The process first identifies a subset of Matrix emission rates for calendar year, fuel, month, and meteorology information. Then, MOVES-Matrix scripts grab applicable emission rate cells for the fleet and operating conditions and weight the rates by on-road activity (per cell) to assemble the fleet emission rate (the same way that MOVES does).
MOVES-Matrix is grabbing emission rates that have already been adjusted by MOVES for meteorology, fuel, I/M, etc. Hence, MOVES-Matrix does no modeling calculations at all. This concept makes the emission rate assembly process much faster than running MOVES. The system also provides the potential for real-time and large-scale emission estimation. In this paper, MOVES-Matrix will be implemented with the travel demand model to demonstrate that the modeling approach yields the same emissions as direct MOVES runs, but with significant time savings. Users just need to link regional travel outputs with the applicable Matrix emission rates, and the paper demonstrates the method.

3. Travel Demand Model (TDM)

A travel demand models (TDM) is developed by metropolitan planning organization (MPO) as technical tool to assist in the development of the Regional Transportation Plan (RTP) and the policy decision making process. TDMs are typically implemented with post processors to output hourly traffic volumes and applicable on-road operating conditions. Conventionally, the TDM models utilize the four-step method (also known as four-step model or four-step forecasting process), which includes trip generation, trip distribution, modal choice, and traffic assignment (Meyer and Miller, 2013; Weiner, 1999). The four-step method assumes that travel is derived from the demand for activity participation, and trips are first predicted. However, this trip-based method is likely insufficient either in considering dependence between trips or capturing the organization (scheduling) of trips. In this case, the activity-based travel demand modeling approach is proposed to capturing activity participation and focusing on sequences or patterns of activity behavior (Bhat, et al. 1999). The activity-based approach in regional transportation planning is becoming more popular in recent years because it provides an improved behavioral causality linkage between individual activity patterns and the travel environment.
In metropolitan Atlanta area, the Atlanta Regional Commission Travel Demand Model generates regional travels by utilizing activity-based model process for the 20-county non-attainment area (ARC, 2012). Coordinated Travel-Regional Activity-Based Modeling Platform (CT-RAMP) is implemented in the travel demand model system to facilitate the regional activity forecasting with 30-minute resolution. The generated activities are sub-divided into trips based on the origin and stop information and allocated to links within the local transportation networks during different time periods. The activity information can be an applicable source for estimating emission distribution on the network through linkage to emission estimation tools.

4. Linkage between MOVES-Matrix and ARC Travel Demand Model

The major objective of this study is to develop and demonstrate the methods to employ MOVES emission rates in MOVES-Matrix into the MPO travel demand model emission analyses. The programming linkage will be built between MOVES-Matrix and travel demand models in order to assist state implementation plan (SIP) development and transportation air quality conformity analysis.

The methodology of connecting current activity-based travel demand model and MOVES-Matrix follows the workflow diagram below. First, scenario information used in the travel demand model are identified, such as region location (county), calendar year, and meteorology data, and used to extract the corresponding MOVES-Matrix subset. Then, the regional trip information and network information will be extracted by running the TDM. The trips generated by the ARC model will be allocated to vehicle source and model year distributions using regional fleet composition distributions. The average speeds on the network from the TDM will be calibrated with real-world speed distribution coming from observed traffic data to achieve realistic speed bin distributions. Also, the vehicle mile travelled (VMT) will be adjusted by data from Highway Performance Monitor System (HPMS) and seasonal factors. Next, using the travel information and network information provided by TDM, the emissions will be estimated by multiplying average speed bin of each vehicle type for each link with applicable emission rates for that source type, road type and operating mode condition from MOVES-Matrix. The unit emission will be aggregated by adjusted VMT for each link. Finally, the link-based emission results will be aggregated and displayed by roadway type and time period for different analytical purposes using ArcGIS. The results will also be merged into TDM outputs for users. The proposed modeling approach will be evaluated by repeating the same analysis using MOVES and comparing two groups of emission results and processing speeds.
Figure 2. Workflow of Proposed Linkage

The effort spent in this study will assist MPOs perform environment assessment plans with handy tools developed and conform to the current environmental regulations. The time and effort of doing conformity analysis can be significantly reduced with emission results exactly same as MOVES output. And great flexibility is provided by this linkage, allowing users to simply change their scenarios by editing TDM input or few csv tables in post-process module such as regional vehicle type composition and age distribution.

Reference


