Linking Modal Emissions Models With Vehicle Activity Estimates

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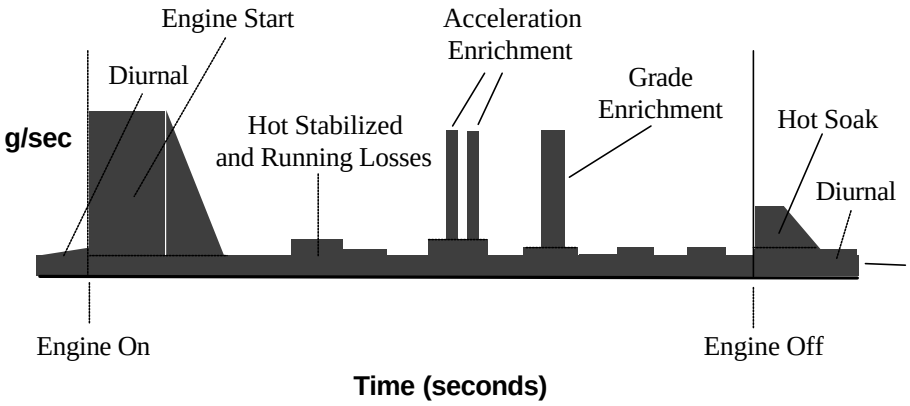
Hydrocarbon Emission Rates for a Hypothetical Trip



Bachman and Guensler, 1996

Factors Affecting Emission Rates

Vehicle Parameters

Fuel Parameters

Environmental Factors

Vehicle Operating Conditions

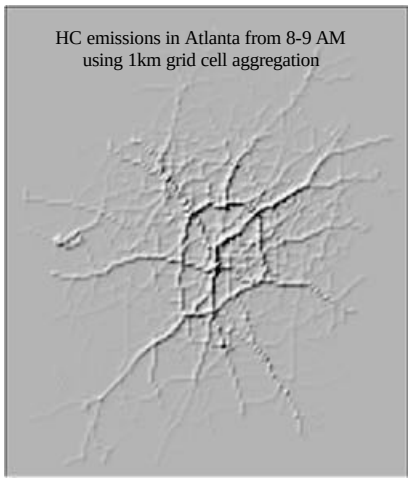
Modal Modeling

- **Predict emissions as a function of vehicle operating parameters that lead to elevated emissions**
  - **Cycle correction factors**
  - **Speed/acceleration look-up tables**
  - **Statistical models that account for interactions between vehicle technologies and load surrogates**
  - **Models that estimate engine load and use enrichment thresholds (mass airflow) to predict elevated emissions**
  - **Models that employ engine physics (predict engine load, gearing, computer response, catalyst efficiency, etc.)**
- **Each modeling approach provides improved emissions estimation but has unique activity data deficiencies**

MEASURE

Mobile Emission Assessment System for Urban and Regional Evaluation

- **Modal model undergoing validation and regulatory approval process for conformity determination**
- **GIS-Based: emissions are a function of fleet technology, operating modes, and environmental conditions**
- **Inputs: regional or local transportation data (variety of formats)**
- **Outputs: gridded, hourly CO, HC, and NOx emissions**



Engine Load and Modal Emissions

BHP = ([(W)/32]a + (Ra) + (Rr) + (Rg) + (Ru) + (Rc)) (v/550)

BHP = engine brake horsepower demand (horsepower)

[(W)/32]a = inertial load	**vehicle parameters, speed, acceleration**
Ra = aerodynamic drag load	**vehicle parameters, speed^x**
Rr = rolling resistance load	**vehicle parameters, speed**
Rg = grade load	**vehicle parameters, speed**
Rc = consumer equipment load	**vehicle parameters, speed**

Relationships between engine load, onboard technologies, and emissions response are approximated for groups of vehicles

Speed, acceleration, grade, and parameterized vehicle characteristics yield engine load estimates

Activity Data Requirements for Modal Emissions Inventories

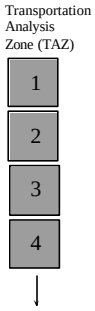
- **Travel demand estimates**
  - **Vehicle ownership and demographics**
  - **Land use and transportation infrastructure**
  - **Traffic volume estimates lead to vehicle miles of travel or seconds of vehicle operation**
- **Onroad vehicle fleet mix (technology characteristics)**
- **Vehicle operating characteristics (speed and acceleration characteristics)**

Travel Demand Modeling Traffic Volumes

- **4-Step travel demand models**
  - **Developed in the 1950's and 1960's to evaluate regional system capacity under rapid growth conditions**
  - **Predict traffic volumes and congestion levels on freeways and major arterials**
  - **Never designed to answer current policy questions at the corridor level**
  - **Simplified approach employs readily obtainable data**
  - **Internal inconsistencies allowed**
- **Emission rate models constrained to match 4-step**
  - **Link-based traffic volumes**
  - **Average speed correction factors**

Bachman 1998

Travel Demand Modeling



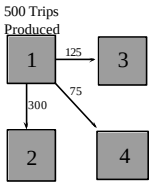
TRIP GENERATION

Estimates # of trips produced and attracted by a land use zone

Developed from socio-economic data for the zone (household,income,etc)

By trip purpose (home-based work, home-based school, etc)

Trip rates determined through analysis of travel surveys (regression or cross-classification)



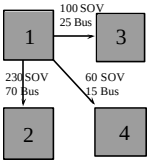
TRIP DISTRIBUTION

Distributes trips between zones

Gravity model using distance and 'attractiveness' of zone

Productions ? Attractions

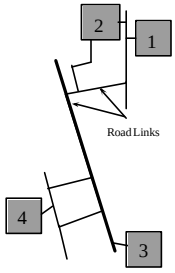
Internal and external trips



MODE SPLIT

Predicts travel mode for trip (SOV, Bus, Bike, ...)

Developed from travel survey data



TRIP ASSIGNMENT

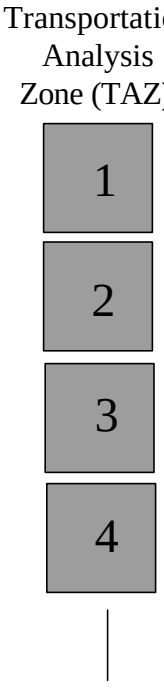
Assigns trips to the road network using capacity restraint methods

System (not individual) optimization of routes

Determines link volumes

Link speeds are based upon internal model relationships between volume and capacity

Bachman 1998



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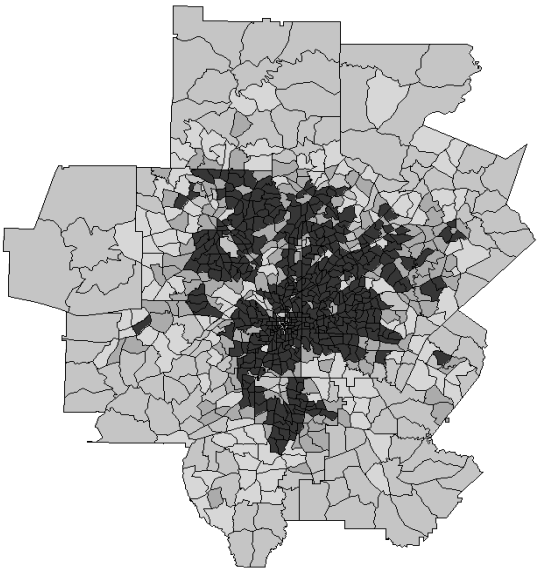
Trip Generation

1995 Spatial Distribution of Engine Starts, 7-8 AM

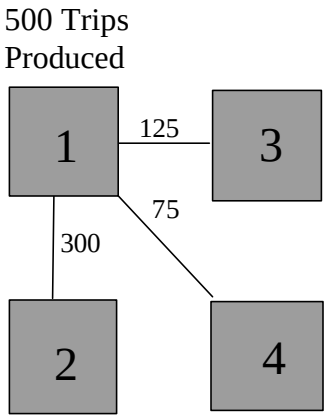
(Estimated 1995 Vehicle Trip Origins from the regional travel demand forecasting model)

Home Based Work Attractions



By TAZ
Trips/square mile

Red > 1000
Brown 500-1000
Tan 200-500
Blue < 200



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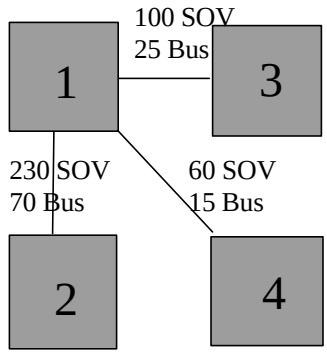

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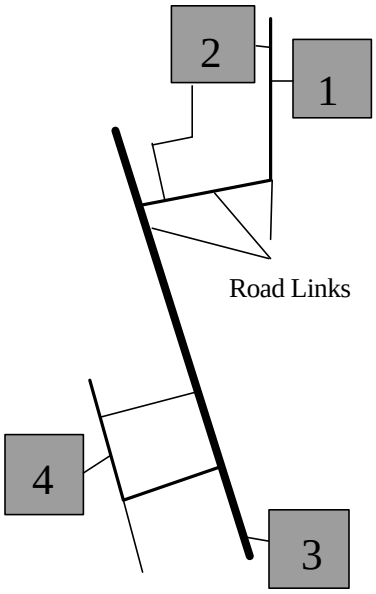

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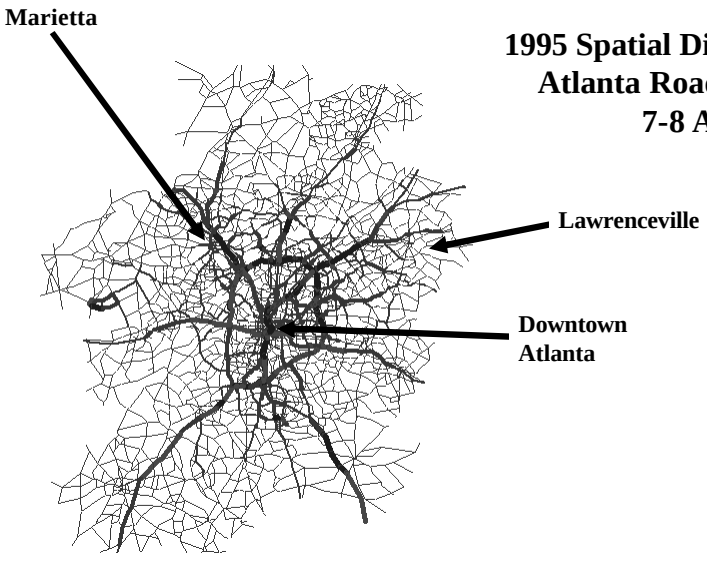
Traffic Volumes



1995 Spatial Distribution of Atlanta Road Volumes 7-8 AM

4-Step Model Shortcomings

- **Trip-based modeling predicts independent sequential trips rather than dynamic chains (e.g. home to daycare to work)**
  - **Mode-dependent trip chain components eliminate mode alternatives for subsequent trips**
- **Lacks a true time-of-day dimension (cannot handle peak spreading effects directly)**
- **Limited behavioral response (sets of explanatory variables) making models unresponsive to most TDM measures**
- **Trip generation (and distribution) are unresponsive to congestion delay and trip price**
- **Modeling employs independent land-use, vehicle choice, economic and socio-demographic inputs (non-dynamic)**

Improved 4-Step Travel Demand Models

- **Adding feedback loops to existing models**
- **Enhancing data and statistical analysis**
- **Increasing temporal resolution (more and better data)**
- **Supplementing travel surveys (parking turnover studies)**
- **There is still a great deal to be gained here…the main limitation is the cost of enhanced data and analysis**
  - **Atlanta will be collecting standard 4-day paper travel diaries in 6000 households in 2000-2001**
  - **Instrumented data from 600 households**
    - **250 passive GPS**
    - **250 electronic diaries/GPS**
    - **100 electronic diary/GPS/OBD monitoring)**

Activity-Based Demand Models

- **Activity-based models are improved behavioral models that examine the underlying reason for making a trip**
  - **Employ household and person descriptors**
  - **Include sequencing of activities (tours, or trip chains)**
  - **Include tour origin time periods as well as destination time constraints (hours of operation)**
  - **Coded as logit and nested logit discrete choice models**
  - **Account for household activity substitution and lifestyle stage dynamics (as households age or have children)**
  - **Requires more detailed travel survey data, such as Atlanta's (information on why the trip was made)**
  - **Can also employ stated preference surveys**

Stochastic Demand Microsimulation

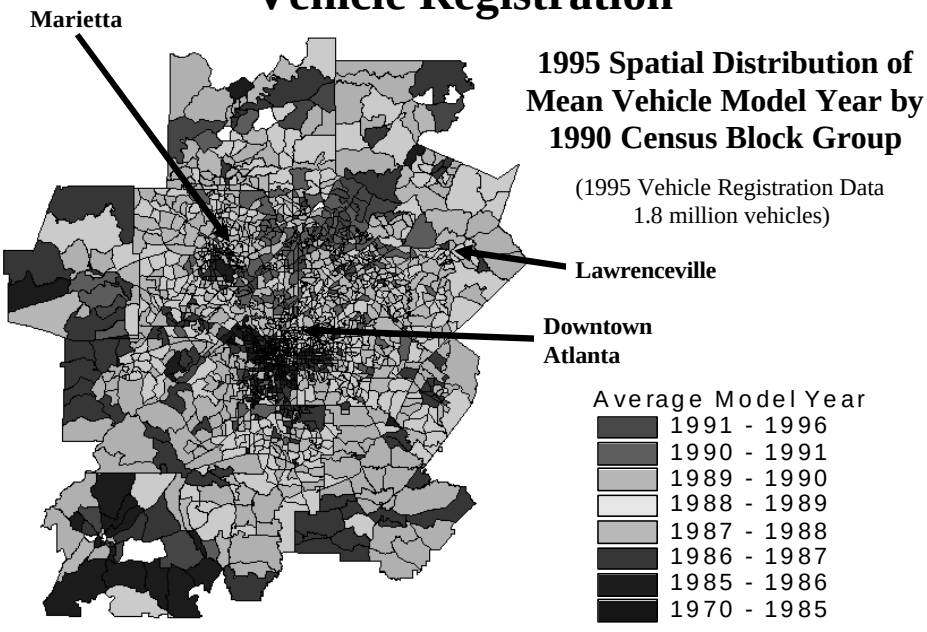
- **Trip modeling flows from activity-based framework**
- **Assumes travel decisions are complex, subject to external constraints, and influenced by numerous stochastic factors**
  - **Travel choices governed by mental "rules of thumb" and incomplete or inaccurate information**
- **Microsimulate trips at the household level**
  - **Origin and destination activity and parking location**
- **TRANSIMS will feed household tripmaking simulation into roadway network simulation using a cellular automata approach and car following theory**
- ***Note: microsimulation can only be as good as the underlying travel survey data and generated relationships***

Onroad Vehicle Fleet Mix

- **Spatial and temporal emissions are a function of vehicle technology operations**
  - **New technologies are low emitting and well controlled**
- **Many urban areas (such as Atlanta) exhibit extreme spatial distributions in auto ownership (income-related)**
- **Technology distributions on local roads mirror local registration and on freeways mirror regional registration**
- **High emitters track vehicle registration**

- **Onroad mix can be developed statistically for 4-step and activity-based models or directly for microsimulation**
  - **Requires solid registration data and validation studies**

Vehicle Registration



Registration of High CO Emitters (Orange > 3%, Light Green < 1%)

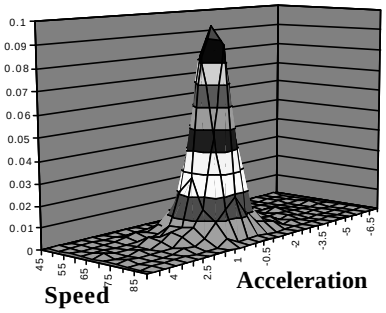
(Dark Green = Insufficient Data)

Bachman, 1997

Vehicle Operating Characteristics

I-85 South at North Druid Hills

Fraction of Activity

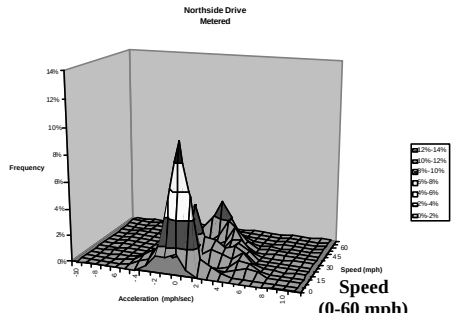


Watson Plot

Speed (mph)	Acceleration																						
	-6.5	-6	-5.5	-5	-4.5	-4	-3.5	-3	-2.5	-2	-1.5	-1	-0.5	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
50	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
55	0	0	0	0	0	0	0	1	0	0	0	2	8	12	4	3	1	2	1	0	0	0	0	0
60	0	0	0	0	0	0	0	1	1	1	2	9	16	32	15	2	1	0	0	0	0	0	0	0
65	0	1	0	0	0	2	0	2	3	1	5	29	36	81	44	21	6	2	3	0	0	0	1	0
70	0	0	0	0	0	1	1	1	1	6	10	29	57	95	81	28	6	5	2	0	1	0	0	0
75	0	0	0	0	0	0	1	0	3	3	8	14	49	87	46	14	7	4	0	0	0	0	1	0
80	0	0	0	0	0	0	0	1	0	3	4	5	11	19	14	9	3	1	1	0	0	0	0	0
85	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	3	0	0	0	0	0	0	0	0
90	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Metered vs. Non-Metered Ramp Profiles
Northside Drive

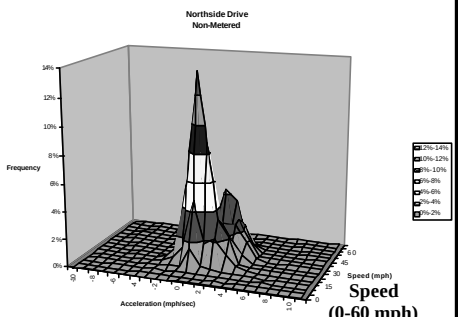
Ramp Meters On



Speed (0-60 mph)

Acceleration (-10 to +10 mph/sec)

Ramp Meters Off



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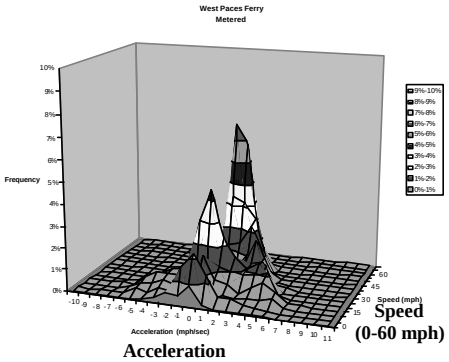
Acceleration (-10 to +10 mph/sec)

Metered vs. Non-Metered Ramp Profiles
West Paces Ferry

Ramp Meters On



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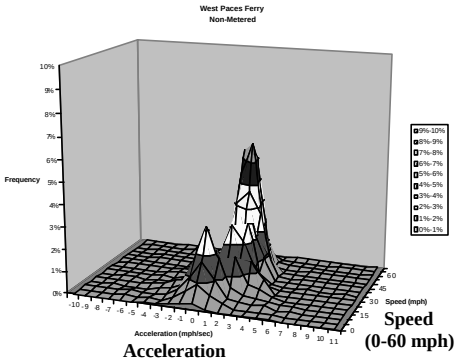


Speed (0-60 mph)

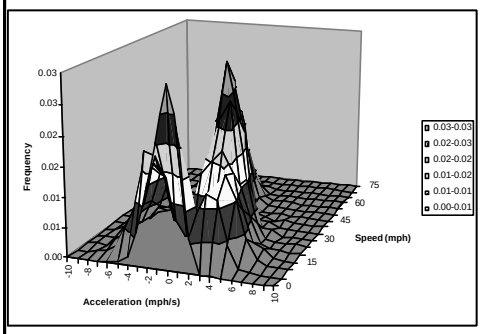
Acceleration (-10 to +10 mph/sec)

Vehicle Operating Characteristics Load Related Parameters

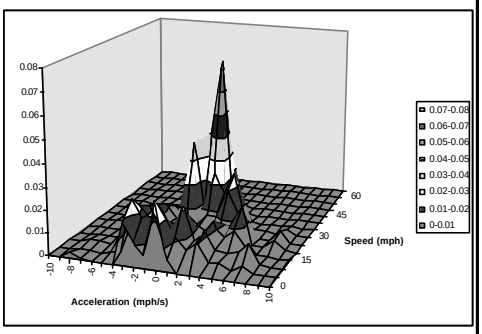
- **Speed/Acceleration Profiles**
  - **Speed and acceleration are components of load components (inertial, aerodynamic, etc.)**
  - **Modal operations differ significantly across road classes and as a function of highway engineering principles (grade, truck volumes, capacity, freeflow speeds, etc.)**
- **Options:**
  - **Derive speed/acceleration profiles statistically as a function of roadway capacity, traffic volume, lane width, and other Highway Capacity Manual parameters**
  - **Simulate speed/acceleration profiles using car following algorithms integrated in simulation models (e.g. TRAF-NETSIM or TRANSIMS)**

Comparison of Corsim and Field Data Simulation Outputs vs. Measured Profiles

Field Data Frequency Plot



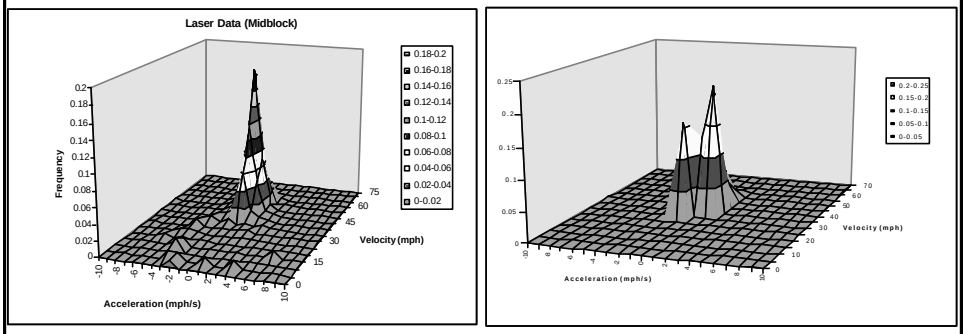
CORSIM Frequency Plot



Total Intersection Activity
(-250 to 250 from Stopline)

Comparison of CORSIM and Field Data Simulation Outputs vs. Measured Profiles

Field Data Frequency Plot **CORSIM Frequency Plot**



Midblock Vehicle Activity

Intersection Simulation Results

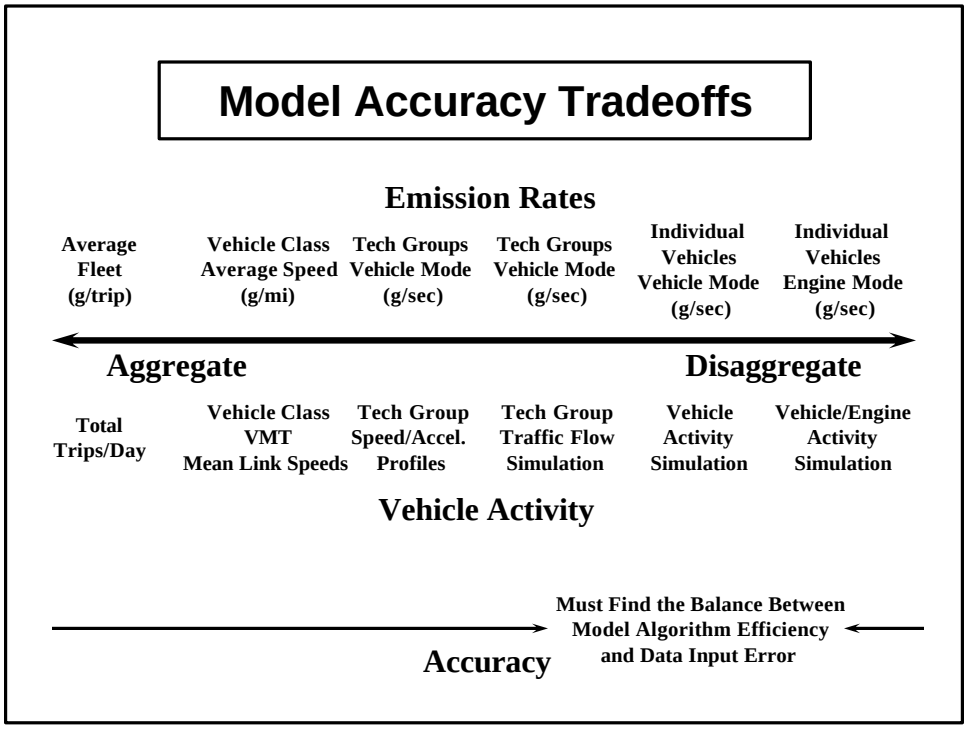
- **Field data indicate Atlanta intersections are characterized by significant "hard" accelerations (>6mph/sec)**
- **CORSIM simulations tend to underestimate high load activity conditions**
- **Current car following algorithms used in traffic engineering/simulation models work in predicting intersection traffic volumes, but are not necessarily accurate for predicting actual speed/acceleration profiles**
- **GT has had best success to date deriving fraction of high load activity as a statistical function of HCM parameters (Grant, 1998) but we are also working on improving the imbedded CORSIM car following routines**

Driver Behavior

- **Significant differences in driving patterns have been noted across cities**
- **Insufficient data were collected to attribute these differences to: infrastructure characteristics, traffic congestion levels, vehicle technology characteristics, or driver interactions with the above parameters**
- **Driver behavior studies begin in 2000 in Atlanta, examining how driver characteristics and combined driver/vehicle characteristics affect interactions with speed/acceleration and throttle position**

Validation

- **Validation and peer-review are the cornerstones of new model and model algorithm development**
- **Data need to be made available to all parties and assembled on the Internet (with adequate and detailed documentation)**
- **Models and model algorithms require detailed documentation and statistical methods presentation**
- **National efforts on validation of emissions and activity modeling needs to be strengthened (make resources available)**
  - **Top down emissions validation**
  - **Bottom up algorithm validation**


Model Accuracy Tradeoffs
Emission Rates
Average Fleet (g/trip)
Vehicle Class Average Speed (g/mi)
Tech Groups Vehicle Mode (g/sec)
Tech Groups Vehicle Mode (g/sec)
Individual Vehicles Vehicle Mode (g/sec)
Individual Vehicles Engine Mode (g/sec)
Aggregate
Disaggregate
Total Trips/Day
Vehicle Class VMT Mean Link Speeds
Tech Group Speed/Accel. Profiles
Tech Group Traffic Flow Simulation
Vehicle Activity Simulation
Vehicle/Engine Activity Simulation
Vehicle Activity
Must Find the Balance Between Model Algorithm Efficiency and Data Input Error
Accuracy