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GreenSTEP Model Overview

A new model, GreenSTEP[1], was developed by the Oregon Department of Transportation (ODOT) for the specific purpose of estimating and forecasting the effects of various policies and other influences on the amount of vehicle travel, the types of vehicles and fuels used, energy consumption, and the resulting GHG emissions. Work on GreenSTEP started in 2008 as a result of an inquiry by the Oregon Global Warming Commission into the availability of models that could be used to provide information support for transportation planning decisions aimed at reducing GHG emissions. ODOT modelers made a decision to develop GreenSTEP because other transportation models could not address the scope of relevant factors and could not be readily adapted to do so. The development of GreenSTEP was reviewed extensively by state, national and international travel and emissions modeling experts in multiple venues. Evaluation at the national level lead to the Federal Highway Administration adopting GreenSTEP as the basis for their EERPAT[2] model. In 2010, the American Association of State Highway and Transportation Officials (AASHTO) awarded ODOT staff its Presidents Award for Planning for the development of the GreenSTEP model.

The GreenSTEP model estimates vehicle ownership, vehicle travel, fuel consumption, and GHG emissions at the individual household level. This structure was chosen to account for the synergistic and antagonistic affects of multiple policies and factors (e.g. gas prices) on vehicle travel and emissions. For example, because a household residing in a more compact mixed-use neighborhood will tend to drive fewer miles each day, a higher percentage of their driving would be powered by electricity if they use a PHEV. Modeling at this level makes it possible to evaluate the relationships between GHG emissions and the characteristics of households, land use, transportation systems, vehicles, and other factors of interest. In addition, household level analysis makes it possible to evaluate the equitability of the costs and benefits of different GHG reduction strategies. The following diagram shows a schematic of model calculation steps.[3]

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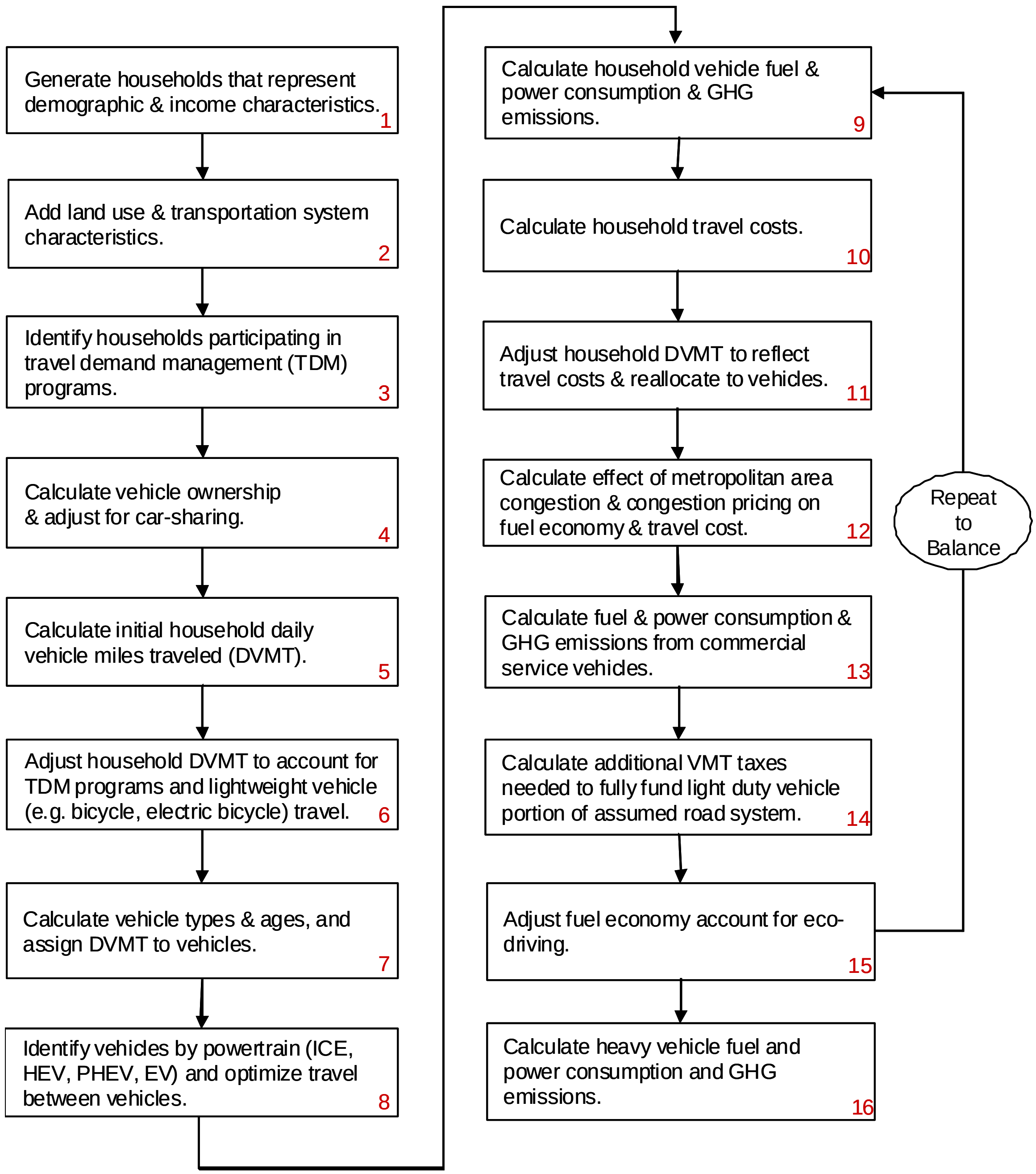
[1] GreenSTEP is an acronym which originally stood for Greenhouse gas State Transportation Emissions Planning. The meaning of the acronym was changed later to reflect revisions to the model to enable it to be applied at a metropolitan area level and to address a more general set of transportation energy considerations as well as greenhouse gas emissions. The current full name for GreenSTEP is Greenhouse gas Strategic Transportation Energy Planning.

[2] EERPAT is an acronym for Energy and Emissions Reduction Policy Analysis Tool. It is based on the version of GreenSTEP used for the first few rounds of modeling for the STS.
https://www.planning.dot.gov/FHWA_tool/default.aspx

Several changes have been made to GreenSTEP since then to technical and policy issues identified by the technical and policy advisory committees.

[3] The diagram shows the current structure of the GreenSTEP model. Changes to the model have been made over the course of the STS study.

GreenSTEP Model Schematic



Each calculation step is composed of a number of calculations that operate on the results of the previous calculation step and on input data that reflect scenario assumptions. The nature of each calculation was determined through the statistical analysis of several data sources such as the National Household Travel Survey. Each component calculation was estimated and checked using source data. The following summary descriptions of each step identify the scenario inputs that affect the results of the calculations.

1. ***Generate households:*** A set of households is created for each forecast year that represents the likely household composition for each county given the county-level forecast of persons by age. Each household is described in terms of the number of persons in each of six age categories residing in the household. A total household income is assigned to each household given the ages of persons in the household and the average per capita income of the region where the household resides.

2. ***Add land use & transportation system characteristics:*** Households are assigned to metropolitan, other urban, and rural areas based on scenario assumptions regarding the proportions of population growth occurring in each area. Neighborhood population density and mixed-use character are assigned based on scenario assumptions regarding the growth of urban boundaries and mixed use development targets. In metropolitan areas, transit and road service levels are assigned based on scenario assumptions regarding expansion of these services and facilities.

3. ***Identify households participating in TDM programs:*** Each household is assigned as a participant or not in a number of travel demand management programs (e.g. employee commute options program, individualized marketing) and/or to vehicle operations and maintenance programs (e.g. eco-driving, low rolling resistance tires) based on policy assumptions about the degree of deployment of those programs and the household characteristics.

4. ***Calculate vehicle ownership and adjust for car-sharing:*** Each household is assigned the number of vehicles it is likely to own based on the characteristics of the household and the land use and transportation characteristics of its location. Households are identified as participating in a car-sharing program based on the characteristics of the household and scenario assumptions regarding the future extent of car-sharing. The vehicle ownership of car-sharing households is adjusted.

5. ***Calculate initial household DVMT:*** An initial estimate of average daily vehicle miles traveled (DVMT) is calculated for each household based on the household characteristics determined in previous steps. Household demographics, income, transportation services, and land use are all important to the calculation.

6. ***Adjust household DVMT to reflect TDM and bicycle travel:*** Household DVMT is reduced for households identified as participating in TDM programs. Calculations are also done to estimate the amount of single-occupant vehicle travel that might shift to bicycles or other light-weight vehicles like electric bicycles based on scenario input targets for shifting a portion of short distance single occupant vehicle (SOV) trips.

7. ***Calculate vehicle characteristics and assign household DVMT to vehicles:*** Household vehicles are assigned to be either autos or light trucks (e.g. SUV, pickup truck, van) based on the household and land use characteristics and light truck percentage targets that might be established for the scenario. The age of each vehicle is determined based on current age profiles by vehicle type and household income and any objectives for adjusting the vehicle age distribution that might be established for the scenario. Average household DVMT is assigned to vehicles without regard to optimizing use to minimize fuel consumption; which is done in the next step.

8. ***Identify vehicles by powertrain and optimize travel between vehicles:*** The powertrain of each household vehicle is identified as being either an internal combustion engine (ICE), hybrid-electric vehicle (HEV), plug-in hybrid electric vehicle (PHEV), or electric vehicle (EV). The identification of vehicle powertrain type is based on scenario input assumptions regarding future market shares by model year. Vehicle fuel economy and power efficiency (for PHEV and EV) is assigned to each vehicle based on the vehicle type, age and powertrain and corresponding input assumptions for the scenario for each model year. Households are identified as fuel economy optimizers based on scenario input assumptions regarding the proportion of households that will optimize their use of vehicles to minimize fuel use. Vehicle DVMT shares of optimizing households are switched between vehicles so that the most miles are assigned to the vehicle with the highest fuel economy. The proportion of household DVMT powered by fuel vs. electricity is also calculated.

9. ***Calculate household fuel and power consumption and GHG emissions:*** Total household fuel consumption is calculated based on the DVMT assigned to each vehicle, the proportion of the DVMT that is powered by fuel, and the average fuel economy of the vehicle. Likewise electrical power consumption is calculated for the miles of household vehicle travel powered by electricity. GHG emissions are calculated based on the future lifecycle carbon intensity of fuels and electricity production assumed for a scenario.

10. ***Calculate household travel costs:*** Household travel costs are calculated from the amounts of miles driven, fuel consumed, electricity consumed, and GHG emitted. In addition, a parking model is applied to calculate how much each household would pay for parking based on scenario input assumptions about what proportions of employees pay for parking, what proportions of

non-work trips also involve paid parking, and what the long-term daily parking rates would be. Scenario input assumptions establish the rates for fuel costs, power costs, fuel taxes, VMT taxes, PAYD insurance, and several external costs (i.e. costs imposed on society by driving that drivers do not pay for such as pollution). Scenario input assumptions also establish what portion of external costs will be paid by drivers.

11. ***Adjust household DVMT to reflect travel costs:*** A household budget model is used to adjust household DVMT to reflect the effect of household travel costs on the amount of household travel. The adjusted household DVMT is allocated to vehicles in proportion to the previous allocation.

12. ***Calculate the effects of metropolitan area congestion and pricing:*** Total light duty vehicle (household and commercial service vehicle), truck and bus DVMT is calculated for each metropolitan area and assigned to portions of the road system (freeway, arterial, other). Congestion levels are calculated and the effects of congestion on speeds are estimated considering the traffic loads, scenario input assumptions regarding the deployment of traffic operations programs (e.g. ramp metering, traffic signal coordination), and scenario input assumptions regarding congestion pricing. Fuel economy adjustments are calculated for each vehicle powertrain type based on the calculated speeds and scenario input assumptions regarding the congestion efficiency of powertrains in the future. The average added travel cost per mile due to congestion pricing is also calculated.

13. ***Calculate fuel & power consumption & GHG emissions from commercial service vehicles:*** Commercial service vehicle DVMT is split between different vehicle types, powertrains, and fuels based on input assumptions for the scenario being analyzed. The vehicle age distributions and fuel economy and power efficiency by vehicle type, powertrain and model year are the same at those used for household light duty vehicles.

14. ***Calculate additional VMT taxes needed to fully fund road system:*** In the future, as vehicle fuel economy improves and PHEVs and EVs become more prevalent, fuel taxes will be insufficient to pay the cost to maintain, operate and improve the road system. In order to maintain a fair comparison of scenarios having very different assumptions about fuel economy and EV use, it is assumed that in all cases sufficient revenues would be collected from VMT taxes to pay for the road system that is assumed to exist. This is accomplished by calculating total costs imposed by light duty vehicles and total revenues collected from light duty vehicles. The revenue gap is divided by the total light duty vehicle VMT to calculate a VMT surcharge fee to make the system whole.

15. ***Adjust fuel economy to account for eco-driving:*** The average fuel economy of households identified as eco-driving is adjusted to reflect the effect that eco-driving has on improving fuel economy. Although this step is

included in the loop of steps that is repeated several times, it is only executed once in the loop.

At this point, the calculation process cycles back to step #9. This is necessary because the congestion calculations change fuel economy and thus affect the amount and cost of fuel consumed. The congestion calculations also estimate the effect of congestion pricing on the cost of vehicle travel. The calculated VMT surcharge fees affect the cost of vehicle travel as well. Eco-driving improves fuel economy and thus reduces fuel costs. The effect of these adjustments to household travel costs need to be included in the total household travel costs and the adjustment to household DVMT. This is accomplished repeating steps 9-14 several times until DVMT changes very little between iterations.

16. ***Calculate heavy vehicle fuel and power consumption and GHG emissions:*** Public transportation VMT is calculated from scenario input assumptions about future revenue miles per capita, future population, and the average ratio of vehicle miles of travel to revenue miles of travel. VMT is split between vehicles powered by on-board fuels vs. electricity based on scenario input assumptions. The amount of fuel consumed is calculated from the VMT powered by fuel and input assumptions regarding the age distribution of vehicles and the fuel economy of vehicles by age of vehicle. GHG emissions from fuel powered vehicles are calculated based on input assumptions regarding the mix of fuels used in the future (e.g. diesel, biodiesel, CNG). Electric power consumption is calculated from the VMT powered by electricity and input assumptions regarding the age distribution of vehicles and the power efficiency of vehicles by age of vehicle. GHG emissions from electrically powered vehicles are calculated based on the amount of power consumed and scenario input assumptions regarding the carbon intensity of electrical power generation.

Components of GreenSTEP were tested throughout the development process to check the reasonability of results and whether the model could replicate observed behavior and conditions. Sensitivity tests were also performed to check whether the sensitivity of the model is consistent with results reported by other studies.[4]

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[4] For example, the sensitivity of GreenSTEP to changes in urban area population density and land use mixing was compared to findings published in the Transportation Research Board Special Report 298, *Driving and the Built Environment: Effects of Compact Development on Motorized Travel, Energy Use, and CO2 Emissions*. September 2009.