

UC Berkeley

Earlier Faculty Research

Title

The Evaluation of Transportation and Land Use Plans Using Linked Economic and GIS Models

Permalink

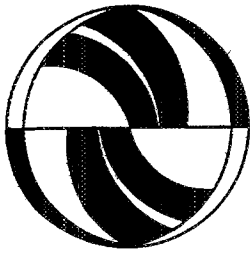
<https://escholarship.org/uc/item/5ch0s1cd>

Author

Johnston, Robert A.

Publication Date

1995-07-01



**The Evaluation of Transportation
and Land Use Plans Using Linked
Economic and GIS Models**

Robert A Johnston

Working Paper
UCTC No 268

**The University of California
Transportation Center**

University of California
Berkeley, CA 94720

**The University of California
Transportation Center**

The University of California Transportation Center (UCTC) is one of ten regional units mandated by Congress and established in Fall 1988 to support research, education, and training in surface transportation. The UC Center serves federal Region IX and is supported by matching grants from the U S Department of Transportation, the California Department of Transportation (Caltrans), and the University.

Based on the Berkeley Campus, UCTC draws upon existing capabilities and resources of the Institutes of Transportation Studies at Berkeley, Davis, Irvine, and Los Angeles, the Institute of Urban and Regional Development at Berkeley, and several academic departments at the Berkeley, Davis, Irvine, and Los Angeles campuses. Faculty and students on other University of California campuses may participate in

Center activities. Researchers at other universities within the region also have opportunities to collaborate with UC faculty on selected studies.

UCTC's educational and research programs are focused on strategic planning for improving metropolitan accessibility, with emphasis on the special conditions in Region IX. Particular attention is directed to strategies for using transportation as an instrument of economic development, while also accommodating to the region's persistent expansion and while maintaining and enhancing the quality of life there.

The Center distributes reports on its research in working papers, monographs, and in reprints of published articles. It also publishes *Access*, a magazine presenting summaries of selected studies. For a list of publications in print, write to the address below.



**University of California
Transportation Center**

108 Naval Architecture Building
Berkeley, California 94720
Tel 510/643-7378
FAX 510/643-5456

DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the information presented herein. This document is disseminated under the sponsorship of the Department of Transportation, University Transportation Centers Program, in the interest of information exchange. The U S Government assumes no liability for the contents or use thereof.

The contents of this report reflect the views of the author who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California or the U S Department of Transportation. This report does not constitute a standard, specification, or regulation.

The Evaluation of Transportation and Land Use Plans Using Linked Economic and GIS Models

Robert A Johnston

Division of Environmental Studies
University of California at Davis
Davis, CA 95616

*Working Paper
July 1995*

Presented at the Conference on Carrying Capacity, Comenius University, Bratislava, Slovakia
April 3-7, 1995

UCTC No. 268

The University of California Transportation Center
University of California at Berkeley

THE EVALUATION OF TRANSPORTATION AND LAND USE PLANS USING LINKED ECONOMIC AND GIS MODELS

Abstract:

U.S. law requires consistent land use and transportation plans for metropolitan regions and the evaluation of economic efficiency for projects and plans. Policies being examined for reducing travel demand include land use policies. The Clean Air Act regulations require the proper simulation of latent demand in travel modeling for conformity analysis. Current models in use by regional agencies in the U.S. cannot represent the interactions of land use and transport systems in an economically rigorous way and cannot project changes in economic efficiency (locational and traveler surplus). Regional travel demand models in use in the U.S. can represent latent demand as it affects trip distribution, but cannot represent latent demand for auto ownership and for trip generation. Integrated urban models do exist that can perform all of these functions, for regions and for states. We describe a modeling project that applies such a model to an urban region in California and also makes use of GIS to project environmental impacts of scenarios. This set of models may be of use for regional and national planning in Slovakia.

INTRODUCTION

Great advances have been made in the last two decades in computable urban modeling. These models have been used in Europe, Asia, and South America, but have not been applied in the U.S. The Surface Transportation Act (ISTEA) requires the development of an intermodal transportation system "that is economically efficient and environmentally sound" and also states as a goal increasing international competitiveness (Sec. 2). The evaluation of

"economic...impacts" is required in the metropolitan and statewide planning sections of the Act. Hook (1994) has shown that the U.S. spends about 18% of GNP on transportation, whereas Japan spends about 11%. The disparity in costs for commuting is much larger and, of course, increases the relative cost of labor in the U.S. It appears that Congress finally has decided to make economic efficiency a major issue in transportation planning.

The Act contains many other objectives and the past tendency of agencies to evaluate plans and projects with a disorganized set of overlapping performance measures and to emphasize a subset of them when advocating certain projects seems to be continuing. Furthermore, USDOT and the state DOTs do not appear to be developing models that can forecast changes in net economic benefits for regions and states. No regional transport agency in the U.S. uses an integrated urban model for projecting land use and travel and so no comprehensive measures of consumer surplus are obtainable for the evaluation of regional plans. As far as we can tell, no state is using such a model for statewide projections and so economic efficiency cannot be projected in state planning under the Act. No national research project statement seems to address this problem directly. Current practice involves the use of pseudo-economic indicators such as jobs created or reductions in travel costs. Attempts to base the economic evaluation of transportation plans on reducing travel costs are very misleading, since costs can rise but utility can rise more.

Integrated urban models have been in use for many years and have been widely reviewed (Webster, Bly, and Paulley 1988; Wegener 1994; Mackett 1994). These authors have categorized the various models in terms of their capabilities, including whether they are based on random utility theory and include all land use types.

In this paper, we present a description of the application of TRANUS, the most tractable of the fully economic integrated urban models, to the Sacramento, California, region. This project is funded through the USDOT Transportation Centers for FY 1994-95. Subsequently, we plan to apply the model to the state of California, for state goods movement modeling and for Intermodal Transportation Management System use.

We not only use TRANUS to give coherent land use/transportation projections and measures of consumer surplus, but we feed the land use projections for each large zone into a second model, CUFM (Landis 1993), that allocates land uses to small polygons, according to locational rules. The locational rules represent physical site characteristics, location with respect to urbanized areas and freeways and roads, and land ownership. CUFM land use coverages are then overlaid onto natural and cultural coverages in Arc/Info and measures of environmental impact derived. Mobile emissions are projected with the California travel emissions models. TRANUS itself projects energy use in vehicles and structures.

A RESEARCH PROGRAM TO DEVELOP METHODS FOR STRATEGIC REGIONAL PLANNING

A. Importance of the Research:

In terms of the University of California Transportation Center research objectives, we are going to develop systems analysis methods for projecting the effects of transportation and land use scenarios on all major urban subsystems. Our models will account for latent travel demand and for land use changes due to changes in accessibility. Emissions will be forecast, along with their costs. Medium-range, tactical scenarios will be examined with 20-year projections and long-term, strategic scenarios with 50-year projections.

Travel and economic impacts will be broken out by household income class and by trip purpose. Uncertainty will be handled with statistical measures of error in the models and by parametric evaluation of changes in critical input variables.

We are responding to the need for better methods of decisionmaking in fast-growing areas. The subject region, Sacramento, is growing rapidly and is implementing new carpool lanes on freeways and expanded light rail transit, and is considering an outer beltway. We will also address the need to identify transportation policies that will reduce costs for firms and households. The integrated transport/land use model that we will implement and test (TRANUS) includes measures of all producer and consumer surplus in an urban economy and so can be used for financial and economic evaluations. We also respond to the call for devising and evaluating regional policies that will reduce environmental impacts. TRANUS will produce measures of energy use, standard emissions models will produce emissions measures, and we will also modify and apply a GIS model to evaluate other environmental impacts.

Under pressure from the Clean Air Act and the surface transportation act, regional transportation planning agencies are studying various land use and pricing measures to reduce travel. They are also improving their travel models and are adding land use models to their capabilities. The travel models in our region are now as good as any operational ones in the U.S. The regional agency (SACOG), however, is implementing a rudimentary set of land use models (DRAM\EMPAL by Putman). These models do not clear land markets with prices or rents and so are not theoretically strong. They also do not produce complete measures of consumer and producer surplus.

In general, there is a strong, nationwide need for a tractable integrated urban model that agencies can use in formulating "consistent" land use and

transportation plans under the surface transportation act. This act also calls for the economic evaluation of regional transportation plans, and so the urban model should account for supply and demand for transportation and all land uses, at least residential and nonbasic employment. Such models do not exist in the U.S., but several ones are in use in other countries. We will test the most promising one in our region and subject it to outside expert evaluation. If it proves to be economically accurate and comprehensive in concept and fairly tractable, it may become the starting point for the next generation of urban models in this country.

There is also a need for better environmental impact evaluation methods that can be linked to the urban model outputs or to standard travel demand models. Many have been designed, but are not transportable and well-published. We are attempting to help develop improved urban models that are theoretically sound and utilize the capabilities of GIS to analyze and display data in many ways, as recommended by Klosterman (1994).

B. Past Work:

On Caltrans PATH funding for several years, we have operated a standard set of travel demand models for the Sacramento region and produced papers evaluating travel demand reduction scenarios (Johnston and Ceerla, in press a), automated freeway lanes (Johnston and Ceerla 1993a), and comparing modeling with and without equilibration of trip distribution on assigned impedences (Johnston and Ceerla 1993b).

Our work for the California Energy Commission last year, funded by them and by the UC Energy Institute, reviewed travel demand models in use by regional agencies in California (Johnston and Rodier 1994). We are now using a new set of travel demand models that overcome most of the weaknesses that we

found in that study.

Our past work has led us to see three main shortcomings with practice in the U.S.:

1. Short time horizon. We need longer development periods, in order to bring about larger land use changes and to evaluate transportation systems with more-congested roadways than we project in 20-year scenarios. Several regions in the U.S. have done 40- or 50-year studies. The Portland, Oregon region is currently doing a 50-year strategic study. Luckily for us, Caltrans has produced a set of 50-year scenarios for the Sacramento region in an evaluation of an outer beltway, and we can adapt those basic datasets to the new transportation/land use model (TRANUS).

2. Lack of a land use model. Many regional transportation agencies in the U.S. are implementing DRAM/EMPAL, but better models are available. The regional agency, SACOG, will also implement DRAM/EMPAL, which is a Lowry-type land use model, during late 1994. This model is off-the-shelf, more or less, and relatively easy to calibrate and operate. It is well-documented and there are many users in the U.S. It is, however, phenomenological, that is it replicates past land use changes with basic functions derived only generally from economic theory. It does not use utility-based equations, and so does not reliably replicate microeconomic behavior, especially over extended time periods. It also does not provide comprehensive measures of economic benefit for scenarios tested. It has no bid-rent market-clearing mechanisms using prices for land or rents for floorspace, a critical weakness. Much better models are in use in Europe and South America. A very comprehensive but efficient one is TRANUS (Barra, Perez, and Vera 1984). It includes all sectors of the regional economy, equilibrates land use supply and demand with prices, and includes sophisticated travel models. It operates on PCs and is

well-documented internally. Several applications of the model have been published in English (Barra 1989; Barra, Perez, and Vera 1984).

3. Lack of an environmental assessment system. In this region, environmental assessments of regional transportation and land use plans are done on an ad hoc basis, without reference to on-going, established databases and geographic evaluation formats. The lack of a ready evaluation system makes it impossible to evaluate very many scenarios or to isolate components of the regional plans and test the effects of changing them.

Considerable amounts of geographic data are now available in digital form and most agencies have some expertise in Arc/Info. Also, many GIS-based models are available for plan evaluation. All of California is being digitized for the Gap Study of habitats, the Sierra study, the Rivers study, the Department of Forestry's vegetation mapping, and other studies. Much of this data is available in our Department's computer lab at UC Davis. Many standard coverages are available through the USGS, Census Bureau, and other agencies.

4. The need for better evaluation formats for decisionmakers. Past evaluations in most regional transportation agencies have consisted of tables of aggregate outputs from travel demand models, emissions models, and incomplete economic models, such as the REMI model (approved by the EPA). Better formats are possible. The work of Manheim on the evaluation of transportation scenarios in the early 1970s was interesting. Montgomery County, Maryland, did some useful graphics evaluating broad transportation alternatives (Replogle 1991). More use of maps is needed, as well as better graphs. Tufte (1983) has developed a theory of the visual display of information. Caltrans is developing an interactive database for use in the Intermodal Transportation Management System. It is going to use Arc/Oracle and present maps with tables for baseline and future scenarios.

In this project, we will calibrate and apply the TRANUS integrated land use/transport model in 20-year evaluations and in 50-year sketch planning studies, using the long-term datasets. We will also feed the land use files from the completed runs on TRANUS into a GIS system and evaluate various environmental impacts, based on map overlays and simple related models. We will test various formats for the evaluation outputs on staff people and on decisionmakers in the region.

C. Literature Review:

Overview of Transportation, vehicle holdings, and land use models.

Needed improvements in travel modeling are summarized by Harvey and Deakin (1993) and by Stopher (1993). A good review of land use models for use in planning applications was done by Berechman and Small (1988). The most detailed comparison of integrated land use/transport models can be found in Webster, Bly, and Paulley (1988); and Paulley and Webster (1991). A recent review of integrated urban models is found in Wegener (1994).

In their review in 1988, Berechman and Small concluded that no models existed that had all of the desirable attributes: behaviorally based, preferably on stochastic economic decisions; dynamic; zonally based, and so useable in real urban applications; all employment and building endogenous, as well as transportation; correctly accounting for congestion in transport and agglomeration among firms; and tractable, having been applied to actual regions. That review missed a superior model (MEPLAN), developed and applied during the early 1970s by Echenique (Cambridge University), but not documented very extensively in English in journals.

In an exhaustive review of land use/transport models, Webster, Bly, and

Paulley (1988) found MEPLAN to be superior to all other models reviewed in most of the attributes discussed here. It was found to be fairly difficult to calibrate and apply, however.

In his recent review, Wegener (1994) reviews MEPLAN and also finds it comprehensive and theoretically sound. At the Transportation Research Board meetings in January 1994, we spoke with Roger Mackett of University College London, and he said that MEPLAN took over a year to calibrate in the Naples study. A paper by Hunt (1992) describes the input and calibration data for the Naples study in detail and states that 6 man-years went into the calibration. That discouraged us from applying MEPLAN. Wegener (1994) also found TRANUS by de la Barra (a past student of Echenique's at Cambridge) to be comprehensive and theoretically robust. This model, conceptually similar to MEPLAN, is more tractable, however, because of improvements in convergence algorithms and because of its hierarchical structure. There are functions for energy use in vehicles and for heating buildings. It runs in Windows 3.1 and has a friendly user interface. An educational version is available. It was developed with the best attributes of integrated urban models, including random utility-based choice models, economic base theory, and input-output methods. Like MEPLAN, TRANUS includes many economic measures of net benefit (consumer and producer surplus).

Integrated urban (land use/transport) models.

We have shown generally that most existing and developing methods are not adequate for projecting the total net benefits of transportation and land use scenarios on a regional scale. Let us review the class of models that can perform the required general equilibrium empirical simulations. Wegener (1994) argues that the new generation of integrated urban models (urban models,

hereafter) have overcome the weaknesses of the earlier ones and are now theoretically robust and useful for policy evaluations in actual urban regions. Mackett (1994) reviews existing urban models and finds that they are very useful for evaluating transportation policies that reduce congestion.

The principles of general equilibrium urban models can be found in Sullivan (1983a 1983b, 1983c). His models were economically complete, but were not empirically based on a real urban region. Nevertheless, his work serves to identify the sectors that need to be simulated and the goods and services that must be included.

A review of urban models, both academic and applied, is by Anas (1987). He found that we were on the verge of having comprehensive and tractable models and that spatially disaggregated econometric models would fill the need if employment location and other functions were added. Berechman and Small (1988) also reviewed urban models and found that they were either economically comprehensive or empirically tractable, but not both. Their review, like Anas', is a useful primer on requirements for modeling. A major comparative study of urban models (Webster, Bly, and Paulley 1988) reviewed the structures of several urban models in detail and then ran them on their own urban datasets but testing identical transport, land use, and pricing policies. One of the models they found to be theoretically robust was MEPLAN by Echenique, but it was considered to be difficult to calibrate. MEPLAN is discussed in detail in Hunt (1993) and in Hunt and Simmonds (1993).

A recent paper by Wegener (1994) reviewed a somewhat different set of urban models and found that some of them were theoretically complete and somewhat tractable. He found the TRANUS model by de la Barra to be the easiest to use. It is well-documented, runs in Windows 3.1, and has been applied in several urban regions (Barra, Perez, and Vera 1984; Barra 1989). It

represents all land markets with endogenous clearing with prices and uses multipath equilibrium assignment in the travel submodels. Travel and land use demands are all expressed in random utility form with nested logit equations and so measures of consumer surplus can be derived. The model is very computationally efficient, primarily because of its hierarchical structure and its efficient convergence algorithms (Barra, Perez, and Vera 1984).

In this project, we will calibrate the TRANUS model, using the zone system being used by the regional agency (SACOG) in its land use modeling with DRAM/EMPAL (120 zones). We will aggregate the existing Caltrans 2040 datasets to fit this zone file, so that we can run TRANUS for 2010 and 2040.

D. Objectives and Methods:

1. Learn, calibrate, and apply the TRANUS urban model in 20- and 50-year studies of scenarios for the Sacramento region.

2. Output the land use files to the GIS model and calculate environmental effects (ag land conversion, habitat conversion by priority rankings, measures for surface water pollution from urban runoff, others).

3. Present to decisionmakers and interest group representatives descriptions of the scenarios and the evaluation data on: travel; net economic benefits, including external costs and government subsidies; air pollutant emissions; environmental impacts. Test various data formats and graphics.

Methods for calibrating and using the land use/transport model.

We have called Tomas de la Barra in Caracas and acquired the models. We will run the educational version and learn the model. We will determine the data needed for applying it in our region and solicit help from SACOG to get the data. SACOG already has assembled most of the needed data, because they

are implementing DRAM/EMPAL this summer. Most of the land use data is available, including vacant land by land use designation in each zone. Apparently, all of the travel demand data needed is available from the Caltrans/SACOG 1991 household travel survey.

We know that we will need land prices and/or building rents for the two calibration periods, 1985 and 1990. Sales prices, acreages, and land use types are available for all 6 counties in our region for all years, through TRW, Inc. We have found software that gives input-output tables for California and all counties (IMPLAN). We need household expenditures for housing, transportation, and other goods for our region.

TRANUS will calculate internal net benefits, and to those data we will add our estimates of external travel costs and government subsidies. This we will do with a spreadsheet, as we have done in the past. External and subsidy costs by passenger-mile by mode have been derived from several published studies. The California Energy Commission has also produced ranges of estimates for these values. Mark Deluchi at UC Davis is attempting to produce better estimates for many of these cost categories in 1994-95. Better data are needed.

Why did we decide on TRANUS, when other urban models are available?

1. Briefly, Boyce's models run on large computers and so are not implementable for agencies. They also do not have endogenous land prices.
2. The HUDS (NBER) model of Kain and others has no transport network. It has very disaggregate land use categories and so is data-hungry. It is not very transportable. Its calculations are not very transparent and so it is hard to interpret results. Some of its simulations are not closely based on economic theory.
3. The MEPLAN model of Echenique is not calibrated entirely with statistical

estimation and so is hard and slow to calibrate. It is proprietary and not very portable.

4. The POLIS model of Prastacos is very efficient but lacks a network and does not have land prices or floorspace rents to clear land markets. He may add land market processes in late 1994.

5. DRAM\EMPAL (ITLUP) by Putman has no prices and is not econometric, but is mainly a Lowry-type model.

6. The CATLAS model by Anas does not include nonresidential land uses, although a student of Anas' is adding them in 1994-95.

7. The LILT model of Mackett's has no prices and does not use multipath assignment.

8. The DORTMUND model of Wegener's has very disaggregate land uses, and so is data-hungry (rents by building type, age of residential units, housing units by several demographic characteristics of the occupants). It does not have readily available economic measures and does not produce equilibrium states, because different time lags are used for different variables.

This review came from Webster, Bly, and Paulley (1988), Anas (1987), and Wegener (1994).

We propose to perform medium- and long-term simulations with TRANUS. The necessary long-term datasets were built in a study done for Caltrans of a bypass freeway in the south and east areas of our region. The population and employment projections were approved by the planning staffs of the involved cities and counties, which saves us considerable time and effort. We will aggregate the land use zones to fit the 120-zone datasets of the DRAM/EMPAL models, and then use these zones for TRANUS. These changes will be reviewed by the regional agency (SACOG) staff. It is a major boon to us to have this dataset completed and approved by the member jurisdictions' staffs. We will

use the network files, land use files, and zone files for the years 2010 and 2040.

The much greater population in 2040 will permit us to compare heavy rail service with other long-range concepts, such as the 360-degree outer beltway (conventional freeway). We can also evaluate various scenarios under conditions of much greater congestion than is forecast for 2010.

These simulations will be viewed as *ceteribus paribus* sketch planning exercises, since no cross-sectional models are very useful for such long time periods, not even sequentially calibrated models. Also, the emissions characteristics of the fleet in 2040 are not known and so we will use the 2015 tables now available and treat the results as rank orders only. Such evaluations are common in other countries and have been done in several regions in the U.S. Portland, Oregon is doing a 50-year evaluation of an outer beltway now. USDOT and Caltrans did a 50-year study of a beltway in the Sacramento region.

In future projects (1995-96), we will experiment with the broad cognitive methods of strategic planning, using TRANUS plus a GIS. For example, contingency planning can be based partly on sensitivity analysis of variables, such as household incomes. We will also use pathway analysis to examine future policy options that are foreclosed by near-term choices.

Developing a GIS for projecting environmental impacts.

We have acquired the CUFM model from John Landis (City Planning, UC Berkeley) (Landis, 1993) and are in the process of adding all of the counties for our air quality region, under current funding. This model is for land development forecasting and for this project we will use this capability and use its GIS capabilities for impact assessment. If the data analysis is not

easy in CUFM with ArcView, we will keep the data in the Arc/Info system and produce maps and tables directly with it. We have several experienced Arc/Info users in our Departmental computer lab, and project organization, digitizing, editing, and data analysis are greatly facilitated by having so many people to help us.

Basically CUFM will be used as a second-stage growth allocator by taking the land uses forecast by TRANUS in rather large zones and will disaggregate them to polygons based on site characteristics such as slope, distance from freeway ramps, distance from cities, etc. CUFM allocates only residential uses and so we will have to develop rules for the allocation of employment uses. City and county general plan maps can be entered and used as constraints for the 20-year scenarios. Interviews with local planners will help us devise constraint rules and locational rules for the fine-scale location of employment uses.

Plant and animal habitat maps will be obtained from the Natural Diversity Data Base (California Fish and Game). Vegetative cover maps will be obtained from the Division of Forestry. We have USGS topo maps and software to determine the direction of surface water flows and also slope and aspect. We will add general soil types and soil interpretive types for the region. Soil erosion models are available from faculty members at UC Davis. We will design our own model for a first approximation of surface water pollution from urban runoff, using functions of urban area draining to surface waters of what volumes. We will consult with the US Army Corps of Engineers Hydrologic Lab in Davis for more sophisticated models. They operate many GIS software packages, some of them transportable and free.

Under existing funding, we should be able to have all of the datasets digitized and edited by the start of this project, so with UCTC funding, we

can concentrate on the modeling. The Principal Investigator has done similar modeling in the past, with much less tractable, homemade software (Singer, Johnston, and Thorpe 1975; Johnston, Thorpe, and Long 1975). The air pollutant mobile emissions will be modeled with the standard state models (BURDEN, EMFAC, PC-DTIM), which we have used in the past. They will read travel data from TRANUS.

Presenting results to decisionmakers.

This project is supported by the executive director of the regional transportation agency (Mike Hoffacker). (We have cooperated with the staff people at SACOG for over 20 years.) We will test scenario evaluation formats and map graphics on the staff at SACOG and at other agencies, such as the Sacramento City and Sacramento County planning departments.

Then, we will improve the presentation and try it out on the SACOG Board transportation committee members. The Principal Investigator has some experience with the issue of impact assessment formats (Cramer, Dietz, and Johnston 1980; Johnston 1977). He sits on advisory committees for Caltrans concerned with data presentation and evaluation methods for the Intermodal Transportation Management System for the State. Especially for long-range, strategic planning, goal tradeoffs are a central focus of impact portrayal.

REFERENCES

- Anas, Alex 1987. Modeling in Urban and Regional Economics. Harwood (New York).
- Barra, Tomas de la, 1989. Integrated Land Use and Transport Modelling. Cambridge University Press (New York).

Barra, T. de la, B. Perez, and N. Vera, 1984. "TRANUS-J: Putting Large Models into Small Computers," Environment and Planning B, vol. 11, pp. 87-101.

Berechman, J. and K. A. Small, "Research Policy and Review 25: Modeling Land Use and Transportation: An Interpretive Review for Growth Areas," Environment and Planning A, vol. 20, no. 10, pp. 1285-1309 (October).

Cramer, James C., Thomas M. Dietz, and Robert A. Johnston 1980. "Social Impact Assessment of Regional Plans: A Review of Methods and Issues and a Recommended Process." Policy Sciences, 12, pp. 61-82.

Harvey, Greig and Elizabeth Deakin, 1993. "A Manual of Regional Transportation Modeling Practice for Air Quality Analysis," for the National Assoc. of Regional Councils, Version 1.0, Washington, D.C.

Hook, Walter 1994. "The Evolution of Japanese Urban Transportation and Non-Motorized Transport," paper presented at the Transportation Research Board Annual Meeting, January.

Hunt, J.D. 1992. "Calibrating the Naples Land Use and Transport Model," conference paper, Martin Centre, Cambridge University, Cambridge, England, October.

Hunt, J.D. 1993. "A Description of the MEPLAN Framework for Land Use and Transport Interaction Modelling," submitted to the Transportation Research Board for presentation at the Annual Meeting, January, 1994.

Hunt, J.D. and D.C. Simmonds 1993. "Theory and Application of an Integrated Land-Use and Transport Modelling Framework," Environment and Planning: B, vol. 20, pp. 221-244.

Johnston, Robert A. and Raju Ceerla, in press a. "Effects of Land Use Intensification and Auto Pricing Policies on Regional Travel, Emissions, and Fuel Use." Paper presented at the TRB/EPA/USDOT conference on energy and sustainable transportation, Asilomar, CA, August, 1993. In press with the ICEEE as a special symposium report.

Johnston, Robert A. and Raju Ceerla, 1993b. "A Comparison of Modeling Travel Demand and Emissions with and without Travel Times Fed Back to Trip Distribution," resubmitted to the Transp. Res. Record.

Johnston, Robert A. 1993. "The Analysis of New High-Occupancy Vehicle Lane Projects Under the U.S. and California Clean Air Acts." Resubmitted to Transp. Res.:A.

Johnston, Robert A. and Raju Ceerla, 1993a. "A Systems-Level Evaluation of Automated Urban Freeways: Effects on Travel, Emissions, and Costs." J. of Transp. Engin.

Johnston, Robert A., Linda J. Thorpe, and T. Long 1975. "Land Use Mapping Programs," Second Edition with User's Manual. Division of Environmental Studies, UC Davis.

Johnston, Robert A. 1977. "The Organization of Social Impact Information for Evaluation by Decisionmakers and Citizens," chapter 8 in Handbook for Environmental Planning, ed. by J. McEvoy and T. Dietz. Wiley and Sons, New York, pp. 283-322.

Klosterman, Richard E. 1994. "An Introduction to the Literature on Large-Scale Urban Models." J. of the American Planning Assoc., 60:1, pp. 41-44.

Landis, John 1993. "CUF Model Simulation Results: Alternative Futures for the Greater Bay Area Region," Institute of Urban and Regional Development, University of California, Berkeley, Working Paper 595, April.

Mackett, Roger 1994. "The Use of Land-Use Transportation Models for Policy Analysis." Preprint 940012 for the Annual Meeting of the Transportation Research Board, Washington, D.C. (January).

Paulley, N.J. and F.V. Webster 1991. "Overview of an International Study to Compare Models and Evaluate Land-Use and Transport Policies." Transp. Reviews, 11:3, pp. 197-222.

Replogle, Michael 1991. "Computer Transportation Models for Land Use Regulation and Master Planning in Montgomery County, Maryland." Transportation Research Record 1264, Transportation Research Board, Washington, D.C., pp. 91-100.

Singer, Michael J., Robert A. Johnston, and Linda Thorpe 1975. "Land Use Mapping Programs (LUMP): Computer Help for Land Use Decision Making," Calif.

Agriculture, 29, 12-14.

Stopher, Peter 1993. "Deficiencies of Travel-Forecasting Methods Relative to Mobile Emissions." J. of Transp. Engin., 119:5, pp. 723-741.

Sullivan, Arthur M., 1983a. "A General Equilibrium Model with External Scale Economies in Production," J. of Urban Economics, vol. 13, pp. 235-255.

Sullivan, Arthur M., 1983b. "The General Equilibrium Effects of Congestion Externalities," J. of Urban Economics, vol. 14, pp. 80-104.

Sullivan, Arthur M., 1983c. "Second-Best Policies for Congestion Externalities," J. of Urban Economics, vol. 14, pp. 105-123.

Tufte, Edward R. 1983. The Visual Display of Quantitative Information. Graphics Press (Cheshire, CN).

Webster, F.V., P.H. Bly, and N.J. Paulley, 1988. Urban Land-Use and Transport Interaction. Avebury (Brookfield, MA).

Wegener, Michael. "Operational Urban Models." J. of the American Planning Assoc., vol. 60, no. 6, pp. 17-29 (Winter).