Travel Demand Mechanisms for Emission Reduction Strategies: A Case Study of Montgomery County, Maryland

by

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Motivation
In search of emission reduction strategies, researchers have formulated numerous policies that attempt to curb vehicle emissions. Each of these policies have been independently tested in example problems or case studies, but never measured against each other, in a single application, to determine the most likely candidate to achieve substantial emission reductions.

The objective of the paper is threefold. (1) Develop models of four unique emission reduction policies. (2) Apply each framework in a case study of a multimodal transportation network to estimate emission reduction outcomes. (3) Compare the model results. The complete framework is implemented in a joint travel demand and emission model.

Objective
In this study we develop various models to reduce total system emissions (in terms of CO₂, NOx and VOCs) in a given network to test the best policy.

Model Descriptions
1) Base-case
   • Four-step TDM for Maryland Region
   • Emissions from integration with EPA’s MOVES model
2) First Best Road/Emission Pricing
   • Emission charge calculated for marginal user and marginal social cost, plus all external costs, on all links
3) Second Best Pricing – Gas Tax
   • Emission charge implemented when doubling of gas tax, does not contemplate marginal social cost
4) Transport Control Measures (TCM)
   • Selected light duty vehicle (LDV) use reduction strategies from Clean Air Act: a) transit improvement; Increase: b) ride sharing c) telecommuting d) parking cost e) bike/ped trips
5) Commute Efficiency through Jobs Housing Balance (JHB)
   • Determine excess level commuting from lack of intra-zonal commuting, optimization of travel time

Model Formulations
1. Base-case
   
   Minimize \( \sum_{x} \left( f_{x}(x) + \frac{g_{x}(x)}{\tau_{x}} \right) \)  
   
   Subject to:
   
   \( \sum_{x} f_{x} = 0 \)  
   
   \( x = \sum_{x} \sum_{x} x_{ij}^{a} \)  
   
   \( f_{x}^{a} \geq 0 \)  

2. First Best Road: Emission Pricing
   
   \( u_{x}^{a}(x_{ij}, s_{x}) = t_{x}(x_{ij}) + \frac{f_{x}(x_{ij})}{\tau_{x}} + e_{x}(x_{ij}) + \frac{e_{x}(x_{ij})}{\tau_{x}} \)  

3. Second Best Pricing – Gas Tax
   
   Autos: \( u_{x}^{a}(x_{ij}, s_{x}) = t_{x}(x_{ij}) + \frac{f_{x}(x_{ij})}{\tau_{x}} + e_{x}(x_{ij}) + \frac{e_{x}(x_{ij})}{\tau_{x}} \)  

   Trucks: \( u_{x}^{a}(x_{ij}, s_{x}) = t_{x}(x_{ij}) + \frac{f_{x}(x_{ij})}{\tau_{x}} + e_{x}(x_{ij}) + \frac{e_{x}(x_{ij})}{\tau_{x}} \)  

4. Transport Control Measures (TCM)
   a) Transit Improvement: 50% fare and headway reduction
   b) Ride share: 3% reduction in drive alone (SOV) trips, 2% converted to double occupancy trips (HDV2) and 1% converted to greater than double occupancy (HDV3+)
   c) Telecommuting: 1% reduction in all home-based work trips (HBW)
   d) Parking cost: minimum $1.50/hour parking cost in all zones, double current charge if greater than minimum
   e) Bike/Ped: 0.5% increase in non-motorized intra-zonal trips

5. Commute Efficiency through Jobs Housing Balance (JHB)
   
   \( T_{r} = \frac{1}{2} \sum_{x} t_{x} n_{x} \)  

   minimize commute cost (time) for all workers:

   \( \sum_{x} \frac{n_{x}}{n_{x}} \)  

   Subject to:

   \( \sum_{x} n_{x} = 0 \)  

   \( \sum_{x} n_{x} = 0 \)  

   \( n_{x} \geq 0 \)  

   average required commute:

   \( T_{r} = \frac{1}{2} \sum_{x} t_{x} n_{x} \)  

   excess commute as proportion of actual commute:

   \( T_{r} = \frac{1}{2} + \frac{T_{r}}{180} \)  

Case Study
The proposed framework is applied to Montgomery County, Maryland. Montgomery is the most populous county in the state with a population close to one million, 400,000 households, and employment of 600,000.

There are a total of 4,302 highway links in Montgomery County consisting of all facility types representing a total of 3,600 lane miles. In addition, the network consists of 73 bus lines, one heavy rail line and one commuter rail line.

Each of the model formulations is applied to the study area and modeled within a statewide (regional) modeling framework (which includes a national highway network).

Multi-State Highway Network

Montgomery County Network
## Case Study Results

In this study we formulate one Base-Case (do nothing) and four different categories of models to measure the impact of several transportation demand management approaches on emissions. The models show that substantial emissions reductions are achievable but within a limited geographic scope and at the risk of political or practical limitation.

### Summary of Case Study Network Results

<table>
<thead>
<tr>
<th>Model</th>
<th>Facility Type</th>
<th>TST (mins)</th>
<th>TSE (gm)</th>
<th>Volume</th>
<th>Average Speed (mph)</th>
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### Case Study Network Results: Emissions and Congestion

- Each of the models reduce emissions in the study area, but have a larger impact on congestion.
- Emission Pricing (Model-1) causes significant congestion increases as users seek to minimize emissions over travel time.

#### Statewide Net Results: Emissions and Congestion

- The models generally have little impact on emissions and congestion beyond the county-level study area
- The congestive effects of vehicle re-routing in Model-1 has a significant impact on the entire state; causing more emissions

### Conclusions

- No “silver bullet” for emission reduction, the best candidate is likely one that combines feasible elements of each.
- Many of these “theoretical” methods of emission reduction are adopted from congestion reduction work, as a result, they have a larger impact on travel time than emissions; suggests a need for:
  - better understanding of complex network emissions
  - new methods targeted specifically at emissions reduction
- Due to the complexity of multi-modal networks and optimization, the simultaneous minimization of travel time and emissions is not possible; which leaves three options:
  1. Minimize travel time (congestion)
  2. Minimize emissions
  3. Settle for reductions in both
- Results show that pricing is the most effective method of reducing emissions – but also comes with a cost:
  - Travel time and emissions on local roads significantly increase for Model-1 (emission pricing)
  - Travel time and emissions increase outside the jurisdictional travel time
- Effect on local roads and other jurisdictions may make pricing politically infeasible.
- Non-pricing options may be more politically feasible, but implementation may not be possible and cost may outweigh (small) benefits of implementation.

### Acknowledgement

The authors are thankful to the Maryland State Highway Administration (SHA) for their continued support in the development of Maryland Statewide Transportation Model (MSTM). The tremendous effort by the staff at Parsons Brinkerhoff in the data collection and model development is also greatly acknowledged. The evolution of MSTM is a result of continued research for the last four years at the National Center for Smart Growth Research and Education, at University of Maryland. The research on emission reduction strategies are aimed at development of a real world model that can be used by the state, county and local agencies. The opinions and viewpoints expressed are entirely those of the authors, and do not necessarily represent policies and programs of the agencies mentioned in the paper.