Integrated Urban Modeling in Support of Environmental Justice and Sustainable Communities Planning in California

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Abstract
Since the Civil Rights Act of 1964, attention increasingly has been focused on social justice issues, mainly human health and access to services. With the Clinton executive order in 1994, Federal agencies were mandated to avoid disproportionate adverse environmental impacts to minority and low-income populations, in all agency actions, including both plans and projects. Subsequent USDOT rules expanded this order to include all social and economic impacts in transportation planning and project funding. Metropolitan Planning Organizations (MPOs) are the most-relevant agencies, in terms of this type of equity analysis, and generally have not used their existing modeling tools to project plan or project impacts on protected groups in any detail. We will use California as a case study, because a recent State law requires the State's 18 MPOs to adopt Sustainable Communities Strategies to reduce greenhouse gases in their Regional Transportation Plans, starting in 2012. This law requires certain environmental justice analyses and also substantial improvements in MPO modeling capabilities. California's largest four MPOs are developing improved travel models and land use models. We evaluate if these improved models will be capable of evaluating the equity effects of regional plans.

INTRODUCTION

In this paper, we will review the theory and practice of environmental justice (EJ) analysis, Federal and California EJ requirements, and our research on EJ measures. Then, we will review the California law requiring that regional transportation plans include land use and transportation policies to reduce greenhouse gases (GHGs), and the EJ requirements in this law.

The California state travel modeling guidelines will be outlined, as well as the progress made by MPOs in improving their models. This will be followed by a brief review of our model development program for Caltrans, developing statewide land use and travel models. Finally, we review all the EJ indicators required or recommended and determine if the new travel models and land use models coming into use in California can produce these measures.

REQUIREMENTS FOR ENVIRONMENTAL JUSTICE ANALYSIS

Background

Some EJ concepts come from Social Justice theory, a body of work based on religious teachings and now part of Green Party ideology worldwide. Social Justice is based on concepts of human rights and equality and is strongly related to ideas in economic theory of redistribution of income. Indeed, most modern societies rely on taxation and redistribution to foster at least minimum levels of income for all.

The earliest economic theorists, such as Adam Smith, dealt with equity as a part of Utilitarianism, the concept of the greatest good for the greatest number. It is part of the standard canon of classical economic theory that redistribution of income downward in the income ranks leads to increased societal welfare, as the poor have a higher preference for money.

U.S. Federal Law and Guidelines

Environmental Justice examines whether low-income and minority populations are disproportionately denied a fair share of the benefits of public actions, or are subjected to a disproportionate share of the burdens of those actions. Many of the roots of EJ come from the earlier Civil Rights Movement of the 1960s. Much litigation was based on the Equal Protection Clause in the U.S. Constitution, and later, on Title VI of the the Civil Rights Act of 1964, prohibiting discrimination based on race, color or national origin by agency recipients of federal funds. The Act prohibits unintended disparate impacts from policies that are neutral on their face, so intent is not an issue. Neither the Equal Protection clause nor Title VI provide protection from discrimination based on income status. Early EJ lawsuits in the U.S. were to reduce the exposure of low-income and minority communities to toxic waste dumps and other nuisances sited by government agencies.

The Federal Executive Order on Environmental Justice (EO 12898, Feb. 11, 1994) states that all Federal agencies shall achieve environmental justice by "identifying and

addressing" disproportionately high adverse human health or environmental effects on minority and low-income populations. The memorandum accompanying the order specifies that environmental impacts include human health, economic, and social effects.

The USEPA Final Guidance, April 1998, which applies only to USEPA impact statements, defines minority or low-income populations as both contiguous communities and also dispersed individuals that experience the same impacts. So, we can see that the EPA is to evaluate disproportionately high and adverse impacts of all kinds on minority and low-income populations who are affected by the project. Since cumulative impacts must be assessed, an historical study approach is needed for some impacts, such as health. The effects of urban growth are defined as a type of indirect impact and so must be covered. This guidance expands the definition of affected groups to include children and the elderly, HHs in high-density dwellings or high-growth areas, HHs in areas with poor water supplies or in industrial areas, as well as subsistence farmers or fishers. It is useful guidance for determining good practice, even though it does not apply to the MPOs.

The USDOT Order 5610.2 in 1997 described the EJ process for its agencies. In the subsequent FHWA's Actions to Address Environmental Justice (Order 6640.23, Dec. 2, 1998) EO 12898 is interpreted to address not only human health and environmental effects, but also interrelated social and economic effects of programs. Low-income households are defined as below the Federal poverty guidelines. Adverse effects are defined to include noise, air pollution, and displacement of persons, as well as the denial or delay of FHWA funds. Impacts are to be avoided, minimized, or mitigated and offsetting benefits may be considered. EJ issues are to be defined in each region, with a substantial public participation program involving EJ communities. A memorandum from FHWA and FTA of October 7, 1999, Implementing Title VI... says that MPOs are to gain participation from underrepresented groups, and may provide financial assistance to them, if needed.

SAFETEA-LU of 1998 requires that 7 broad planning topics be considered in RTPs, but MPOs cannot be sued if they fail to consider some of these. So, these topics do not serve as performance indicators, or even as consistent indicators, nationally.

It can be seen from this review that EJ started out in Federal regulations as simply pertaining to government agency programs and plans, and it is likely that MPOs originally thought of this as equitable levels of highway and transit service. It is important to note, however, that the USDOT Order widened the scope of EJ to include social and economic effects. MPO practice does not seem to have caught up to this change made in 1998.

In a review of the documents for 50 large MPOs in the U.S. in the early 2000s (Sanchez and Wolf, 2005), it was found that about 25% had produced reports on EJ issues. The authors found that the documents mostly were responses to Civil Rights Act Title VI or to the Presidential executive order. In general "targeted" populations were mapped using GIS, as were proposed transportation improvements, to look for disproportionate impacts,

spatially. Some of the reports included EJ indicators such as access to regional employment, transit access, and auto ownership. Few examined secondary impacts such as unemployment, wages, or regional accessibility. The authors claim that the methods for addressing "social exclusion" in the U.K. involve such broader impact measures, such as access to education and access to transit at off-peak times. Only 15% of MPOs surveyed said they had specific staff assigned to equity issues.

NCHRP Project 8-36(11), Technical Methods to Support Analysis of Environmental Justice Issues (April, 2002) reviewed legal issues and methods of analysis in use by MPOs, local transit agencies, and state DOTs. They then reviewed other methods that could be useful for the analysis of EJ issues in regional plans and in corridor and subarea analyses. Overall, they found that there had been some progress by the MPOs, but the state DOTs were not very far along in developing methods of analysis. The MPOs assessed conditions in the base year, using Census data to indentify HHs by income or minority status. Some MPOs had developed methods for projecting HHs by income, using basic statistical methods, such as regression. As far as modeling in RTPs, the focus of this paper, the MPOs measured accessibility in future years, generally with time thresholds. Some MPOs also measured transit availability with proximity measures. In the RTP process, the MPOs did not attempt to measure degrees of burden on various communities, as that usually happens at the project stage. The emerging methods were GIS and the microsimulation of HHs. It is noteworthy that the two issues that MPOs and state DOTs wanted to address better were: 1. the secondary and cumulative impacts of transportation system investments, and 2. the public health impacts of facilities. In an appendix, ten commonly used EJ indicators are described in detail. Re. data, we note that the CTTP includes O-D flows for minority and mobility limited persons. These data can be used to evaluate EJ in the base year.

From this review, we can see that current Federal law requires the assessment of a broad array of impacts on a great number of interest groups and that the local EJ community must be consulted in defining the actual EJ measures. Also, MPOs and some state DOTs are beginning to develop EJ analysis methods. Even though the USDOT Order requires the analysis of social and economic impacts, MPO practice generally has been confined to the analysis of the relative service levels available to households (HHs), by income class.

Current Practice in California

The L.A. Bus Riders Union settled a lawsuit against the Los Angeles County Metropolitan Transportation Authority in 1996, resulting in a consent decree that required LACMTA to reinstate monthly bus passes and to fund bus service more fully. Although this suit did not involve and MPO, it illustrates the importance of bus services to EJ communities.

The Union claimed that 81% of bus riders were minorities, compared to 48% of rail riders, and that bus system funding was being diverted to building and operating new rail transit projects, which serve mainly middle- and upper-income people. The decree also required the agency to provide new bus routes to connect minority areas to job and

medical sites. In addition, bus service had to be increased on some lines to reduce overcrowding. This decree was based on the Civil Rights Act and expired in 2006. The analysis of the EJ impacts of changes in bus v. rail transit requires that these modes be separately represented in conventional travel models.

The four largest California MPOs performed basic EJ analyses of their most-recent regional transportation plans (RTPs) (SANDAG's 2007 RTP, SCAG's 2008 RTP, SACOG's 2008 RTP, and MTC's 2009 RTP). Three of them did not have a substantive policy stating that the MPO "will" take action to avoid disproportionate impacts, as required by the Civil Rights Act and by the FHWA Order. These four analyses used conventional trip-based travel models, and were confined to traditional noneconomic measures, including threshold-based accessibility estimates, such as the percentage of jobs accessible to HHs within 30 minutes by car, and separately by transit, for each of three or more income groups of households. This measure of accessibility to employment may be useful, but does not describe overall travel costs for HHs or changes in traveler economic welfare, both measures that can be derived from 4-step travel models (Johnston, et al., 2005; Rodier and Johnston, 1997). The accessibility measures miss trips longer than 30 minutes and define trips by low-income HHs as trips from TAZs with some large proportion of such HHs, which misses a large number of such HHs, who reside in other TAZs (half of such HHs, in one analysis). Since none of these MPOs forecast HHs by income, using a housing market model, they assume that these HHs reside in the same TAZs as in the Base Year, determined from the 2000 Census. This is an inaccurate method, for projections of more than 10 years. Some of the MPOs use this same TAZ-based, time-threshold accessibility measure for nonwork trips. Some MPOs used some measures based on percentage of HHs in a TAZ that are minority or either meet an income criterion or a minority criterion. Since projecting HHs by minority status is infeasible at the TAZ level, and since Census minorities are majorities in many regions, we do not discuss those measures here.

None of the MPOs performed an evaluation that includes rent paid, as well as travel costs, for EJ HHs. This is because none of them use an economic land market model to forecast housing costs. It is well known that for low-income HHs, rent can be over half of gross income. It is also accepted in urban economics that most HHs locate based on the combined cost of travel and housing. Some of the MPOs did a pollutant exposure analysis, based on distance from CO and PM concentrations on major corridors, or based on emissions density using emissions data from the California spatial emissions model. Only one MPO did an evaluation of noise impacts, which were very regressive, by income. Some calculate average travel time and average travel distance for worktrips, by HH income class, using the TAZ-based method. Some of the MPOs also used a measure of the proportion of HHs by income within 1/4 mile of a transit stop. None of the MPOs calculated travel costs by including full auto ownership cost in the medium term, which is around $1.00/mile, and use the typical out-of-pocket cost of around 10 cents, which biases the measures substantially for the majority of low-income HHs that use one or more cars. One MPOs did a threshold measure for access to parks. One tried to do an analysis that included taxes paid for transportation, but included personal income taxes, which are not tied to transportation services. Even the local sale taxes devoted to roads

and transit that is paid should not be included, as they are paid by all HHs, regardless of their usage of transit or roads. One MPO included a threshold measure for access to major medical facilities. One did a similar measure for access to retail jobs, with these jobs representing low-skill jobs available to most low-income people.

It should be clear from this description of the EJ measures used in the most-recent RTPs done by the four large MPOs in California that they use a variety of measures and so comparisons across MPOs are difficult to perform. Many of them noted that their measures were somewhat or mostly different from those used in the previous RTP, and so even comparisons of sequential RTPs by the same MPO are difficult or impossible to do. The most outstanding problem with all of these noneconomic methods, however, is simply that none of them give a straightforward measure of how the RTP affects HH monetary travel costs, by HH income class. Time costs are the major component of travel costs, on average, and for all HH income classes. Time costs for the top income class are 5-10 times those for the lowest class, depending on the number of income classes in the mode choice model. This means that time savings are not equal in value across HH groups and so measures of time savings in minutes and measures of jobs accessible within 30 minutes hide this critical impact. The traveler economic benefits measure is quite easy to calculate, for any MPO with a logit mode choice model and so technical feasibility cannot be the impediment here. The source article was published in 1981 (Small and Rosen, 1981). Many of the other measures will be useful for specific analysis of certain problems (pollutant and noise exposure, distance to transit, access to parks, access to major medical facilities), but the time-threshold accessibility measures are inaccurate and biased. In theory, the taxation side of the equation should also be done in an equity analysis of public services, but personal income taxes and local sales taxes tied to transportation improvements are both mandatory for all HHs in the region, and so can't be counted as HH expenditures that depend on the travel behavior of the HH members. Only transit fares and auto ownership and operating costs are controllable by the HH.

Assembly Bill 32, The California Climate Warming Solutions Act

AB 32 (2006) requires all State agencies to reduce greenhouse gases (GHGs) to 1990 levels by 2020. A Governor's executive order requires GHGs to be reduced by 80% by 2050. The Climate Change Scoping Plan was adopted by the State air board in 2008, outlining dozens of actions to be taken by State agencies. AB 32 also requires that State policies to reduce GHGs not disproportionately impact low-income communities.

Senate Bill 375: Redesigning Communities to Reduce GHGs

SB 375 (2008) implements California's overall GHG reduction goals with respect to reducing personal auto travel. Its basic strategy is to coordinate regional transportation planning with local land use and housing planning so as to bring jobs and housing closer to one another, and closer to transit. SB 375 requires that RTPs include "Measures of equity and accessibility, including, but not limited to, percentage of the population served by frequent and reliable public transit, with a breakdown by income bracket, and percentage of all jobs accessible by frequent and reliable public transit service, with a

breakdown by income bracket" (Cal. Govt. Code sec. 65080(b)(1)(E)). These requirements are a very basic subset of the Federal requirements for EJ analysis.

SB 375 requires the 18 MPOs to adopt Sustainable Communities Strategies in their RTPs, starting in 2012. These plans are to include transportation policies and land use policies to reduce on-road GHGs for cars and light trucks, in 2020 and 2035. The Scoping Plan requires that the GHG reduction targets for these sustainability plans be set by the air board to be the "most ambitious achievable."

Under SB 375, the RTP must include a Sustainable Communities Strategy (SCS) and it shall identify residential areas in the region sufficient to house all economic segments of the population over the planning period, and set forth a development pattern and transportation networks that will reduce GHGs from automobiles and light trucks, to achieve the targets set by the State air board (Cal. Govt. Code sec. 65080 (b)(2)(B)). If the SCS cannot meet the GHG reduction target, an Alternative Planning Strategy that does meet the target shall be prepared and may be adopted outside of the RTP. The APS may include different transportation policies and development patterns than the RTP (Cal. Govt. Code sec. 65080 (b)(2)(H)). The alternative development pattern is exempted from the Federal RTP "latest planning assumptions" rule, which states that RTP land use projections must conform to adopted local land use plans.

SB 375 set up an advisory committee to recommend to the air board methods for MPOs to use in devising and evaluating SCSs. This committee recommended that SCSs evaluate housing affordability, jobs/housing fit, transportation affordability, displacement/gentrification, and overall housing supply. The suggested measure for affordable housing planning was percent of affordable housing units within some distance of transit service. Measures of jobs/housing fit are total jobs/housing balance and housing affordability relative to local wages.

For the GHG Target Setting process, the MPOs submitted policy scenarios for 2020 and 2035 in the Spring of 2010 and the air board staff issued suggested GHG reduction targets on June 30 of 2010. There were workshops all over the State in the Summer and Fall of 2010, with the board adopting targets for each region in September. The RTPs must contain Sustainable Communities Strategies to achieve these reduction targets, starting in 2012.

In the Spring of 2010, 14 of the 18 affected MPOs submitted test scenarios for the years 2020 and 2035, using their conventional travel models, with one exception (the Sacramento region agency used a household activity-based travel model). The output data reported for all agencies included vehicle-miles traveled (VMT), on-road GHG emissions for autos and light trucks, and per capita on-road GHG emissions. The MPOs submitted their model outputs in a standard format, as requested by the air board staff. No EJ indicators were calculated in these modeling exercises. Since this phase of modeling was preliminary and intended for the MPOs to show scenarios and GHG outputs in order to argue for GHG reduction targets that they consider feasible for their regions in 2020 and 2035, they focused on the GHG outputs.

The four large MPOs (the Southern California, San Diego, San Francisco Bay Area, and Sacramento regions) and two others did submit information about the budget in their last adopted RTP, as to the percentages going to transit capital, highway capital, transit operations, and highway system operations. These policy input data were considered useful by most participants in the workshops, in terms of determining the effort projected for transit system improvements. Mode shares (all transit modes together) and transit seat-miles were also given, as were lane-miles of roadways by facility type, for 2005, 2020 and 2035.

The four large MPOs also submitted data on regionwide jobs/housing ratios, and the percentages of housing units that are attached and are small-lot single family (relatively affordable housing).

Interest Group Recommendations in California

In a letter to the air board chair on July 20, 2010, over 50 EJ and related interest groups requested that the initial test scenarios submitted by the MPOs in the Spring of 2010 be enhanced to include EJ measures (http://www.climateplanca.org/CARB%20Social%20Equity%20Letter_FINAL.pdf.). These groups requested that the board require the scenarios to evaluate, for minority and low-income groups: Jobs/housing fit (housing affordability by household (HH) income group, near to relevant jobs), housing affordability, housing stress (percent of HH income paid for housing), percent of HHs with access to transit, changes in AQ, and displacement of households. They also asked for the board to request that the MPOs run one or more EJ scenarios, focused on transit provision, better housing supply through more multifamily zoning near to entry-level jobs, and other policies. All of these recommendations and all of those from the advisory committee conform to the Federal requirements. These EJ groups also asked the board to fund model improvements by the MPOs, as conventional trip-based travel models are not capable of producing most of the requested EJ measures.

MODELING TO SATISFY REQUIREMENTS FOR EJ ANALYSIS

Current Practice in the U.K.

Project and plan evaluation rules and practice in the U.K. have been more detailed and have relied more on economic indicators than in the U.S. Recently, their guidance has been expanded to cover distributional issues. In 2006, the U.K. Department for Transport adopted their Accessibility Planning Guidance (http://www.dft.gov.uk/pgr/regional/ltp/accessibility/guidance/gap/). This report recommends a variety of threshold access measures, such as number of jobs accessible by transit for low-income HHs, within a certain travel time. It also recommends a variety of continuous measures, especially those using generalized cost of travel and not just travel times. The report recommends continuous measures, as they include all destinations and all modes. Origin-based measures are those that describe the cost of reaching opportunities (destinations), while destination-based measures describe the ease of accessing facilities and are often used by hospitals, schools, and other major destinations.

A review of accessibility measures can be found in Halden (2009). As noted above, conventional 4-step MPO travel models in the U.S. can produce generalized accessibility measures by HH income group, but such EJ measures are not calculated in practice.

Lucas (2002) describes the U.K. approach as comprehensive (across all departments of government) and as focused on defining those neighborhoods (often areas of public housing) that have poor transit access and few if any services. The national department of the environment and transport committed to improving access to these areas in a 1998 policy. Women, children, and the elderly are generally included in these evaluations, as well as lower-income households. Research began to focus more closely on the role of transportation accessibility in the late 90s. It was found that poor transit inhibited job seekers from finding work, college students from attending college, and lower-income HHs from getting to hospitals. Many HHs had difficulty getting to supermarkets and to visit friends. Causes of these access problems were found to include: low incomes, lack of auto ownership, and low density developments with poor transit. The consolidation of hospitals and supermarkets into fewer, larger units has worsened access problems. It was found that women, living longer than men on average, had greater access problems, beyond the car driving years. Transit services have declined in the U.K. as average incomes have risen, further isolating poor HHs. Deregulation has allowed the private transit providers to consolidate bus lines into fewer higher patronage corridors. In addition, bus fares have risen far faster than has the cost of auto driving. Lucas' findings are very useful in guiding our thinking about EJ issues in the U.S., where the actual legal requirements are just as broad.

Model Features Needed

To detect disproportionate impacts on the protected groups, one must evaluate the relevant impacts on all population groups, by income, race/ethnicity, age, and other characteristics of interest. Current practice in the U.S. is to examine trips originating in minority and low-income zones, using base year Census data, which are not accurate for future years. These trip lengths and accessibility levels are then compared to trips from all other origin zones. It would be much more accurate to use an economic or demographic model to forecast HH characteristics and individual trips for all such HHs. This will require the microsimulation of HHs, which could be done with an activity-based travel model, or with integrated (economic/land use and travel) models, both using microsimulation of HHs. The Statewide economic/land use model being developed in California will project HHs by income and size, but other characteristics could also be forecast, such as race/ethnicity and age of HH members. Race and ethnicity of HHs are more difficult to project than are income and size, which interact strongly with the housing stock, which is slow to change. The four large MPOs are also developing similar economic/land use models.

Contiguous low-income or minority populations may be defined by Census block groups or tracts, but typical travel model zones would be quite large for identifying dispersed members of these groups. Using individual HHs in a microsimulation model system would be more accurate. Populations in industrial areas can be easily defined, as can those with poor water supply in California, where we have drinking water data.

Subsistence farmers, fishers, etc. would be impossible to find unless an economic/land use model with all occupations represented was used, and these occupations were separated out. The economic/land use models being developed could do this.

Transit accessibility, overall (multimodal) accessibility, and travel costs by HH income group can be evaluated with most 4-step and 5-step travel models, but only for a few HH income and size groups. Housing supply, rents, affordability, jobs/housing balance, and jobs/housing fit cannot be measured with travel models and require economic/land use models that represent floorspace explicitly and also match HHs by income to housing by rent and also match workers by HH income to employment by type. Displacement of HHs also can be projected with these models.

Human health and economic impacts must be projected, according to Federal law. Only the economic/land use models can project wages, rents, and travel costs and give a measure of change in HH economic welfare, the summary measure. Human health impacts, as related to land use and transportation planning could be limited to exposure to roadway noise and to localized on-road air pollutants. This can be done by examining HHs near to freeways and major arterials, by low-income and minority status, using GIS, but future projections will be inaccurate. Pollution from factories and other facilities that emit air pollutants, likewise would require an economic/land use model that explicitly projects floorspace by economic activity type.

Accessibility to workplaces, colleges, and hospitals could be projected with a conventional travel model, but here the problem is the arbitrary linking of trip origins and destinations in this type of model. Workers in HHs are not linked to appropriate employment by type in such models, so the calculations would be inaccurate. In an integrated model set with an economic/land use model and a travel model, workers are linked to appropriate jobs by HH income and job skill level, based on the CTPP data on employment occupation type and location and worker income and residential location. This remark assumes one wants to measure accessibility to the actual jobs chosen by the workers in the model (actual equity). On the other hand, one might want to measure access to all employment (equity potential, or opportunity). This can be done with a conventional 4-step travel model, with or without a land use model. The integrated type of model set will be more accurate, however, as the land uses adapt over time, as accessibility changes, giving a more-realistic land use (economic activity) pattern. Modeling access to friends for social visits will be very difficult with any model.

Modeling aggregate accessibility for HHs by income and size can be done with composite cost in 4-step travel models. Or it can be done for worktrips and for nonwork trips, separately. The relative service levels of bus service and rail transit service can be projected with any travel model that has these modes explicitly represented. If the purpose of this evaluation, however, is to project changes in access by HH income group, accessibility for HHs by income would be a better measure.

So, we can see that a few EJ measures can be produced by existing 4-step travel models and more measures can be produced by activity-based travel models. The remaining EJ indicators, however, require an economic/land use model, in order to be calculated.

California Travel Modeling and Land Use Modeling Guidelines

In response to a State legislative leader's request, the RTP modeling guidelines administered by the California Transportation Commission were updated in 2007, to improve the accuracy of travel modeling, in terms of projecting on-road GHGs. SB 375 required these guidelines to be updated again and a new version was adopted in April of 2010. These are probably the most-detailed modeling guidelines ever adopted by a state in the U.S. (http://www.catc.ca.gov/programs/rtp/2010_RTP_Guidelines.pdf).

The Social Equity and Environmental Justice section states: Social equity factors relevant to RTP development include, but are not limited to, housing and transportation affordability, access to transportation, displacement and gentrification, and jobs/housing fit. Most of these require an economic/land use model. The Modeling section recommends analysis capabilities for travel models and land use models appropriate to five groups of MPOs, depending on their growth rates, AQ nonattaiment, and potential for transit service. All MPOs are urged to have a continuous program for model improvements and to document all models in detail. It is worth reviewing these modeling requirements, as they are critical to better EJ evaluations, and so are useful in all states and regions in the U.S.

Rural counties with little growth do not need network based travel models, while those with moderate growth should have 3-step travel models (no mode choice step) and use post-processing to account for the effects of land use and other policies on travel.

In regions with moderate growth and nonattainment AQ, or the potential for significant transit, 4-step travel models should be used, including a basic freight model, all run for peak and off-peak periods. Simple, GIS-based land use models are also recommended in the short term. In the longer term, economic/land use models should be implemented. Output measures should include effects on lower-income households, including traveler economic welfare measures or travel costs.

Regions that are nonattainment and over 200,000 population should do the above plus use 4-step travel models that are sensitive to travel times and costs. An auto ownership step should be added and be sensitive to land use variables. The mode choice equations for non-auto modes and the trip generation step should also be sensitive to land use variables and to transit accessibility. The walk and bike modes should be explicit. Freight models are recommended for the short term and commodity flows models within a few years. Outputs should include the above plus traveler economic welfare, jobs/housing fit, and combined housing and travel costs, all for households by income group.

The largest MPOs with established transit systems are urged to develop activity-based travel models and economic/land use models and to closely integrate the models and run them through time together. Commodity flows models that include truck and van tours

should be used, as soon as possible. The microsimulation of households is recommended, also (all HHs represented individually). Policy evaluation capabilities should include the analysis of time-of-day tolls, cordon charges, and many other measures, using an activity-based travel model. Transit crowding should be explictly modeled.

All modeling for all MPOs, to the extent feasible, should include the "co-benefits" of GHG reductions, which include improved AQ, congestion relief, increased production and productivity, lower travel costs, lower housing costs, less water pollution, less open space converted to urban uses, and improved human health. It is recommended that MPO modeling, county modeling, and Caltrans district modeling be done using consistent models. Under the California Environmental Quality Act (CEQA) the RTP impact report should use the same model set for the No Action, Proposed Plan, and Environmentally Preferable alternatives. All MPO models should be peer reviewed. Model validation and sensitivity testing is spelled out in detail. Growth inducing impacts of RTPs must be assessed under CEQA. MPOs are encouraged to use visioning tools to portray EJ and other impacts.

Now that we have reviewed desireable model traits for EJ projections and the new California modeling guidelines, we can see that the model improvements recommended will greatly improve EJ analysis by the large MPOs. Let us now outline the model improvements being made by the four large MPOs and by Caltrans.

MODELING EJ IN CALIFORNIA

The New Generation of Travel Models

The four large MPOs are all developing activity-based travel models, which reduce geographic aggregation error by defining origins and destinations by street address and reduce temporal error by projecting tripmaking by time of day. These models are sensitive to land use, as destinations are parcel-specific and the travel tours are affected by the actual land uses. Such models permit the evaluation of road tolls and area cordons, with different fees by time of day and vehicle type. They also use a 100% synthetic sample of households (HHs) with any characteristics that exist in the Census PUMS data on which the sampling is based. This complexity allows HHs and individuals to be defined by race/ethnicity and income. With these HH characteristics in future years, one can perform classic EJ analysis for minority and lower-income HHs, in terms of travel costs.

All four large MPOs are also developing PECAS economic/land use models. This model framework also uses a 100% sample for households and employees and so permits detailed equity analyses for many household and individual characteristics. Since this model represents all floorspace explicitly, along with rents and incomes, one can perform housing affordability analysis (rent/income) calculations. Because workers in households are matched to job types by HH income, based on PUMS and CTTP data, one can get the jobs/housing fit measure, which is jobs/housing balance by HH income group and corresponding housing rent levels. PECAS models contain the full input-output table (all

exchanges of goods and services) for the region and so one can also derive indicators for change in household locator welfare, by income and race. This measure aggregates changes in travel costs, housing rent, and all other inputs to households as producers. Since this measure captures changes in travel costs and household rents, it covers most of the costs affected by the SB 375 land use and transportation policies.

Some of the 8 San Joaquin Valley (medium sized) MPOs are upgrading their 3-step travel models to 4-step models, which will be more accurate and also more sensitive to many policies, such as transit and land use measures. They are also developing a regionwide travel model, which will be more accurate in representing inter-county travel. These models all will represent high speed rail impacts more accurately. These 8 counties, all use simple, non-economic land use models, and so will not be able to evaluate housing affordability and fit. However, we believe that the statewide PECAS model and travel model being developed by the authors also could be used together to represent land use policies, transit policies, and high speed rail adequately, for this multi-county region.

The smaller SB 375 MPOs have mostly 3-step travel models and use simple, GIS-based land use models that are not market based. So, these travel models are not adequate for representing transit improvements and these land use models will not give housing costs or household welfare measures. One can compute changes in travel costs with a 3-step travel model, for all households together, or for low-income origin zones, though. The smaller counties' models are not adequate to represent transit improvements or pricing of roads or parking. The MPO self-assessment of modeling capabilities for SB 375 is here: http://www.arb.ca.gov/cc/sb375/rtac/report/092909/finalreport.pdf

None of the MPO models is considered adequate to model the effects of interregional travel, such as air travel, conventional rail, and high speed rail, due to not capturing the whole system. The statewide travel model will be used to model changes in these systems and the results passed down to the MPO models, to be used as external highway and transit trips. Likewise, the statewide travel model will be used to project freight modes, routes, and link volumes and these data will be passed to the MPOs.

New Economic/Land Use Models

Our research group has been applying integrated urban models on the Sacramento region since 1998 (Hunt et al., 2000; Johnston and de la Barra, 2000; Johnston et al., 2005). In 2006, we evaluated advanced integrated urban models for Caltrans and the major MPOs and it was decided to recommend the PECAS economic/land use model for use by the large MPOs. In addition, Caltrans decided to develop a statewide model. There are advantages to Caltrans and the four big MPOs all developing and operating the same model framework. There is the obvious advantage of MPO and Caltrans staff sharing data sources and programming ideas. Critically, it will be much easier for the air board staff to learn one model, instead of four, in their evaluations of the SB 375 modeling to be done by the big four MPOs. Last, some of the MPOs started their regional PECAS models by running their portion of the statewide model, to learn how it works, and then changed zones, activities, HH types, commodities, etc. to suit their needs.

In non-spatial input-output models, which are used in most developed countries the input -output table (or social accounting matrix) contains data on all production, intermediate consumption, and final consumption of goods and services. Dollars flow one way in the table and goods and services flow in the opposite direction. Taxes, transfers, and savings are also accounted for. With a social accounting matrix, as long as households are disaggregated into several categories by income, equity analysis can be done. This type of equity analysis is called vertical equity analysis (by HH income group).

In a previous paper (Johnston, 2008), we developed a theory of personal goodness from the stated well-being literature and then applied it to discuss the expected outputs from our statewide land use and travel models that are under development. The authors believe that our economic/land use model, PECAS, is the first spatial economic urban growth model that will give a theoretically valid measure of household, county, region, and state economic welfare for all locators (HHs and employees), as it is based on proven computable general equilibrium model structures, but with more zones and with floorspace made explicit. All supply and demand for goods and services is based on bidding with firms minimizing costs and households maximizing utility.

The model bidding is based on random utility theory, which permits the representation of heterogeneous goods and actors with heterogeneous tastes, with prices for goods varying by zone. Also, in PECAS the implementation of discrete choice theory using logit equations permits partial utility to be represented, which is useful in welfare analysis of alternative goods and locations. For a statistical discussion, see Abraham and Hunt (2005).

The PECAS model will give several outputs representing economic welfare for firms by sector and households by size and income, as well as housing rents and housing affordability for households by income class. PECAS will also give macroeconomic indicators such as product by county, region, and state, and exports for these geographic units. It will also produce indicators concerning changes in natural resources, such as amount of land converted from agriculture and grazing, or from various habitat types, to urban and suburban development. Other environmental impact measures will include energy use in buildings and resultant GHGs. We will also produce basic measures of water quality at various watershed levels.

The statewide travel model will produce typical measures of transportation system performance such as VMT (vehicle-miles of travel), person-hours of delay, mode shares for air, auto, bus, rail, and high speed rail, and roadway LOS (level of service). The California air board's on-road vehicle emissions model (EMFAC2007) will give levels of pollutant emissions, as well as energy use. This emissions model also gives the output of 6 GHGs, in CO2-equivalents.

In our earlier paper (Johnston, 2008), we argued for State agencies to use the regional and statewide macroeconomic indicators and the microeconomic welfare measures, for all HHs and employees, as indicators of economic efficiency and economic growth. We then argued that, to use model indicators for actual decisionmaking, all indicators should

be exhaustive and mutually exclusive in their definitions. So, we proposed that all indicators be aggregated into either Social, Economic, and Environmental categories and perhaps monetize the Environmental impacts, which would then result in the minimum categories of Economic (Efficiency) and Social Equity. These are the minimum and incommensurable categories of value. All of the subcategories of indicators would be kept available for analysis, but all indicators would be aggregated into the top two or three categories, for tradeoff analysis. Strong sustainability, for example, requires that Social, Economic, and Environment conditions all stay the same or improve and so the three category system would work well for this type of analysis. Double-counting must be avoided, for the values that aggregate to the top 2 or 3 categories.

The distribution of HH income is an essential equity measure. The work of Easterlin (2003; 2005) has shown that there is a zero or very low marginal utility of additional income for HHs, above middle-income levels in the U.S. and in other countries. This finding comports with arguments by early utilitarian economists in the U.K. who advocated progressive taxation to redistribute income to HHs with a higher utility for money. Easterlin also found that higher education and better health were highly correlated with expressed happiness. These conditions are both highly correlated with income, up to middle incomes and so reinforce his basic findings. These findings also show the importance of affordable housing and transit services for lower-income households, in the context of SB 375 planning. We also note that real hourly wages for workers in California have fallen for over 30 years, for the bottom three quintiles of income. California, like the U.S., has an increasing equity problem.

The authors believe that the most-useful measure of equity is change in HH economic welfare, by income and location, as this is the most-comprehensive representation of economic changes for HHs. Measuring equity in this way will capture vertical (income) equity and also spatial equity, so important when analyzing land use and transportation policies. Other equity measures will include change in product by economic sector, by county and region, to show how firms are affected, by sector and location. High speed rail, for example, may have large effects on productivity, worker location, and growth in some sectors, as firms re-sort spatially, due to the resulting larger labor markets. The Oregon Bridges study (Weidner, 2005) projected considerable change in product for some sectors and counties, due to widespread bridge closures during a statewide repair program. Recent studies in the U.K. have found that changes in accessibility can change agglomeration economies and productivity in some sectors (Feldman, et al., 2008).

Specialized, narrower measures will be developed for interest groups and State agencies that are interested in particular issues, or wish to see effects within the urban system in more detail. These measures will also be useful for model calibration and for validation in scenario testing. Rent levels for HHs and for employees will be evaluated in calibration and validation, for example. Housing affordability by zone by HH income class will be useful for housing analysts. Change in travel costs for HHs will be similarly useful for transportation agencies and groups. Accessibility to employment centers for lower-income HHs can also be calculated, but we believe that the locator economic welfare measure is more useful.

The SB 375 measure of percent of population by income served by frequent transit can be measured by percent of HHs within some distance of a transit stop. This is an opportunity measure, not one of actual transit use in the model. Percentage of jobs served by frequent transit could also be measured with a distance ring, and this would be an opportunity measure. Since we really care about access to the appropriate jobs for each HH income group, it would be better to measure actual projected worktrip costs for HHs by income class, using the PECAS economic/land use model, along with a compatible travel model.

All of the housing measures recommended by the advisory committee can only be derived from the PECAS class of models. The housing affordability, jobs/housing balance, and jobs/housing fit measures requested by the EJ groups can also only be calculated only with these economic/land use models. Again, we suggest that the overall measure, change in HH economic welfare also be used, as a summary measure. The more-specific measures can be used to analyze why the overall welfare measure changes up or down, over time, and across scenarios. Accessibilities to workplaces, colleges and hospitals are provided by PECAS. The linkages to labor markets by occupation are also indicated, providing a much more complete representation of access to work for each household category.

Other EJ measures that are inputs, not model outputs, include percent of MPO budget devoted to transit capital and operations, which can be calculated independently of models being used. Percent of residential zoning that is multifamily and its location near to employment centers can be mapped.

Last, it is important to emphasize that it is the breadth of alternative policy scenarios identified and evaluated that will actually enable decisionmakers and the public to select an RTP that maximizes the reduction of GHGs while also maximizing EJ outcomes, such as discussed above. In the Target Setting scenarios offered by the California MPOs in May and June of 2010, none of those recommended as feasible included workplace parking pricing or other strong pricing measures to reduce VMT and GHGs. No scenarios were examined that removed freeway widenings from the previous RTP. So, there generally has been a reluctance on the part of these MPOs, so far, to study scenarios where the primary focus is improving transit and letting highways become congested in order to increase transit ridership. It is very likely that such congestion is necessary to get transit system ridership up, which then starts the "virtuous cycle" of more transit improvements, more riders, etc. This is the transportation planning procedure in the London region, for example.

As far as portrayal goes, the MPOs should produce a variety of graphics and see what works best in workshops, especially with EJ groups. Maps and graphs, 3D cityscapes, Day in the Life stories, etc. can all be tried. We have not discussed the EJ participation requirements in law, but they are quite strong.

Even more important, and closely linked to impact portrayal, is the basic issue of which EJ impacts make the most sense to the relevant decisionmakers and EJ groups. There are some impacts, such as Change in HH Economic Welfare, that will be somewhat difficult to explain ("think of it as change in HH income...") and others that are more straightforward. Some indicators are broad and difficult to define, and some are narrow and easier to understand, but explain fewer behaviors. These indicators will have to be developed and portrayed in various ways and tried out in workshops. With the four large MPOs and the several medium-sized ones in the San Joaquin Valley all doing this, we are sure to learn a lot from these different publics.

Since there is very little experience with EJ indicators, the California MPOs will be able to lead the nation on this improvement in RTP procedures. SB 375 will help to push this plan evaluation work along, even though it has been required for many years.

Overall, then, it appears that the models being developed for regional use by the largest MPOs and by Caltrans for statewide use, will be capable of performing all EJ analyses required by Federal and State law and also those recommended by interest groups and researchers. On the other hand, it is clear that conventional trip-based travel models are not capable of such evaluations. This finding indicates that all large MPOs in the U.S. should upgrade their models, as outlined here, in order to perform better EJ analyses. Both activity-based travel models and PECAS economic/land use models are expensive to develop and difficult to operate. Activity-based travel models are being developed by many MPOs outside of California. Many MPOs also are gaining experience with simpler land use models and may be willing to adopt the PECAS system, if the California experience is successful.

CONCLUSIONS

The ambitious EJ measures required in Federal law and in California law, and those recommended by interest groups and scholars all can be implemented with the advanced travel models and land use models currently under development by the four large MPOs in California and by Caltrans for statewide use. Taken together, the EJ measures require the analysis of housing markets, as well as travel markets, to evaluate changes in costs for various types of HHs. Only activity-based travel models and economic/land use models, both with microsimulation of HHs, can represent these interrelated markets and produce the necessary indicators. The 8 medium-sized MPOs in the San Joaquin Valley can perform the required analyses using the statewide model set currently under development. These 12 MPOs together contain about 90% of California's population. The smaller MPOs falling under SB 375 will be limited to calculating traveler welfare, if they have a mode choice model, or travel costs, if they have simple 3-step travel models. They also could perform some types of threshold accessibility evaluations, such as number of jobs within 20 minutes by car and 40 minutes by transit for low-income HH origin zones.

These conclusions also apply to all MPOs and states in the U.S. and to such regional and national agencies in other countries. Conventional travel models are very limited in terms of the EJ measures they can produce.

When activity-based travel models are run along with economic/land use models, the problem then becomes one of plenty. Agencies will be able to produce many EJ measures and discussions will center on which measures are the best ones to use. This is a rather good kind of problem, of course, and can be worked out best with the EJ community in each region.

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