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The Evaluation of Multimodal Transportation Systems for Economic Efficiency and Other Impacts

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The University of California Transportation Center
University of California at Berkeley

THE EVALUATION OF MULTIMODAL TRANSPORTATION SYSTEMS

FOR ECONOMIC EFFICIENCY AND OTHER IMPACTS

Abstract:

ISTEA 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. Major capacity increases with automated highway systems are also being examined and such systems will have major effects on land use patterns. The Clean Air Act regulations require the proper simulation of latent demand in travel modeling for conformity analysis. Current models in use by MPOs 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. The statewide Intermodal Transportation Management System models to be used in California do not represent latent demand at all. 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.

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. 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 MPO 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 NCHRP or TCRP 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 econometric 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, CUFS (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. CUFS 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.

First, we will go through the research program, which develops a set of regional models for strategic transportation and land use planning. Then, we will comment on the usefulness of these models for the economic evaluation of IVHS in regional planning and for statewide modeling in Intermodal

Transportation Management Systems.

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 HOV 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 1993a), and comparing modeling with and without equilibration of trip distribution on assigned impedences (Johnston 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 desireable 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).

Are other models available that we could use? We review the other integrated urban models below, but let us first briefly discuss microsimulation and dynamic travel demand models. Microsimulation models have been proposed for several years and outlined by several researchers, such as Kitamura. With USDOT funding, work is underway in three groups: Kitamura (RDC, Inc.), Cambridge Systematics, Inc., and Los Alamos National Lab. In California, the major development projects are a microsimulation travel and emissions model being developed by UC Riverside workers on UCTC and other funds and a microsimulation vehicle holdings and travel model being developed by UC Irvine and UC Davis researchers for electric utilities in Southern California and the Energy Commission.

These models will be data-hungry and difficult for regional transportation agencies to use. It is unclear if we can ever get vehicle modal emissions data sufficient to support microsimulation of vehicle travel and emissions. Even then, it may be impossible to account for differences in driving behaviors, even in same-model vehicles. This model type will not include land use models, and so is not adequate for simulating major changes in regional road capacity.

The microsimulation vehicle transactions and travel models will suffer from the same limitations, in terms of our research objectives. Even the much-improved version of the California Energy Commission's personal vehicle model, due in late 1995, however, will not include land use decisions and so will not be useful for simulating major capacity expansion policies accurately.

We have spoken with Art O'Sullivan (Oregon State, Corvallis) about this problem and have read his articles (Sullivan 1983a, 1983b, 1983c) on general equilibrium urban modeling. We believe that the TRANUS model set is the best available model for application to an actual urban region. Let us now look at the literature on integrated urban models.

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 IRANUS, 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 CUFS 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 CUFS 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 CUFS 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. CUFS 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.

Overall review procedures.

All of our work will be reviewed by a local advisory committee composed of SACOG staff, Caltrans modelers, consultant operators of the SACOG travel models, and city and county planners. We will make all of our datasets useful for SACOG modeling by meeting with them and agreeing on data types in detail.

We will also have our TRANUS model equations and data and outputs reviewed in detail in writing by Alex Anas (SUNY at Buffalo), who has developed one of the most theoretically sound applied econometric models (CATLAS) and is extending it to include nonresidential uses. He has also published two books reviewing urban models (Anas 1987, 1982).

We will produce an analysis of the strengths and deficiencies of the TRANUS model and recommend further research. Such an external review is needed because of the difficulty of correctly representing the supply and demand for all important goods and services in an urban region. Overlapping measures of consumer and producer surplus must be avoided. Data must be accurate and measure the phenomena being simulated. Even slight differences in equations must be evaluated, in terms of economic theory. Many advances have been made in theory and methods during the last 20 years and we are on the verge of having families of models that will be useful for the comprehensive evaluation of transportation, land use, and related policies.

APPLICATIONS TO REGIONAL IVHS EVALUATION AND TO STATEWIDE ITMS

In addition to its use for regional strategic transportation and land use planning by MPOs, this model set will also be useful for the evaluation of regional automated freeway systems (IVHS) and for statewide planning with Intermodal Transportation Management Systems.

A. Economic evaluation of IVHS:

Ostria and Lawrence (1994) review the various forms of IVHS and find that some programs, such as enhanced I&M, transit scheduling, and vehicle pricing, are likely to reduce emissions, whereas incident management and route guidance may increase NOX and vehicle control may increase all emissions. This article is conceptual, with reference made only to theory and to general findings from earlier studies. It is, however, a very useful overview of these issues.

Dobbins et al. (1993) performed a comprehensive empirical study of the effects of increasing highway capacity on travel, using longitudinal panel datasets of metropolitan roadway lane-miles and vehicle-miles traveled (VMT). They found that the medium-term (arc) elasticities (VMT per capita/major roadway capacity per capita) averaged about 0.5 to 0.6, for times of 6-9 years after the capacity expansions. The literature was in fairly good agreement with their own data. The authors note that elasticities will be higher in the future when congestion levels are worse.

A paper that shows the need for empirical simulation is by Brand (1994). He proposes to evaluate IVHS projects with a mix of economic efficiency criteria and output (demand) criteria, while noting that these groups of measures overlap. The use of such a set of overlapping criteria confuses evaluations with double-counting and makes the weighting of the categories of measures overly political. A comprehensive economic evaluation should be done, instead, and the effects on other criteria discussed outside of the economic evaluation. His economic analysis method explicitly assumes that capacity increases will not induce additional tripmaking or longer trips, while acknowledging that these assumptions are unrealistic. He then uses these unrealistic (and incorrect) assumptions to demonstrate that large capacity increases will produce net benefits. This paper serves to illustrate the dire straits agencies and others interested in IVHS could get into if they do not develop sound evaluation methods based on economic theory.

Another recent paper by Horowitz (1994) assesses the user benefits of transit system improvements using an integrated set of land use/transport models. However, the land use models are of the Lowry-Garin type, which do not allocate new land uses with a market mechanism based on floorspace rents or land prices. This weakness makes the simulations limited and also results in a lack of measures of locational surplus.

Another paper illustrates the need for complete models. Weisbrod and Beckwith (1992) evaluate economic impacts of new highway alternatives in Wisconsin using the REMI model, which is a regional input-output model based on national and statewide input-output tables. Changes in direct and time costs for trucks and autos are evaluated with travel demand models. Then, the reductions in the cost of doing business in various sectors leads to increases in those activities. Land markets are not represented in the REMI models and so no projections of land use patterns can be made and no measures of locational surplus are available.

The TRB Conference on Transportation, Urban Form, and the Environment (TRB 1990) recommended that both empirical and modeling research be done on the effects of capacity expansions on travel, emissions, and land use (pp.

149-150). Brand's paper in this report (Brand 1990) recommends that long-run general equilibrium models of land use and transport be implemented. He states that changes in capacity and speeds (due to vehicle control) are relatively easy to evaluate using such models, compared to other IVHS programs. He also recommends research on the changes in social costs and their incidence that would result from various transportation investments. And, most interestingly, he states that we need more work on the issue of whether there are social costs of travel that vary inversely with congestion, such as the costs of inefficient land use patterns. Small (1992) recommends the use of comprehensive urban models to account for the effects of major transportation system changes on both travel and land use (pp. 139, 157).

The proposed research will be the first application of a model that is capable of projecting the land use impacts of freeway automation, or any other major regional addition to roadway capacity. TRANUS will also permit the evaluation of net economic benefits for travelers and locators. Past studies showing increased travel costs under full automation have implied that IVHS may not be economically beneficial to regions. The proper test, however, is whether utility in increased, not whether costs rise. If travelers choose to spend more to travel faster and farther, they must be gaining benefits at least as large, especially when we consider locational surplus in the more remote suburban locations. The most interesting test will be when we add in external travel costs and government subsidies, to see if social net benefits are positive in IVHS scenarios.

B. Statewide Intermodal Transportation Management Systems:

ISTEA requires several management systems. Perhaps the most ambitious is the Intermodal Transportation Management System (ITMS), which is to identify problems with intermodal connectivity on a statwide basis. As our example, we will use the California system that is under development and discuss its analytical weaknesses.

The consultants are developing a complex interactive database in Arc/Oracle that will permit the user to point and click on "buttons" that select: 1. state, air basin, or Caltrans district for 1990 base year system; 2. select future year (2000, 2010, or 2020) no build case; 3. select deficiency class in 1990 system; 4. select project or policy type to address deficiencies; 5. select evaluation data categories. The system will display ArcView maps and tables, will run freestanding on PCs and Macs, and will permit MPOs to add additional databases. It will be a very sexy tool.

Our reservations are the expected ones from academics. The mode choice models inside are very crude and do not account for latent demand, now recognized as one of the key issues in modeling under ISTEA and the Clean Air Act. For example, the Clean Air Act transportation conformity analysis regulations require modeling in serious and severe ozone nonattainment areas to account for the effects of changes in capacity on trip length. The California ITMS modeling will not do this and so will produce results very different from those from MPO modeling for conformity analysis. Also, the ITMS model, which use fixed trip tables from the MPOs as its basic datasets for each region, does not permit the evaluation of land use policies directly within the database. This is a serious bias: the main two types of travel demand reduction policies being examined under ISTEA and the Clean Air Act, travel pricing and land use intensification near to transit lines, cannot be accurately modeled. The latter cannot be simulated at all and the former will result in underprojection of travel reduction, due to the fixed trip tables.

This is just the first-cut system and Caltrans intends to improve it in the next few years, but bad models are worse than none at all in our opinion. The lack of a capability to produce economic evaluations is equally disturbing. The evaluation indicators include ones for mobility, safety, quality of life, environmental, financial, and economic. The economic indicators do not include changes in welfare (net benefits), because no existing models used by Caltrans or the MPOs can perform such calculations. The measures under financial are user costs per person-mile and average annual costs to service providers. As discussed above, these are not useful indicators of utility.

The first economic indicator is average number of jobs supported per year, which is conceptually misleading. Jobs created from state spending are merely geographic transfers of income within the state and jobs created from federal spending are transfers within the nation, from USDOT's standpoint, and can be viewed as an increase in state production, from the Caltrans standpoint. From the state perspective, however, the job gains should be compared with other ways to spend the same amount of funds, to evaluate job creation meaningfully. The second economic indicator is change in gross state product, which is measured by projecting spending on capital and operations and multiplying by a basic/nonbasic multiplier. This concept suffers for the same reasons stated for the jobs indicator. The final economic indicator is cost of pollution, accidents, fatalitites, and lost time per person-mile. Even assuming the units of the last item are fixed to be total lost time, this set of measures of external costs leaves out many categories of external costs, such as lost property taxes for right-of-ways, government subsidies to energy and travel services and parking, and increased accessibility costs due to sprawl. It also ignores hidden costs, such as garaging autos, and parking subsidies by employers and retail owners, some of which fall on households that do not own autos.

The main problem, however, is that there is no measure of consumer surplus for travelers and locators. This critique is not intended to diminish the efforts made to date on the California ITMS, which are heroic, but to show that this first system is inadequate. It is incomplete and, worse, it is biased in terms of policies that can be examined and it is biased in terms of travel and other evaluations, because it omits latent demand. Caltrans needs to take the next step, which is to operate TRANUS or a similar integrated urban model for the state and its urban regions. TRANUS has been applied in World Bank-funded national studies. Large zones are used to estimate interurban travel and then each urban region has smaller zones nested within the large ones to use in projecting regional travel. Goods movement is well simulated, with all transfer and fixed costs included in multipath search. Stochastic multidimensional assignment avoids the problems of overassignment to shortest routes in uncongested networks.

Caltrans and other states need to apply such models for ITMS, so that land use-transport interactions can be properly simulated, land use policies can be tested, and economic welfare can be evaluated.

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