GreenSTEP: Greenhouse Gas Statewide Transportation Emissions Planning Model

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Abstract

Global warming is the most serious and urgent issue facing the U.S. transportation sector. Major reductions in greenhouse gas emissions from the transportation sector will be needed in order to stabilize the climate and avoid the most serious effects of global warming. Travel models can play an important role in evaluating potential policies for reducing greenhouse gas emissions. To do so, however, models will need to be expanded to address factors that are relevant to the management of greenhouse gas emissions. The GreenSTEP model was developed to fill this gap at a statewide level. The model combines household level modeling of vehicle types and useaage with more aggregate level modeling of factors such as fuel types. The model is being used to assist in the development of a statewide strategy for reducing greenhouse gas emissions from the transportation sector in Oregon.

Context

Global warming is the most serious and urgent issue facing the U.S. transportation sector. Left unchecked, global warming will dramatically change climatic patterns around the world and people living in the U.S. will experience more frequent and severe heat waves, more prolonged droughts in some areas, and more frequent flooding in other areas (Karl). The problem is urgent because emissions of greenhouse gases have been increasing rapidly in recent decades. To put this in perspective, it has been estimated that the oil consumed between 2000 and 2010 will equal one quarter of all oil that has been consumed (Sperling).

Global warming is a particularly important problem for U.S. transportation professionals to address. The United States, with less than 5% of the world’s population, accounts for about 28% of global greenhouse gas emissions (Karl). Emissions from the transportation sector account for about 28 % of U.S. emissions (Cambridge Systematics). Changes in climate due to global warming are forecasted to have a number of adverse consequences for U.S. transportation systems (TRB SR290).

Fortunately, many policy makers have begun to recognize and act on the urgency of this problem. Many states, like Oregon have adopted targets for reducing greenhouse gas emissions and are developing strategies and actions to achieve the targets. Policies are targeting vehicle technology, fuels and the amount of vehicle travel. Efforts are currently focused at the state and federal levels, but more attention is being focused on the metropolitan level as well. California law establishes a requirement for metropolitan areas to plan for reducing greenhouse gas emissions from transportation. Oregon followed suit for the Portland and Eugene metropolitan areas and is considering extending this requirement to all metropolitan areas in the state. The most recent global warming legislation being considered by the U.S. Senate also contains a provision that would require MPOs to develop plans to reduce greenhouse gas emissions from the transportation sector.

Travel modeling will play an important role in the formulation of policy at the state and metropolitan levels. However, current travel models do not have adequate capabilities for addressing the range of policies that are likely to be considered for reducing greenhouse gas emissions. Models need to be extended to consider factors that are not handled by standard transportation models. For example, models need to estimate the types and ages of vehicles owned in addition to the number of vehicles owned. It is also important that models be able to address factors for which there is incomplete data and a large amount of uncertainty (e.g. electric vehicles).

Previous Work and General Approach

Several modeling approaches have been used to estimate the effects of various policies and actions on transportation sector greenhouse gas emissions. The *Moving Cooler* study applied factors, derived from the literature, in policy bundles to estimate the effects of different policies on the amount of vehicle travel and greenhouse gas emissions (Cambridge Systematics). Boies et. al. used a "wedges" analysis approach that modeled the effects of vehicle and fuel strategies using the LEAP model (Long-Range Energy Alternatives Planning) and a factoring approach to evaluate the impacts of land use and transportation policies (Boies). Yang et.al. developed the LEVERS (Long-term Evaluation of Vehicle Reduction Strategies) spreadsheet model to evaluate emissions policies using the Kaya identity for evaluating the effects of different transportation and land use policies (Yang).

The Oregon Department of Transportation (ODOT) developed the GreenSTEP (Greenhouse gas State Transportation Emission Planning) model to provide modeling support for the development of a statewide strategy for reducing transportation sector greenhouse gas emissions. The decision was made to develop GreenSTEP after it became apparent that existing models would not be able to address the wide variety of policy actions that would make up a statewide greenhouse gas strategy. GreenSTEP was first envisioned to be an aggregate sketch level planning model using a factoring approach to calculate the joint effects of a variety of policies, much like the models mentioned above. But not long into the development process, the decision was made to model household vehicle ownership and use at a household level. This would be combined with a more aggregate treatment of other factors that do not lend themselves to modeling at a household level. This decision was made in order to make best use of household travel survey data in the development of the model, and to reduce the double-counting problem that factoring models have.

Although GreenSTEP "microsimulates" households and their vehicle and travel characteristics, it does this at a low level of spatial resolution (county level) and treats vehicle travel in an aggregate fashion (average DVMT). This is in keeping with the purpose of supporting the development of statewide greenhouse gas reduction strategies. It is important that the model be kept simple enough so that a very many strategies can be modeled. Complex household level microsimulations like those used in travel activity and land use models would be excessive for the purpose and would limit the number and range of strategies that could be explored.

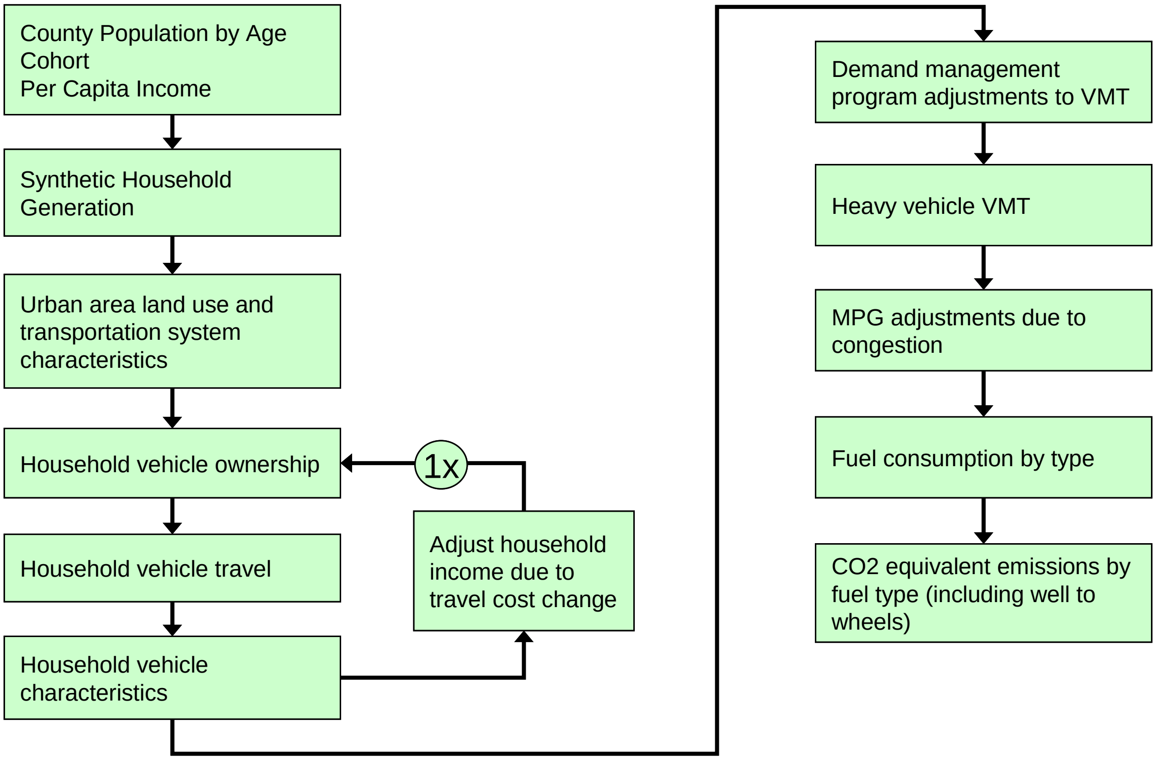
Model Description

Figure 1 illustrates the structure of the GreenSTEP model.

GreenSTEP creates a population of synthetic households from county-level population projections by age cohort. Households are composed of persons in each of 6 age categories. A simple income model assigns a household income based on number of people in each age category and the average per capita income for the region where the household is located. These attributes make the model emissions calculations sensitive to long-run demographic and economic changes.

Households are attributed with several relevant land use and transportation characteristics. The first of these is a development type – metropolitan, other urban, or rural – based scenario input assumptions about the proportions of new development that will locate in each of these areas. Households are also assigned a density for their neighborhood/community of residence based on scenario inputs related to urban growth boundary expansion policies. Whether or not the household is located in a mixed-use "urban" neighborhood is modeled based on population density, but may be overridden based on scenario policy inputs. Finally, metropolitan area households are also assigned public transit, freeway and arterial service levels based on the metropolitan area where they are located and scenario inputs for the growth rates of each service relative to population growth rates.

Figure 1. Design of GreenSTEP Model for Estimating GHG from Passenger and Truck Travel



Once households are provided with each of their socioeconomic, land use and transportation attributes, a series of models are applied to calculate household vehicle ownership, vehicle travel, and vehicle types. These models are sensitive to the land use and transportation systems attributes of the households as well as their socioeconomic attributes.

The vehicle ownership model determines the number of vehicles owned by the household. It does this in two stages. First, it determines which of the following categories of vehicle ownership the household belongs to: zero vehicles, less than one vehicle per driving age person, one vehicle per driving age person, more than one vehicle per driving age person. This model is applied as a set of sequentially applied binary logit models. Then it determines how many vehicles are owned by drawing from distributions tabulated from the household survey dataset.

The average daily vehicle miles traveled for each household is calculated in a two-stage process as well. In the first stage, a binomial logit model is used to predict whether a household is likely to have no vehicle travel on any given day. In the second stage, the amount of miles of vehicle travel predicted.

A set of models is used to determine the more detailed characteristics of the vehicles owned by each household including:

- Vehicle type (auto, light truck)
- Vehicle age
- DVMT by vehicle
- Electric vehicles

A binary logit model is used to predict the type of each household vehicle based on the income of the household, the number of vehicles owned by the household, the population density where the household resides, and urban mixed-use characteristic where the household resides. This model includes an algorithm for adjusting the model constant so that different assumptions about overall light truck ownership rates can be modeled.

Vehicle ages are modeled using joint distributions of vehicle ages by income group and vehicle type drawn from the survey. An iterated proportional fitting process is used to adjust the joint distribution based on changes to the vehicle type and vehicle age margins. The vehicle age margin may be varied to reflect increased or decreased fleet turnover rates. Figure 2 compares the age distributions that result from 20 model simulations with the actual distributions from the household survey dataset.

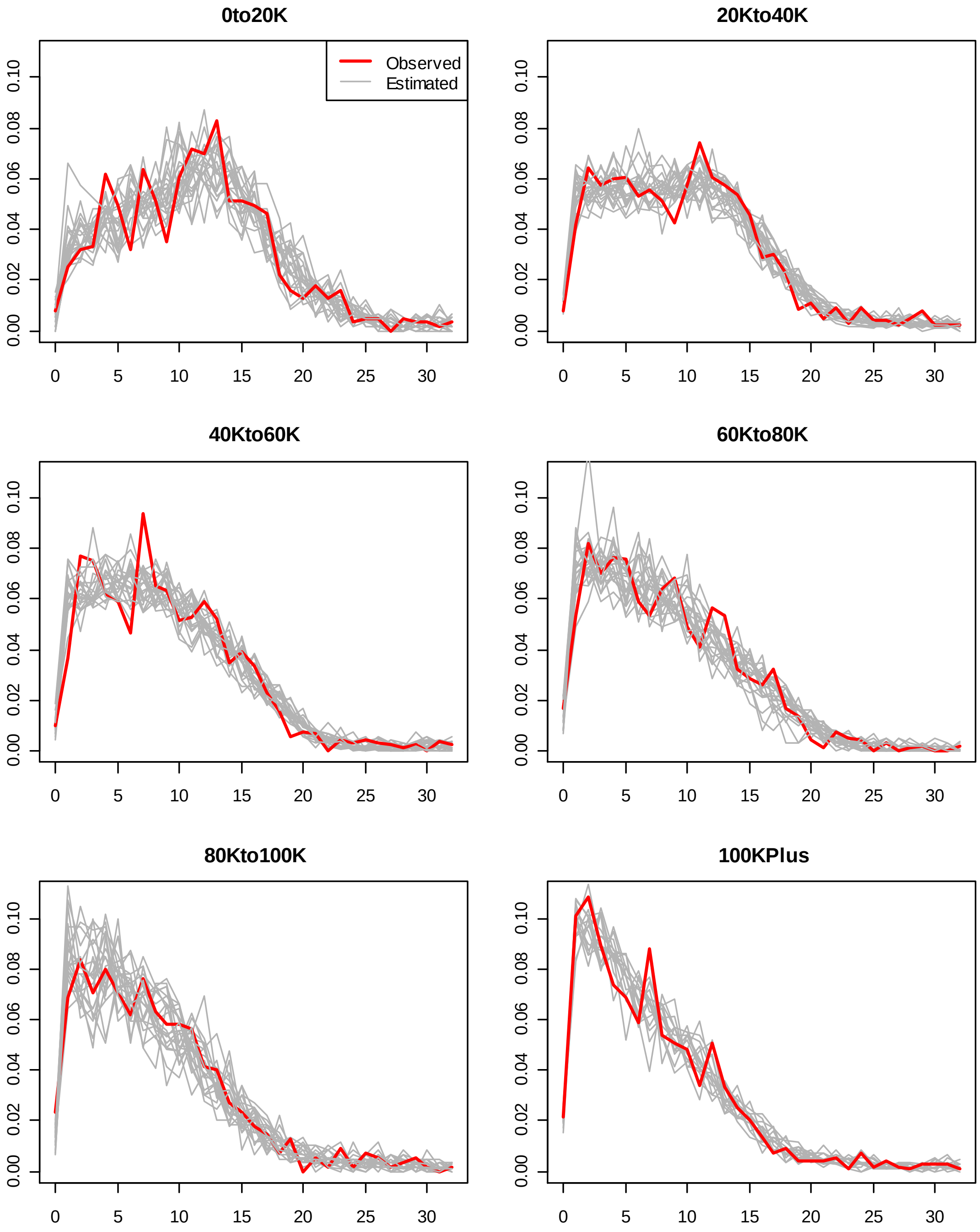
A vehicle use allocation model allocates average DVMT to each household vehicle. This is done using a regression model to estimate use proportions based on the number of vehicles in the household, the age of each vehicle and gas cost per mile of travel for each vehicle. Once average DVMT has been assigned to each vehicle, simple model is applied to identify EVs based on input assumptions about the driving range of EVs by model year and the proportion of vehicles whose daily mileage with within the range that will be EVs.

The influence of transportation costs on vehicle ownership and travel is treated as an income effect in GreenSTEP because of a lack of cost data and the potential that future costs may be much higher than present costs. To estimate the effect of future costs, GreenSTEP calculates what the travel costs would have been at the base year costs levels and what it would be at the future scenario cost levels. The difference is then subtracted from the household income and the vehicle ownership, travel and vehicle characteristic models are rerun using the adjusted household income levels.

After the 2nd iteration of the vehicle characteristic model, the GreenSTEP modeling process switches to an aggregate level. The household characteristics are summed up into arrays by county, income and development type. The first step that follows this is to make adjustments for demand management programs in metropolitan areas. Scenarios will specify demand management programs of different types by the proportion of households in each metropolitan area that will be affected by each program type.

Truck, bus and urban passenger rail VMT are estimated with several simple calculations. Truck VMT is calculated from a growth rate that is based on the rate of statewide income growth. Truck VMT is split among metropolitan areas and non-metropolitan areas based on current year proportional splits of truck VMT on state highways. Bus and urban passenger rail VMT are calculated from scenario inputs for revenue growth. These are adjusted to account for non-revenue service miles.

Figure 2. Comparison of Observed and Estimated Auto Age Proportions By Income Group (20 model runs)



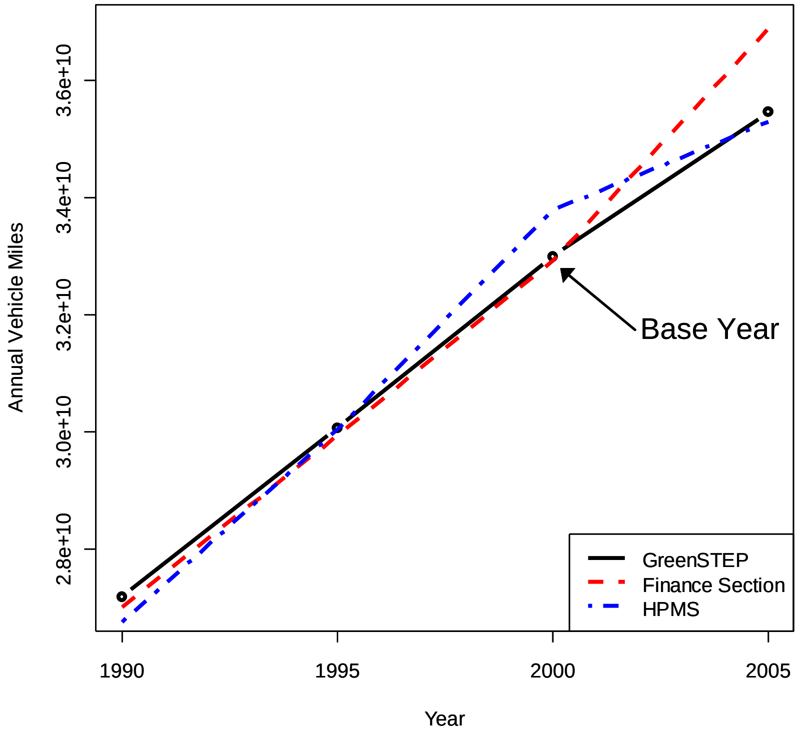
Adjustments are made to the fuel economy of vehicles to account for the effects of metropolitan area congestion on travel speeds. VMT in each metropolitan area is split between freeways and arterials using a simple linear regression model that is a function of the lane mile ratio of freeways and arterials in the metropolitan area. Then estimates are made of the proportions of VMT experiencing each of five different levels of congestion based on the systemwide ratio of average daily traffic to lane miles. Each congestion level is associated with average trip speeds according to models developed by the Texas Transportation Institute for the Urban Mobility Study. Speeds are estimated with and without consideration of the effects of incidents. This makes it possible to test the effects of different levels of incident management on greenhouse gas emissions. Once metropolitan VMT has been allocated to speed bins, fuel economy is adjusted using response curves compiled by the Federal Highway Administration using the Environmental Protection Agency's MOVES model.

In the final steps of the model, the fuels consumed are allocated to fuel types. Each fuel has an associated carbon intensity. To date, the carbon intensity values have been based on the work of the California Air Resources Board. Oregon-specific values are being developed for model application. Once the fuels are computed by type it is a straight-forward calculation to calculate greenhouse gas emissions.

Conclusions

Each component of GreenSTEP was tested as it was being developed to determine that it behaves reasonably. Backcasts were performed using historic data to determine whether the model as a whole could reproduce statewide VMT estimates for past years (Figure 3). In addition, a preliminary set of test runs were performed to test the response to various policy inputs. Now a more extensive set of tests are being performed on all of the policy inputs to ready the model for application.

Figure 3. Comparison of GreenSTEP VMT Backcast with Other VMT Estimates



The testing is showing that GreenSTEP is performing well and will have the capabilities needed to support the development of a statewide strategy for reducing transportation sector greenhouse gas emissions.

GreenSTEP should be transferable to other locations without too much effort because national datasets were used to estimate most of its components. The code for GreenSTEP and for estimating its components will be made available under an open source license to encourage further applications and development of the model.

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