An Evaluation of Likely Environmental Benefits of a Time-dependent Green Routing System in the Greater Buffalo-Niagara Region

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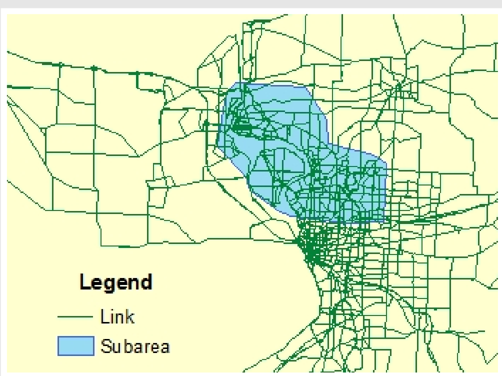
Greater Buffalo-Niagara TRANSIMS Model

Study network:

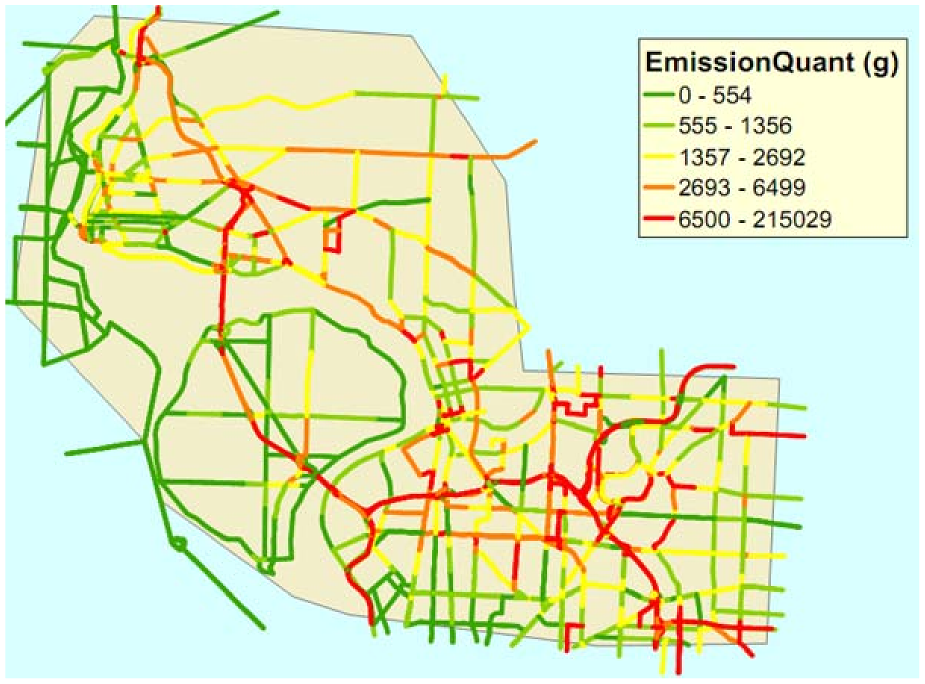
- A medium-sized metropolitan area with a population of about 1.2 million
- Includes a major tourist attraction (Niagara Falls), several congested border crossings, and the I-90/I-190/I-290 corridor within the U.S.



- The full network has a total of 7,798 road links
- The subarea network (shaded in light blue) includes a total of 2,605 links
- TRANSIMS micro-simulation was only executed within the subarea network

General Concept of Green Routing

CO emission quantity of each road segment within the subarea (8am – 9am)



- Provide dynamic route guidance information to travelers based on the lowest emission routes.

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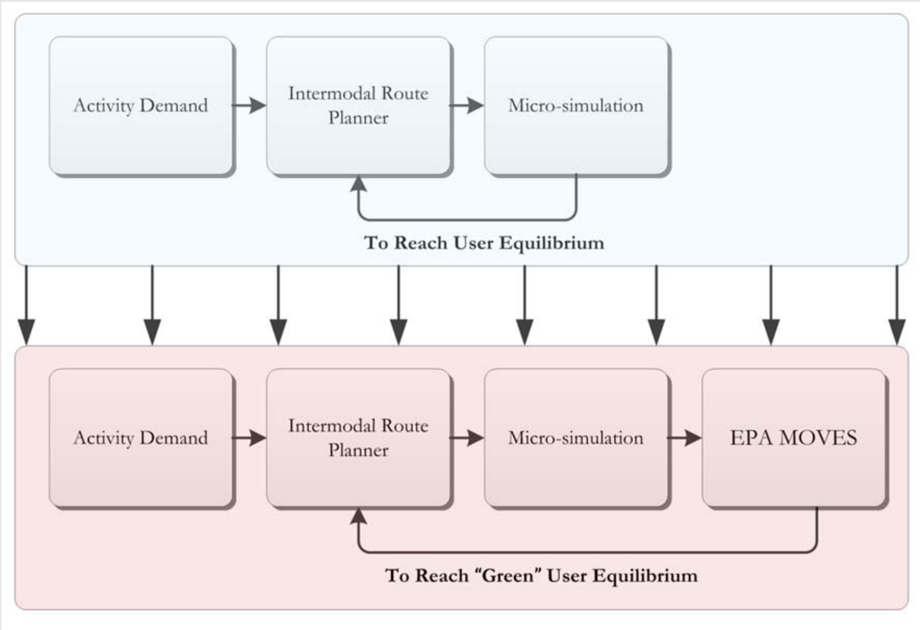
- An Emission Production Factor (EPF) is calculated for each link based on estimated emissions from MOVES.

- "Green assignment" is implemented by considering the link-based EPF as the measurement of a link's travel cost (instead of travel time or monetary expenses).

Integrated Framework of TRANSIMS & MOVES

Transformation from the original TRANSIMS framework to the integrated MOVES framework



- TRANSIMS performs time-dependent routing and passes second-by-second dynamic traffic information to MOVES.
- MOVES then performs emissions analyses based on TRANSIMS information.
- A new feedback procedure was designed to let TRANSIMS and MOVES work in an iterative loop to approximate green route assignments.

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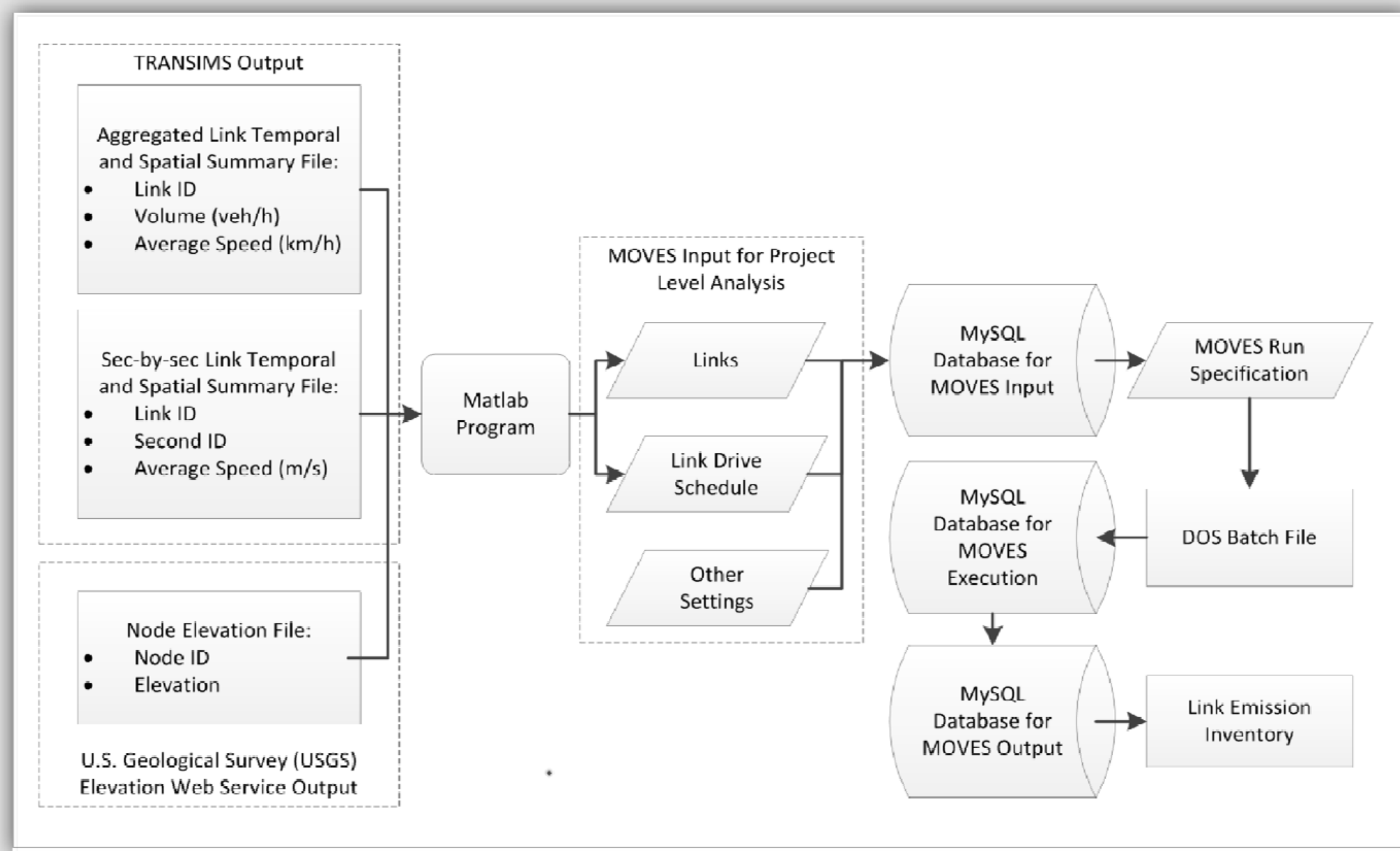
TRANSIMS-MOVES Integration



TRANSIMS-MOVES Integration

Major Challenges

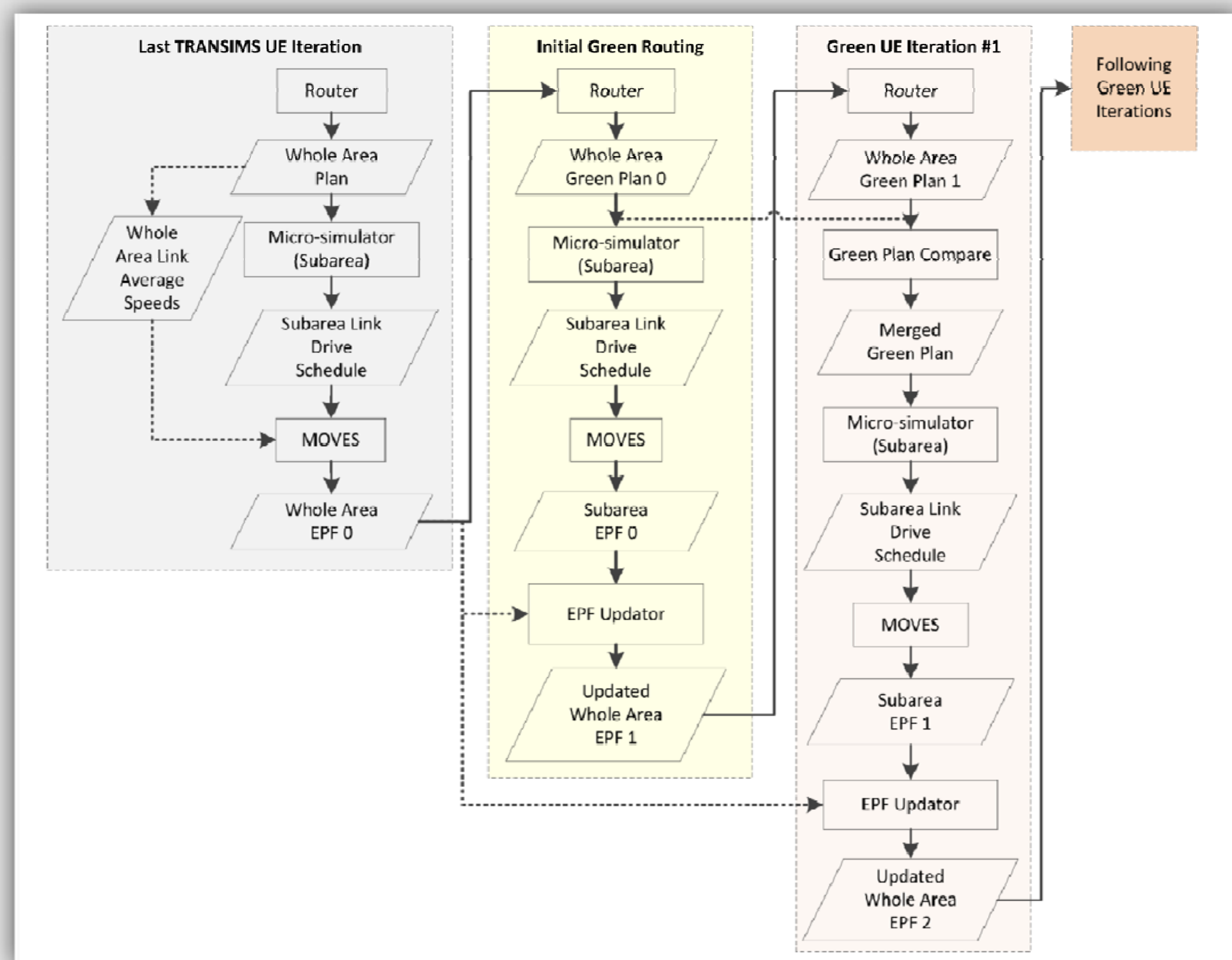
Format conversion

- A Matlab program was developed to convert the required inputs and outputs for TRANSIMS and MOVES by calling the MySQL database, and running the two models.
- For links within the subarea network, detailed second-by-second vehicle speed trajectories were used to derive the link drive schedules.
- For links outside the micro-simulated area, emissions were based on the average speeds.

Incorporation of the gradient information

- Another program was developed to extract the elevation of the nodes of each link through the U.S. Geological Survey (USGS) Elevation Web Service.
- Calculated roadway gradients were manually validated and incorporated into MOVES input using MySQL tables

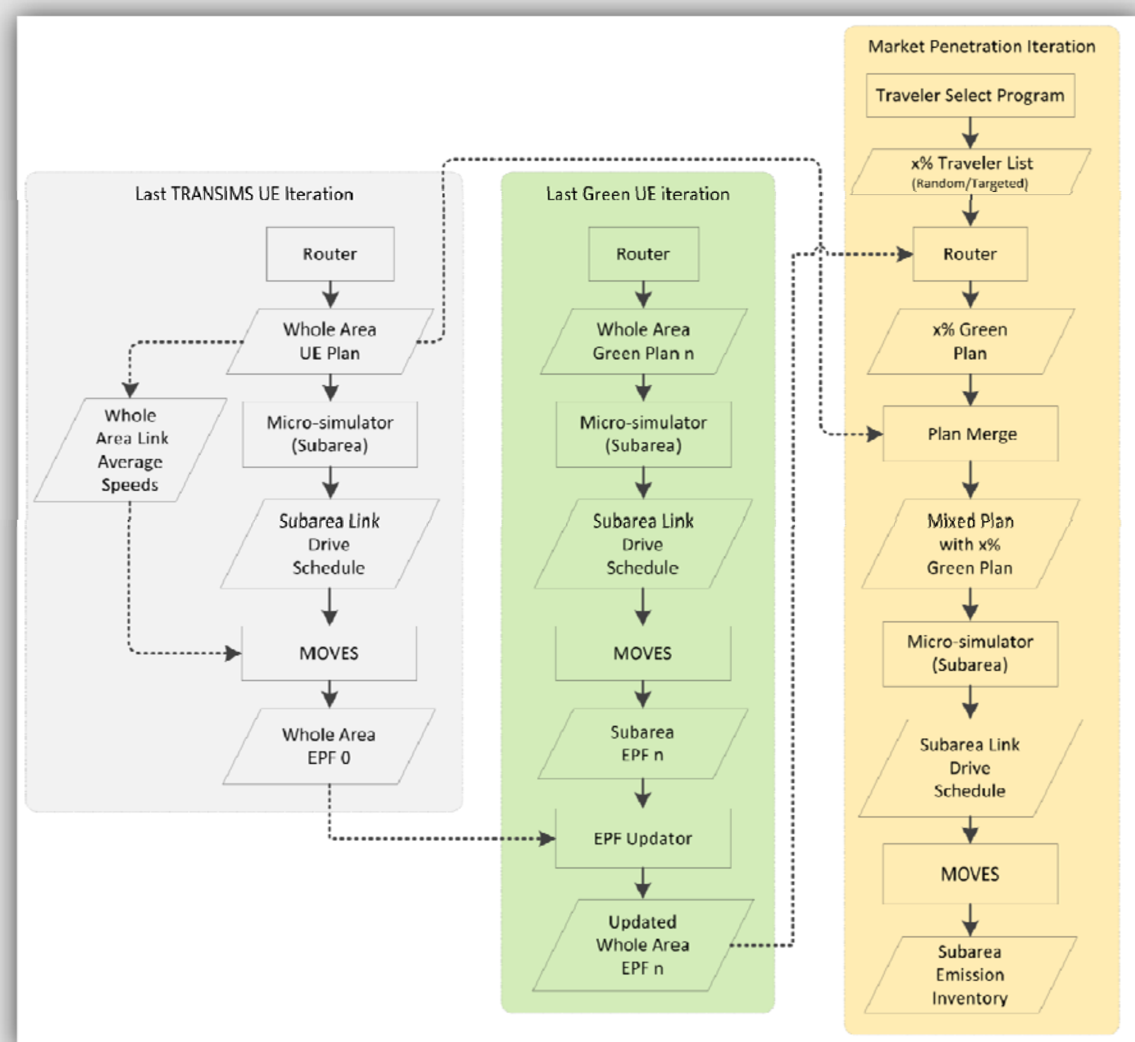
Feedback Design for Green User Equilibrium (UE)



Explanation of Green UE Procedure

- Following the last iteration of the stand-alone TRANSIMS model run, initial EPFs are calculated and fed back into the Router.
- The Router uses these EPFs to start the initial (or first) green routing assignment. Upon its conclusion, an updated list of EPFs become available as a result of running the integrated TRANSIMS – MOVES model.
- The new EPFs are then used by the Router to start a new iteration resulting in a new set of routing plans.
- New routing plans are compared with previous plans in terms of emissions reduction (using the “Green Plan Compare” program). Plans improving savings replace older plans. This continues for several iterations to approximate green user equilibrium (UE) routing.

Market Penetration of Green Routing Users



Market Penetration Procedure

A list of travelers (representing 10%, 20%, etc. market penetration) is rerouted based on the computed EPFs from the Green UE assignment. Remaining travelers continue to follow their original plans. The two sets of plans are then merged and simulated by the micro-simulator.

Random Market Penetration

- Travelers who choose to use the green routing guidance system are randomly distributed in the study area.

Targeted Market Penetration

- Advanced ITS technology is available to support real-time vehicle-to-infrastructure communication, and travelers who have the greatest potential for emissions reductions are led to take the green routes to their destinations.

- Targeted drivers are selected by sorting travelers based on their emission reduction potential in a descending manner and selecting the travelers from the top of the list.

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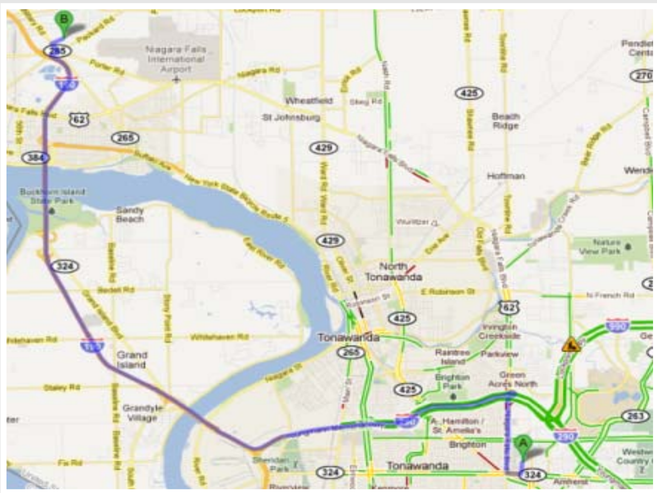
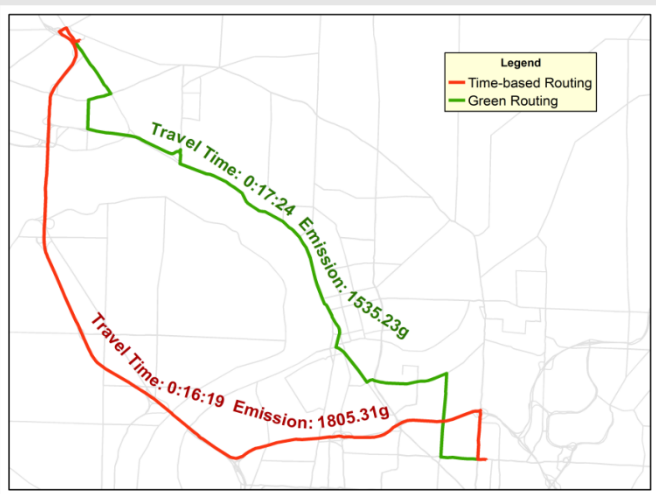
Individual Traveler's Routing Results





- Differences exist between lowest emissions and shortest travel time assignments for individual travelers:
    - The shortest travel time route (shown in red) went through the faster I-I90; this was consistent with the fastest route provided by Google.
    - The green route travelled along a parallel arterial.
- For that individual driver, green routing resulted in approximately a 15% reduction in CO emission, but this comes at the expense of approximately a 6.6% increase in travel time.

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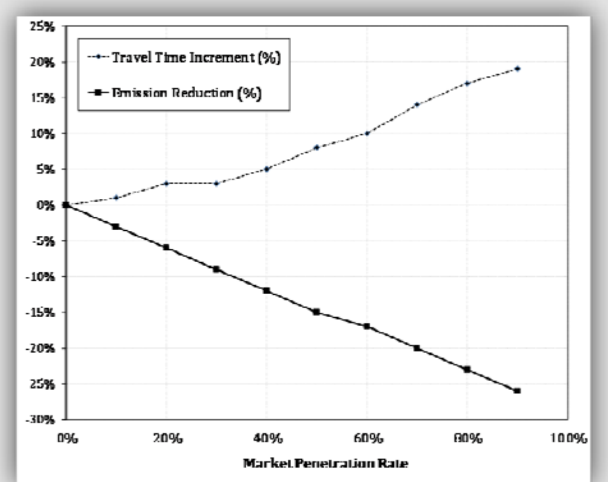
Green "User Equilibrium (UE)" Result

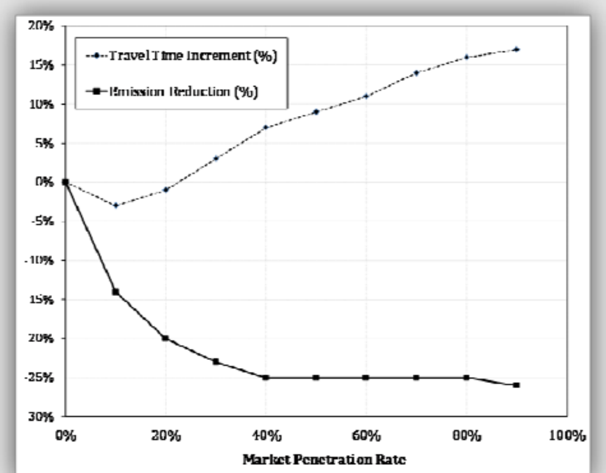
- Total CO emission were reduced from 21,840 kg to a range between 14,926 kg and 16,176 kg (approximately a 26% reduction).
- Average travel time in the subarea network increased from 5.6 minutes to a range between 6.5 minutes and 8.1minutes (this represents a 11% to 35% increase).
- Changes in emissions estimates between one assignment and another are within a reasonable threshold (6%).

Iteration ID	Travelers Emission (kg)	Emission Variation	Total Travel Time (hr)	Average Travel Time (min)	Travel Time Variation	Emissions-to-Time Savings Index
Shortest Path	21839.92	/	5022.59	5.866	/	/
Green Routing #1	15038.22	-31%	6269.10	7.322	25%	1.25
Green Routing #2	15001.59	-31%	6270.46	7.323	25%	1.26
Green Routing #3	15446.61	-29%	6486.66	7.576	29%	1.00
Green Routing #4	15944.43	-27%	5573.42	6.509	11%	2.46
Green Routing #5	15649.66	-28%	5906.93	6.899	18%	1.61
Green Routing #6	15072.23	-31%	6762.85	7.898	35%	0.89
Green Routing #7	15143.08	-31%	6791.67	7.932	35%	0.87
Green Routing #8	16176.23	-26%	5780.01	6.750	15%	1.72
Green Routing #9	16046.36	-27%	5933.33	6.929	18%	1.46
Green Routing #10	14925.5	-32%	6908.10	8.068	38%	0.84
Green Routing #11	15213.77	-30%	6705.03	7.831	33%	0.91

Market Penetration Results



- **Random market penetration**
  - Environmental benefits steadily increase~~ing~~ with the increase in market penetration rate. A corresponding increase in travel time can also be observed (although rate of increase appears lower at low penetration rates).



- **Targeted market penetration**
  - Environmental benefits grow dramatically at first. After reaching a 40% market penetration rate, the benefit becomes less significant with further increases in penetration rates.
  - For travel time, the overall trend of increment is close to linear except for the 10% case (an anomaly caused by the stochastic nature of the system and the fact that UE is only approximated).

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Conclusions

- For the Buffalo-Niagara metropolitan area, green routing has the potential to result in significant emissions reductions, with reductions in CO emissions in the range of between 26% to 32%

- The corresponding increase in travel time for the case study was in the range of 11% to 35% (e.g. Strategy #4 reduced emissions by 27% at the expense of an 11% increase in travel time)

- It is possible to devise strategies that strike a balance between reduced emissions and increased travel times

- With targeted market peneration, significant emissions reductions can be achieved at relatively low market penetration values. Moreover, in that case, the increase in travel time is quite reasonable (e.g. a 40% targeted green routing market penetration yielded 25% reduction in CO emissions at the expense of an 8% increase in travel time).

Major Contributions

- Adapted the MOVES model to work with a microscopic traffic simulation model to calculate emissions for a realistic regional network
- Developed an automated procedure for integrating TRANSIMS and MOVES
- Confirmed the conclusions of previous research studies regarding differences between shortest travel time & least emissions assignments
- Demonstrated the potential of green routing strategies to result in significant emissions reductions using a real-world large transportation network
- Devised green routing strategies that strike a balance between emissions reductions and the expected corresponding increase in travel time
- Assessed the impact of market penetration rates of green routing users on the system-wide emissions and travel time
- Demonstrated the potential achieving significant emissions reductions at low market penetration rates if travelers with the largest likely emissions savings are intelligently selected for green routing

THANK YOU!