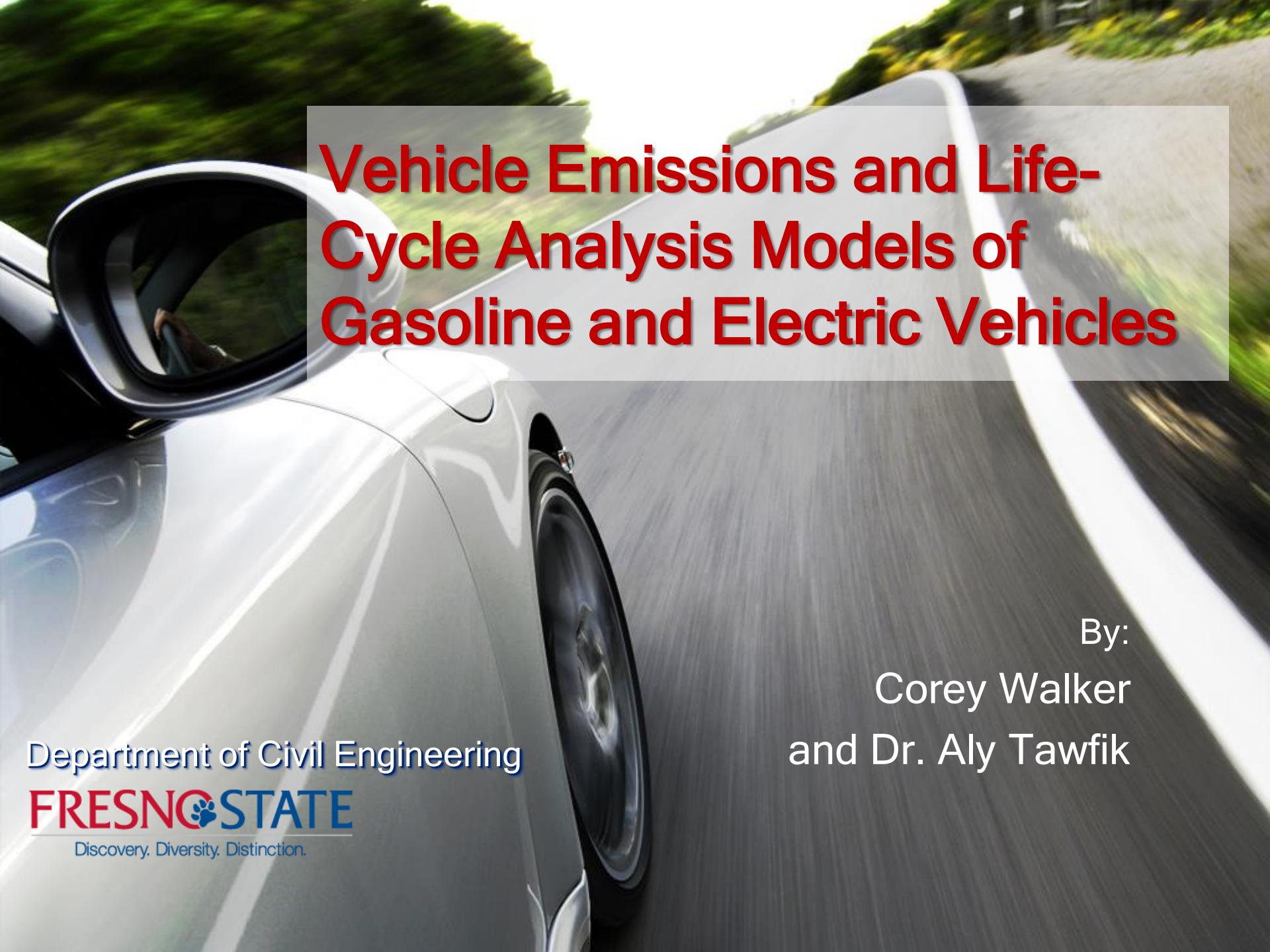


Vehicle Emissions and Life-Cycle Analysis Models of Gasoline and Electric Vehicles

By:
Corey Walker
and Dr. Aly Tawfik

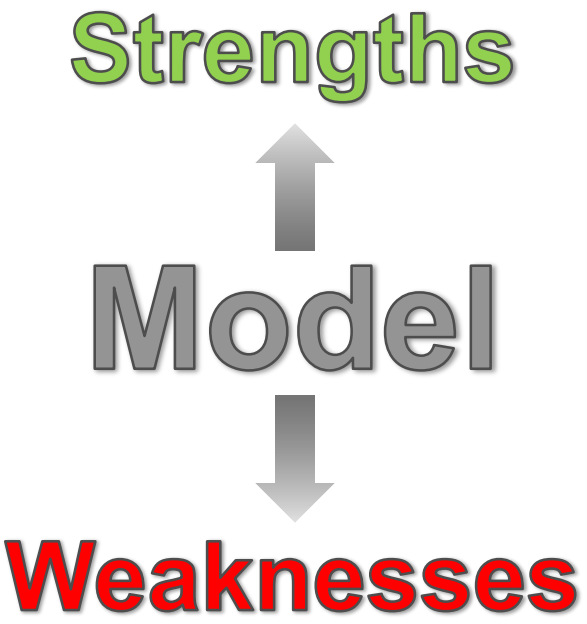
Department of Civil Engineering
FRESNO STATE
Discovery. Diversity. Distinction.

Presentation Outline

- Project Background
  - Emissions Data Collection
- Gasoline Models
  - Macro, Meso, Micro
- Electric Models
  - MOVES and EMFAC
- Life-Cycle Models
  - GREET
- Summary
- Current Work
  - Numerical Simulation

Project Background
Research Needs

- Need for Research
  - Lack of Comparisons in Literature
  - Better Model Choices
  - Gasoline vs. Electric
  - Life-Cycle Analysis



Project Background
Emissions Data Collection

Laboratory Test Methods

Typical: Chassis Dynamometer

Photo Sources: http://www.land-and-sea.com/chassis-dyno/chassis-dyno.htm

Project Background
Emissions Data Collection

Laboratory Test Methods

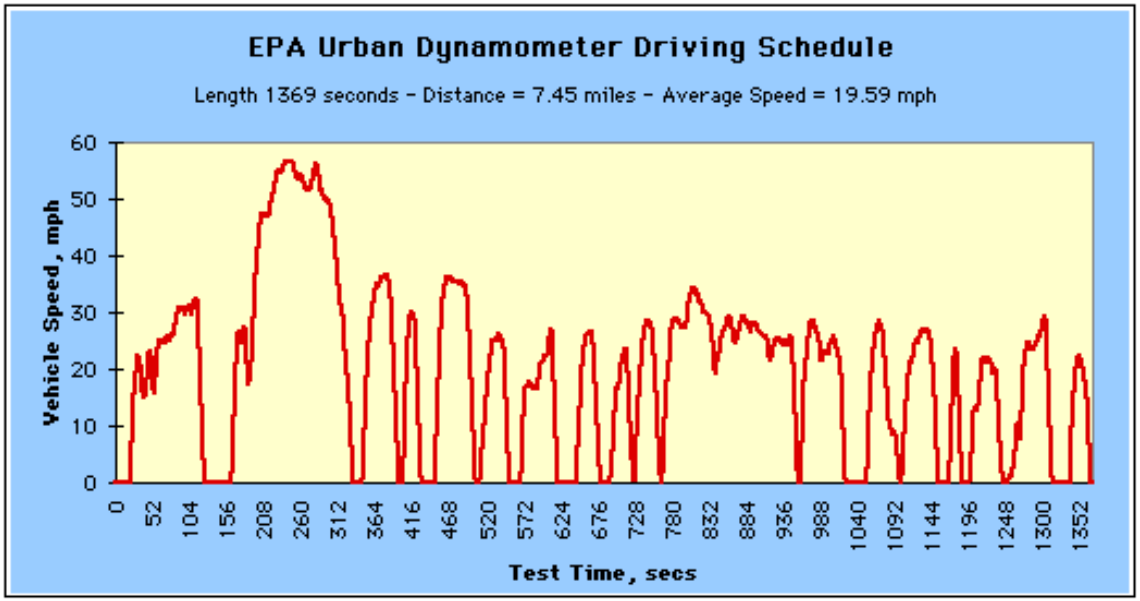


Photo Sources: http://www.epa.gov/nvfel/methods/uddsdds.gif

Project Background
Emissions Data Collection

Field Test Methods

Typical: Portable Emissions Measurement Systems

Photo Sources: http://www.sensors-inc.com/ecostar.html

Project Background
Gasoline/Electric

Electric Models →

Gasoline Models →

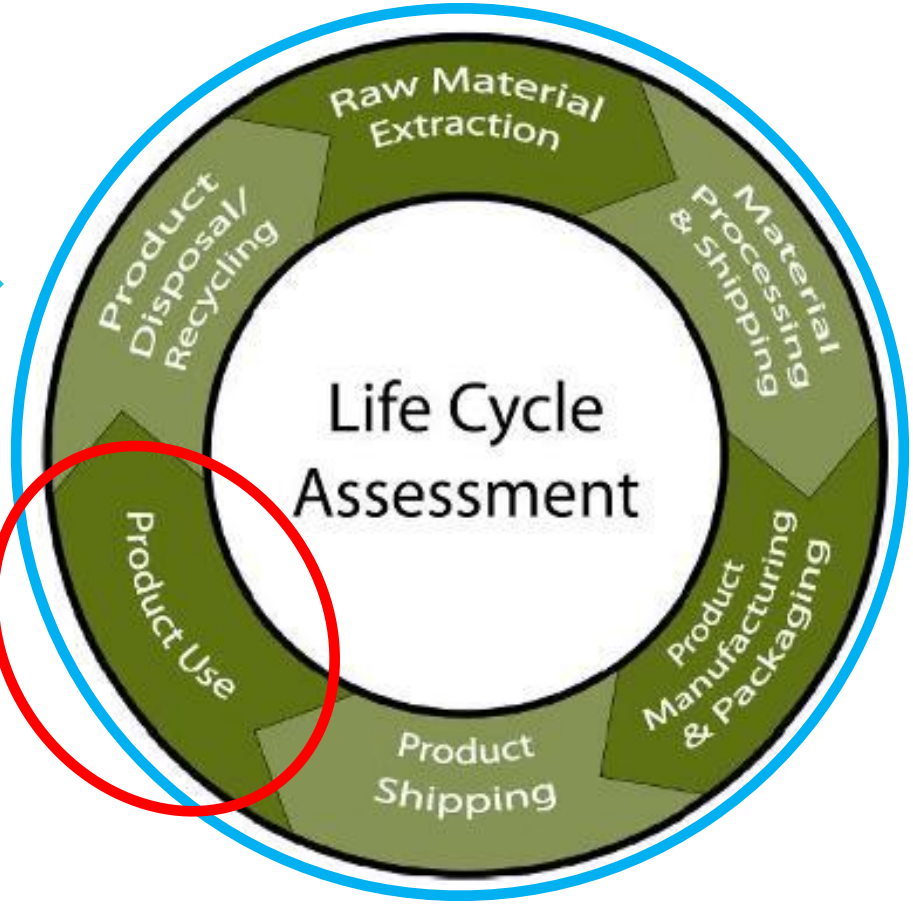
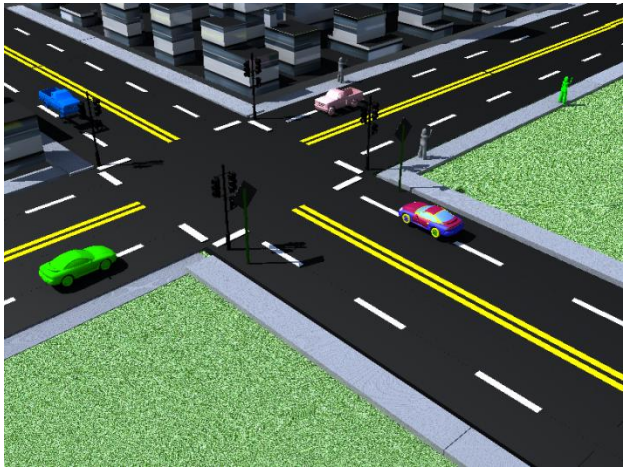


Photo Sources: http://www.sustainablesolutionscorporation.com/lca.html

Gasoline Models
Model Scales

Macro →

← **Meso**



Micro →

Photo Sources: https://thisisthestoryof.wordpress.com/2012/08/16/new-york-citys-central-park-aerial-photo/
http://communityplan.dublinohiousa.gov/transportation/projections/
http://www.cs.bowiestate.edu/~sharad/vrlab/traffic.html

Gasoline Models
Macro Scale Models 1/2

MOVES 2014

- Sorts terrain types and locations into different bins
- Distributes vehicles into various bins
- Applies time each vehicle spends in bin
- Calculates total activity of vehicle
- Estimates emissions using total activity

EMFAC 2011

- Sorts data into categories based on vehicle type and model year
- Calculates vehicle miles traveled, population, and speed distribution
- Applies vehicle emissions factor to estimate emissions

Photo Sources: https://thisisthestoryof.wordpress.com/2012/08/16/new-york-citys-central-park-aerial-photo/

Gasoline Models
Macro Scale Models 2/2

MOVES 2014

Advantages:

- Large Database
- Wide Capabilities
  - ✓Can be used for meso and micro-scale analysis
  - ✓Estimates dozens of contaminants
- Covers all periods of vehicle activity

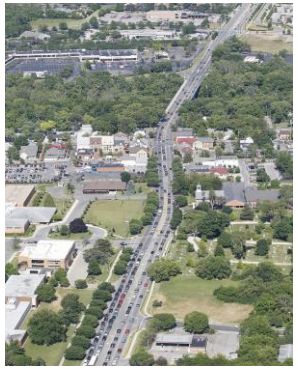
EMFAC 2011

Advantages:

- Large Database
  - ✓ Most data specific to California
- Wide Capabilities
  - ✓Can be used for meso and micro-scale analysis
- Modular Structure

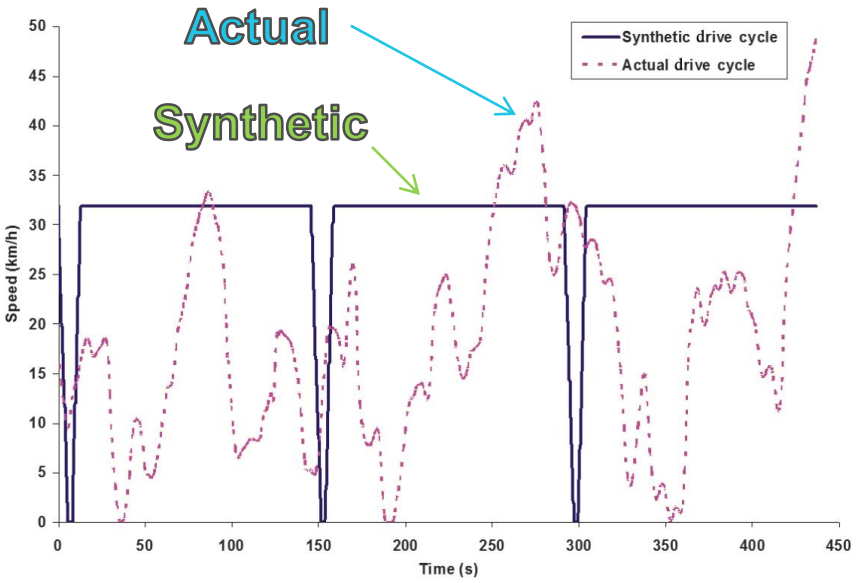
Photo Sources: https://thisisthestoryof.wordpress.com/2012/08/16/new-york-citys-central-park-aerial-photo/

Gasoline Models
Meso Scale Models 1/2



VT- Meso

- Uses input data to create a synthetic drive cycle



- Applies emissions factors to calculated cruise, idle, accelerating, and decelerating periods

Advantages:

- More detailed analysis that macro scale analyses
- Less data needed than in micro scale analyses
- Simple and straightforward

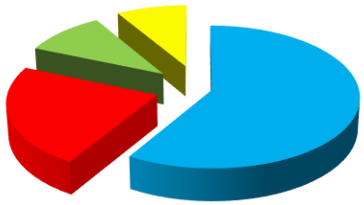
Photo Sources: http://communityplan.dublinohiousa.gov/transportation/projections/

Rakha, H.; Yue, H.; Dion, F., *VT-Meso model framework for estimating hot-stabilized light-duty vehicle fuel consuption and emission rates.*

Gasoline Models
Meso Scale Models 2/2

MEASURE

- Uses statistics to compute most probable values for emissions estimates
- Developed for use with a GIS database
- Inputs include travel demand forecasts, vehicle registration data, and zone-based socioeconomic data

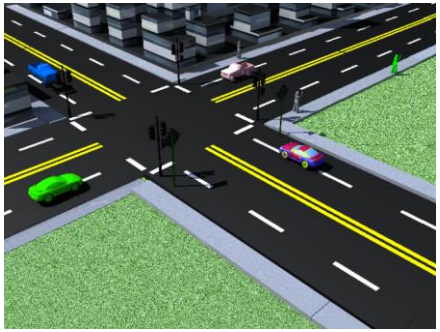


Advantages:

- Statistical Approach removes bias in model
- Input data is easily obtained from travel demand model
- Ability to use GIS databases gives flexibility to model

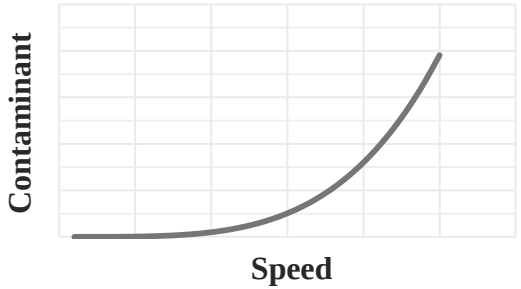
Photo Sources: http://communityplan.dublinohiousa.gov/transportation/projections/

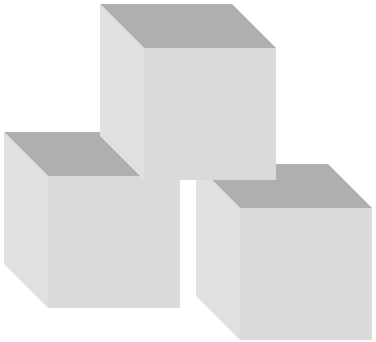
Gasoline Models
Micro Scale Models 1/2



VT- Micro

- Simple Structure
- Uses instantaneous speed and acceleration as inputs
- Utilizes non-linear regression models to estimate emissions



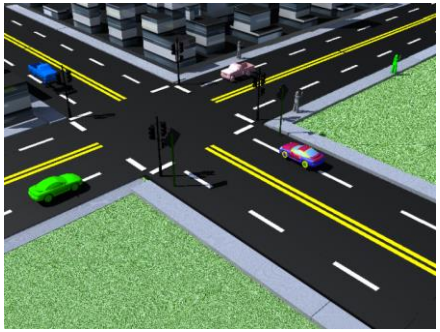


Advantages:

- Structure of model allows abnormal estimates to be tracked to the source
- Can predict emissions for both positive and negative accelerations
- Simple and straightforward

Photo Sources: http://www.cs.bowiestate.edu/~sharad/vrlab/traffic.html

Gasoline Models
Micro Scale Models 2/2



CMEM

- Power-based emissions model
- Uses instantaneous speed and acceleration as inputs
- Breaks operating cycle into six phases and calculates emissions for each

Advantages:

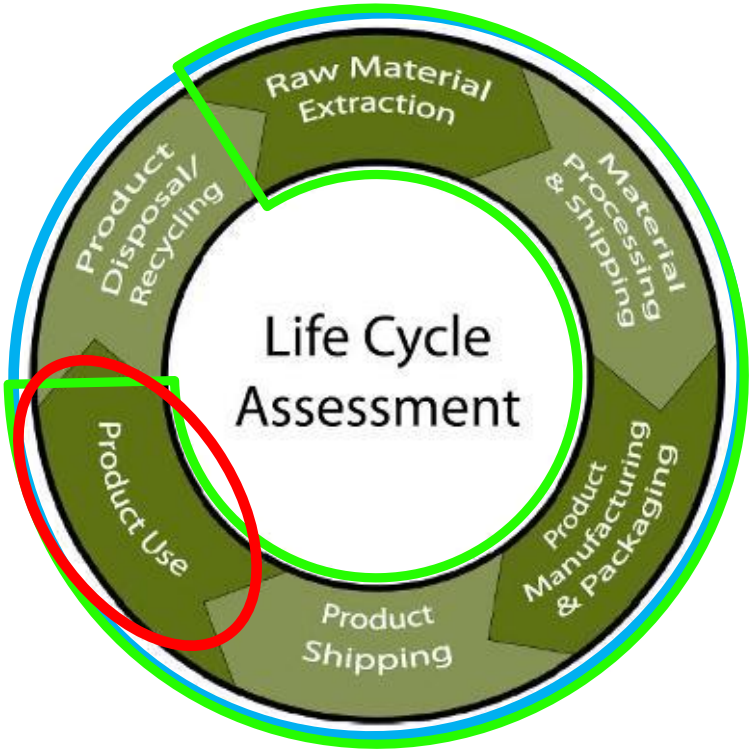
- Allows for modeling emissions from deteriorated or damaged vehicles
- Modal approach enables user to find emissions during each operating phase
- Simple and straightforward

Photo Sources: http://www.cs.bowiestate.edu/~sharad/vrlab/traffic.html
http://cartype.com/pages/230/car_cut-aways

Electric Models
MOVES 2014 and EMFAC 2011

- Both MOVES 2014 and EMFAC 2011 have the capability of evaluating emissions from hybrid and electric vehicles
- Emissions estimates are limited to product use phase of life-cycle

Life-Cycle Models



MOVES 2014
GREET
EMFAC 2011

Photo Sources: http://www.sustainablesolutionscorporation.com/lca.html

Walker, C. and Tawfik, A. Vehicle Emissions and Life Cycle Analysis Models

Life-Cycle Models
Scopes of Analysis

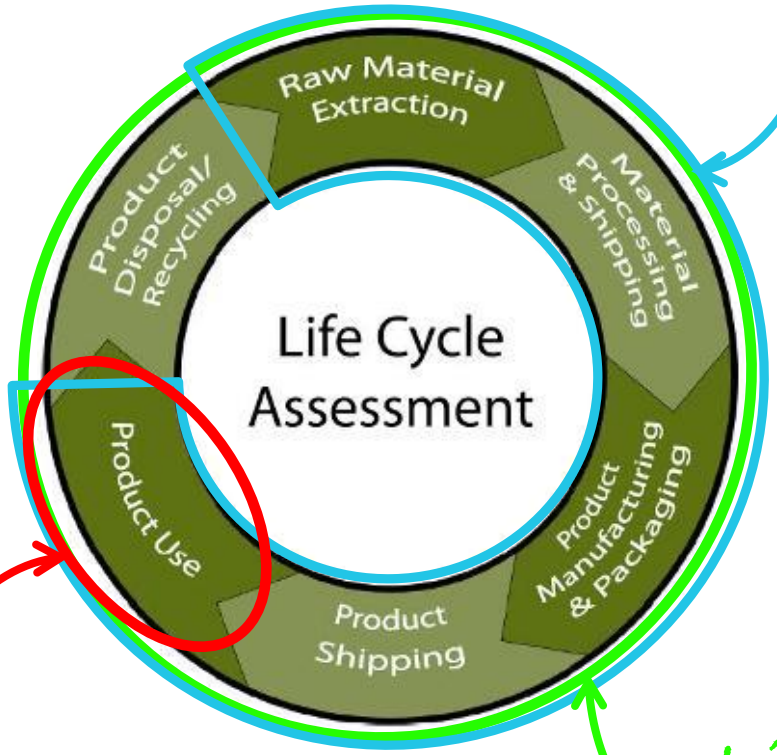


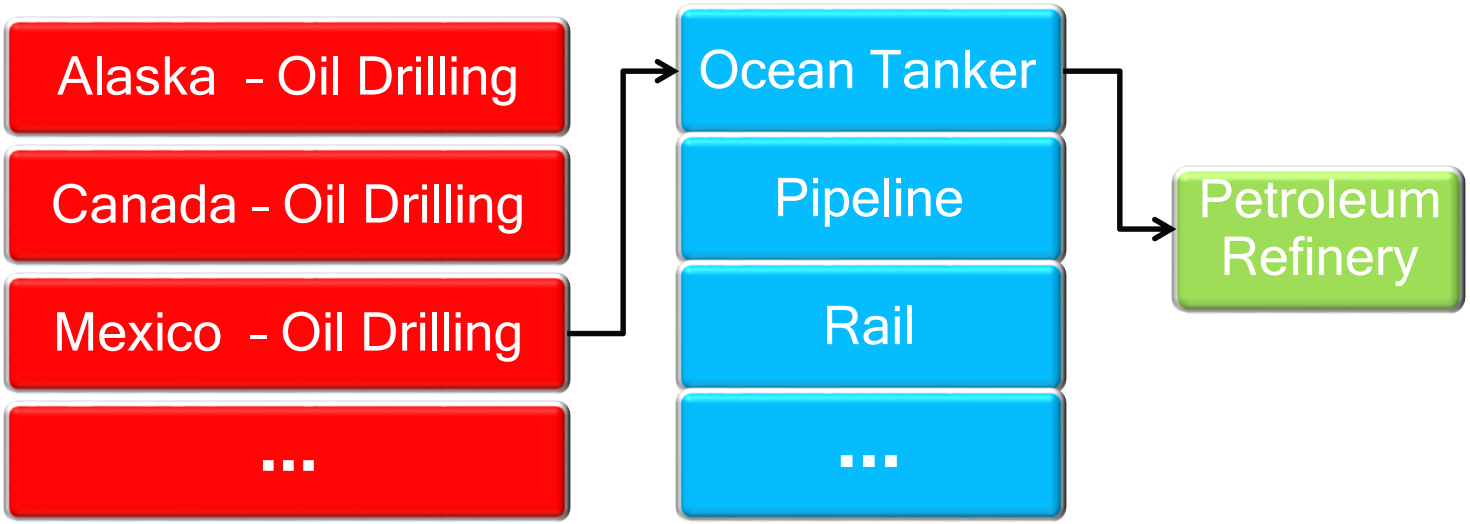
Photo Sources: http://www.sustainablesolutionscorporation.com/lca.html

Walker, C. and Tawfik, A. Vehicle Emissions and Life Cycle Analysis Models

Life-Cycle Models
GREET

- Uses pathways to calculate emissions
- Each portion of the pathway contributes an emissions factor
- At the end of the pathway, the emissions factors are summed up and used to compute estimated emissions

Beginning components of sample GREET pathway:



Conclusions

✓ No single model will be ideal for every situation:

Scope → **defines** → **Model Choice**

✓ Comparisons between models must be done at same scale:

Life-Cycle ≠ Macro ≠ Meso ≠ Micro

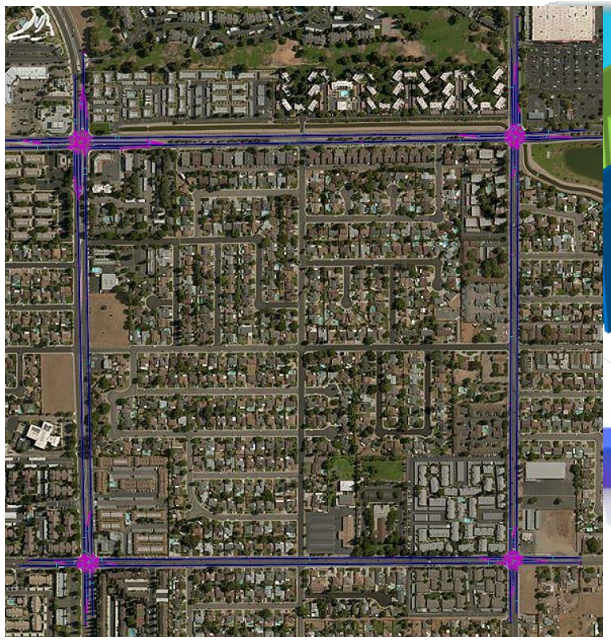
✓ Do your research when determining which model to use. Different models require different input parameters and analyze different contaminants.

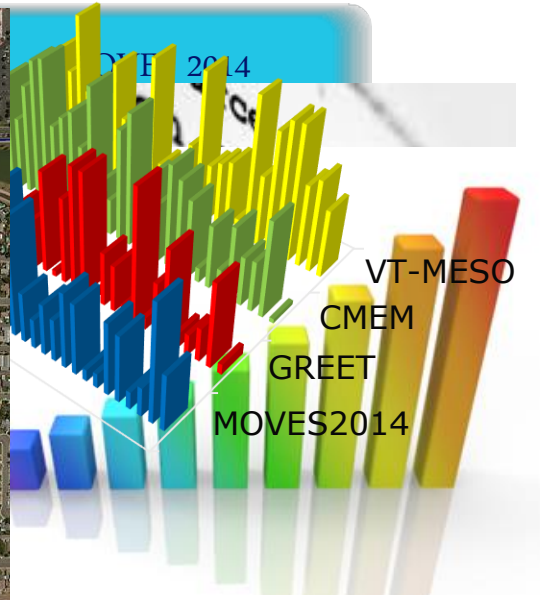
Current Work
Model Comparison

Emissions Model	Energy Source	Scale	Significant Input Parameters	Strengths	Weaknesses	Best Use
MOVES 2014	Gasoline, Diesel, Compressed Natural Gas (CNG), Liquefied Petroleum Gas (LPG), Ethanol (E-85), Electric*	Macro, Meso, Micro	Vehicle Miles Travelled, Road Type, Age of Vehicle, Speed Distribution, Meteorological Data, Vehicle Type, Fuel Type	Uses extensive database from which it draws information; Easy to use; Can use as a framework for other location specific models, allowing users to specify their own constants to be used when calculating emissions factors; Includes emissions estimates for a wide range of vehicle functions (e.g. hot soak, tire wear, idling, etc.)	Poor for situations in which there is highly variable accelerations and decelerations; Do not include life cycle analysis	Any "Pump-to-Wheels" analysis
EMFAC	Gasoline, Diesel, Electric*	Macro	Fuel Type, Technology Group, Model Year, Total Activity, Population, Vehicle Miles Traveled, Trips Generated per Day,	(See MOVES strengths above); Provides much more accurate emissions estimates for California projects as compared to the MOVES model	(See MOVES weaknesses above); Model developed using data specific to California	Any "Pump-to-Wheels" analysis in California
VT-Meso	Petroleum-Based	Meso	Average Vehicle Speed, Number of Stops made, Stopped Delays	Requires very few input parameters; Predicts HC, CO, and CO_2 levels accurately; Less data and time intensive than micro emissions models	Is less accurate in situations where there are large amounts of speed variations or stop-and-go traffic	Projects in which a high level of accuracy is required, but the amount of collected data is limited.
MEASURE	Petroleum-Based	Meso	Vehicle Registration Data, Travel-Demand Forecasts of Flows, Speed and Acceleration Distribution Tables, Socioeconomic Data	Works extremely well with GIS database systems; Can also be used to predict congestion levels and distributions of modal activities; Statistical approach removes bias and can result in more accurate emissions estimates	Statistical approach may cause results to be vary slightly from past data	Scenarios involving GIS databases
VT-Micro	Petroleum-Based	Micro	Instantaneous Speed and Acceleration of Vehicle	Accurately predicts emissions for highly variable speed and acceleration situations ; Can be used with micro-simulation and traffic signal optimization software	Cannot take into account vehicle operating conditions such as deteriorated or malfuntioning equipment	In conjunction with micro-simulation software where the operating conditions of the vehicles make little difference and where a high level of accuracy is required
CMEM	Petroleum-Based	Micro	Vehicle Speed and Acceleration, Road Grade, Engine Friction Factor, Cold Start Coefficients	Uses a physical, power-based approach that takes into account different vehicle operating conditions; Takes into account engine condition when evaluating emissions	Predicts constant emissions for deceleration events	In conjunction with micro-simulation software where the operating conditions of the vehicles are a concern and where a high level of accuracy is required
GREET	All	Life-Cycle	Fuel Source, Fuel Type, Fuel Transportation Pathway, Fuel Extraction and Vehicle Production Locations, Vehicle Miles Travelled	Uses life cycle analysis to predict emissions; Can evaluate a wide variety of vehicle types and fuel pathways; Easy to use; Best life cycle analysis currently available for vehicle emissions analysis	Is less accurate in the prediction of in-vehicle emissions; Can only provide rough estimates of emissions related to fuel extraction, transportation, and refinement; Does not cover recycling or disposal phases	Any "Well-to-Wheels" analysis

Current Work
Numerical Simulation

- Traffic simulation for 4 urban intersections
- Embedding code for 4 emission models
- Comparing emission estimates
- Analyze the relative variance between and simplicity of models





Thank You

Questions

Comments