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INTERPRETING PERFORMANCE INDICATORS FROM A STATEWIDE INTEGRATED TRANSPORTATION-LAND USE MODEL

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Abstract:

We are developing a statewide urban growth model for California. It will be run in iteration with the California statewide travel model to evaluate major transportation improvement scenarios, such as freeway widenings and high speed rail. In addition, we will evaluate land use policies intended to provide for more affordable housing and for habitat protection. This model is uniquely capable of providing performance measures for total travel, travel delay, mode shares, economic development, wages, economic welfare, economic equity, rents paid by households and firms, energy use in vehicles and buildings, greenhouse gas emissions, vehicular air pollution, loss of agricultural lands, habitat loss, and erosion potential. We propose a framework for interpreting all of these data, based on recent advances in the theory of well-being for persons and for nations.

Keywords: Urban modeling, integrated modeling, land use modeling, multi-attribute policy evaluation, indicators.

1. 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 then be taken to likely agency users for comment, then a Demonstration Model with better data and refined capabilities, and the Working Model in 2009. The land use model will be run in iteration with the Caltrans statewide travel model. The primary purpose for developing this integrated model set for Caltrans headquarters and district staff is to capture more of the feedbacks within the economy driven by changes in transportation systems, such as induced travel and consequent land development.

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 modelwide (regional or statewide) utility. For a discussion of how PECAS differs from its progenitor model, MEPLAN, see Abraham and Hunt (2002). PECAS combines the 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 nested logit overall structure of PECAS also gives a regionwide or statewide utility measure, useful for aggregate welfare evaluation. The statistical discussion of the consistency of the model set with random utility theory is given in Abraham and Hunt (2005).

The California model set will produce typical measures of transportation system performance such as VMT, delay, mode shares, and congestion. These measures can be broken out by trip purpose and by household income class. The models will also give a broad array of outputs representing economic welfare for households and firms, economic equity for households, housing rents, and housing affordability for households by income class (monthly rent/monthly income). It will also produce measures 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. Related environmental impact measures will include energy use, on-road air pollution, and greenhouse gases. We will also produce basic measures of water quality 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 measures and energy and greenhouse gas outputs. State and Federal natural resources agencies will likely

be focused on air pollutant emissions, habitat conversion, erosion potential of developed lands, and water quality.

We hope that the Governor and the State Dept. of Finance, however, will be interested in our broader projections of overall economic growth. 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. PECAS will give measures of total State product, product per worker, and producer surplus for all firms and households. 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 traveler 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, in principle. Our work in the next two years will determine if we can develop useful measures, in practice.

From our past work (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 equity and political issues. These impacts can then be summarized in graphical and narrative fashion to enable the evaluation of tradeoffs across the three mutually exclusive categories. This method 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 the weighting or other transformation 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.

The modeling exercise that most closely resembles 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 modeling and indicators portrayal greatly. No regional economic growth or productivity measures were developed and no locator utility measures were used, either.

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.

2. A THEORY OF PERSONAL WELL-BEING

Easterlin has shown that there is a zero perceived marginal utility of income 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 probably do not apply within the lower-income range in the U.S. and in other countries, where we expect utility to rise.

In a previous 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 more money 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 their wages and products to comment on the effects of various levels of spending on transportation improvements. PECAS does not represent the education level of households or their health status, though. But, we can examine the effects of spending various amounts of money on the healthcare and educational systems in the State, off-model, and compare those expected outcomes to the increases in personal well-being for low-income households from changes in income caused by changes in transportation spending. These are relevant issues today, as the State Legislature regularly determines how much to spend on transportation bonds versus on education and on healthcare for the poor. Starting up a statewide single-payer health system has been debated in recent years. There are many studies that estimate the income effects of better healthcare and of better education.

More specifically, 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 (Johnston et al., 2001). Easterlin's work provides evidence that such redistributive transportation policies would increase total societal well-being, if the extra

tax burden fell on high-income households. We also intend to test land use policies intended to increase the amount of affordable housing and to spread it into formerly exclusionary cities. Requiring multifamily zoning in all cities would be expected to increase the locator utility of lower-income households by lowering their commuting costs and by allowing them access to more jobs. 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. As noted, we can also perform off-model analyses of also increasing education and healthcare expenditures.

3. 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. Also, assets (wealth), he argues, 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 declining natural capital. Some nations are becoming poorer not only on

a per capital basis, but also overall. The changes in genuine wealth would 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 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 have 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. All of the 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 high 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 some measures of human assets and of manufactured assets.

4. APPLICATION OF THE FRAMEWORK TO UNDERSTANDING THE PECAS MODEL OUTPUTS

These two related theories, then, of personal well-being and national well-being, can 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, but not double-count them. 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 income and income gains for lower-income households (or lower housing costs for those households).

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, durable goods, and buildings), 2. the values of human assets (education and healthcare expenditures), and 3. environmental assets. Our suite of models will give a quite inclusive set of measures for manufactured and constructed goods, for health and educational services, and for related 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.

5. PROPOSED MODEL OUTPUTS AND ANALYSIS CAPABILITIES

Model outputs and policy analysis uses will be determined from the Initial User Interface/Business Process research, which will occur in late 2006. These user surveys will precede the design on the Set-Up Model in 2007. However, we give here a tentative list of feasible model outputs and analysis capabilities, for discussion purposes.

We start by noting that SAFETEA-LU, passed in 2005, now requires many more indicators than the earlier surface transportation acts. For example, regional and state transportation plans must attempt to reduce greenhouse gases and air pollution. The statutory wording seems to indicate that these goals apply to air quality attainment regions, as well as to nonattainment ones. Regional and state plans must attempt to increase economic development, as well as mobility. Greenhouse gases are fairly easy to project, based on vehicle fuel use. Economic development, however, is not well-

defined in U.S. practice. It is usually taken to mean change in one 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. The PECAS model set has an input-output table in its core and the model set is driven through time by assumed growth in state product. We can use total state product as an output, if we add in all non-market goods and services. This measure will still differentiate among policy scenarios. In addition, for a statewide welfare measure, we will use change in total statewide utility from the Base Year, or from the Trend Future case in the same year. This total composite utility will be the logsum of the entire choice set for each economic activity, summed across all activities. See Abraham and Hunt (2007), equation 1 (the utility function) and equation 15 (the calculation of this value).

States and regions are now 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. Also, 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.

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. 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 ag., nonprime ag., 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 pollution from roads (factored from average daily traffic) and parking lots (factored from land uses). We will also demonstrate a measure of runoff acceleration from roadways, dependent on lane-miles of roads. We will probably be able to construct an indicator of water

quality 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 consumer surplus by household income class and producer surplus 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). All of these measures will be by zone, by county, or statewide. 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.

6. THE PORTRAYAL OF THE PERFORMANCE MEASURES

The most comprehensive and understandable method of portraying these many performance data is likely to be to show:
1. Aggregate Economic Welfare (measured both as change in utility for firms and households and as total state economic product, net of non-market changes); and
2. Equity Effects (measured as changes in utility to firms by type and location and to households by income class and location). This measure will focus on strong winners and losers.

Total state product (GSP) will be the same for all scenarios in a given year and we will need to net out changes in all non-market goods and services, including the annual values for environmental services. 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 amount and quality of habitats and surface water bodies. We will attempt to monetize such measures, to see how well this can be done. Several studies have attempted to place economic values on "nature's services," which range up to larger than the market economy (see an overview by the Ecological Society of America at http://www.actionbioscience.org/environment/esa.html; also, Costanza, 1997).

The equity effects measures will be difficult to summarize, for all of the types of firms and for geographic areas, such as counties. 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. We will use the same approach for portraying changes in household utility and income by broad income class and county. We will highlight big winners and losers in the text.

Other, specialized measures will be provided for single-purpose State agencies. For example, the Dept. 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.

7. 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 product and maximize total utility for firms and households. 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, treating one policy at a time.

After further model calibration/validation, we will test policy packages to see how they affect state product and aggregate utility, in an attempt to maximize them. Then, we will see if we can keep aggregate welfare 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 utility, state product, and equity. We will also test modal capacity expansion alternatives for certain key interregional corridors, such as the Altamont Pass, leading from the 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.

8. 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 will greatly facilitate our understanding of the statewide policies that we will test.

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