Indicators for Sustainable Transportation Planning

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ABSTRACT

Worldwide, there is an ongoing debate about what indicators to use, in order for policymakers to evaluate progress toward sustainable transportation systems. In general, indicators studies lack an overall normative framework that allows decisionmakers or the public to make sense of the many overlapping and partial measures. A statewide urban growth model for California will be run in iteration with the California statewide travel model to evaluate major transportation scenarios, such as freeway widenings and high speed rail. In addition, we will evaluate transport and land use policies intended to provide for more-affordable housing accessible to jobs, widespread habitat protection, and strong reductions in greenhouse gases. This model provides many performance measures for travel, economic welfare and equity, rents paid, energy use, greenhouse gas emissions, vehicular air pollution, and habitat loss. We propose a framework for interpreting these data, based on recent advances in the theories of well-being for persons and for nations. This theory framework for evaluating model outputs used in planning applies as well to the analysis of empirical indicators, used to track actual outcomes.

BACKGROUND

Research teams from the University of California, Davis and the University of Calgary are developing an integrated urban model of California during 2006-09. The PECAS model will go through three stages of development, a Set-Up Model in the first 18 months, which will be taken to likely agency users for comments, then a Demonstration Model with better data and reasonable calibration for futher agency comments in 2009. If the model set is validated, the Working Model will then be developed. The PECAS land use model will be run in iteration with the Caltrans statewide travel model. The primary purposes for developing this integrated model set for Caltrans headquarters and district staff are to capture more of the feedbacks within the economy driven by changes in transportation systems, such as induced travel and consequent land development, and to represent the economic effects of policies.

We believe that PECAS is the first spatial economic urban model, using zones and a network-based travel model, to give a theoretically valid measure of regional and statewide utility for locators. For a discussion of how PECAS differs from its progenitor model, MEPLAN, see Abraham and Hunt (2002) and Abraham and Hunt (in press). PECAS combines concepts from traditional Walrasian (general equilibrium) economics with random utility theory. Random utility theory permits the representation of heterogeneous goods and actors with heterogeneous tastes, with prices for goods varying by zone. Also, 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. This model structure gives utility measures for households and for firms, both as producers and as consumers. The statistical discussion of the consistency of the model set with random utility theory is given in Abraham and Hunt (2005).

The California travel model will produce typical measures of transportation system performance such as VMT (vehicle-miles of travel), PHD (person-hours of delay), mode shares, and roadway LOS (level-of-service). The California on-road vehicle emissions model will give levels of pollutant emissions, as well as energy use and greenhouse gases. The PECAS model will give a broad array of outputs representing economic utility for firms by sector, households by income, housing rents, housing affordability for households by income class, and economic development (State product, wages, exports). It will also produce measures concerning changes in natural resources, such as amount of land converted from croplands and grazing lands or from various habitat types to urban and suburban development. Related environmental impact measures will include energy use in buildings and resultant greenhouse gases. We will also produce basic measures of nonpoint water pollution (urban runoff) at various watershed levels.

A model set with such a comprehensive set of indicators raises interesting issues of how to manage such a large set of outputs so as to be useful for public policy analysis. Single-purpose State and Federal agencies will probably concern themselves mainly with measures that relate to the issues within their jurisdiction. So, the State housing agency will be interested in housing affordability, while Caltrans headquarters and districts will be chiefly concerned with delay, congestion, and pollutant emissions. The State energy agency must report on the cost-effectiveness of transportation scenarios and on energy use and so will be interested in the economic cost and utility measures and energy use and greenhouse gas emissions. State and Federal natural resources agencies will likely be focused on air pollutant emissions, habitat conversion, erosion potential of developed lands, and water quality. In 2006, the California Climate Warming Act was adopted, which requires the reduction of greenhouse gases by about 30% in 2020. A related Governor's Executive Order requires a reduction in 2050 on 80%, in accord with the recommendations of recent international studies. Many State agencies are now implementing this statute, which will reach into every aspect of California's economy.

We hope that Caltrans Headquarters, the Governor, Legislature, State Department of Finance, and Department of Economic Development will be interested in our broader projections of overall economic growth and of economic welfare (utility) for counties and the State. In the U.S., the use of economic welfare measures is not common among MPOs and state DOTs. Such measures are in fairly widespread use in EC nations. We have demonstrated the use of a traveler welfare measure (compensating variation) when using a travel model (Johnston and Rodier, 1998; Rodier and Johnston, 1998) and in using an urban model (Johnston et al., 2001). The problem with this measure, which is similar to consumer surplus, is that it does not capture changes in locator surplus for the households and firms. This omission could result in misleading conclusions. For example, if a radial freeway were widened, a traveler could pay increased travel costs to travel farther out to a larger parcel and home. She would experience higher utility as a locator, but pay higher costs as a traveler, so the traveler welfare measure would be negative. The PECAS model gives both producer and consumer surplus measures for locators (households and firms), which is inclusive of changes in travel and goods movement costs, and so this measure captures almost half of the urban economy.

Virtually all of the effects of changes in transportation systems can be captured by PECAS, except for social effects such as loss of community.

Why a Comprehensive Method of Modeling Impacts is Needed

Most transportation planning and project evaluation exercises use lists of indicators, as required by state and federal law. These systems are generally incoherent, that is, the list of indicators is incomplete and overlapping. It is not enough to have lists of indicators, whether empirical (historical) or modeled. Public groups and decisionmakers will tend to emphasize the measures related to those issues they favor. This leads to a lack of rigor in discussions of the impacts of policies. We need some normative framework that allows us to aggregate indicators, or at least to place certain ones at a higher level in the analysis.

A recent example of the list approach to sustainable transportation indicators is the draft paper of the TRB Sustainable Transportation Indicators subcommittee ADD40 [1] (Litman, 2007). In this paper, 21 indicators are chosen to represent economic, environmental, and social issues. These indicators do not cover all impact types, overlap, and mix outcomes (impacts on the world) with transportation performance measures. This problem of lack of theoretical framework may be illustrated by the treatment of VMT, where it is said that whether more VMT is good or bad is uncertain. VMT is not an impact on society, it is just an attribute of the users of the transport system, who are not explictly seeking more or less VMT, per se. This specific difficulty points to the larger problem of the lack of an overall theory of well-being. Another difficulty is the adoption of a priori criteria in this paper where it asserts that transport should be safe, fair, and efficient. These criteria overlap and are incomplete. There is no objective way of deciding among alternative policies when the indicators are incomplete and overlapping. This paper represents a large literature on indicators, where similar methods are used. Most agencies, indeed, use such evaluation lists. For a recent discussion of sustainable transportation indictators and of several organization schemes for indicators, see Ralph Hall's dissertation at http://esd.mit.edu/people/dissertations/hall_ralph.pdf

From our past work on environmental impact assessment and on multi-objective planning (Johnston, 1975; Johnston, 1977), we believe that, in general for policy evaluation, outputs should be kept in their natural units and presented in tables under the general headings of Economic, Environmental, and Social. The first category includes monetized effects, environmental measures are for changes to natural systems, and social outputs include mainly equity measures. These impacts can then be summarized in graphical and narrative fashion to enable the evaluation of tradeoffs across the three mutually exclusive categories. This overall set of accounts conforms with generally accepted theories of democratic decisionmaking, where indicators are all kept in the open and tradeoffs are highlighted, not minimized. This three-part system also gives equity a top-level listing, which is in accordance with methods now used in evaluating sustainable development, worldwide. We strongly resist weighting and summing, or other transformations, of the indicators, as this often, in practice, hides value judgements.

The decisionmaker, then, is faced with making the tradeoffs among the types of impacts. In the past, elected officials often have tended to approve grab bags of policies, in order to please most interest groups and to spread benefits around geographically. For example, MPOs in the U.S. have only slowly moved toward putting higher percentages of capital funds into transit, even though it has been generally accepted for some time that fuel prices will rise rapidly in the first decades of the 21st century. MPO boards, in my opinion, have continued to fund roadway expansions, in part because these expenditures can be spread around all of the counties in a region, whereas transit improvements tend to occur in the urban counties in the center of the region. Also, decisionmakers, even if they care about economic growth or economic welfare in their region or state, have not had the tools with which to project these measures. In practice, they have assumed that increasing road capacity will reduce costs for firms and increase economic growth. We hope that this model set will assist decisionmakers in evaluating broader arrays of scenarios for the State and its regions, based on a more formal analysis and a set of fairly complete and non-overlapping indicators. We also think it is critical to use a coherent model, or related set of models, to project the indicator outputs. Only in this way, can one be assured of conceptual consistency and accuracy. A model can fix the relationships among the indicators, so that they are determined by the same theory.

A previous modeling exercise that used comprehensive models similar to what we are attempting in California is the PROPOLIS program in the EC (PROPOLIS, 2004). This research program implemented three urban models on seven urban regions in Europe and developed a complex set of indicators and database and viewing software for portraying these outputs. The measures were depicted in maps, bar graphs, tables, and other graphics without much aggregation. Overall, this effort advanced urban and transportation modeling greatly. No regional economic growth or productivity measures were developed and no locator utility measures were used, though. Also, no overall theory of goodness was used and so one is faced with long lists of indicators for each policy measure.

A recent study in the U.K. (Simmonds, et al., 2006) used land use and travel models and pioneered the comprehensive evaluation of macro and micro economic effects of transport schemes, including changes in regional product, locator welfare, agglomeration economies, and productivity changes due to jobs movement. Transport agencies in the U.K. are now required to model these indirect economic effects when evaluating plans and large projects. This was an initial methodological study of a small urban region and some data were approximated and some calculations simplified. The authors found that the agglomeration effects were larger than the direct welfare effects for some of the studied policies. They studied road improvements, transit improvements, and road tolls. The authors did not examine environmental impacts or equity effects. The PECAS model captures agglomeration economies and other productivity changes and so our work should be comparable to this groundbreaking study, but more-inclusive in indicators used.

Recently, two useful theories of well-being have been put forward by economists that help in conceptualizing changes in personal welfare and in national (state) welfare. First, let us review the research on personal well-being.

A THEORY OF PERSONAL WELL-BEING

Easterlin has shown that there is zero marginal utility of income, above middle-income levels for each household size, in both inter-country comparisons and in interpersonal comparisons in the U.S. (2005). Utility here is measured by stated well-being in surveys. The range of incomes in the cross-country survey of 14 nations was 700% and the range in the U.S. data was about 300% ($10,000-$30,000 in 1994 $, 29 years of annual data). These studies used time-series data from age cohorts to eliminate cohort bias. His findings contrast with those from previous bi-variate cross-sectional studies which found increasing utility, but diminishing marginal utility of income. Easterlin's findings do not apply within the lower-income range in the U.S. and in other countries, where we expect utility to rise with income.

In an earlier paper, Easterlin (2003) reached the same conclusion regarding income, using U.S. data. As income rises within age cohorts, expectations also rise and the marginal utility of added income is zero. However, he found that changes in life events can have lasting effects on stated well-being. Married people are happier than unmarried, separated, and divorced people and people in good health are happier than persons with poor health and these changes in well-being do not diminish over time. Also, people with higher education levels are consistently happier. Easterlin concludes that "happiness would be increased by greater attention to family life and health rather than economic gain" (p. 21).

This pathbreaking work by Easterlin gives us a useful concept for examining economic growth in using our California PECAS model. We do represent the health and education sectors in the model set and can use changes in their products as indicators of the effects of various levels of spending on transportation improvements on health and education levels in California.

More specifically for this model set, however, Easterlin's work gives us a valuable framework in which to consider the equity effects of transportation investments and of land use policies. For example, our past work has shown that heavy investments in transit can benefit lower-income households, using a traveler surplus measure (Johnston et al., 2001). Easterlin's work provides evidence that such redistributive transportation policies would increase total (stated) societal well-being, if the extra tax burden fell on high-income households. This idea actually comes from the beginnings of economics in the 19th century, where many utilitarians believed in redistributive policies. We also intend to test land use policies intended to increase the amount of affordable housing and to spread it into formerly exclusionary suburbs. We have also shown that peak-period tolls increase total regional traveler welfare, but hurt lower-income households. But, by also increasing transit coverage and service, we found that we could increase the economic welfare of all household income classes (Johnston et al., 2001). So, we intend to use PECAS to investigate peak-period tolls, transit investment, and inclusionary zoning in various combinations to see the economic welfare effects on households and firms, using the locator surplus measure. The other economic impacts will also be evaluated in these equity scenarios to see the tradeoffs.

A THEORY OF NATIONAL WELL-BEING

Societies are becoming increasingly concerned with sustainable development, especially as certain natural resources become degraded or depleted. "Weak sustainability" is defined as not reducing the total assets of a nation that are bequeathed to future generations. This definition allows substitution among categories of assets so, for example, losses of natural assets can be substituted for with additions of human assets or manufactured assets. This is a risky and morally fraught strategy. "Strong sustainability" is defined as all three classes of assets must be maintained or increased, inter-generationally. Whichever definition one chooses for policymaking purposes, we still must be able to measure a nation's (or, in our case, a state's) assets comprehensively.

Resource economists and others have developed a useful concept for the more-accurate accounting of national well-being. Dasgupta (2003) maintains that measuring increases in national well-being with GNP is incorrect, because it omits changes in the value of assets, which affect product. Also, assets (wealth) is a more-important indicator of the future well-being of a nation. He then says that assets are composed of manufactured capital (roads, buildings, etc.), human capital, and natural capital (oil, natural gas, minerals, fisheries, forests, soil, water, air, ecosystems). He then argues that free markets can damage common resources (natural capital) because of lack of ownership and lack of exclusion. Natural capital has only recently been accounted for and, specifically, the World Bank has been asked to include it in their reports. He then discusses a paper by Hamilton and Clemens (1999) on what he calls Genuine Investment (changes in assets), including changes in natural capital. Only commercial forests, oil and minerals, and greenhouse gas emissions were included in the analysis. Water resources, fisheries, air and water pollution, soil, and biodiversity were excluded, most of which are in negative growth in most nations. He then cites their data for growth rates of GNP per capita and of Genuine Wealth per capita for several poor counties and shows that some, such as India, have positive growth in GNP per person but negative rates of growth of Wealth per capita when including only this limited set of measures for natural capital. Some nations are becoming poorer not only on a per capital basis, but also overall. The changes in genuine wealth would very likely be more strongly negative if all components of natural capital were included.

Valuing resource depletion and degradation in national economic accounts has been a topic of discussion for decades. This policy push has led to several formulations of "green accounts" and to other methods, such as the "value of nature's services." Hamilton and Clemens (1999) build on this work and conceptualize Genuine Wealth and Genuine Savings and discuss how this field of research led the World Bank to publish "Expanding the Measure of Wealth" in 1997. They present a formal model of genuine wealth and then construct a preliminary set of measures for all nations, with available data. Data on changes in natural assets are limited to oil and minerals, depletion of forests below replacement levels, and the social costs of greenhouse gas emissions. Water resources, fisheries, and soil are not included, due to data limitations. With data for selected countries and groups of countries they show that this new measure gives different results (negative growth rates of Genuine Wealth in nations with positive growth rates of per capita GNP), and so Genuine Wealth should be considered in discussions of sustainable development policy.

They then adjust their figures also to include changes in human capital, measured as expenditures on education, and many nations still have negative savings rates for total capital and, for most nations, the results are the same. The worst-off countries are those with rapid mineral or oil depletion. They conclude that this new comprehensive set of measures of wealth should be employed by nations and by global banks. Also, data should be gathered on all natural resource types, include water resources, fisheries, air and water pollution, soils, and biodiversity. Their policy conclusions are that most countries need stronger pollution controls, better resources management policies (resources tenure, royalties), and resource depletion and pollution should be correctly priced. All of these findings apply to California, of course, as its resources are declining (The Changing California, 2003; California Wildlife, 2006).

It is interesting to note, in their Table 3, that most high-income countries had higher Genuine Savings rates than the U.S. in the 1970s, the 1980s, and 1990-93. These figures include educational expenditures. Some N. European countries have recently passed the U.S. in terms of growth rate of economic productivity. Many of the EC nations have stronger air and water pollution controls than we do in the U.S. Most of the core (original) EC nations have national health services and stronger welfare support systems than we do. Lindert (2003) found that higher social spending, as a percentage of GDP, is not associated with lower rates of economic growth. This was found to be due partially to high levels of human capital (education, health, and childcare). The high growth rate of these nations is also partly due to their higher taxes on fuel and personal automobiles, which reduces negative externalities.

Refering to the Hamilton and Clemens work and the Easterlin findings, these data would seem to indicate that people should be happier in the EC countries and that those nations are on a more sustainable path.

We will apply the genuine wealth concept to the interpretation of our model outputs, as we will have many measures of natural assets and of manufactured assets and some measures of human assets.

APPLICATION OF THE FRAMEWORKS TO UNDERSTANDING THE MODEL OUTPUTS

These two related theories of personal well-being and national well-being give us a conceptual framework for analyzing the indicators that come out of the California models. Our earlier assertion that the indicators should be kept in three categories, economic, environmental, and social, is supported by these theories of well-being. However, we will attempt to collapse the environmental measures into the economic category by monetizing the value of these assets. This is controversial, so we will keep the separate measures of environmental changes available. The social measures chiefly are concerned with economic equity and we will keep this as a first-level category.

These related theories reveal how much more useful our discussion of equity could be if we conceptualized it in terms of personal well-being. For example, we should examine the tradeoff between growth in aggregate wages (or utility) and wage (or utility) gains for lower-income households. All of these indicators will be for differences across two scenarios, typically the policy scenario minus the trend scenario, both for the future year. This is because the welfare measures are only available for differences.

We can also apply these ideas when evaluating aggregate statewide economic performance. For example, we should categorize our outputs so as to include: 1. changes in the value of manufactured assets (new transportation systems and buildings, net of depreciation of existing ones), 2. changes in the value of human assets (represented by education and healthcare products), and 3. changes in the value of environmental assets. (We will not be able to project percent of households married, education levels, and health status, because they are not explicit in the model. Our suite of models will give a quite inclusive set of measures for the value of manufactured goods, for health and educational product, and for environmental changes. We will attempt to analyze these outputs in the genuine wealth framework. We will strive to include all environmental services that are affected by transportation and land use policies in our evaluation models and accounts. Monetizing the value of environmental services is quite difficult (Pagiola, 2004), so we may not be able to do this adequately.

Proposed High-Level Model Outputs: Equity and Genuine Wealth

We start by noting that SAFETEA-LU, passed by Congress in 2005, now requires many more factors to be considered than the earlier surface transportation acts. It would seem useful to develop indicators for these factors. Regional and state plans must attempt to increase economic development, as well as mobility. Economic development, however, is not well-defined in U.S. practice. It is usually taken to mean change in one or more of: employment, personal income, property values, business sales, value added, or business profits (Assessing the Economic Impact, 1997). Another report states that economic development consists of improving one or more of: income, job choices, activity choices, economic stability, and amenities (Forkenbrock and Weisbrod, 2001). The FHWA website focuses on increasing employment and wages (www.fhwa.dot.gov/planning/econdev/ and others). In most countries, total product is the usual measure (GNP) and for states GSP. Since the PECAS model has an input-output model in its core model set, it will give a measure of total state product for all market goods and services. This can be viewed as the annual addition to the value of manufactured and human assets. We will add in annual changes in the value of natural assets. Depreciation of existing human and manufactured assets must be included using basic accounting rules.

This approach, then, gives us the Genuine Wealth measure. The second high-level measure will be Equity, measured as change in household utility, by income class.

Other, More-Specific Indicators

Under SAFETEA-LU, regional and state transportation plans must strive to reduce greenhouse gases, as well as air pollution. Greenhouse gases are fairly easy to project, based on vehicle fuel use and on floorspace in buildings, which we project by building vintage, structure type, and economic activity occupying it.

States and regions are now also required by SAFETEA-LU to consider resource conservation issues in planning and also are encouraged to develop cumulative impact mitigation programs. So, a comprehensive model, such as PECAS, which will include GIS data for important habitat lands and waters, will be useful for such proactive resources protection and mitigation planning and banking. The MPOs and state DOTs are encouraged to perform the evaluation of cumulative environmental impacts at the plan stage, but if they choose they can defer this analysis to the project stage. So, with these new requirements in mind, let's look at the range of outputs that we will have available.

The statewide travel model will produce typical travel measures, such as VMT, VHD, mode shares, and lane-miles of LOS E/F. We will also include accident costs (deaths and injuries), which are significant and vary with VMT, speed, and facility type. Also, we will include consequent emissions of pollutants and production of greenhouse gases. We will also calculate lifecycle whole-system energy use and consequent greenhouse gas emissions. Goods movement will be added to the travel model in a later phase, which will increase its economic scope and accuracy in projecting goods movement costs. The model currently represents heavy trucks with a fixed trip table. In the future, we will replace this model with one that projects goods movements in tours, based on the dollar flows among sectors, by zone, in PECAS.

With PECAS we will track total floorspace by building vintage and type, by economic activity type, and so we will be able to project energy use in buildings and consequent greenhouse gas production by the relevant utilities. We can also project population exposure to noise, using GIS. Land development will be shown, by type of lands converted, such as urban, suburban, prime agriculture, nonprime agriculture, grazing, important habitat types, floodplain, high fire hazard, and other categories to be determined from agency interviews. Our land use maps will be in 50m grid cells, which will allow fairly detailed evaluation of land consumption. We will attempt some water quality measures, such as nonpoint runoff from roads (factored from average daily traffic). We will construct an indicator of nonpoint water pollution (urban runoff) at the small watershed scale, based on percent impervious surface from development (major roads and land uses). These output indicators will be provisional, to get State departments' comments and suggestions.

We will be able to get locator producer surplus by household income class and by type of firm. From PECAS, we can also get monthly housing costs by household income class and also housing affordability (housing costs/household income). We will also be able to calculate number of households by income in the noise bands and also in the particulate fallout bands near highways.

The emphasis in our presentations and reports will be on the two high-level indicators of Equity and Genuine Wealth. All of the various indicators that aggregate to Genuine Wealth, however, will be kept in sub-accounts for viewing.

The Portrayal of the Performance Measures

This is a vast undertaking, since we will have dozens of measures, for each year, for 50 years, for 530 economic zones, 58 counties, and the State. We have a vizualization specialist working on methods of mapping these data, spatially and over time in graphs, and nesting the datasets in linked formats, but we still must face the issue of how to portray the data so that the most important concepts, normatively, get the most attention. That is, we need a hierarchy of datasets.

The most comprehensive and understandable method of portraying these many performance data is to show:

1. Genuine Wealth (measured as the difference between two scenarios in annual change in total state genuine wealth, as noted above); and

2. Equity (measured as changes in annual utility for households by income class and location).

The total state Genuine Wealth measure will result in one grand number, representing the monetary change for the evaluation year, but will actually be composed of many components. Many of these latter measures will be provisional and conceptual, with estimated values. We will be able to model natural capital in some ways, such as the value of environmental services from floodplains, terrestrial habitats, wetlands, and surface water bodies. We will attempt to monetize such measures, using willingness-to-pay data, whenever available. Otherwise, stated willingness-to-pay values will be used. Several studies have attempted to place economic values on "nature's services" (see an overview by the Ecological Society of America at http://www.actionbioscience.org/environment/esa.html; also, Costanza, 1997). Pagiola et al. (2004) have critiqued Costanza and many other studies and review the pitfalls of valuing environmental services.

The equity effects measures will be difficult to portray. In the Oregon Bridges Study, the changes in product for several broad groups of sectors were portrayed by county using percent growth classes in a GIS map (Weidner, et al., 2005). That approach worked well and so we will start with such maps for changes in household utility, for income groups.

Other, specialized measures will be provided for single-purpose State agencies. For example, the Department of Housing and Community Development will be interested in percentage of income spent on housing for lower-income households by county. This agency will also find other measures useful, such as percent of housing units under certain rent levels in each county. Caltrans, MPOs, and county-level poverty agencies will be interested in changes in travel costs for lower-income households, especially for worktrips. Also, county welfare agencies may make use of measures of change in accessibility to employment for lower-income households.

Relevance to STPs and RTPs

This model set will be tested on various policies relevant to the State Transportation Plan, that is, state and inter-regional projects. Of current interest in California is the High-Speed Rail proposal, an expensive improvement with potentially large economic and land development effects. Also of concern are numerous freeway widening projects, expansions of airports, and improvements on the landside of seaports. As discussed above, this model set will enable Caltrans to evaluate the new factors in SAFETEA-LU, such as greenhouse gases, economic development, and cumulative impacts on natural resources and the environment.

Two MPOs also are developing PECAS models, the Sacramento MPO and the San Diego one. These model sets will similarly be useful in their Regional Transportatation Plans, as well as for the analysis of major investments such as new rail lines, freeway widenings, and multi-modal corridor projects.

Besides being used for plan evaluation, this model set could be used at the program level for analysis of the ITIP and the RTIPs and the resultant STIP for bundles of projects. RTIPs in California are currently evaluated for progress toward goals set in the various RTPs. So, there is no set of statewide goals against which the RTIPs are evaluated. The evaluation criteria are mostly transportation performance measures and even these are overlapping. There are no general economic impact measures.

A more-unusual planning process that also could use such a model set is the Blueprint Planning going on in over a dozen California counties. This is a long-range broad scenario development and evaluation process, intended to explore smart growth and related transportation improvements. This process has already occured in the larger MPOs and is now being done in the non-MPO county transportation planning agencies. The counties are already using a simple GIS-based land use model, along with their travel models, in their Blueprint processes. Caltrans has funded this work.

In 2006 a bill passed that requires a 30% reduction in greenhouse gases statewide by 2020. The related Executive Order also sets a policy for an 80% reduction in 2050. These are strenuous objectives. As noted above, this model set can be used to project greenhouse gases in vehicles and buildings. The policies already adopted regarding vehicle fuels and vehicle energy efficiency will be supplemented by many future laws concerning land use and transit development. These complex policy sets will have myriad economic and social impacts which can be evaluated if the PECAS model set works as envisioned.

PROPOSED POLICY TESTS

After developing as many measures as we can and then working out methods for aggregating and portraying the model outputs, we will then experiment with various policy packages in an attempt to find policy sets that maximize aggregate State Genuine Wealth. Much of this effort, at least initially, will be a form of validating the models, in that we will compare the model outputs to what economic theory predicts, in various sensitity tests, one policy at a time.

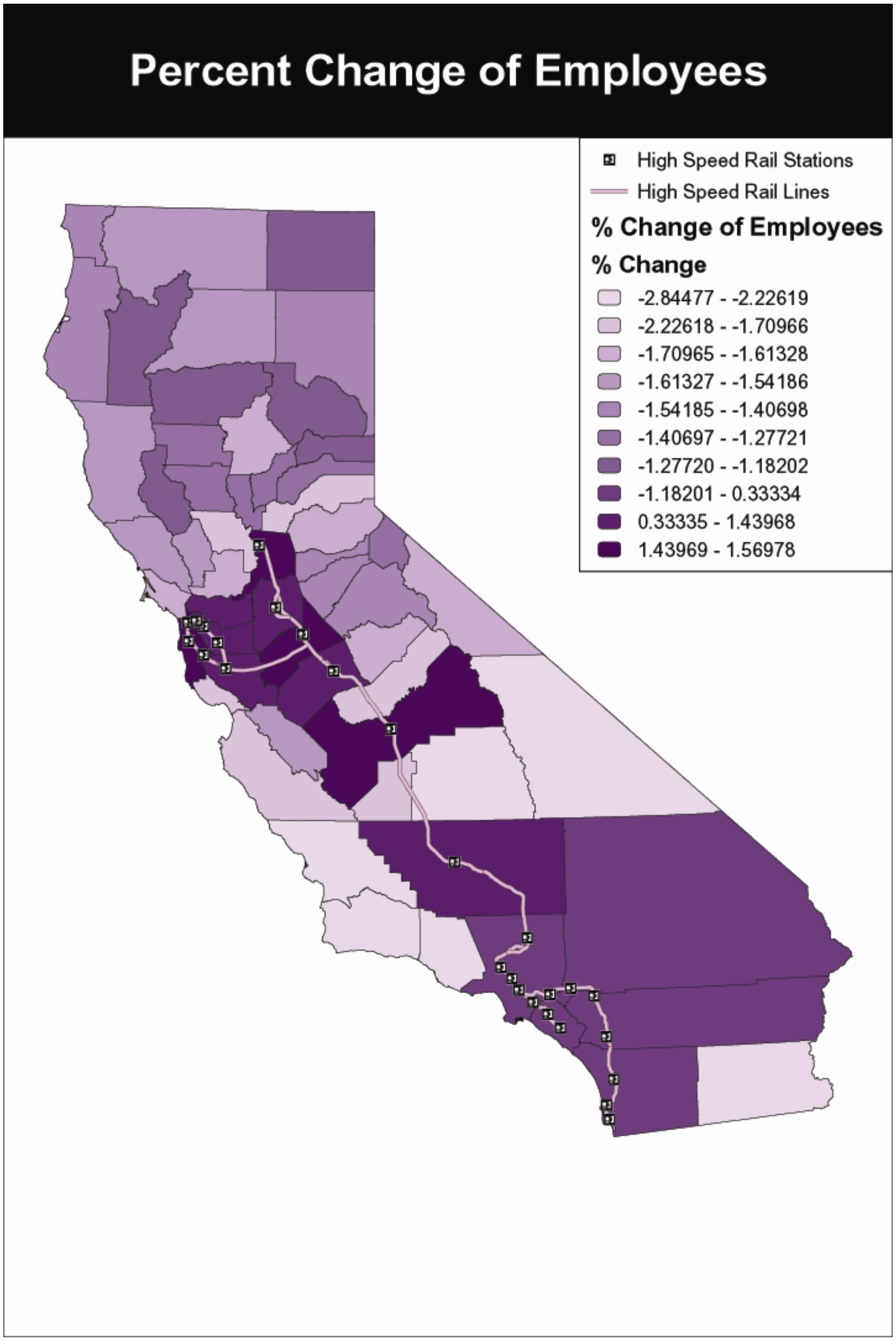
After further model calibration/validation, we will test policy packages to see how they affect state Genuine Wealth. Then, we will see if we can keep aggregate Genuine Wealth high, while at the same time not damaging lower-income households or certain types of firms, statewide and by region. Since this work is funded by Caltrans, we will test high-speed rail to see what its effects are on aggregate wealth and on equity. We will also test modal capacity expansion alternatives for certain key interregional corridors, such as the Altamont Pass, leading from the South San Francisco Bay Area to the Central Valley.

The most-interesting policy packages may well be ones that promise broad benefits, such as high-speed rail, combined with intensive infill development around the rail stations, plus large-scale habitat protection, and with inclusionary zoning (multifamily zoning near to employment centers in all cities and counties). We will take the results from these preliminary scenario tests out to the State agencies in charge of transportation, housing, habitats, and other services, to get the responses of managers. This exercise will then result in making improvements to the models, to our methods of portraying performance measures, and to the design of scenarios that more closely serve the interests of the agencies and the State.

As mentioned above, the major policy push in the State is now the Climate Warming statute. So, we will test various policies and policy sets intended to reduce VMT and greenhouse gases. Is is not enough to project their impacts on greenhouse gases, though. We must also see what the economic and other impacts are for these transformative policies. In this regard, the California experience may help show the way forward for the U.S. and other nations. Virtually all of the policies identified so far as useful for reducing greenhouse gases can be represented in our model set.

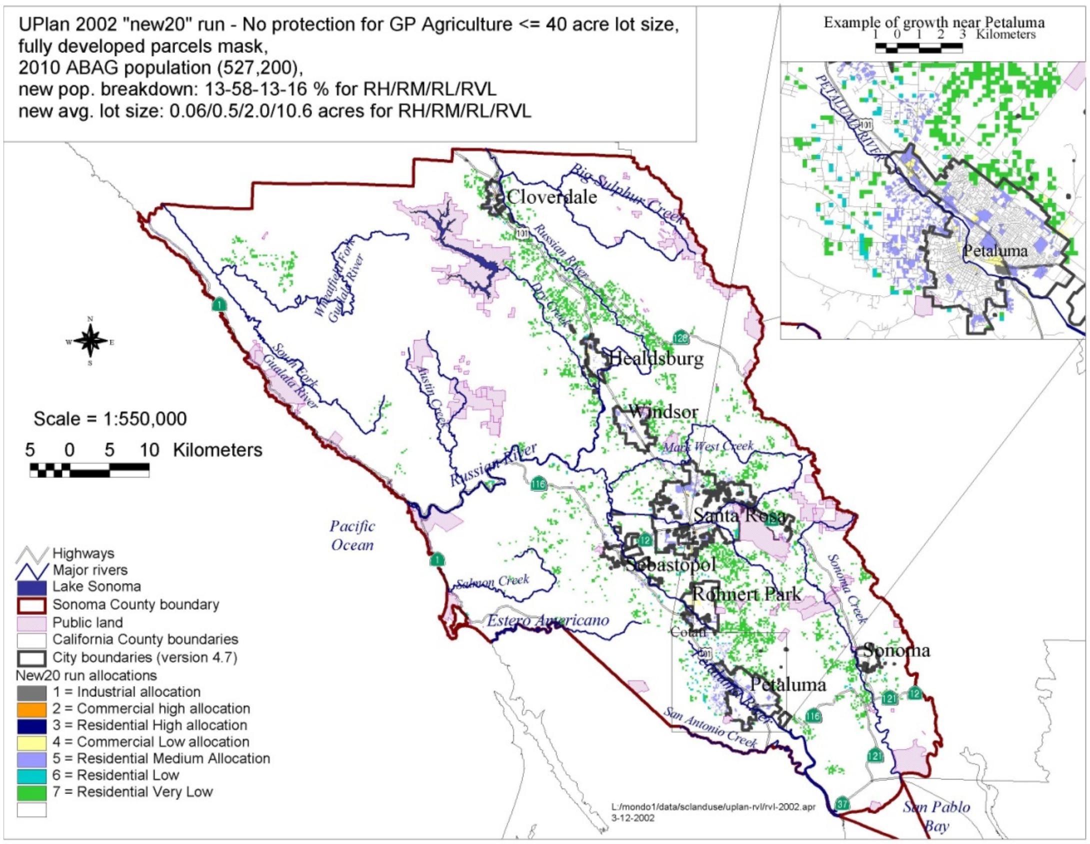
Below is an example of how we might represent impacts, using county-level outputs from our current initial version of the PECAS model. It shows the effects that High-Speed Rail would have on county employment in the year 2000, compared to without it.

FIGURE 1: Example Map of County Economic Change



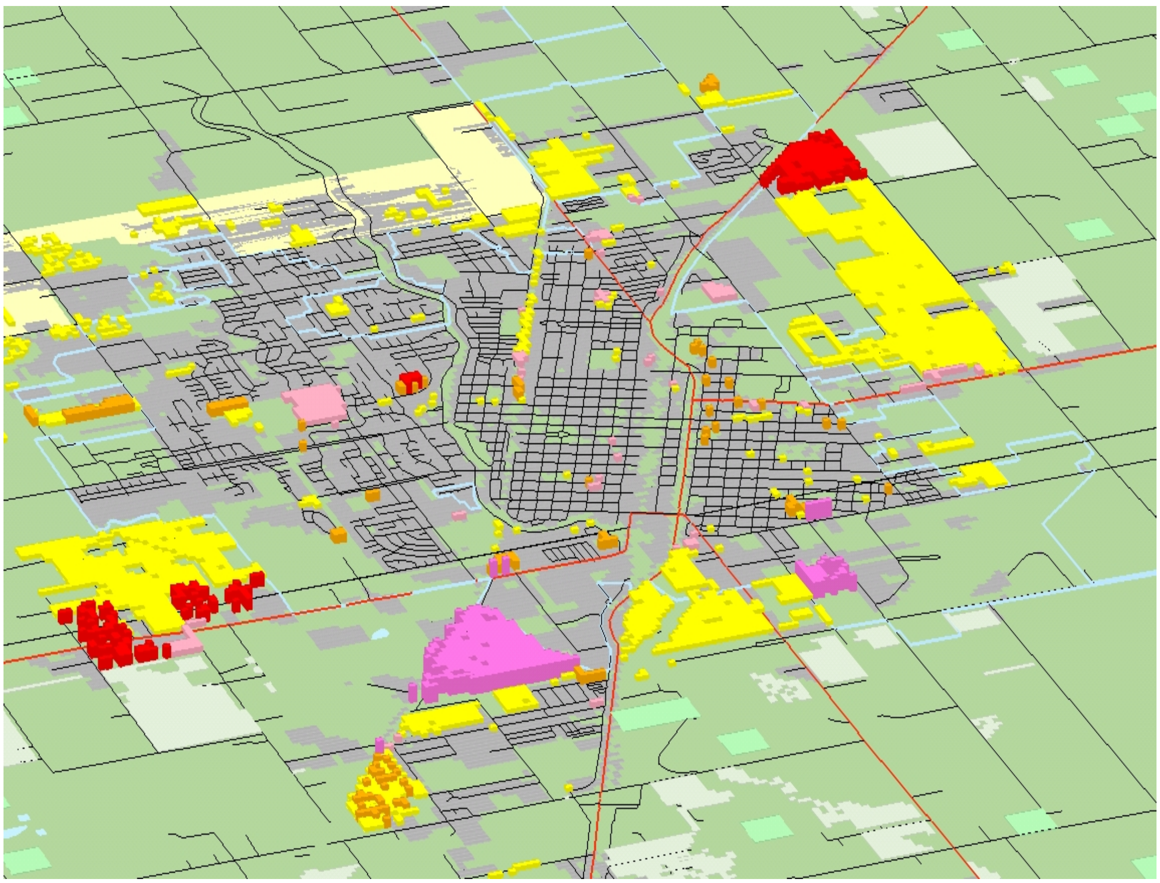
The second map, below, shows what the environmental impact maps will look like. This is using a simpler model, but with the same 50m gridcell outputs, showing the effects of development on oak woodland habitats in Sonoma County, California.

FIGURE 2: Habitat Fragmentation in 2010 in Sonoma Co., California



We will use various 3-D map types to help citizens understand the local impacts of various policies. The map below shows how this would look for the City of Merced, again using an earlier model with only 7 land use types. Our PECAS application will have 20 land use types. This is a simple ArcInfo 3-D Analyst map, showing new development for the year 2020, looking SE.

FIGURE 3: Urban Growth in the City of Merced, CA, in 2020



CONCLUSIONS

For decades, planners have sought out models that can represent the effects of transportation and land use policies on the economy and on the natural environment of regions and states. At last, we now have these capabilities and, in addition, our models can address economic equity issues. The California models will be a test of these ideals of comprehensive policy evaluation and so present the challenge of portraying the many outputs in a theoretically consistent fashion. Recent theories of personal and national well-being greatly facilitate our understanding of the many indicators that will result from our policy tests. We will present two high-level indicators, Equity and Genuine Wealth, that we believe best represent overall societal well-being. Also, we will portray dozens of indicators of interest to certain agencies and for statutory reporting requirements.

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I will reformat the references, if accepted for publication.