Modeling the Short- and Long-Term Behavioral Impacts of a Low Emission Zone Policy: The Application of an Integrated Model of the Urban Continuum (SimTRAVEL)

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Introduction

It is widely recognized that various policy actions have both short and long term impacts on location choices and activity-travel behavior choices of individuals. A policy action of much interest that falls within this domain is that of low emission zones. Several low emission zone polices have been successfully implemented in various cities around the world. In the United States, this has become a topic of much interest to the researchers and regulatory authorities in the recent years to curtail ever increasing motorized travel and reduce emissions. In this effort, a low emission zone policy is tested in an integrated modeling framework where people driving cleaner (eco) vehicles receive incentives to travel to low emission zones while others (non-eco vehicle drivers) might have restricted access to low emission zones. An eco-vehicle is a vehicle that complies with the emission standards set forth by a low emission zone policy. In order to benchmark a specific type of vehicle as an eco-vehicle in the context of this modeling effort, hybrid, plug-in hybrid and electric vehicle types are considered as eco-vehicles. The intent of instituting low emission zones is that people would acquire and use cleaner and sustainable vehicles (read eco-vehicles) in the context of travel to low emission zones. In order to encourage sustainable travel behavior in general, transit services are enhanced to low emission zones to encourage a mode shift (especially for non-eco travellers).

In response to these policies, individuals may alter destination/mode choice in the short term, or change vehicle type (hybrid or electric vehicle) and residential/work location choices in the long term. In the absence of an integrated microsimulation model system that captures the full range of long and short term activity-travel and location choices, it is difficult to forecast the impacts of such policies. The objective of this paper is to present results from the application of a novel integrated microsimulation model system of land use and activity-travel behavior, called SimTRAVEL (Simulator of Transport, Routes, Activities, Vehicles, Emissions, and Land), to analyze the impacts of a low emission zone policy.

Test Area

The test area chosen for this microsimaultion effort is a three city subregion (Chandler, Gilbert and Queen Creek) from the Greater Phoenix Metropolitan Area. The geography chosen for analysis consists of about 250,000 people and corresponding travel of 1.1 million trips per day. The test area consists of a total of 175 traffic analysis zones (TAZs). Twelve TAZs with heavy retail development are chosen as low emission zones, with an intent to identify the impact on discretionary activity-travel patterns of individuals in response to a low emission zone policy. A map of the test area with low emission zones identified is shown in Figure 1.

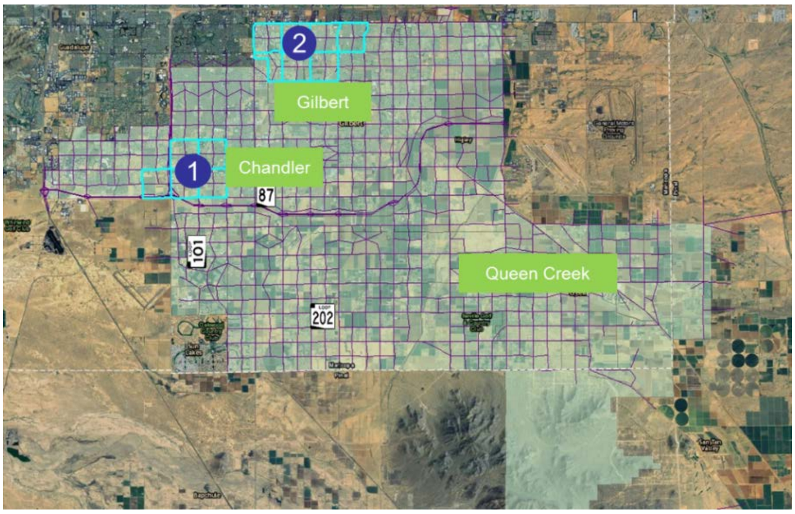

FIGURE 1. Test Area for Low Emission Zone Policy Simulation
(Source: Google Maps, https://www.google.com/maps)

The modeling effort is intended at carrying out extensive tests on a smaller network, before proceeding to implement and test the impact of a low emission zone policy on the larger Phoenix Metropolitan Region Network, which has daily traffic close to 14 million trips. Full range of activity travel choices including activity choice, trip chaining, time of day, destination choice, mode choice and vehicle type choice are studied in response to a low emission zone policy.

Methodology

The components of the integrated model system are estimated on a household travel survey data set from the Maricopa County (Greater Phoenix Metropolitan Area) region of Arizona in the United States. The model system is calibrated and validated to a subarea of the county where detailed land use, building stock, and socio-economic data are available. The integrated model system comprises three major model components namely: a land use microsimulation model system (UrbanSim), an activity-based travel behavior model (openAMOS), and a dynamic traffic assignment model (DTALite). The activity-based travel behavior model and the dynamic traffic assignment model are integrated in such a way that there is continuous communication between the two model systems along the time axis (see Figure 2).

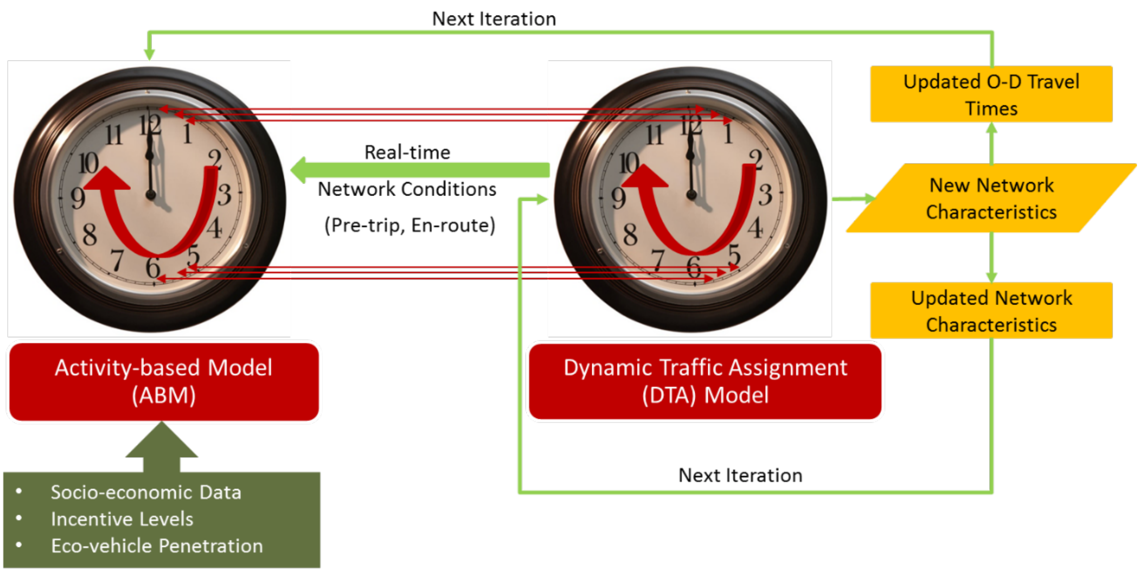

FIGURE 2. Integrated Model System: SimTRAVEL

The time resolution for exchange of information between the activity based model and the dynamic traffic assignment model is set as one minute. Every minute, openAMOS sends all the trips that depart in the given minute to DTALite. DTALite in turn sends all the trips that reached their destinations back to openAMOS for determining subsequent activity-travel choices of individuals. The dynamic traffic assignment module is able to provide both historical as well as real time traffic conditions as input to the activity based model, facilitating provision of pre-trip as well as enroute information to travelers. This tight coupling between both the model systems provides a robust framework to test policies that are static as well as dynamic in nature. The model system simultaneously reflects impacts of policy actions on both demand and supply related choices, as well as the interactions between demand and supply phenomena, in a robust and behaviorally realistic way. In this research effort, the SimTRAVEL model system is applied to see how a low emission zone policy would impact activity-travel patterns on the demand side and route choice on the supply side. A detailed description of SimTRAVEL and its components is available in Pendyala et al (2012).

Scenario Development

An incremental scenario development scheme was adopted, starting with an incentive only policy for low emission zones. Under this policy, eco-vehicle drivers are provided an incentive to travel to low emission zones, whereas non-eco travelers are not penalized in any way. The incentive might be a monetary one such as a fixed dollar amount for each trip made to a low emission zone or a non-monetary one such as free parking, eco-credit etc. The intent behind implementation of this scenario is that individuals would acquire and utilize their eco-vehicle in the context of travel to low emission zones and realize the benefits of the incentives provided. Level of incentives and corresponding market penetration of eco-vehicles is estimated based on existing (limited) research in the area. Three levels of incentives are tested: $0.50, $1.0 and $1.50 per every eco-trip (trip made using an eco-vehicle) made to the low emission zones, with an annual cap for each of the incentive levels. The expected output of such an incentive only scenario is higher but cleaner VMT, in these sense that this scenario will encourage purchase and utilization of 'cleaner vehicles'.

Next, in addition to the incentive policy, transit service is enhanced to LEZs with an intent to encourage model shift to LEZs for non-eco travelers. This market segment represents the majority of travelers in the region (95%) even under the assumption of an aggressive market penetration of eco-vehicles. In order to reduce the emissions from personal travel of this segment an 'attractive' transit option is provided. Under the enhanced transit service scenario, the frequency of transit operation to low emission zones is doubled and fare is reduce by half (w.r.t to baseline scenario). This enhanced transit service is available to all travelers alike, with an expected higher impact on the non-eco traveler segment. The incremental scenario development allows for the flexibility to clearly identify the benefits of an incentive only policy vs. a combination of policies. Such disaggregate modelling scheme provides the decision makers with a variety of options, enabling them to choose a policy that caters to the region's environmental as well as financial goals.

Findings

The results of the effort show how low emission zone policies impact activity-travel choices in the integrated simulation run. The initial tests from the 'incentive only' scheme, where cleaner 'eco' vehicle travelers are incentivized to travel to low emission zones suggest modest reductions in emissions with increasing market penetration of eco-vehicles. Other vehicles in the system are not penalized to travel to low emission zones. The hypothesis for this scenario test is that reduction in emissions will be realized due to acquisition and usage of cleaner vehicles in response to the policy. It is found that the policy does impact route choice, activity generation and destination choice in the short run, whereas long term implications of low emission zone policies include acquisition and usage of 'cleaner' vehicles. It appears that eco vehicle drivers choose low emission zones more often to realize the benefits of the incentive though this might involve a slightly longer trip. Individuals who drive non-eco vehicles choose low emission zones all the same as they are not being tolled/incentivized to travel there. Overall emission profile of the region shows a downward trend with increasing level of the incentives due to higher acquisition of cleaner vehicles.

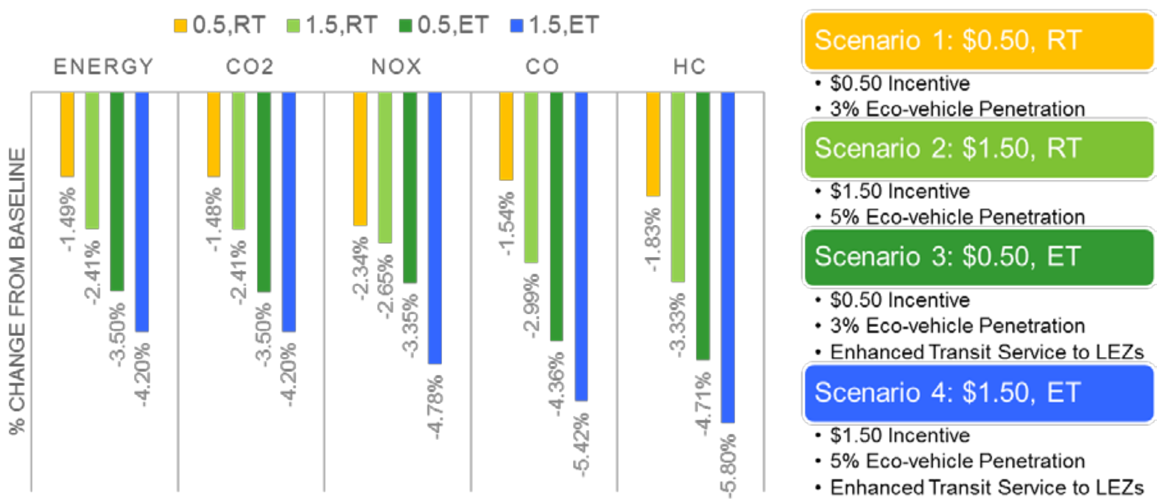

FIGURE 3. Reduction in Energy and Emissions from Baseline Scenario

Next, the incentive only policy is augmented by enhancing the transit services to low emission zones. The energy and emission savings from baseline for different scenarios is shown in Figure 3. It can be observed from the figure that greatest reductions in energy/emissions are realized with the introduction of enhanced transit service to LEZs. An intuitive reason behind this is that this policy impacts the majority market segment (i.e., non-eco travelers) thereby bringing greater benefits. From the model test runs it was learnt that a successful low emission zone policy should be a combination of incentives and enhanced transit services to cater to all market segments and bring higher emission reductions. Tolling of non-eco vehicles is a scenario test underway.

Implications for Research/Policy

This paper offers a new integrated microsimulation model system of land use and travel behavior that is capable of reflecting impacts of policy actions in a behaviorally robust framework. The modeling framework and approach could have important implications for modeling practice in agencies around the world. Moreover, the empirical results of the application of the model will shed light on the impacts of low emission zone policies of different levels on activity-travel behavior and the social equity implications of such policies. The results can help inform policy makers who are contemplating low emission zone strategies.

From this research effort, it was realized that an effective low emission zone policy is a combination of incentives to eco-vehicles as well as enhanced transit services to attract non-eco travelers. It was observed that transit enhancements amplified the emission savings realized in the context of a low emission zone policy. This is an intuitive finding as transit enhancements are aimed at inducing mode shift on the majority market segment of non-eco travelers, thereby propelling higher emission reductions. Overall, a 3% to 5% energy and emission saving is realized at modest levels of eco-vehicle penetration coupled with enhanced transit services. Tolling of heavily polluting vehicles would offset the cost of incentivizing eco-vehicles to some extent and is a scenario test under consideration.

The low emission zone policy tested in this effort is static in nature (fixed zonal boundaries, fixed incentives), but the concept of low emission zones is dynamic, where any set of zones can be geo-fenced in specific times of day with an intent to improve air quality within the area. The incentives/tolls in the context of low emission zones can also be dynamic in nature and the integrated model system described is fully capable of accommodating such measures. The low emission zone modelling framework is tested using open source softwares, facilitating the extension of this methodology to any region.

References

Pendyala, R.M., K.C. Konduri, Y-C. Chiu, M. Hickman, H. Noh, P. Waddell, L. Wang, D. You, and B. Gardner (2012) Integrated Land Use – Transport Model System with Dynamic Time-Dependent Activity-Travel Microsimulation. *Transportation Research Record* **2303**, *Journal of the Transportation Research Board*, pp. 19-27