A Framework for the development of an International version of the MOVES model

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Introduction

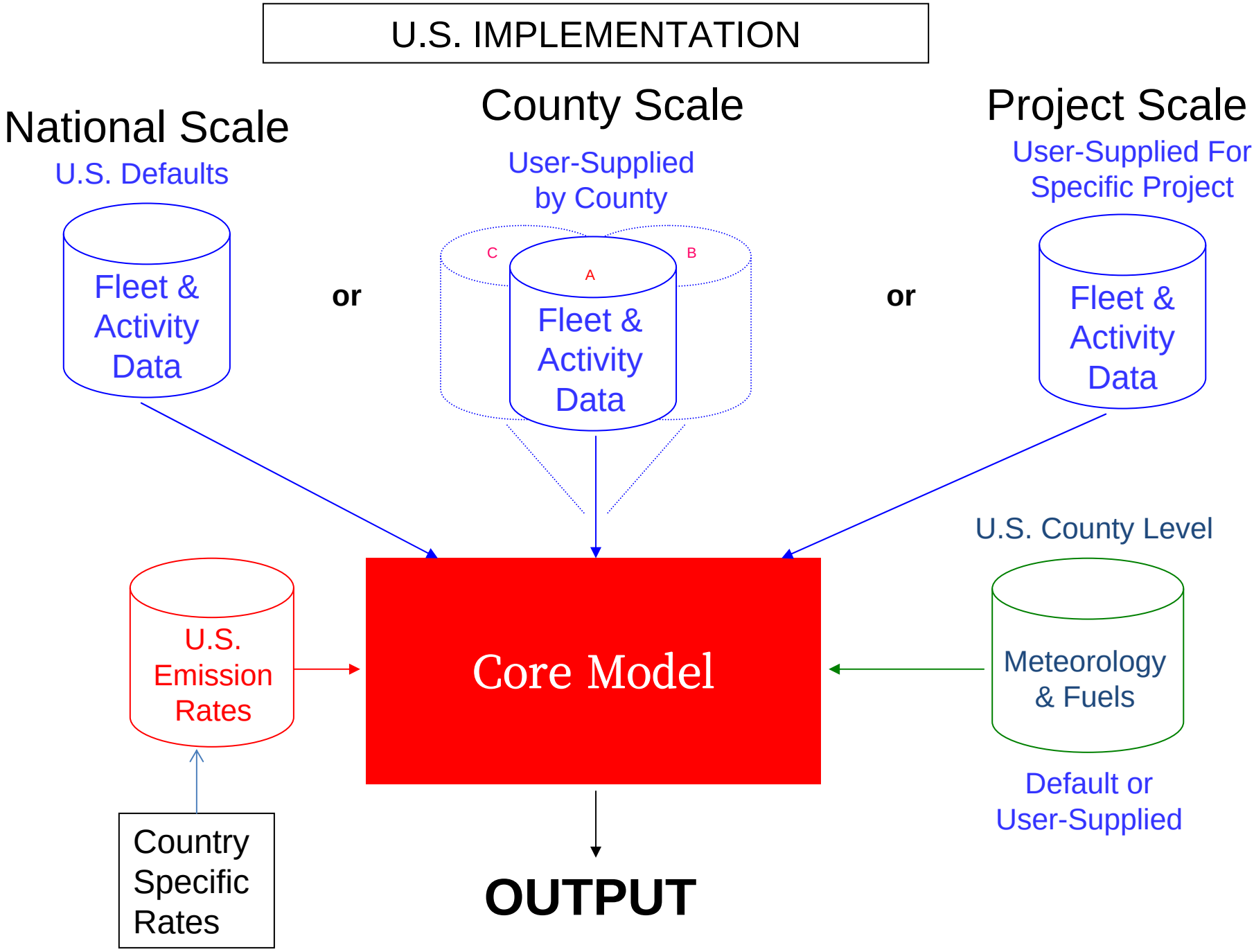
- EPA intends to modify MOVES for the purpose of estimating vehicle emissions in other countries
- Initial research into MOVES International development documented in a white paper by Koupal et al.
  - http://www.epa.gov/oms/models/moves/MOVES2010a/paper137-tap2010.pdf

MOVES International Approach

- Overall goal is to create a generalized process for modifying MOVES for Int'l application.
- Initial project will create a *framework* for MOVES expansion
  - Identify preliminary steps
  - Begin applying steps to Java codebase and MySQL structure
  - Initially, intended to be used in limited analysis conditions for light duty vehicles
  - Identify potential future improvements

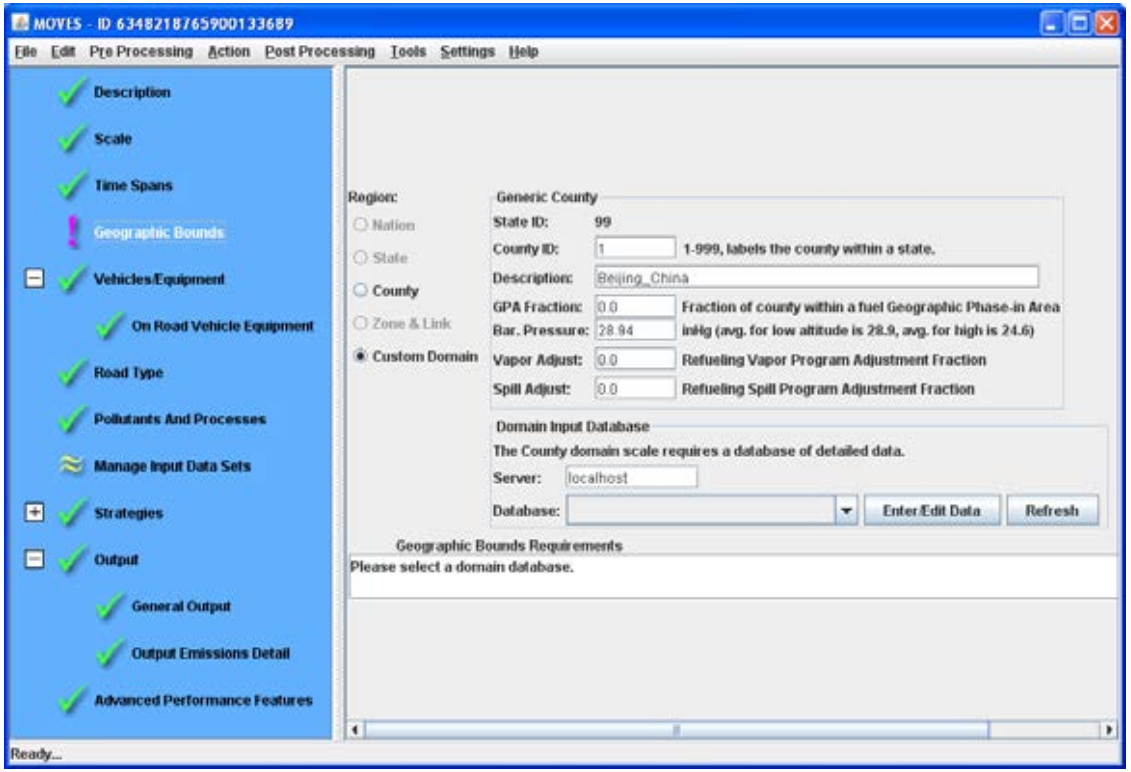
Recommend a "Tiered" approach to customization

- EPA's Tiered Approach – required because full customization of the model would require intensive data collection and analysis
  - Tier 1: Use MOVES County Data Manager for input of local data
    - Activity, fleet, fuel data and other parameters
    - Would still use US-centric emission rates and drive cycles
  - Tier 2: Implementation of Int'l Emissions Standards
    - Develop alternate emission rate tables
    - Take into account fleet penetration and implementation dates
    - Would still use US-centric drive cycles, vehicle classes, road types, etc.
  - Tier 3: Complete Java / MySQL code transformation
    - Allow for customized vehicle classes, road types, drive cycles
    - Requires most effort in both development and data analysis


U.S. IMPLEMENTATION
National Scale
U.S. Defaults
Fleet & Activity Data
or
County Scale
User-Supplied by County
C
A
B
Fleet & Activity Data
or
Project Scale
User-Supplied For Specific Project
Fleet & Activity Data
U.S. County Level
U.S. Emission Rates
Core Model
Meteorology & Fuels
Default or User-Supplied
Country Specific Rates
OUTPUT

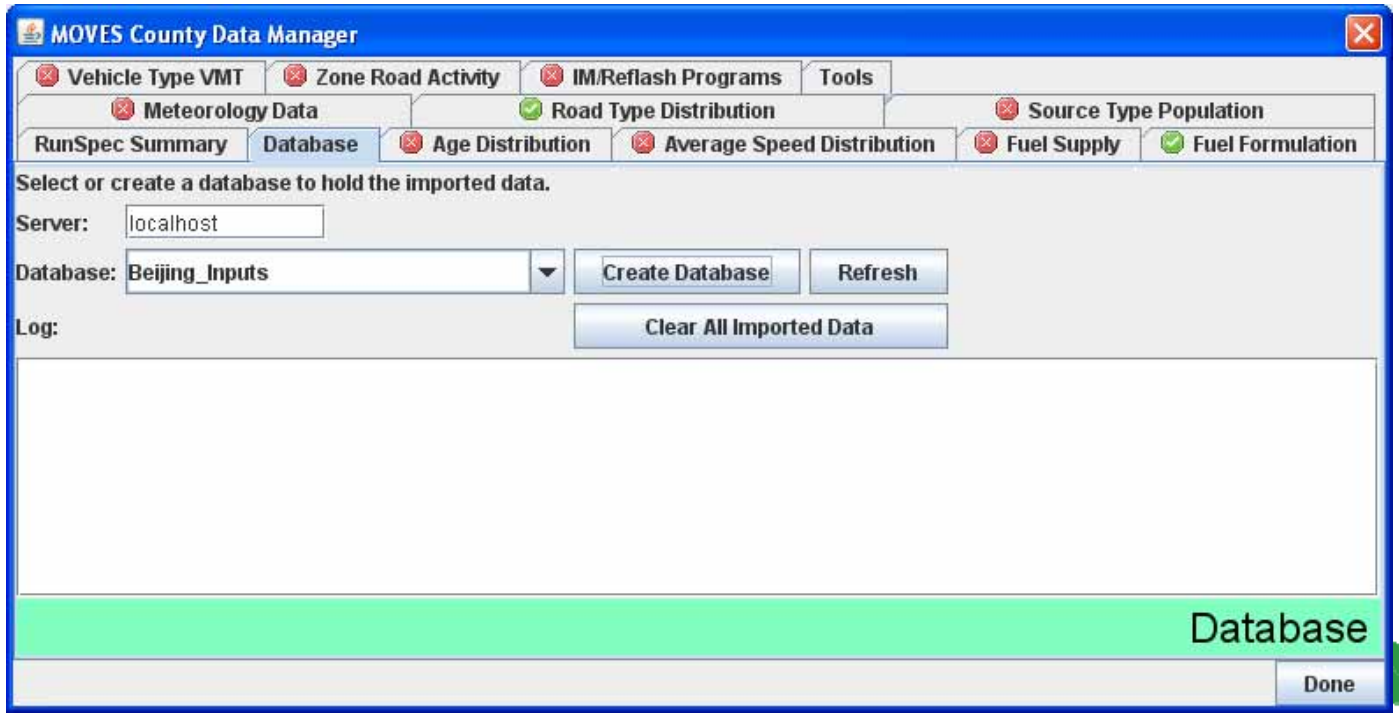
MOVES designed to be adapted for international use

- "Custom domain" option allows international users to define and customize their region



MOVES County Data Manager can be used to easily set up custom database of "1st Tier" data

– Accepts inputs for custom fleet, fuel and activity in MS Excel format, converts to MySQL data used by the model



Initial MOVES Coding Changes

- Allow for use of the MOVES Custom Domain option in input of localized data
- Code updates proposed:
  - Allow for the fleet to be certified to any US or Euro standard
  - Fuel Effects Generator (Java) must be generalized
  - Sulfur Model (SQL) must be generalized
  - Importer will account for metric and English units
  - InputDataManager to be restricted during import of int'l data
- MySQL Table Updates: *numerous,* see below

Initial MOVES Coding Changes

Partial List of MySQL Tables Requiring Update

Table	Model Year	Model Year Group	Source Bin	Age	Rates	Ratios or Coeffs
atBaseEmissions						X
atRatioGas2						X
atRatioNonGas		X				
crankcaseEmissionRatio		X				X
cumTVVCoeffs		X				X
		X			X	
emissionRate			X		X	
emissionRateByAge			X	X	X	
fuelModelWtFactor		X				
fuelModelYearGroup		X				

Emission Rate Converter

- ERG will develop a software tool to create a suite of emission rate tables for input to MOVES
- Tool will allow user to enter standards and phase-ins by vehicle class and model year
- If no new data are available, tool will map existing MOVES rates to desired standards

Emission Standard Ratios: Euro to U.S. Tier 1

- ERG will use data available from Europe and/or Hong Kong to develop FTP, US06 and LA92 emissions estimates for Euro-cert vehicles
- For this data, instantaneous VSP will be calculated on a sec-by-sec basis

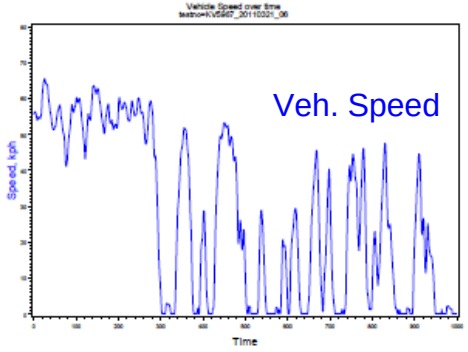
$$VSP_{v,t} = \frac{Av_t + Bv_t^2 + Cv_t^3 + mv_t a_t + mgv_{vertical}}{m}$$

- HC, CO, and NOx emissions will be binned by VSP and vehicles speed, and average emissions calculated. See example below.

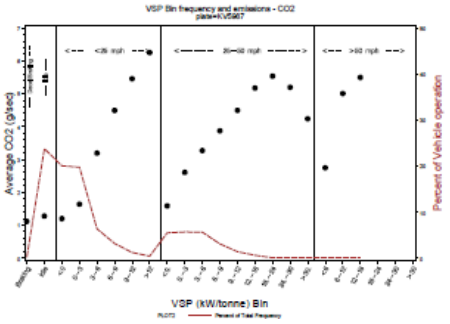
Analysis of Emissions Data by VSP

Method for Estimating FTP-Equivalent Emissions

Calculate VSP from vehicle speed, acceleration, mass, and road grade for each



Classify data observations into 32 bins depending on VSP and vehicle speed



Find average emission level in each VSP bin

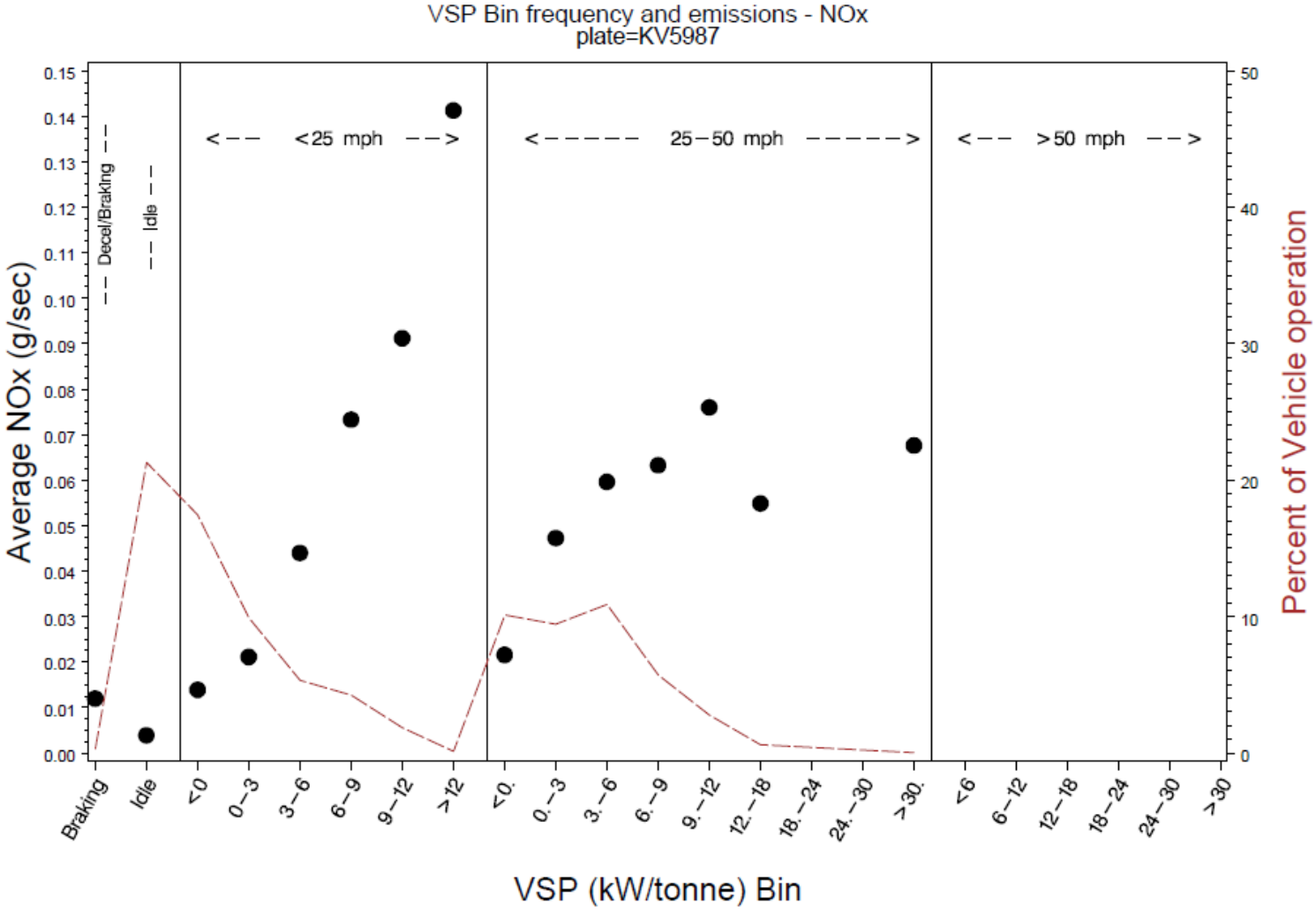
Find distribution of time spent in each VSP bin for a similar weight vehicle over the FTP cycle

Multiply calculated average emissions by the FTP's VSP bin time distribution and sum for all bins

FTP-Equivalent Emission Level

ERG

Example Emissions and Operation by VSP



Conversion to FTP-Estimated Emissions

- We then have average emissions binned by VSP from the test vehicle (Em_i), and the distribution of operation time in each VSP bin over the FTP cycle ($T_{FTP,i}$)

32 VSP Bins

$$\sum Emissions = \sum_{i}^{\#Bins} Em_i \times T_i$$

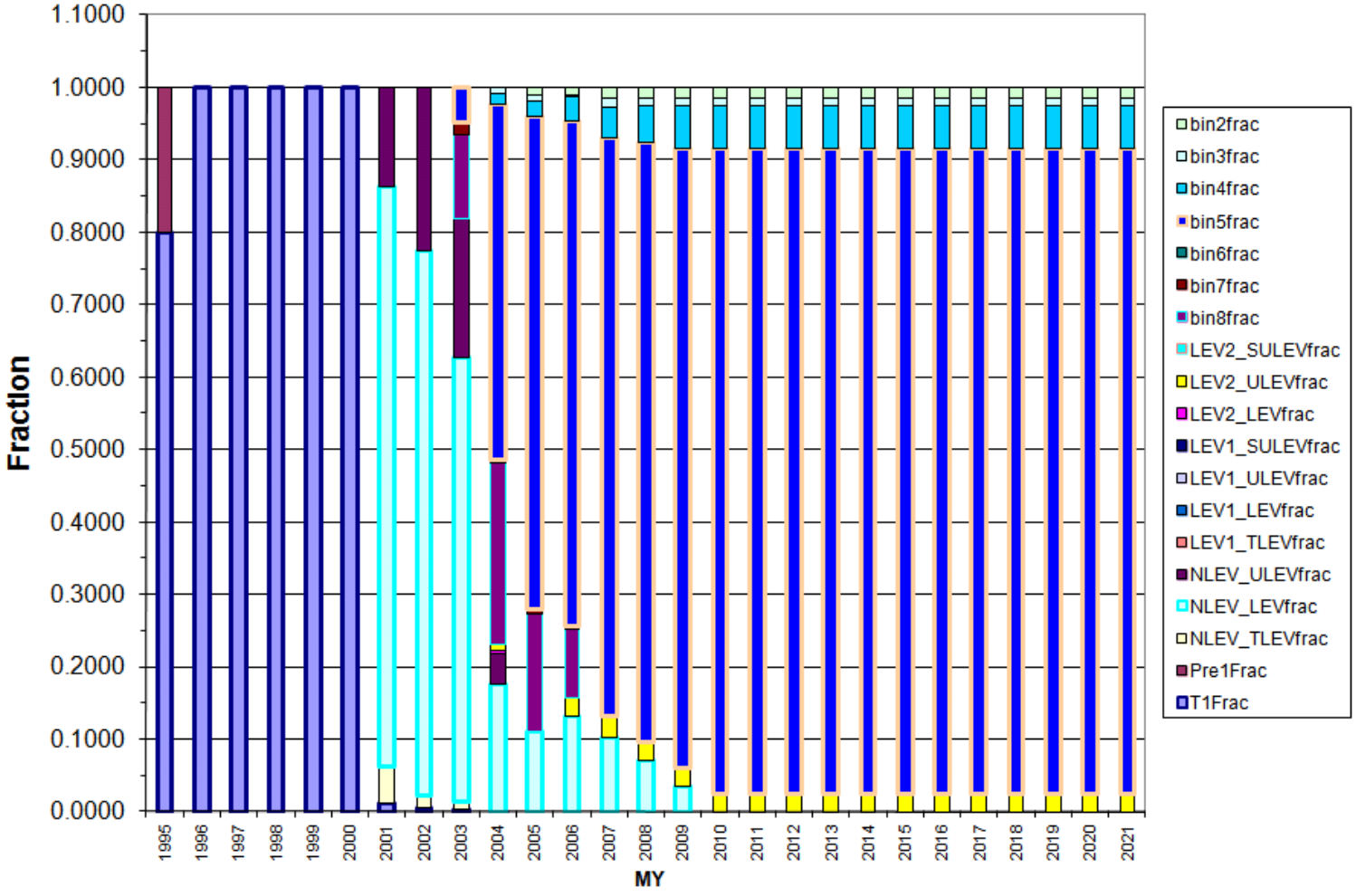
Total Emissions equal the sum of the average emissions of each bin multiplied by the time operating in each bin

$$\sum Emissions_{FTP} = \sum_{i}^{\#Bins} Em_i \times T_{FTP,i}$$

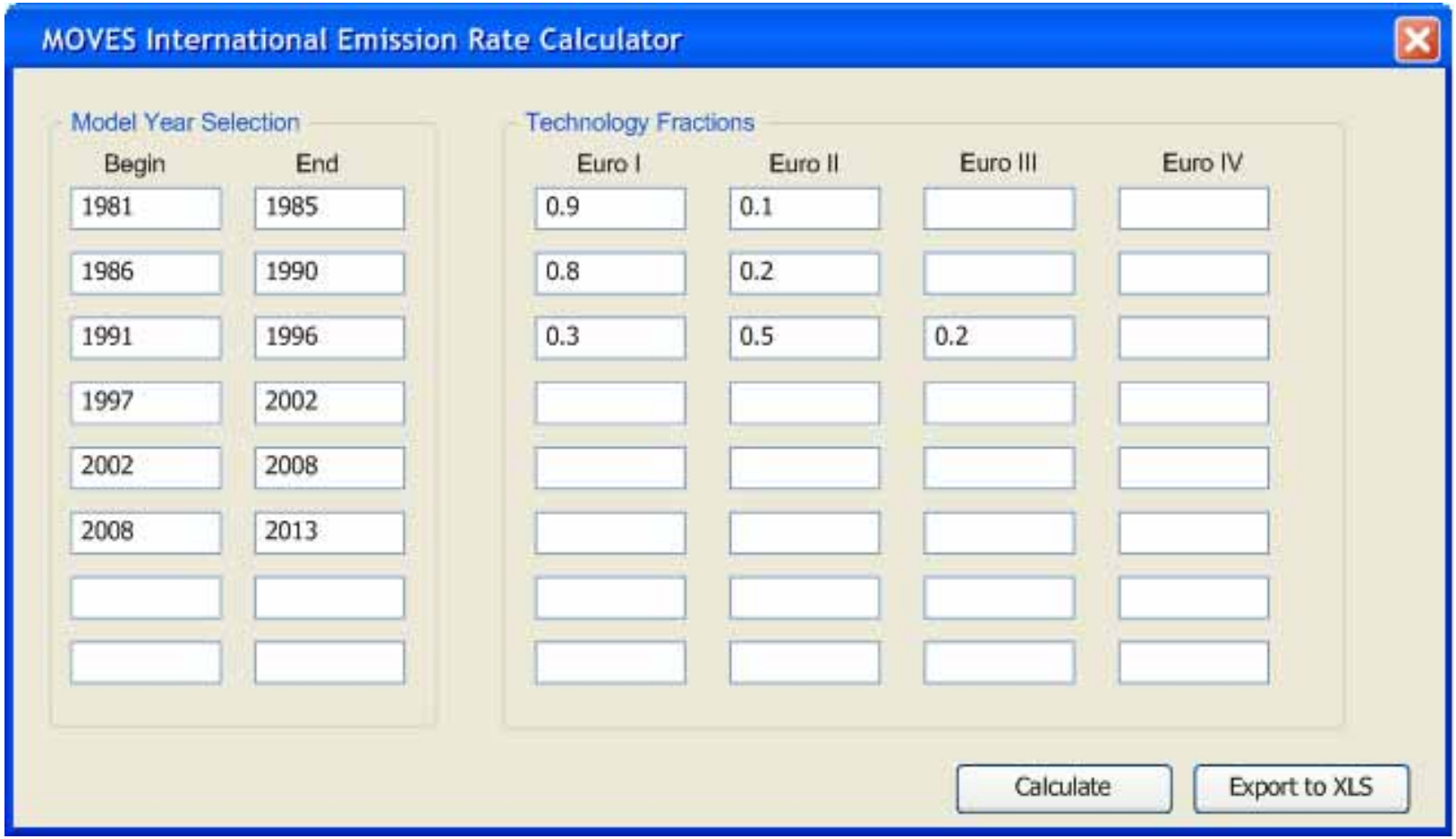
FTP Emissions equal the sum of each bin's average emissions multiplied by each bin's operating time in the FTP cycle

- Using this re-weighting method, equivalent FTP cycle emissions can be estimated
  - Not all test vehicles were operated over all VSP bins encountered in the FTP. For these vehicles we can extrapolate the trends seen in the lower VSP and speed bins

Develop Model Year Matrices by International Area



Proposed Input Screen for MOVES International



Future MOVES Int'l Updates

- Addition of vehicle classes (taxis, BRTs, etc)
- Additions/updates to road types or drive schedules
- Additional language support
- All updates will require extensive code testing, execution of model test cases, and documentation

Drive Cycle Temporal Distribution