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Adapting Travel Models and Urban Models to Project Greenhouse Gases in California

Bob Johnston, Mike McCoy, and Shengyi Gao
Information Center for the Environment
University of California, Davis, CA 95616
rajohnston@ucdavis.edu
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Political Background:
In 2006, the California Legislature passed a law requiring greenhouse gases (GHGs) to be reduced by about 25% in 2020, to achieve 1990 levels. A related Executive Order by the Governor requires GHGs to be reduced 80-90% in 2050. This latter target conforms to recommendations by the most-recent UN panel (IGCC) and by the Stern Commission in the U.K. State agencies are busy writing reports and moving toward implementing these laws. It appears that the State will adopt a cap-and-trade program for reducing GHGs, but the details have not been worked out. A carbon tax may also be adopted, as well as carbon-intensity limits for fuels, electricity generation, and other commodities.

The GHG laws are affecting local land use planning and regional transportation planning. The Attorney General has issued opinions and sued some counties that are revising their general plans for land use, demanding that they include GHGs in their impact statements. Currently, cities and counties are developing makeshift methods as fast as they can for assessing energy use and GHG emissions from land uses. In addition, legislative leaders have requested that regional transportation plans include Low-GHG scenarios, which include measures to reduce VMT. Past regional modeling work by Johnston and others, using integrated urban models, has shown that transit investment by itself does little to reduce VMT. It must be backed by land use intensification or pricing of fuels, parking, and roads, or both. For a review see: http://www.vtpi.org/johnston.pdf So, California local planners are intensely interested in implementing land use models now, so that all available policies can be simulated and so that the effects of transportation investments on land use can be represented.

Our Past Model Development Work in California:
Our research group at UC Davis developed a simple urban model, UPlan, that runs in ArcView/Spatial Analyst, several years ago. It is a deterministic, rule-based model, where growth goes near to services and roads, subject to land use plans and other constraints identified by the user. UPlan may be run on subcounty areas, a county, or a group of counties. It can be run by itself or with a county or regional travel model. It is free and open-code. About 14 counties now use UPlan and it is the chief land use modeling tool in use in the current group of Blueprint counties, where long-range land use, transportation, and natural resources planning is being funded by California DOT.

Our other land use modeling work is the application of the PECAS model to the whole State. This project is also funded by Caltrans and will run from 2005 to 2010. Pecas is a computable general equilibrium model of the California economy. This application of the Pecas model will have about 50 sectors and labor types, 12 land use types, and 14 household types and will operate on 530 economic zones. Also, land uses within each zone will be suballocated to about 200 million 50m gridcells for mapping. The detailed footprint of new development will allow us to investigate impacts on habitats, runoff and water quality, flooding costs, and wildfire costs. The Pecas model will be iterated with the Statewide Travel Model which includes auto, conventional rail, high speed rail, and airline modes of travel. This model also includes almost all transit networks in the State.

Because Pecas is a macroeconomic model, with a county-to-county input-output table spatialized to 530 zones, it can project several indicators of economic development, such as state product, total exports, and total wages. These can also be projected for counties or zones and by sector, for equity analysis. Because Pecas floorspace consumption operates through bidding, and all decisions of households and employees are cost-minimizing, this microeconomic model can also project indicators of household welfare (utility) and do the same for employees. Again, these measures may be portrayed by county or household income class or by sector of the economy, permitting various kinds of equity analysis.

This project was started in order to inform the State transportation planning process and to help determine interregional travel volumes that could then be used by MPOs and counties in their travel modeling. We also were to investigate high speed rail, new freeways, airport expansions, and port expansions as they may improve system performance and the economy of the State. Nevertheless, the GHG legislation has begun to affect all agencies in California and so we are now developing an impact model that can project energy use and GHG emissions from land uses in Pecas, as well as in UPlan.

Initial Development of the GHG Model:

First, we are developing a simple GHG model to be run with UPlan. Users can identify any land use categories they wish, when using UPlan. So, in the interface for the Energy and GHG Impacts model, we ask them to define all land uses as Residential High, Medium, or Low Density; Commercial High or Low Density; or Industrial. We then categorize all gridcells in the county by climate zone and utility area, using California Energy Commission (CEC) maps. Next, we define floorspace per household is for each residential land use and floorspace per worker for the non-residential uses. We then apply CEC energy use data to the land uses, according to floorspace for residential and commercial and by number of employees for industrial. These data give energy use by size of dwelling and by sq. ft. for commercial, so land use density and building space consumption per household and worker will affect energy use in residential and commercial uses. We will give default values for each land use type, but the user will be able to enter local data, if they get them from their electric utility and natural gas companies.

Then, we disaggregate the electricity use in buildings into the primary energy types used to generate it, using CEC data on generation mix for each utility. Then, we apply data from Argonne Lab on GHGs per Kwh for each generation type. Direct natural gas (burned in the building) is also converted into GHGs. All GHGs are expressed in metric tonnes of CO2-equivalents, using the standard 100-year atmospheric residence method used by all agencies.

GHG emissions for on-road vehicles will be calculated from the county or regional travel model, by using the California emission model, EMFAC2007, which includes GHGs. We suggest travel models be run correctly, following the guidelines recently adopted by the California Transportation Commission. Travel models should be run to full equilibrium; include transit, walk, and bike modes; have an auto ownership step; and have land use variables in the auto ownership step and in the mode choice equations for transit, walk, and bike. Peak and off-peak time periods should be used, with several trip purposes. Models should be completely documented on the web, peer reviewed, and sensitivity tested. Freight heavy truck models should be used, with large regions going to commodity flow models. Commercial car, van, and light truck trips should be represented.

In our initial model, we exclude agriculture and a few other small sectors. We may add these later, as fixed amounts of energy and GHGs, so that the county emissions in the base year will match the county emissions inventories being developed by the State. Large stationary source emissions from refineries and power plants, will be added, manually. The user interface will allow the user to model local building standards that are stricter than the statewide energy conservation standards, by factoring energy use in buildings downward.

UPlan can be used to increase land use densities, create urban limit lines, mix land uses, and develop high-density nodes around rail transit stations and corridors along BRT lines. A proper travel model will capture the effects on travel of these policies, as well as the effects of improved transit systems, road tolls, parking charges, and fuel taxes. California may adopt a carbon tax, in addition to cap-and-trade limits on GHGs, and these will both increase fuel prices, which can also be represented in a travel model. So, this set of models, UPlan plus an existing travel model, will capture 80-90% of GHG emissions in a county. This simple model set will also allow the user to examine many kinds of transportation policies and land use policies, including building codes.

Application of the GHG Model to Pecas:

Cal-Pecas has nine residential space types ranging up to high-rises, commercial high and low density, and industrial. So, we will adapt the initial GHG model to take into account the greater range of residential building types. We will get energy consumption data disaggregated over the residential types. Then, the GHG model will work as described for UPlan, above.

The Statewide Travel Model represents travel by auto, rail, high speed rail, and airline. We will apply the EMFAC2007 emissions model to these VMT, to get GHGs. The

Statewide Travel Model includes interregional and intraregional trips, including local transit trips. This model does not have an auto ownership step and does not have land use variables in the mode choice equations for transit. It also does not represent walk and bike trips, due to the limited network. We may modify the mode choice model to include land use variables, in the future. Also, we could add an auto ownership step or use the existing CEC household fleet holdings model. The Travel Model has fixed trip tables for heavy freight, but does allow truck or rail mode choice. We may upgrade this to a commodity flows model, based on the dollar flows of goods between sectors and zones in Pecas. This would increase the accuracy and policy sensitivity of goods movement, which creates almost half of the time value on the State's roads.

Since the travel model has already been used to test a variety of high speed rail scenarios, we have several such networks to use in our work. We also can model improved local transit service on existing networks easily and conventional rail service improvements on those interregional networks. Pricing of fuels, roads, and parking can be represented. Urban growth boundaries, higher densities, mixed land uses, and infill nodes and corridors can all be modeled with Pecas, either through changes in zoning maps or through financial incentives to infill and disincentives to sprawl. We have good data on vacant parcels and on underutilized parcels for the whole State, so we can represent infill and demolition/reuse quite accurately. Stronger local building codes or stronger state codes can also be represented in the GHG emissions model. California law now requires all electric utilities to generate at least 20% of their electricity with renewables, such as wind, geothermal, and central solar. Also, utilities must subsidize about 200,000 rooftop photovoltaic systems over the next few years. These changes in electric generation mix can be represented in the GHG emissions model. Downtown parking limitations, such as used in Portland, Oregon, can be input as high parking charges or high terminal access times.

We will also add GHGs as a commodity in Pecas, produced at no cost by the various sectors per dollar of output, according to the State GHG Inventory, and consumed at no cost by households. This will allow us to model the carbon tax and cap-and-trade as a tax on GHGs or a limit on their production, respectively, and their effects on energy use and GHG emissions. The electricity sector is separately represented in Cal-Pecas and so costs to this sector and effects on production will be obtained.

All policies modeled with Pecas and the Statewide Travel Model will affect production costs for employees and households. We can then derive indicators of changes in household welfare (utility) by zone, county, and income class. This also can be done for employees by zone, county, and sector. So, we can do aggregate welfare analysis and also equity analyses of various types. Pecas also gives state product and total exports. These indicators can be used to represent Economic Development, as can total wages.

Conclusions:

This paper illustrates two ways to use land use models, along with travel models, to evaluate the effects of land use and transportation policies on energy use and GHG emissions. A simple land use model that can be applied in a few days can give useful results using standard energy use data, or using local data. A much more-complex economic land use model can perform a similar analysis, but can also calculate the effects of such policies on economic welfare for employees and households and on statewide or regional economic development. The Sacramento MPO and the San Diego region MPO are also developing Pecas models, so these regions will also have the ability to do detailed evaluations of GHG-reduction policies. We will cross-validate our statewide model against these models, for similar policies.

California has decided to transform its whole economy, in order to reduce GHGs by 80% or more in 2050. A tremendous range of policies affecting every aspect of our lives will have to be adopted, to achieve these difficult goals. It is vitally important to be able to model the whole system of land uses and travel and goods movement in the State, so that we can avoid the most-costly policies and seek ones that achieve economic development and equity goals.