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Evolution of the household vehicle fleet: Anticipating fleet composition, PHEV adoption and GHG emissions in Austin, Texas

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A B S T R A C T

In today's world of volatile fuel prices and climate concerns, there is little study on the relationship between vehicle ownership patterns and attitudes toward vehicle cost (including fuel prices and feebates) and vehicle technologies. This work provides new data on ownership decisions and owner preferences under various scenarios, coupled with calibrated models to microsimulate Austin's personal-fleet evolution.

Opinion survey results suggest that most Austinites (63%, population-corrected share) support a feebate policy to favor more fuel efficient vehicles. Top purchase criteria are price, type/class, and fuel economy. Most (56%) respondents also indicated that they would consider purchasing a Plug-in Hybrid Electric Vehicle (PHEV) if it were to cost $6000 more than its conventional, gasoline-powered counterpart. And many respond strongly to signals on the external (health and climate) costs of a vehicle's emissions, more strongly than they respond to information on fuel cost savings.

Twenty five-year simulations of Austin's household vehicle fleet suggest that, under all scenarios modeled, Austin's vehicle usage levels (measured in total vehicle miles traveled or VMT) are predicted to increase overall, along with average vehicle ownership levels (both per household and per capita). Under a feebate, HEVs, PHEVs and Smart Cars are estimated to represent 25% of the fleet's VMT by simulation year 25; this scenario is predicted to raise total regional VMT slightly (just 2.32%, by simulation year 25), relative to the trend scenario, while reducing CO_2 emissions only slightly (by 5.62%, relative to trend). Doubling the trend-case gas price to $5/gallon is simulated to reduce the year-25 vehicle use levels by 24% and CO_2 emissions by 30% (relative to trend).

Two- and three-vehicle households are simulated to be the highest adopters of HEVs and PHEVs across all scenarios. The combined share of vans, pickup trucks, sport utility vehicles (SUVs), and cross-over utility vehicles (CUVs) is lowest under the feebate scenario, at 35% (versus 47% in Austin's current household fleet). Feebate-policy receipts are forecasted to exceed rebates in each simulation year.

In the longer term, gas price dynamics, tax incentives, feebates and purchase prices along with new technologies, government-industry partnerships, and more accurate information on range and recharging times (which increase customer confidence in EV technologies) should have added effects on energy dependence and greenhouse gas emissions.

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1. Introduction and motivation

Climate change is one of the planet's top issues. The US contains 4% of the world's population but produces 25% of all greenhouse gas (GHG) emissions (BBC, 2002), with 28% of these emanating from the transportation sector alone (EIA, 2007). Rising gasoline prices, emerging engine technologies, and changes in fuel-economy policies are anticipated to result in a variety of behavioral changes. These changes include adjustments in vehicle occupancies, trip destinations, trip chaining, and mode choice in the short term. In the longer term, a wider sphere of decisions will be affected, including household vehicle holdings (number, make and model), vehicle purchase and retirement timing, and home and work location choices.

Automobile ownership plays an extremely important role in determining vehicle use, vehicle emissions, fuel consumption, highway capacity, congestion, and traffic safety. A relatively new yet key objective of transportation planners and researchers is to know how many and what type of automobiles are owned by households, how they adjust their fleet, and how many miles they drive each of their vehicles. The benefits that a household derives from its fleet depend on use levels, type of vehicles owned, household demographics and other factors. To accurately anticipate future fleet attributes (and therefore emissions, gas tax receipts, crash counts, and so forth), planners must have dependable forecasts of vehicle ownership and use.

This study examines opinions on vehicle policy in Austin, Texas (as found in a public opinion survey) and models the evolution of the household fleet via transaction and choice decisions over a 25-year period (from 2009 to 2034). A microsimulation framework based on a set of interwoven models for vehicle ownership and use yields future vehicle composition mix along with GHG emissions forecasts in Austin, Texas. The following sections discuss recent literature on vehicle choice, questionnaire design and data acquisition, sample correction, geo-coding and sample data characteristics. The paper then presents results of data analysis, including vehicle choice, vehicle retirement and transactions timing; and the results of a 25-year simulation. The paper concludes with a summary of results, recommendations, conclusions and ideas for topic extension.

2. Existing studies

Much of the existing research on vehicle type choice is based on vehicle attributes, household characteristics, and fuel costs. Manski and Sherman (1980) developed separate multinomial logit models for the number of vehicles owned and vehicle type for households owing one or two vehicles. Lave and Train (1979) controlled for several household attributes, vehicle characteristics, gasoline prices, and taxes on larger vehicles and found that higher income households tend to prefer expensive cars and younger individuals prefer high-performance cars. Berkovec (1985) developed nested logit models, with the upper-level for number of vehicles and the lower-level nest for vehicle class with vehicle attributes serving as exogenous variables. This disaggregate model of vehicle choice was used to forecast US automobile sales, vehicle retirements and fleet attributes for the 1984–1990 period. Results from such studies illuminate the relative importance of capital costs, operating costs, cargo space, and performance on vehicle choice-with findings similar to those in Berkovec and Rust (1985), Mohammadian and Miller (2003a,b) and Mannering et al. (2002).

Consumers' travel habits and behavioral attitudes also affect vehicle choice. Choo and Mokhtarian (2004) found that travel attitudes, personality, lifestyle, and mobility factors are useful in forecasting vehicle types owned and predicting the most-used vehicle within a household. Kurani and Turrentine (2004) found that purchasing households do not pay much attention to fuel costs over time, unless they are under severe economic constraints. A vehicle's overall visual appeal, amenities, reliability and safety, cabin size, acceleration, purchase price and other amenities are found to have a more significant effect on choice. Gallagher and Muehlegger (2008) studied consumer adoption of hybrid electric vehicles (HEVs) in the US and found that groups with strong preferences for environmentalism and energy security prefer HEV. Their results show that rising gasoline prices and certain social preferences result in maximum sales.

Perceived barriers can have a significant impact on consumer adoption of PHEVs. The Electric Power Research Institute's (EPRI) recent (2010) web-based survey of approximately 900 electricity customers in Southern California found that consumers identified lack of electric-vehicle infrastructure, potential increases in electric rates, and lack of choice in vehicles – especially in emergency situations – as barriers to PHEV purchase. A government tax credit was found to have the greatest impact on EV purchases. Nevertheless, almost 50% of non-hybrid owners indicated that they will "likely acquire a vehicle with a hybrid engine" in the next few years. Such optimism bias may be due to the very limited choice nature of the EPRI survey questions (will you or will not you) and the positive information given in educational materials included within the survey.

In earlier work, EPRI (2001) surveyed 400 persons in four major US cities and found gas prices greatly impacting expressions of PHEV purchase interest: an 82% increase in price per gallon increased stated market potential by 35% for a PHEV with a 20-mile range, and by 65% for a 60-mile-range PHEV. Other customer preferences for electric vehicles included reduced maintenance, better handling and reduced air pollution.

Consumer's previous vehicle experiences and brand loyalty can also affect choice and use. Extending Dubin and McFadden's (1984) work, Mannering and Winston (1985) employed a dynamic utilization framework for vehicle choice (and use) as a function of the prior year's utilization (a brand loyalty measure), household characteristics, and vehicle attributes. Roy's Identity (Roy, 1947) was used to link an indirect utility function for vehicle choice with vehicle use (annual VMT). A