AERIS State of the Practice Assessment

Summary Findings

Prepared by Booz Allen Hamilton on behalf of the USDOT Applications for the Environment: Real-Time Information Synthesis (AERIS) Program

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Overview

- Project Objectives
- Summary and Key Findings
  - Behavioral and Activity-based Models
  - Emissions Models
  - Data Acquisition Technologies for Measuring Environmental Impacts
- What Did We Learn?
- Implications for the AERIS Program
- Next Steps

Project Objectives

Answer the key research questions and establish a foundation for the future research work to be conducted for the AERIS Program

Research Questions

- Are behavioral and activity-based models capable of representing behavior changes related to implementation of AERIS strategies?
- What emissions models are best suited to quantify the air quality impacts of AERIS strategies?
- What are the data needs for emissions models?
- What technologies are available to collect data to support emissions models and to monitor air quality?

Three State-of-Practice Reports

- Behavioral and Activity-Based Models (SOP #1)
  - Assess the capabilities of these models to predict changes in travel behavior, in response to AERIS strategies, and evaluate whether the behavior changes can be used to estimate environmental impacts
- Environmental Models (SOP #2)
  - Understand the capabilities of these models to estimate environmental impacts (emissions, fuel consumption, etc.) due to traveler behavior and trip choices
- Technology to Enable Environmental Data Acquisition (SOP #3)
  - Identify technologies that allow the capture of environmental data needed by environmental models and other data needed to measure environmental impacts

Project Objectives

This SOP work supports the AERIS Program through identifying:

- Strengths, weaknesses and data needs of different transportation modeling tools to support evaluation of the AERIS Transformative Concepts (TCs), including: activity-based models, traffic simulation models, and emissions models

- Modeling needs to evaluate air quality and greenhouse gas (GHG) impacts of AERIS TCs

- Data acquisition technologies best suited to support the AERIS Program by providing means to collect environment data, such as monitoring air quality and providing data for emissions models

Summary and Key Findings

- There is no one optimal model for modeling AERIS TCs – pros and cons to each tool
- Much of the modeling is uncharted territory due to the innovative nature and long-range timeframe of AERIS TCs
- Modeling obstacles are surmountable with integration of models, more accurate data, and clear assumptions associated with timeframe
- Large quantity and high quality of transportation and non-transportation data are needed for developing an acceptable level of confidence in conclusions
- Understanding behavior changes related to TC implementation is fundamental to determining effectiveness and prioritization of TCs
- The clarification of modeling procedures, data requirements, assumptions, output, and level of confidence are essential components for understanding how to best move the AERIS Program forward within the next year

Summary and Key Findings
Behavioral and Activity Based Models

A detailed review was conducted on the following types of models to determine their suitability to model AERIS TCs:

- **Traditional Four-Step Models**
- **Activity Based Models**
- **Traffic Simulation Models**
  - *Macroscopic* – simulate traffic on a section-by-section basis rather than tracking individual vehicles
  - *Mesoscopic* – simulate vehicles, but do not consider dynamic speed/volume relationship
  - *Microscopic* – simulate the movement of individual vehicles based on car-following and lane-changing theories

Summary and Key Findings
Behavioral and Activity Based Models

Potential Behavior Changes Due to Implementation of AERIS TCs

Directly Result in Vehicle Miles Traveled (VMT) Reduction	No Direct VMT Reduction but Positive Environmental Impact
• Route change to reduce distance • Mode shift to alternative transportation (e.g. transit) • Number of trips • Trip chaining	• Time of travel • Compliance with variable speed limits • Driving behavior (eco-driving) • Freight planning and operations • Eco-routing (can reduce VMT) • Fuel choices

Summary and Key Findings
Behavioral and Activity Based Models

- Traditional Four-Step Models
  - Are not fully capable of quantifying behavior changes due to aggregate nature of modeling (time period based)
  - Do not consider inter-relationships between trips
- Activity Based Models
  - Can predict changes in traveler choice (mode choice, time of day choice, route choice, etc.) for most ITS strategies that affect trip choices
  - Consider inter-relationships between trips
- Traffic Simulation Models
  - *Microscopic simulation* models are the only way to quantify environmental impacts of strategies that *do not affect trip choices* and/or Vehicle Miles Traveled (VMT)
  - *Mesoscopic simulation* is better suited for regional simulation and microscopic simulation is better suited for operational improvement analyses

Summary and Key Findings
Emissions Models

- Emission Factor Models
  - Use an emissions factor derived using the average value of measurements of total emissions per driving cycle (Example – EMFAC)
- Physical Power Demand Models
  - Predict second-by-second tailpipe emissions by breaking down the entire fuel consumption and emissions process into components associated with vehicle operation and emissions production (Example – CMEM)
- Acceleration and Speed Based Models
  - Estimate emissions as a function of vehicle type, instantaneous speed, and acceleration (Example – MOVES)
- Dispersion Models
  - Use mathematical formulations to estimate the concentration of pollutants at specified ground-level receptors surrounding an emissions source (Example – AERMOD)

Summary and Key Findings
Emissions Models

- MOVES and CMEM are better suited than other emissions models to assess environmental impacts of ITS strategies
- Emissions models need both transportation and non-transportation data
  - *Transportation Data:* Driving schedule, vehicle operating modes, link characteristics (such as grade) and vehicle fleet characteristics
  - *Non-Transportation Data:* Meteorological data (such as humidity, temperature, pressure etc.), fuel supply data and Inspection and Maintenance (I/M) Program data
- Emissions estimates are very sensitive to speed profiles
  - Traffic simulation models are necessary to produce data required for detailed emissions analysis using MOVES or CMEM
- Default data used in emissions models affect emissions results and needs to be adjusted to meet "local" conditions
  - Fleet assumptions, vehicle age distribution, fuel assumptions, meteorological data, other data (tire pressure, etc.)

Summary and Key Findings
Data Acquisition Technologies

- Vehicle Based Technologies
  - CAN Bus with Electronic On-Board Recorders (EOBR)
  - OBD II with EOBR
  - Portable Emissions Measurement System (PEMS)
  - Fleet Systems
  - Connected Vehicle Technologies
- Infrastructure Based Technologies
  - Remote Sensing Devices (RSD)
  - Air Quality Monitoring Systems
  - Environmental Sensor Stations (ESS)

Summary and Key Findings
Data Acquisition Technologies

- Most data acquisition technologies collect different types of data requiring different processing
- Many AERIS strategies will need detailed data (tailpipe emissions) for as many vehicles as possible over large areas. No single technology currently provides this data
  - Connected vehicle on-board equipment (OBE) units and OBD II diagnostics only flag vehicle check engine indicator when emissions exceed a threshold
  - We can model tailpipe emissions using CAN bus data and CMEM
- We do not necessarily need new technologies or enhanced technologies.In general we need more data sources and more ways to exploit and process data we already have
- Using a hybrid (in-vehicle and infrastructure based) approach seems promising

Observations

Data Acquisition Technologies

- Don't necessarily need new technologies or enhanced technologies
  - In general we need more data sources and more ways to exploit and process data we already have
- Deploy more environmental data acquisition technologies
- Add air quality sensors to ESS
- Conduct more research on hybrid approaches, including:
  - Best methods for combining models
  - Weights
  - RSDs per square mile of spatial coverage
- Use connected vehicle data but supplement with additional data to capture gross emitters
- Confirm that more deployment and more environmental data collection likely means more granularity

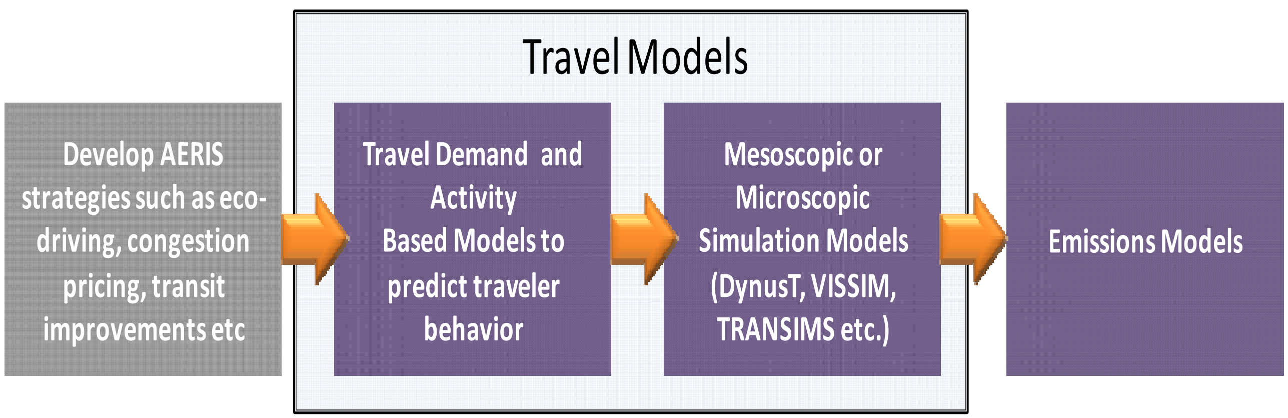
What Did We Learn?

Steps for modeling AERIS TCs

Step 1: Predict behavior changes (change in time of travel, route choice, mode choice, etc.) due to implementation of AERIS TCs

Step 2: Use traffic simulation models (combination of mesoscopic and microscopic simulation) to predict change in network performance (speeds, volumes, driving profiles, etc.)

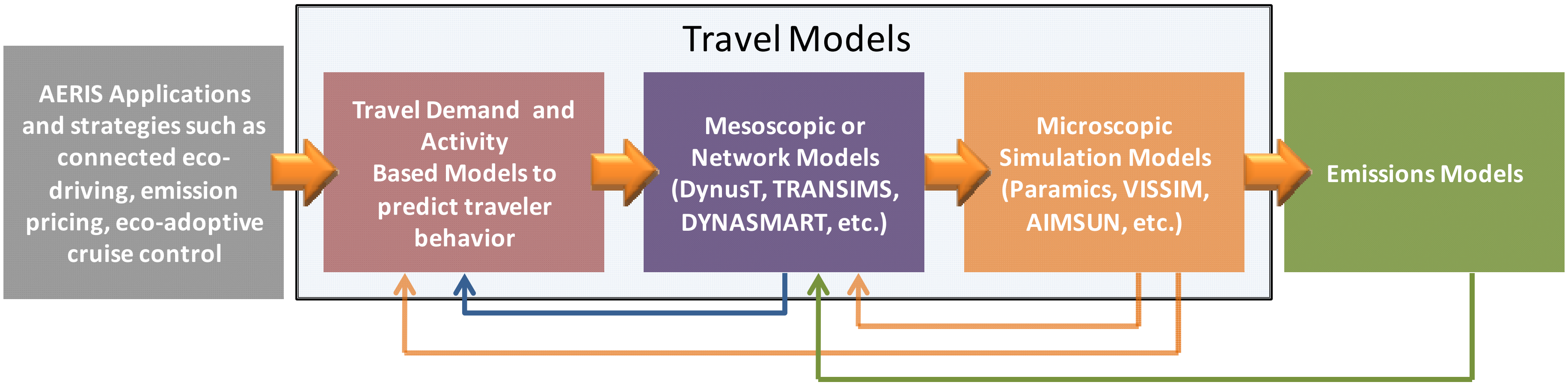
Step 3: Feed detailed speed and volume data to advanced emissions models such as MOVES and CMEM to quantify air quality impact (change in CO_2, GHG emissions, etc.)



What Did We Learn?

Modeling needs for evaluating AERIS TCs

- Need integrated models (travel behavior, traffic simulation, and emissions) with feedback loops



- Need knowledge and in-depth understanding of advanced emissions models (i.e., MOVES, CMEM) to accurately evaluate emissions impacts

What Did We Learn?

Gaps Exist

- Activity Based Models:
  - Are in their infancy and have not been rigorously tested
  - Outputs need to be interfaced with simulation models to predict network performance (speeds, delays, etc.)

- Traffic Simulation Models cannot produce data for micro-level analysis for large networks or regions

- Freight and fleet management strategy impacts need~~s~~ to be addressed using microsimulation models,
  - Not currently being conducted by agencies (Freight planning and modeling are mostly not integrated with travel demand modeling)

What Did We Learn?

Gaps Exist

- Emissions Models:
  - Mainly used as black-box without attention to default data
  - Results depend on quantity and quality of default data available
    - For instance, it is unclear as to which portions of the MOVES default datasets are most robust and which requires supplemental data
  - Need procedures and tools to expand regional impacts to national estimates, however no tools currently exist

Observations
Travel and Emissions Models

- Further research is needed to determine:
  - Effective ways to integrate travel demand model outputs with microscopic models to estimate regional emissions impacts more accurately
  - Which essential non-transportation data (meteorology, tire pressure, fuel types, vehicle age distribution, etc.) needs to be updated in the emissions models using real-time data (that might be collected using data acquisition technologies) to capture the emissions impacts accurately

- Most emissions models are built based on field data collected through various data collection programs. Where applicable, using the advanced data collection technologies available, the emissions models should be validated
  - Example: Vehicle Specific Power (VSP) Bins in MOVES should be reviewed and validated using field data

Implications for the AERIS Program
Modeling Considerations

- Place emphasis on model calibration techniques and results validation
- Don't lose focus on the multi-modal "vision"
- Integrated modeling is doable, but should be done carefully
  - Data intensive – need to be less-reliant on defaults and find ways to use clear data assumptions – outputs depend on input data assumptions
  - Implementation may be cumbersome. Feedback loops may require several iterations before reasonable equilibrium is achieved
  - Need to use consistent (if not similar) approaches while evaluating different TCs (model calibration/validation criteria)

Implications for the AERIS Program
Modeling Considerations

- While there have been a number of advances in models and tools, there is a big risk of directly adopting models developed for other projects for evaluating AERIS TCs
  - Need flexible thinking
  - Special interface is needed with emissions models such as MOVES or CMEM

Implications for the AERIS Program
Evaluation of TCs

- May need application specific considerations and tools (e.g. eco-signal operations vs. low emissions zones vs. support AFV Operations)

- As AERIS Program has a long-term vision, the baseline condition and assumptions should be carefully prepared
  - Point estimates of benefits will not work. Benefits should be estimated as a range of values over a range of assumptions

- Need to consider mobility vs. environmental trade-offs while finalizing AERIS TCs for further research
  - Applications and TCs which do not reduce mobility are likely to get maximum attraction

Implications for the AERIS Program
Evaluation of TCs

- Need to be careful not to create a black box modeling approach
  - Model should produce sensible results to changes in values and assumptions
- Need to be careful that modeling errors can be quantified
- Need robust procedures to expand local benefits to regional impacts
- Modeling should explicitly consider user acceptance which will evolve over time

AERIS Next Steps

- Multi-pronged evaluation of the applications within the TCs:
  - Macroscopic approaches such as benefit-cost models needed. Develop cost-benefit analysis techniques for down-selecting TCs
  - Conduct field tests (if possible)
  - Develop integrated modeling systems
- Need an understanding of how to get the largest impacts from AERIS TCs and clearly understand the tradeoffs between implementation and impacts
- Technology assessment and capabilities need to be emphasized
- Continue to engage the stakeholder community to embrace the AERIS Vision and TCs

Thank You!

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