EQUITY ANALYSIS OF LAND USE AND TRANSPORTATION PLANS USING AN INTEGRATED SPATIAL MODEL

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ABSTRACT

This paper describes a study to investigate how a new form of spatial economic model can be used to evaluate the equity effects of land use and transportation policies that reduce greenhouse gas emissions. The Activity Allocation Module of the PECAS Model of the Sacramento Region is used to simulate two scenarios for the year 2035 arising from a recent planning process, ‘Business As Usual’ and ‘Preferred Blueprint’. Advanced aggregate travel models and activity based travel models have been applied to evaluate distributions of travel time and cost effects of transportation and land use policies across different socio-economic groups. But the PECAS model system, with its representation of the interactions among the transportation system and the rest of the spatial economic system, facilitates an evaluation of the distributions of a wider range of economic impacts, including wages, rents, productivity and/or changes in consumer surplus, for segments of household, labor by occupation, and industry categories. The PECAS model is applied to the policy scenarios to illustrate the distributional measures that can be obtained from this type of model and to provide insights to the equity effects of different transportation and land development patterns. The results shows that a more compact urban form designed around transit stations can reduce travel costs, wages, and housing costs by increasing accessibility, which can lead to substantial net benefits for industry categories and for lower income households. Higher income households may be net losers, since their incomes are more dependent on reduced wages, they are less willing to switch to higher density dwellings, and they are more likely to own their own home.

Key Words: Equity analysis; smart growth, transit-oriented development, land use modeling, travel demand modeling

INTRODUCTION

Recent legislation in California seeks dramatic reductions in greenhouse gas (GHG) emissions. The Global Warming Solutions Act, Assembly Bill 32 (AB32) specifies a target of 100% of the 1990 level for the year 2020. Senate Bill 375 (SB375) – commonly known as 'California's anti-sprawl bill' – mandates regional GHG targets linked to land use plans and transportation policies. This implicitly acknowledges the view (e.g., *1*) that GHG reductions from the transportation sector can only be met by changing the way communities grow, switching from low-density auto-oriented development to compact transit-oriented development. The scoping plan for AB32 places emphasis on SB375 and tentatively calls for a five million metric ton reduction in CO_2 equivalents annually by 2020 from land use and transportation planning. Enforceable GHG targets are to be phased in beginning in 2012. However, prior to the implementation of these targets, AB32 requires analysis of their economic and equity effects.

This paper describes a study to investigate how a new form of spatial economic model can be used to evaluate the equity and economic effects of land use and transportation policies designed to reduce GHG emissions. The Activity Allocation (AA) Module of the PECAS Model of the Sacramento Region is used to simulate two scenarios for the year 2035 arising from a recent planning process, 'Business As Usual' and 'Preferred Blueprint.' Advanced aggregate travel models and activity based travel models (ABM) have been applied to evaluate the distributions of travel time and cost effects of transportation and land use policies across different socio-economic groups (*2*-*6*). But the PECAS model system, with its representation of the interactions among the transportation system and the rest of the spatial economic system, facilitates an evaluation of the distributions of a wider range of economic impacts, including wages, rents, productivity and/or changes in consumer surplus, for segments of household, labor by occupation, and industry categories (*7*).

This paper begins with an outline of the legislative and administrative requirements for equity analyses of federally funded transportation activities and reviews the literature on the state-of-the-practice of equity analyses in regional transportation planning in the U.S. Then the BAU and PRB Scenarios are described. The AA Module of the PECAS Model of Sacramento and its application in this study are then presented. Finally, the results of equity analysis are discussed and conclusions from the study are drawn.

BACKGROUND

Requirements for Transportation Equity Analysis

Executive Order 12898 (1994) codified a renewed concern for the effects of the government's activities on minority and low-income populations. It states that "each federal agency shall make achieving environmental justice part of its mission by identifying and addressing, as appropriate, disproportionally high and adverse human health or environmental effects of its programs, policies, and activities on minority populations and low-income populations." The Order emphasized existing nondiscrimination laws and requirements including Title IV of 1964 Civil Rights Act and the 1969 National Environmental Policy Act. Equity analyses were relatively common in the 1970s, but had largely ceased through the 1980s and into the late 1990s (*8*).

The renewed concern for the equity impacts of government actions had strong resonance in the transportation policy arena. It is a common view that the expansion of the interstate highway system starting in the 1950s exacerbated the sorting of urban America into inner cities dominated by low-income and minority groups, suburbs with more affluent white populations, and increasing separation between housing and relevant employment opportunities. It is also observed that there has been a disproportionate location of transportation infrastructure in low-income and minority communities since the 1980s (*9*).

Not surprisingly, the federal surface transportation acts of the 1990s both (a) emphasized the importance of citizen participation in regional transportation planning and (b) funded programs to improve the mobility of disadvantaged and low-income populations. At the end of the decade, the United States Department of Transportation (USDOT) and the Federal Highway Administration (FHWA) issued Orders (5610.2 and 6640.23, respectively) that articulated three key environmental justice principles to be incorporated into the transportation planning and decision-making process:

- To avoid, minimize, or mitigate disproportionately high and adverse human health and environmental effects, including social and economic effects, on minority populations and low-income populations.
- To ensure the full and fair participation by all potentially affected communities in the transportation decision-making process.
- To prevent the denial of, reduction in, or significant delay in the receipt of benefits by minority and low-income populations.

State transportation departments and metropolitan planning organizations (MPO) – the functional conduits for significant infusions of federal transportation dollars to states, cities, and counties – were then charged with developing data, tools, and measures to evaluate the achievement of these principles in the transportation planning process. For example, USDOT asks state transportation departments to “develop the technical capability to assess the benefits and adverse effects of transportation activities among different population groups and use that capability to develop appropriate procedures, goals, and performance measures in all aspects of their mission” (*10*). They also urge MPOs to “identify residential, employment, and transportation patterns of low-income and minority populations so that their needs can be identified and addressed, and the benefits and burdens of transportation investments can be fairly distributed” (*10*). However, USDOT has generally left it to the states, MPOs, and local jurisdictions to develop specific methods and measures to evaluate the equity effects of transportation investments, policies, and plans (*6, 8, 11*).

Practice of Transportation Equity Analyses

Today, fifteen years after the issuance of Executive Order 12898, the literature documents the response in terms of MPO attempts to evaluate environmental justice and equity effects in transportation plans as well as various challenges to such analyses. Sanchez and Wolf (*8*) conduct a survey of fifty large MPOs and find that several used geographic analyses to map the location of transportation improvements and the spatial distribution of low-income and minority households to "illustrate the distributional equity of MPO plans" (p.12). Such analyses are a start, but they fail to adequately capture the benefits and costs of new transportation projects for low-income or minority populations dispersed geographically, over both the short and long term, because of distortions arising with geographic and demographic aggregation, incomplete representation of modal travel time and cost (*11-12*), and failure to represent the role and impact of the transportation system within the larger spatial economic system (*7*).

More suitable analysis tools are now available.

Some current aggregate travel models that consider segments of households categorized by auto ownership and/or income can be used to calculate the distribution of transportation impacts – including changes in travel times and costs and associated accessibilities – across these segments specifically (*3-5*).

The new generation of ABMs that use microsimulation with synthetic populations can be used to calculate the distribution of transportation impacts across the full range of characteristics included in the population synthesis (*13*). Deakin and Harvey (*2*) developed an early microsimulation model (STEP) that was used to evaluate the distributional effects of auto pricing policies in the major regions of California. More recent versions of the STEP model have been applied for equity analyses in Baltimore, Maryland and Las Vegas (*6*). Most recently, the San Francisco ABM was used to evaluate how the travel time savings arising with a proposed transportation plan would be distributed among specific communities of concern (*6*).

These new ABMs can be used to calculate the distributions of travel time and cost impacts. But calculating the distributions of wider impacts on the economy – including such things as wages, rents, productivity and/or changes in consumer surplus, requires models that include explicit representation of the linkages among the transportation system and the rest of the spatial economic system and these elements within the system. (*7*).

SCENARIOS

The 'Blueprint Project' was a public-participation planning process undertaken by the Sacramento Area Council of Governments (SACOG), an MPO, to develop a common land use and transport vision for the region. A total of over 5,000 residents joined in the effort to consider options for housing, compact and mixed-use development, transportation infrastructure and services, conservation of natural resources, and appropriate use of existing assets in the planning for a doubling of the regional population by 2050.

The result was the 'Preferred Blueprint (PRB)' scenario, which articulates levels and locations of redevelopment and new transit-oriented development linked to a list of preferred transportation projects, resulting in a more compact level of urban development generally. This was contrasted with a 'Business As Usual (BAU)' scenario, which projected Sacramento's future assuming the continuation of current land use and transportation plans and policies, leading to a much larger area of urban coverage and much lower densities of urban development generally. The U.S. EPA permitted SACOG to use land use and transportation components of the PRB Scenario in their official regional transportation plan alternative as part of their air quality conformity process. Similar Blueprint Projects have now been conducted in all the major metropolitan areas in California and one is currently underway in the San Joaquin Valley. The basic process has now also been codified in SB 375.

The PRB and BAU Scenarios are considered in the study described here.

Currently there are approximately one million jobs and 800,000 housing units in the Sacramento Region. This is forecasted to grow by an additional 535,000 jobs and 433,000 housing units in both scenarios. The location and intensity of household and employment location is illustrated in Figure 1 for both the BAU and the PRB scenarios.

In the BAU scenario, transportation investments continue to focus on highway expansion and land development persists in low-density, auto-dependent patterns.

In the PRB scenario, transportation investment emphasizes improvement in transit, sidewalks, and bike lanes over highway expansion. Significant housing development is located near existing employment centers near downtown Sacramento, Rancho Cordova, and Roseville to improve the overall jobs to housing balance and concentrate growth near high quality transit service. There is also a sizable shift from the number of single-family dwelling units to multi-family units (see Table 1).

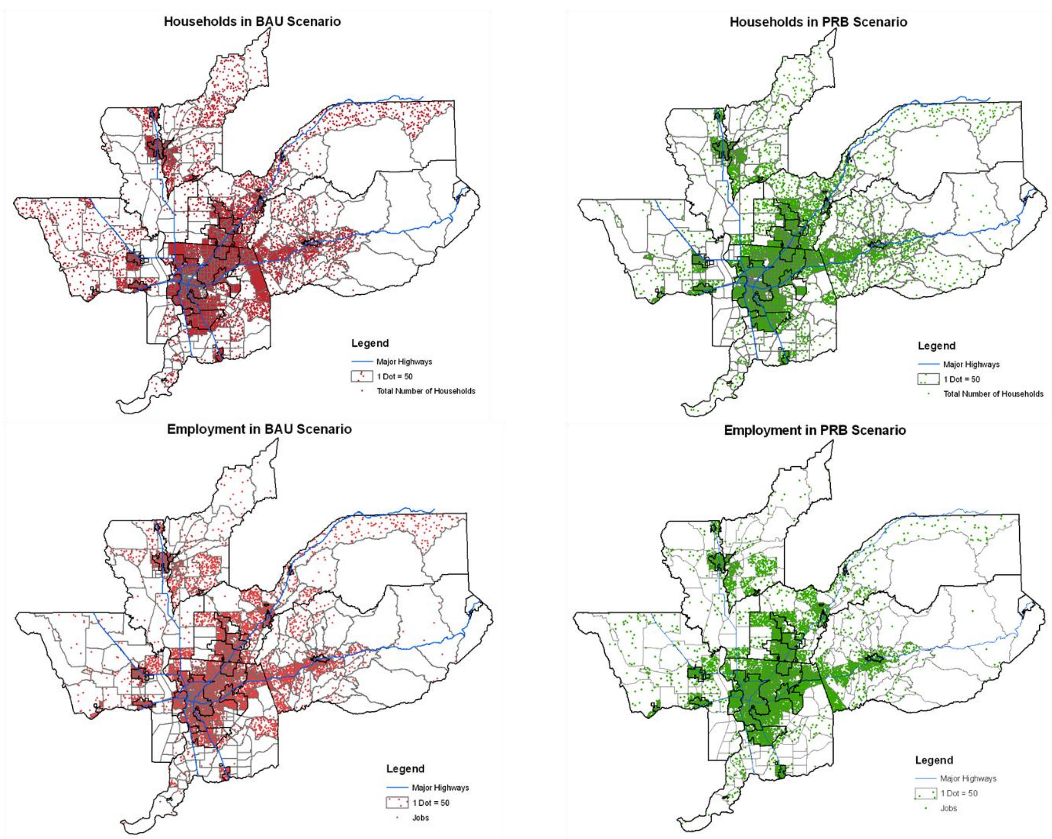

FIGURE 1 Household and employment location in the BAU and the PRB scenario

TABLE 1 Change in Dwelling Units by Type Between the BAU and the PRB Scenarios

Units	BAU	PRB	Percentage Change	Total Change
Luxury SFD	381,570.66	357,665.28	-6.3%	-23,905.39
Standard SFD	669,234.87	673,267.25	0.6%	4,032.38
Total SFD	**1,050,805.53**	**1,030,932.52**	**-1.9%**	**-19,873.01**
Owned MF	35,341.18	38,232.16	8.2%	2,890.99
Rented MF	146,544.68	163,526.70	11.6%	16,982.02
Total MF	**181,885.86**	**201,758.87**	**10.9%**	**19,873.01**

SFD=single family dwelling units
MF=multi family dwelling units

Of interest in this study are the distributions of these impacts, and the related further effects on different segments of the economy and among different groups. These distributions are explored with the PECAS model of the Sacramento Region as described in the next section.

ANALYSIS

The PECAS Model of Sacramento

In this study, the Activity Analysis (AA) Module of the PECAS Model of the Sacramento Region is used to explore the distributions of the impacts of the PRB Scenario relative to the BAU Scenario for the year 2035. The PECAS model of Sacramento also includes a Space Development (SD) Module, but this was not used in the study described here.

The AA Module is a set of additive and nested logit models as shown in Figure 2. A quantity of each activity category is allocated to each location (of which only three are shown in the figure although there are usually several hundred). Activity categories consist of industrial categories and household categories. Within each location each activity is further divided amongst production-consumption options (called "Technology"), to allow an activity to produce or consume more or less of certain things in different locations depending on business conditions. Then the resulting quantities of things (called "Commodities", and consisting of categories of goods, services, labor and floorspace) bought or sold are allocated amongst the exchanges (of which only three are shown in the figure but there are usually several hundred for each category of goods, service, and labor leading to tens of thousands of exchanges). Since activities are both buying and selling, this leads to a supply and demand in each exchange.

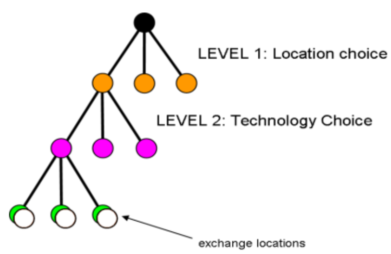

FIGURE 2 AA module of PECAS.

The AA model is a model of short-term equilibrium. The transport conditions (as calculated in the transport model) are used to determine a transport cost for each commodity, for each pair of location zone and exchange zone, and for each direction (buying and selling). The quantity of space (buildings and other physical improvements to land) are normally simulated in the Space Development (SD) module of PECAS over a multi-year simulation, with SD responding to spatial rents as calculated by AA in previous years. In this study, the quantity of space by zone in the future year was determined as an input from the land use patterns of the two scenarios. Given a price for each commodity in each zone, AA calculates the supply and demand quantity of each commodity in each zone through the consistent application of the sequence of models in Figure 2. AA then adjusts the spatial landscape of prices so that each market clears. When the markets have cleared, AA calculates an allocation of activities in zones, together with production and flows of each commodity between zones, consistent with the transport conditions and built form it receives as inputs.

Since AA is based on rigorous application of nested and additive logit theory (*14*) the top level expected maximum utility measure (the “logsum”) at the top of Figure 2 is a representation of the full composite utility (the Consumer Surplus in the case of household activities) of all the choices of where to locate, the quantity of interactions to undertake, and the transport costs, prices and opportunities for each of these interactions.

In particular, for households in the Sacramento model, the top level expected maximum utility takes into account the transport costs for all of the households’ interactions, the relative prices for every category of good, service, labor and housing, as well as the willingness and ability of households to shift their location, their housing type, their occupation and the destination of all of their trips.

Benefits of increased opportunities are considered and weighted against transport costs and other costs in this output measure from PECAS: if a policy or scenario reduces opportunities at any level of Figure 2, costs may be reduced (because opportunities to spend money or travel time have been reduced) but benefits will also be reduced.

See Hunt and Abraham (*15*) and Abraham and Hunt (*14*) for complete documentation of the theoretical formation and calibration methods of the PECAS model. See Abraham et al. (*16*) for a description of the Sacramento PECAS model and its initial calibration.

Calibration of the PECAS AA Module

The PECAS model has been calibrated as part of SACOG’s model improvement program (see *16*). However, additional calibration efforts were performed for this study. In particular, transport cost functions, which translate travel model zone-pair travel attributes into disutility measures for each commodity in PECAS, were refined using improved data from the travel models, wage data by occupation, and from goods movement studies.

The commodity flow distances were calibrated to trip length information, to establish the logit dispersion parameter in the models of buying or selling for each commodity. These dispersion parameters control the random term in the flow allocation. It is important to establish these parameters before undertaking benefit analysis, because they establish the value associated with variety in each commodity. In the case of commodities with low dispersion parameters, additional opportunities for interaction are very valuable, even if they are poorly priced or a long distance away.

The choice model of household lifestyle (the middle level of Figure 2, for household activities) was calibrated based on observed patterns of behavior from the US Census Public Use Microsample (PUMS). This established the tendency of certain types of household to use certain types of housing and make certain types of labor, and the willingness (and/or the ability) to shift occupation and housing depending on conditions. Dispersion parameters for the higher level choices in Figure 2 were refined with the help of the additive logit theory in Abraham and Hunt (*14)* which was not available when the Sacramento PECAS model was first developed.

Other elements of the model that were further calibrated include the treatment of imports and exports (more explicit in quantity and direction than in *16*), and the floorspace short term supply function (which allow large vacancy rates if space demand in any zone is uncharacteristically low).

2035 Input Data

SACOG provided employment, household, and land inputs for the BAU and PRB scenarios in the year 2035 that were used in their ABM (SACSIM) simulations. Employment and household location was not used directly by PECAS – since one of PECAS's functions is to allocate employment and households. Rather, the expectations regarding employment and household locations from the two scenarios were used to develop the inputs on built-form that would normally be provided by PECAS's SD module. A full version of PECAS, with both SD and AA, would predict both the location of employment and households, and the location of built-form, with policy variables (such as zoning regulations) as inputs. A travel model, on the other hand, requires employment locations, household locations and built-form as inputs. In this work, a middle road was taken, with built-form as an input, while employment and household locations are determined by AA.

SACOG also provided the zone-to-zone travel time and cost (or logsums) for all modes by trip purpose. Zone-to-zone travel time and cost were aggregated to PECAS zones using an approach that weighted values by trip frequency. Total economic growth by activity category was assumed to remain constant for both scenarios simulated with the PECAS AA model.

RESULTS

As illustrated in Figure 3 below, the percentage change in the average travel time and cost of commuting to work from a home zone and conducting business from the industry zone. The PRB scenario provides large reductions in overall travel cost over the BAU scenario, but not all zones have reduced travel costs. Across labor categories, the annual average value of this reduction is $370 (a percentage reduction of 11%). See Table 2 below. By labor category, the lowest annual reduction in travel costs is $170 for educators and the highest is $426 for non-retail sales jobs (a percentage reduction of 6.6% to 16%, respectively). Travel costs as a percent of wage income is also lower in the PRB scenario (5%) relative to the BAU (6%) and the percentage reduction is 10.3%.

TABLE 2 Change in Average Annual Transport Costs and Transport Costs as a Percent of by Average Annual Wage Income and across Labor Type(s) (2000 U.S. nominal dollars)

Workers	Change in average transport costs (dollars)	Percentage change in average transport costs	BAU percent of income to transport costs	PRB percent of income to transport costs	Percentage change in percent of income to transport costs
Agriculture	-326	-11.8%	6.0%	5.2%	-12.3%
Construction	-303	-11.1%	5.8%	5.2%	-10.8%
Educators	-170	-6.6%	5.8%	5.6%	-4.8%
Entertainers	-372	-14.2%	5.7%	5.0%	-12.4%
Food workers	-250	-9.9%	5.5%	5.0%	-8.3%
Health workers	-306	-11.9%	5.3%	4.8%	-10.3%
Maintenance & repair	-300	-11.1%	5.9%	5.3%	-9.7%
Managers	-339	-13.0%	5.5%	4.8%	-11.2%
Non-retail sales	-426	-15.9%	5.7%	4.9%	-14.2%
Office & administrative	-323	-12.7%	5.4%	4.8%	-11.0%
Production	-293	-10.9%	5.9%	5.3%	-9.6%
Professionals	-351	-13.4%	5.4%	4.8%	-11.6%
Retail sales	-256	-9.9%	5.5%	5.0%	-8.4%
Service	-306	-12.0%	5.4%	4.9%	-10.7%
Transport	-281	-10.6%	5.9%	5.4%	-9.1%
Total	**-307**	**-11.8%**	**5.5%**	**5.0%**	**-10.3%**

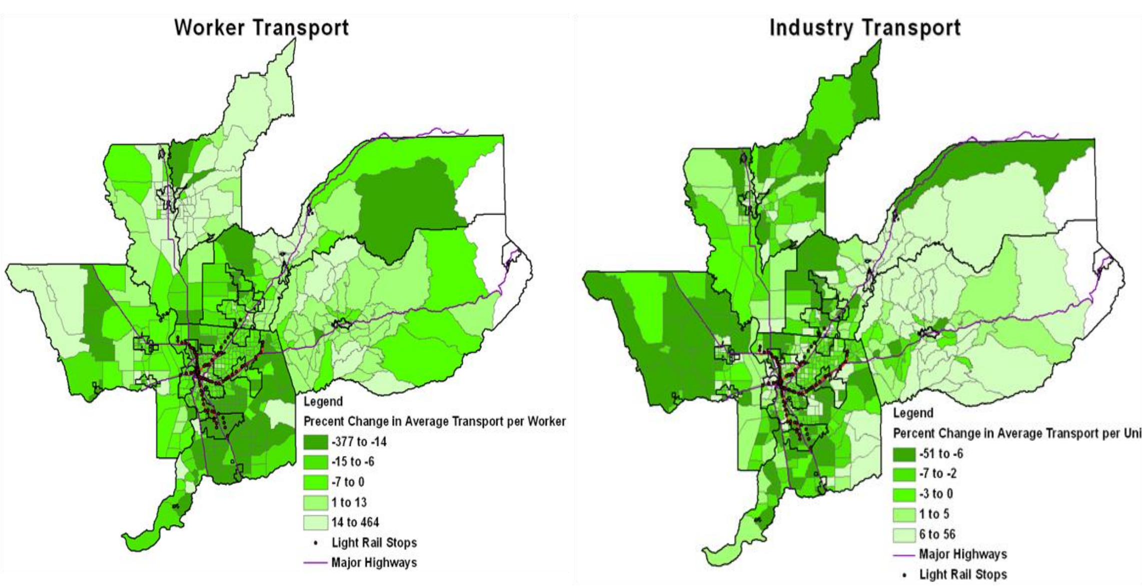

FIGURE 3 Percentage change in worker and industry transport cost from the BAU to the PRB scenario.

Average annual rents also decline in the region in the PRB scenario relative to the BAU (see Table 3). As illustrated in Table 1 above, the total distribution of housing units by type in the PRB scenario represents a 10% increase in the number of multi-family units and 6.3% reduction in luxury single family dwelling units. Because of the greater supply of multi-family housing units, which are typically less expensive than single family dwelling units, average annual rents, for all but the highest income classes, are reduced in the PRB scenario. On average, across all income categories, rents are reduced by $912, which is a 3.1% reduction in average rent and a 1.4 percentage reduction in the portion of median income allocated to rent. Note that this sort of reduction in rents will not necessarily lead to an increase in consumer surplus in AA, since AA also represents the greater preference for single family dwelling units. The PRB scenario reduces opportunities for housing, which reduces consumer surplus, but also reduces rents for housing, which increases consumer surplus. AA represents both of these and weighs them against each other.

The three lowest household income categories experienced reductions in annual rent ranging from $842 to $936 (percentage reductions from 3% to 16%). Note that according to Federal government standards, the lowest household income category (less than $10,000 a year) is considered to be extremely low income (or approximately 30% of the Sacramento area median income or AMI), $10,000 to $19,000 is very low income (or approximately 50% of AMI), and $20,000 to $39,000 is low income (or approximately 80% of AMI). Relative to the other household income categories, these lowest also achieved the greatest percentage reduction in the portion of the median income in each category allocated to rent (4%).

The highest income category sees an increase in rent ($549), which is a 1.1% increase in average rent and a percentage decline in rent as a percent of income of 1.1%. It appears that the preference among the highest income households for larger homes and lots and the relatively diminished supply has driven up average rents for this income group.

The remaining household income categories also experience a reduction in rent but, not surprisingly, this is a smaller percentage of their income (0.2% to 2.0%), but is a larger percentage reduction in rent as a share of income (0.8% to 3.2%).

TABLE 3 Change in Average Rent and Rent as a Percent of Median Income by and across Household Class(es) (2000 U.S. dollars)

Income Class (1000s of dollars)	**Change in average rent (dollars)**	**Percentage change in average rent**	**Percentage change in percent of income to rent**
less than 10	-842	-16.8%	-4.0%
10 to 19	-926	-6.2%	-4.2%
20 to 39	-936	-3.1%	-3.8%
40 to 49	-901	-2.0%	-3.2%
50 to 99	-680	-0.9%	-2.0%
100 to 199	-326	-0.2%	-0.8%
200+	549	1.1%	1.1%
Total	**-912**	**-3.1%**	**-1.4%**

Table 4 shows that the total annual value of owned homes decreases across all income brackets. This is consistent with the general decreases in rental values and indicates a decline in residential property value. The rental data indicates that the value of upper incomes class homes should increase which is true at the average level. Since there are fewer units available there in the PRB scenario there is a decrease in the total annual value.

TABLE 4 Total Annual Value of Owned Homes (2000 U.S. dollars)

Household Income (1,000 dollars)	BAU	PRB
less than 10	138,540,173	137,990,750
10 to 19	312,046,502	309,383,066
20 to 39	1,098,472,167	1,079,142,340
40 to 49	722,045,200	704,108,092
50 to 99	4,308,518,876	4,148,049,109
100 to 199	4,461,977,355	4,249,265,340
200 or more	1,647,653,842	1,561,129,520
Total	**12,689,254,114**	**12,189,068,218**

It appears that lower transportation and housing costs in the PRB scenario have driven down the region's cost of living, and thus average annual wages (see Table 5). Across all labor categories, average income is reduced by $783 (a percentage reduction of 1.6%). By labor occupation category, average reduction ranges from a low of $50 to a high of approximately $1000 (percentage reductions of 0.1% to 2.0%, respectively). Agricultural and constructions workers, typically lower income jobs, experience some of the lowest reductions and professional, sales, and administrative labor groups, typically higher income, experience some of the highest reductions.

TABLE 5 Change in Average Annual Wage Income by and across Labor Occupation Type(s) (2000 U.S. nominal dollars)

Occupation	Change in average income (dollars)	Percentage change in average income
Agriculture	-50	-0.1%
Construction	-282	-0.6%
Educators	-802	-1.8%
Entertainers	-925	-1.9%
Food workers	-752	-1.6%
Health workers	-847	-1.7%
Maintenance & repair	-731	-1.6%
Managers	-922	-1.9%
Non-retail sales	-951	-2.0%
Office & administrative	-892	-1.9%
Production	-670	-1.4%
Professionals	-980	-2.0%
Retail sales	-759	-1.6%
Service	-749	-1.5%
Transport	-719	-1.6%
Total	**-783**	**-1.6%**

Total consumer surplus results for the PRB scenario relative to the BAU scenario in 2035 are presented in Table 6. There is a net increase in total consumer surplus for the region as a result of the changes in land use planning and transportation investment in the PRB scenario relative to the BAU. Lower transport and labor costs produced a surplus for each industrial activity. Total industry surplus is approximately two billion dollars and the average per million dollars of production is 15 thousand dollars. Across all households, consumer surplus is 77 million dollars and the average consumer surplus per household is 63 dollars. In general, household benefits are inversely related to income levels. Average consumer surplus for these low income groups range from approximately $1,000 to $1,200 dollars. The median income range ($40,000 to $49,000) sees an average benefit of $617. However, the higher income groups all experience a loss in consumer surplus that ranges from $93 to $3400. The higher income households have reduced utility for three readily observable reasons: 1) they produce more labor, and hence are affected more by the reduction in wages, 2) they have a larger preference (higher willingness-to-pay) for larger houses which are less available in the PRB scenario, and 3) they are more likely to own their own houses, and hence do not benefit as much from the reductions in rent.

TABLE 6 Total and Average Consumer or Producer Surplus for PRB Scenario Relative to the BAU Scenario (2000 U.S. nominal dollars)

Industry Activities	**Total for Industry**	**Average (per million dollars of production)**
Agriculture	25,409,027	13,819
Construction	94,360,630	8,783
Manufacturing	96,178,539	5,588
Transportation	24,852,327	12,336
Communication	48,259,083	9,630
Wholesale trade	99,621,685	8,532
Retail	535,390,941	20,345
Restaurants	228,149,378	51,192
Financial	196,062,283	18,934
Real estate	133,007,080	6,804
Business services	119,984,002	15,477
Automotive services	30,751,437	13,994
Amusement services	19,693,298	46,647
Education	71,707,003	36,163
Personal services	69,702,673	35,366
Non-profit organizations	56,540,621	48,809
Professional services	121,314,798	17,099
Government	291,590,082	15,227
Total	**2,237,165,860**	**15,008**
Household Activities by Income Category (thousands of dollars)	**Total for Households**	**Average per Household**
less than 10	77,739,198	1072
10 to 19	138,266,716	1211
20 to 39	236,591,541	946
40 to 49	68,354,813	617
50 to 99	-41,164,201	-93
100 to 199	-289,375,872	-1396
200+	-113,337,008	-3420
Total	**77,075,188**	**63**

Note that the two scenarios had equal exogenously specified control totals for industry size. In reality, the gains in producer surplus in the industrial categories shown in the top section of Table 6 would attract more industry to the region. This would lead to reduced benefits (per unit) for industry because of the increased competition for space, labor and other commodities. This can already be seen based on the increases in the annual value of industrial space in the PRB scenario (see Table 7) which would increase at an accelerated rate if additional industry was allowed to move into the region. However, this increased competitiveness would also lead to more jobs in the region and hence increased benefits for households. It is common in PECAS modeling to also have an economic growth model that responds to PECAS's measures of consumer surplus and can adjust economic growth over the years of a multi-year simulation. It is also common, however, to purposely **not** have growth forecasts change in response to consumer or producer surplus, since changing control totals complicate these types of comparisons between two scenarios.

TABLE 7 Totals and Changes in Annual Values of Space Categories (2000 U.S. nominal dollars)

Industry Space	Total Annual Value BAU	Total Annual Value PRB	Change in Total Annual Value	Change in Average Annual Value
Agriculture and Mining	4,309,639	4,775,329	465,691	0.25
Industrial space	342,449,323	350,359,040	7,909,717	0.08
Office space	2,256,092,868	2,272,948,983	16,856,115	0.1
Retail space	2,420,455,390	2,423,994,713	3,539,323	0.02
Medical space	2,615,203,744	2,619,989,274	4,785,530	0.08
Primary school space	743,446,892	743,561,281	114,389	0
Colleges and education space	265,306,182	265,451,633	145,450	0.01
Government office space	3,101,491,777	3,100,188,985	-1,302,792	-0.03
Total	**11,748,755,815**	**11,781,269,239**	**32,513,425**	**0.04**
Residential Space				
Luxury SFD	19,570,693,253	18,540,834,827	-1,029,858,426	549
Standard SFD	15,324,465,745	15,253,098,360	-71,367,385	-243
Owned MFD	897,643,595	932,181,413	34,537,818	-1,017
Rented MFD	2,650,989,948	2,706,913,694	55,923,746	-1,537
Total	**38,443,792,541**	**37,433,028,294**	**-1,010,764,247**	**-820**

CONCLUSIONS

This study shows how a consistent application of random utility theory to location, lifestyle/technology and interaction/trip-distribution choices can lead to powerful consumer surplus measures, by income and industry, that are beyond what can be done with more empirical land use models or with transport demand models alone.

As well, this study shows that a more compact urban form designed around transit stations can reduce travel costs, wages, and housing costs by increasing accessibility. These can lead to substantial net benefits for industry categories and for lower income households. Higher income households may be net losers, since their incomes are more dependent on reduced wages, they are less willing to switch to higher density dwellings, and they are more likely to own their own home.

Maintaining fixed total industry size between scenarios impacts the consumer surplus measures. The PECAS AA model represents how increased accessibility benefits industry directly and indirectly (for example through lower wages), but it does not represent how industry may grow faster in the region because of this benefit. If a separate model of region-wide economy size were to respond to AA's producer surplus measures, industry would grow faster, and some of the benefit currently ascribed to industry would be transferred to households through less wage reductions.

Reductions in rent values for floorspace will lead to an increase in the basic consumer surplus calculated in PECAS AA. But every unit of floorspace is owned by someone, and when rents go down these landlords suffer. For local policy analysis, it is difficult to decide how to weight this disbenefit experienced by the landlords due to a reduction in rent. Certainly it is essential to net out the imputed rents for owner-occupied dwellings, since these households are clearly within the local policy system. Non-residential space, and non owner-occupied dwellings, may be owned by investors outside of the local policy system. Local policy makers may not want to count the full disbenefit of reduced rents on the landlord side, even though the PECAS AA module does count the full benefit of reduced rents on the tenant side. In this paper we have reported non-residential and non-owner-occupied residential rent revenue reductions completely but also separately.

Another actor that is outside of the consistent AA evaluation system is the land developer. The SD module of PECAS could be used to calculate a measure of developer profits, but since this study did not use the SD module it is important to point out that developers may not win in the PRB scenario. Hence developers may not want to build the built-form assumed in the PRB scenario without additional incentives, which could be costly to taxpayers and hence households.

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