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TRANSIT PERSPECTIVES TO THE YEAR 2000: POSSIBLE CONSEQUENCES OF DOING NOTHING

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16. Abstract

The purpose of this study was to examine some often ignored indirect effects of reduction or elimination of transit services. While transit use may be a small percentage of total regional trips, specific urban corridors can have very high transit trip shares. Normal analyses of the consequences of eliminating transit service in such corridors might only consider the costs to the transit users thus forced to find alternative transportation. It is quite likely that many of these former transit riders would use the same corridors, but in private automobiles. This would result in substantial increases in trip volumes and congestion. Tripmakers who had never been transit users might find their trip times and costs substantially increased. There would also be reductions in the economic viability of areas served by these newly congested corridors. Such indirect effects can be quite important and should be included in evaluation of transit service reductions. The study made use of computer models of transportation and land use interactions to make an initial assessment of the potential scale of these often overlooked effects. The results of this preliminary study show these effects to be significant and to produce substantial declines in economic activities in corridors formerly served by the eliminated transit services.

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INTRODUCTION

The past two decades have seen public transit in U. S. metropolitan areas attempting to cope with an apparently unending series of financial difficulties. There are many reasons put forward for these problems, ranging from poor management and excessive labor costs, to the spatial rearrangements of metropolitan areas over the past several decades which militate against adequate concentrations of demand for public transit services. Regardless of the specific causes, there is no question that continued operation of public transit systems has required increasing government subsidies for both capital costs and operating costs. In the public debate regarding these subsidies a common refrain is that of how much money is being spent to meet the needs of declining numbers (at least declining as a percent of total trips taken) of transit passengers. It is being argued that these subsidies should be discontinued, that a "do nothing" position should be taken by the Federal Government, and transit be allowed to succeed or fail on its own. State governments too, seem to be following this lead, and already financially stressed local governments are being pushed to the wall on the issue of transit subsidies.

What are not considered in these discussions are the indirect but very real benefits received by non-users. These benefits fall under two major headings: 1) non-user benefits received directly due to the absence (except in transit vehicles, i. e. not in automobiles) of transit travellers from the highway networks, and 2) non-user benefits received indirectly from spatial patterns of activities not disturbed by roadway congestion which might result were the transit facilities to be eliminated.

Benefits such as these may be illusory. Even if such benefits are real, they may be quite difficult to measure. The purpose of this small, introductory, research effort was to undertake a preliminary examination of these effects. In particular, the intent was to attempt to determine, by use of computer simulation, what magnitudes of effects might be involved. As such, a series of simulations was done for two different metropolitan areas - - San Francisco, and Minneapolis - St. Paul. Simulations were done for each of these regions, in each case, both with and without transit facilities represented. The results, while never intended to be definitive, were quite suggestive. The elimination of transit service in either of the two metropolitan areas produces substantial increases in central area (CBD) roadway congestion. This congestion, in addition to increasing the implicit travel cost to all users of the area's roads, in turn, has long term impacts on the commercial viability of these central areas. It is certainly possible, perhaps likely, that the "do nothing" approach will lead to wholesale abandonment of public financial support for transit. While a good deal more investigation is required, there is a clear indication from the results described here that this will, if it leads to closing down of transit systems, have negative impacts far greater than the simple inconveniencing of former passengers.

In the next section of this report a brief review of statistics on transit use in the U. S. is presented. This is followed by a description of the computer model package used for the simulations. The fourth section of the report describes the simulation results, and is followed by a set of conclusions and recommendations.

TRANSIT IN THE UNITED STATES TODAY

In the mid-1970's the U.S. Bureau of the Census conducted a special study of the transportation characteristics of 61 selected Standard Metropolitan Statistical Areas (SMSA's). The results were published in a series of three reports (Bureau of the Census, 1978a, 1978b, 1981). This special study found that just over 12 percent of the workers in these selected SMSA's used public transit to travel to work. The average percentages of trips by mode for all these SMSA,s were as follows:

Bus or Streetcar	8.7%
Subway or Elevated	1.5%
Railroad	1.9%
Drive alone	67.6%
Carpool	18.0%
Other Means (Motorcycles, Bicycles & Others)	2.3%

Averages, however, can be misleading. Cordon count information for 1970 or later for the 20 largest U.S. SMSA's for which data are available, shows that of all trips entering the central business districts (CBD's) during a twenty-four hour period, between 14% (for Houston) and 49% (for Boston), are by transit. This data excludes New York and Chicago where cordon counts show that 90% of the trips to the CBD's are by public transit systems (Levinson, 1982, p. 291).

The special census transportation survey also provided information on area characteristics of transportation: 1) the section of the country in which public transit users reside, 2) the portion of the metropolitan areas in which they reside, 3) and the population density of those areas. According to this survey, the principal means of transportation to work for 14% of the residents of the Northeastern United States is public transit. For the rest of the country, the percentage is considerably lower, varying from 3% to 5%. Just under 70% of those who ride public transit to work live in central cities of SMSA's. About 28% live outside the central city but within an SMSA, and only a bit over 3% of the transit users live outside an SMSA. In addition, the data show that public transit ridership per capita is related to population density of an area, and that transit ridership per capita increases approximately logarithmically as density increases.

The distribution of means of transportation to work in 1975, by family income, is available as percentages of work trips by mode by family income (Bureau of the Census, 1979). Public transit use increases from 11% for the income group making less than $3000 per year to 12% for the $3000-$7000 group. Transit use then declines smoothly to 4% for the $20,000-$35,000 group, and then varies, with 5% for the $35,000-50,000 group and for the $50,000-$75,000 group, and 6% for the income group over $75,000 per year. For all trips in U.S. metropolitan areas the percentages of transit riders by income class are given in Table 1a. Transit riders are concentrated in the lower

Table 1a - Percent of Transit Riders by Income Class

U. S. Metropolitan Areas - 1975

	Less than $6000	$ 6,000- $10,000	$10,000- $15,000	$15,000- $20,000	$20,000- $25,000	Over $25,000
Bus & Streetcar	28.3%	19.2%	18.7%	13.5%	8.5%	11.7%
Rail Rapid Transit	16.2	17.2	27.7	14.4	11.7	12.9
Commuter Rail	9.3	6.0	7.9	18.9	20.1	37.8
Total Transit	24.9	17.8	19.1	14.1	10.1	14.2

Source: Bureau of the Census, 1978, 1978a, 1981

Table 1b - Trip Purpose and Household Type

Cincinnati, Ohio - 1965

	Percent of Households Owning		
Trip Purpose	No Car	One car	Multi-car
Home-based work	35%	26%	21%
Home-based shopping	19	16	14
Home-based social-recreation	15	17	18
Home-based school	9	7	9
Home-based other	12	13	14
Non-home-based	10	21	24
Trips/dwelling unit/day	1.8	7.0	12.0

Source: Levinson, 1982, p. 269.

income groups, but these statistics show quite clearly that <u>all income groups have significant percentages of riders</u>.

For all public transportation users the mean work trip distance is 9.1 miles, and the mean travel time is 39.5 minutes. Mean trip length on railroad is 24.3 miles, on subway 10.1 miles, and on bus and streetcar 9.1 miles. For central city residents of SMSA's mean travel distance is 7.3 miles, while for residents of SMSA's not living in central areas the mean work trip length is 9.9 miles. For workers with family income less than $3000 the mean travel time to work on public transportation is 36.3 minutes. As family income increases, travel time generally increases, reaching 52.1 minutes for annual incomes of $75,000 or more.

Nationwide, nearly 6% of the employed population uses transit as the principle means to get to work. By comparison, 17% of employed blacks use transit, 12% of the employed Spanish origin population use transit, and 13% of the female workers use transit. According to the special census of transportation characteristics, 12.3% of commuters using vehicles, used public transportation as their principal means of traveling to work during 1975. This is a decline from 15.7% during 1970.

Table 1b shows the percent of trips by the number of cars per household for the Cincinnati area, 1965. Households without autos have a higher percentage of home-based work and shopping trips and a much lower percentage of non-home-based trips. They also have far fewer trips per dwelling unit per day.

Again, one must be careful in using aggregate statistics. In American cities, there are substantial differences between modal choice percentages in specific transportation corridors, and metropolitan area-wide modal choice. Four U.S. cities for which transportation corridor mode choice information is available are: Philadelphia, Rochester, N.Y., San Francisco, and Washington, D.C. Table 2a shows the percentage of travelers by mode to the Washington core area for the morning peak hours period for four transportation corridors. The data is given for three years, during which portions of the city's new rapid transit system were opening. For the most recent year, 1979, transit ridership in the four corridors varied from 31% to 40%. During 1979, transit ridership to the Washington core area during the morning peak period was 36%, while regionwide only 15% of the population used transit to get to work in 1977.

Table 2b shows 1970 transportation mode used by workers in the Frankford El(evated) Corridor in Philadelphia, the city-wide percentages, and the Philadelphia SMSA percentages for 1975. Public transit was used for traveling to work by 33% of population in the Frankford El Corridor, and by 36% of the population of Philadelphia overall in 1970. In 1975 only 16% of the SMSA's population was using transit.

The means of transportation to work for 1970 for the Charlotte-Henrietta transportation corridor, in Rochester, N.Y. was 13.4% versus 5.5% for the region's SMSA (Rochester Metropolitan Planning Authority, 1974, p. IV-56). However, public transit use within the Charlotte-

Table 2a - AM Peak Period Travel to the Washington D.C. Urban Core

Corridor(1)	Year	Auto Driver	Auto Passenger	Bus	Rail	Total Transit
Northern	1977	48.1%	26.7%	25.2%	0 %	25.2%
Virginia	1978	44.5	28.4	12.2	14.9	27.1
	1979	42.4	23.4	11.0	23.2	34.2
Silver	1977	43.4	22.1	31.3	3.3	34.6
Spring	1978	40.9	20.7	20.5	17.9	38.4
	1979	42.1	17.8	19.0	21.2	40.2
New	1977	47.5	21.7	30.8	0	30.8
Carrollton	1978	47.2	18.6	25.0	9.2	34.2
	1979	41.7	20.0	21.1	17.2	38.3
Wisconsin	1977	52.8	18.8	28.3	0	28.3
Connecticut	1978	52.9	19.4	27.7	0	27.7
Avenues	1979	49.8	19.6	30.6	0	30.6
Total Trips	1977	47.6	22.8	28.8	0.8	29.6
to D.C.	1978	45.8	22.3	20.3	11.6	31.9
Core	1979	43.3	20.4	19.0	17.3	36.3
All Work Trips(2)	1977	65.1	19.9	14.5	0.4	14.9

Sources: (1). Dunphy, R. and R. Griffiths, 1981, pp.70-75.
(2). Bureau of the Census, 1981, p. 16.

Table 2b - Transportation Mode Preference: Frankford El Corridor, Philadelphia

Mode	Frankford El Corridor(1), 1970	Philadelphia(1) 1970	Philadelphia(2) SMSA 1975
Auto Driver	39%	42%	63%
Auto Passenger	9	9	11
Bus & Streetcar	23	26	9
Subway and Rail	10	10	7
Working at Home	3	2	2
Walking	15	10	6
Other	1	1	1

Sources: 1. Institute for Transportation Studies, 1977, p. 1.49.
2. Bureau of the Census, 1978, p. 13.

Henrietta corridor varied from 0.4% to 51.0% for certain census tracts.

Table 3 gives the modal split statistics for two San Francisco area corridors, the San Francisco-Oakland Bay Bridge and the Caldicott Tunnel. Peak-hour transit use during 1977 varied from 34% - 52% of total trips versus 18.5% for the San Francisco SMSA total daily journey to work trips.

It is quite clear that this has been a very brief look at transit statistics, and that a good deal more effort is needed here to put together an argument on which actual policy decisions might be based. Yet, in this brief reconnaissance certain points emerge rather clearly. Overall, the evidence suggests that modal choice is very significantly affected by the destination location. In particular, a much higher percentage of travelers to downtown areas use transit than use transit region-wide. The time of day when trips are taken is also important. A much higher percentage of peak hour travelers use transit than do off-peak hour travelers. Finally, a particular transportation corridor may have a higher percentage of transit riders than total downtown destination trips. This was true for Rochester's Charlotte-Henrietta Corridor, San Francisco's Oakland Bay Bridge Corridor and perhaps Washington's Silver Spring Corridor. An important implication of these data is that in assessing transit elimination impacts it will be necessary to consider both the direct and indirect spatially distributed impacts.

Table 3 - Percentage of Trips in San Francisco Transportation Corridors

Corridor	Time Period	1973 Auto	1973 Transit	1977 Auto	1977 Transit
San Francisco -	AM Peak	54.7%	45.3%	48.1%	51.9%
Oakland Bay Bridge(1)	Off-Peak	89.7	10.3	79.4	20.6
Caldicott	AM Peak	73.8	26.2	66.4	33.6
Tunnel(1)	Off-Peak	93.1	6.9	87.0	13.0
San Francisco SMSA(2)	Work Trips	81.5	18.5 (1975)		
	Vehicle Trips	88.0	12.0		

Sources: 1. Department of Transportation, 1979, p. 79, 159.
2. Bureau of the Census, 1975, p. 13.

THE MODELS USED FOR THE SIMULATIONS

1. Introduction

The Integrated Transportation and Land Use Package - ITLUP, used for this project contains both location and transportation models and has been the subject of a long sequence of development and application projects since 1971. A complete description of this work is found in Putman (1983). ITLUP has, of course, evolved over this period, and the current version contains four principal models plus a number of minor submodels. The four principal models are: 1) EMPAL, for employment location, 2) DRAM, for simultaneous residential location and trip distribution, 3) MSPLIT for mode split calculation, and 4) NETWRK, for trip assignment. The general configuration of ITLUP is shown in Figure 1. The minor submodels handle such tasks as calculating intrazonal travel times and various transportation network congestion measures, as well as land consumption. There are also programs for network checking, composite cost calculation, model calibration, data management, and air pollution consequence calculation, which are available to run in conjunction with ITLUP.

In each recursion, the sequence of operation of the principal models of ITLUP is quite straightforward: EMPAL, DRAM, MSPLIT, NETWRK. For the moment the problem of system initialization will be neglected, and it will be assumed that the model package is calculating the n'th recursion, from time t to time t+1.

The recursion begins with the execution of EMPAL. To forecast the location of employment of type k in zone j at time t+1 EMPAL

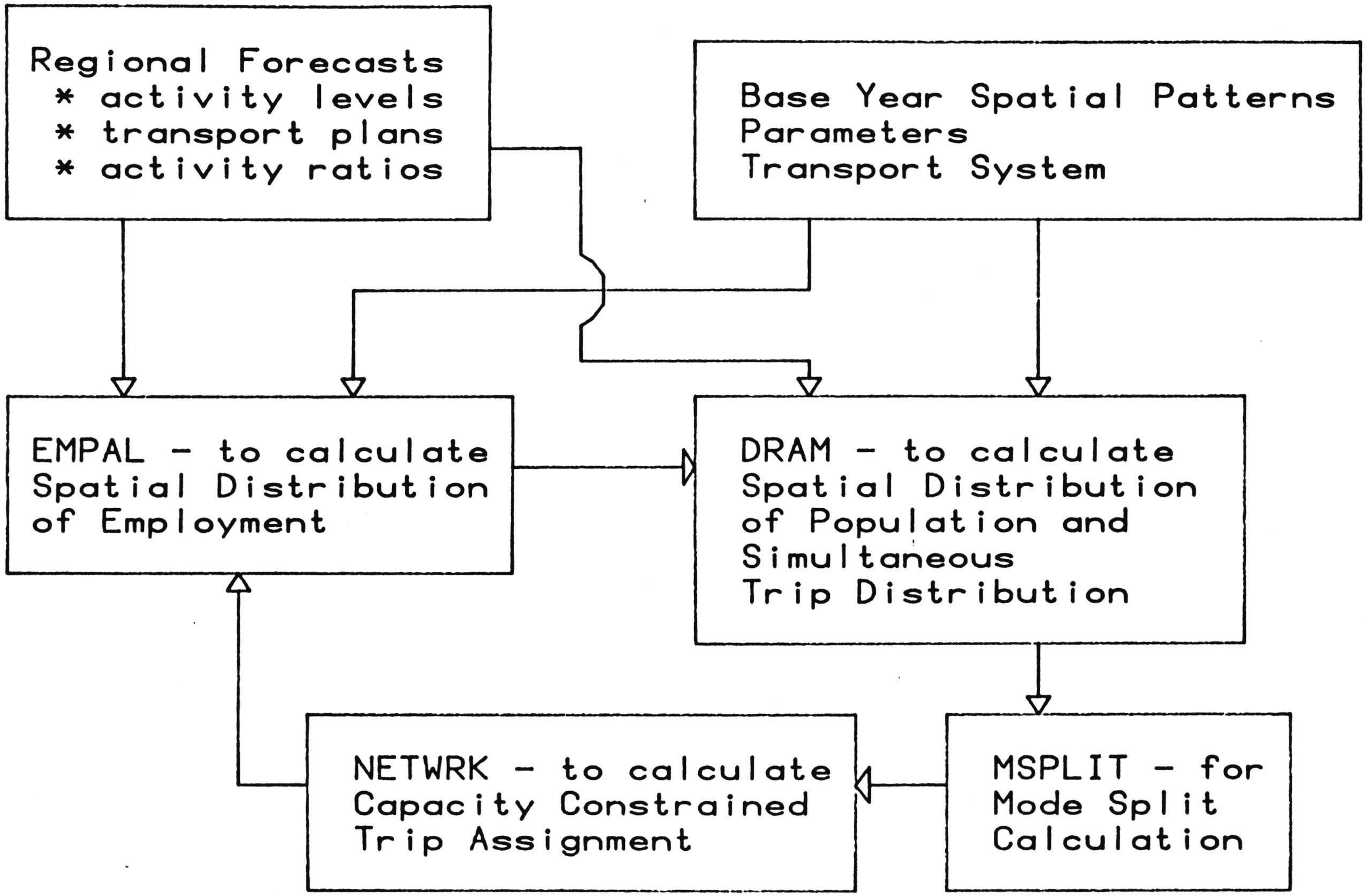


Figure 1: MODEL SYSTEM CONFIGURATION

uses the following input variables: employment of type k in all zones at time t, population of all types in all zones at time t, total area per zone for all zones, zone-to-zone travel cost (or time) between zone j and all other zones at time t. The parameters used are derived from time t and time t-1 data. The model requires regional employment forecasts for time t+1.

Following the employment location forecasts produced by EMPAL, a set of residence location forecasts is produced by DRAM. To forecast the location of residents of type h in zone i at time t+1 DRAM uses the following input variables: residents of all h types in zone i at time t, land used for residential purposes in zone i at time t, the percentage of the developable land in zone i which has already been developed at time t, the vacant developable land in zone i at time t, zone-to-zone travel cost (or time) between zone i and all other zones at time t+1, and employment of all k types in all zones at time t+1. The parameters used are derived from time t data. The model requires regional population forecasts for time t+1.

Following the residence location forecasts produced by DRAM it is necessary to split trips by mode, and to assign vehicle trips to the transportation network(s). The origin-destination work trip matrix is produced in DRAM, simultaneously with residence location. In addition, also in DRAM, matrices of work-to-shop and home-to-shop trips are produced. These three trip matrices must be expanded to represent total trips, and converted from trip probabilities (the actual form in which they are calculated) to actual person and/or vehicle trips. These trips are then split into trips by mode in

MSPLIT, yielding transit person trips plus automobile vehicle trips. The automobile trips are then assigned, using NETWRK, to a highway network for time t+1. The output of NETWRK is a set of zone-to-zone highway travel times (costs) on the time t+1 network. These highway times (costs) are then combined with the transit times in CCOST to yield a composite time (cost) matrix.

2. Employment Location - EMPAL

EMPAL is a modified version of the standard singly-constrained spatial interaction model. There are three modifications: 1) a multivariate, multiparametric attractiveness function is used, 2) a separate, weighted, lagged variable is included outside the spatial interaction formulation, 3) a constraint procedure is included in the model, allowing zone and/or sector specific constraints. The model is normally used for 3-5 employment sectors whose parameters are individually estimated. The simulations done for this project used four employment sectors.

3. Household (Residence) Location - DRAM

DRAM is a modified version of the standard singly-constrained spatial interaction model. There are two modifications: 1) a multivariate, multiparametric attractiveness function is used, 2) a consistent, balanced constraint procedure is included in the model, allowing zone and/or sector specific constraints. The model is normally used for 4 household types (usually income groups) whose parameters are individually estimated. The simulations done for this project used four household types, defined in terms of household income quartiles.

4. Land Consumption

In the current version of ITLUP new locators consume land at the prior average rate. In the forthcoming new release of ITLUP a separate model, LANCON, will calculate land consumption using a simultaneous multiple regression formulation.

5. Trip Generation and Distribution

Trip generation and distribution are calculated in DRAM, simultaneously with household location. In fact the trip distribution is done first by calculating and storing trip-probability matrices during the household location calculations. These probability matrices are later converted to vehicle trips by use of region-specific rates.

6. Mode Split

The trip matrices produced in DRAM are split into trip matrices for each of the available modes (usually 2 or 3) in MSPLIT. This model uses a multinomial logit formulation to do the mode split calculation. The precise functional form of the logit model varies from application to application as a function of data availability.

7. Trip Assignment

Trips are assigned to a capacity constrained network in NETWRK. The usual procedure has been to utilize incremental tree-by-tree assignment with random origin selection. The sizes of the increments can be varied and partially loaded networks can be saved to decrease computational costs in successive recursions. The most recent version of NETWRK can use any of three different assignment algorithms, incremental tree-by-tree, stochastic multipath, or user equilibrium.

8. Utilities

A number of utility programs are available for use with ITLUP. These include: 1) a parameter estimation program - CALIB, 2) policy input programs - DATMOD, IMPMOD, 3) descriptive statistics - DRMSTAT, CALSTAT, and 4) a standard data preparation program - DRMPREP. In addition there is a program for calculating the composite costs, i.e. the costs which result from combining costs for several modes into a single value - CCOST. Finally, there are programs for calculating both the air pollution and energy consumption consequences of alternative transportation and land use patterns.

ITLUP MODEL EQUATIONS

EMPAL

$$E^k_{j,t} = \lambda \sum_i P_{i,t-1} A^k_{i,t-1} W^k_{j,t-1} c^{\alpha^k}_{i,j,t} \exp(\beta^k c_{i,j,t}) + (1-\lambda) E^k_{j,t-1} \quad (1)$$

where

$$W^k_{j,t-1} = (E^T_{j,t-1})^a L^b_j \quad (2)$$

and

$$A^k_{i,t-1} = \left[\sum_i (E^T_{i,t-1})^a L^b_i c^{\alpha^k}_{i,j,t} \exp(\beta^k c_{i,j,t})\right]^{-1} \quad (3)$$

where

$E^T_{j,t-1}$ = total employment (place-of-work) in zone j at time t-1

$E^k_{j,t}$ = employment (place-of-work) of type k in zone j at time t

L_i = total area of zone i

$c_{i,j,t}$ = impedance (travel time or cost) between zone i and zone j at time t

$P_{i,t-1}$ = total population of zone i at time t-1

$\lambda, \alpha^k, \beta^k, a, b$ = empirically derived parameters

<u>DRAM</u>

$$N_i^n = \sum_j Q_j^n B_i^n W_i^n c_{i,j}^{\alpha^n}$$

where

$$Q_j^n = \sum_k a_{k,n} E_j^k \qquad (5)$$

and

$$B_i^n = \left[\sum_i W_i^n c_{i,j}^{\alpha^n}\right]^{-1} \qquad (6)$$

and

$$W_i^n = (L_i^v)^{q^n} (x_i)^{r^n} (L_i^r)^{s^n} \prod_{n'} \left[(1 + N_i^{n'} / \sum_n N_i^n)^{b_{n'}^n}\right] \qquad (7)$$

where

N_i^n = households of type n residing in zone i

L_i^v = vacant developable land in zone i

x_i = 1 plus the percentage of developable land already developed in zone i

L_i^r = residential land in zone i

$a_{k,n}$ = (regional) coefficient of type n households per type k employee

$\alpha^n, q^n, r^n, s^n, b_{n'}^n$ = empirically derived parameters

MODEL APPLICATION

The ITLUP package is a particularly useful method of investigating the impacts of possible policy changes that could lead to the decline of urban transit systems in America. It is a fully integrated land use and transportation model, using data on population, land use and employment to determine trip patterns and modal split for a metropolitan area and then using these to congest the transport facilities and revise the location forecasts. Thus ITLUP can be used to help determine the changes in locational patterns for various land uses that would result from changes in the public transportation system ranging from minor system modifications to wholesale system abandonment.

Base year data, on employment, population, land use and their spatial distributions, are initially required as input into the package. Also required is a representation of the city's transportation system and the parameters calibrated for the city for each of the models that make up the package. In this series of tests, pre-determined automobile impedances, representing congestion on the highway system of the urban area, were also input initially. However, the model can begin by loading the first iteration trips on the system and then calculating the initial impedance matrix, if desired.

During each iteration, covering about 5-10 years, changes in population, land use, and trips are distributed following the distribution of changes in employment. For each of these locating activities regionwide changes or control totals are provided exogenously. Numbers of trips by type (home to work, work to shop,

shop to home) are then generated for each zone. Next, if it is desired to split the trips into two modes, auto and transit, the MSPLIT procedure can be used. This is accomplished by using transit factors derived exogenously from a transit system map, and the automobile impedances. The automobile trips are then assigned to the previously coded transportation network, and the resulting new automobile impedances are calculated using standard volume/delay relationships. Transit and automobile impedances are combined into a composite cost matrix to provide inputs to the next iteration of the employment, population, and land use models. This cycle is then repeated for each of four iterations. In this case covering approximately 20 years (the control totals are input for each of four five year intervals). After each iteration the results are checked to ensure that they are consistent and stable.

In this study, two sets of simulations were run using the model package. One included both the highway and public transit modes and thus using the mode split procedure, and the other without mode split, representing the complete absence of transit facilities in the region. The system configuration without transit simply omits the MSPLIT procedure.

The maximum volume/capacity ratio permitted for any highway network link was 2.50 times that link's design capacity. That is if the volume of trips on a link exceeded 2.5 times its capacity, the resulting congested travel time was restricted to the time which would have resulted from a volume 2.5 times its design capacity. Also for this series of tests loading of trips was done in three increments - 60%, then 20%, and finally 20%. Finally, for this series of tests, previous calibration results were used for all the parameters, i.e. no new calibrations were attempted as part of this project. There was one exception to this however. The MSPLIT procedure used in ITLUP had not previously been run for the Minneapolis/St. Paul region. Thus parameters were calibrated for this urban area for MSPLIT. This calibration is discussed along with the discussion of the Minneapolis-St. Paul tests.

RESULTS OF SIMULATION TESTS

1. Introduction

The rather modest size of this project dictated that certain shortcuts be taken. In particular, the model package used was an unaltered version of the previously developed and tested ITLUP package as described above. Secondly, the data, too, were limited to those urban areas already available from the data archives of the Urban Simulation Laboratory. Even so, there was a good deal of work to be done in preparing the data for use in these tests.

Prior work with the San Francisco data set had been done at several levels of detail, including the 30 zone system used for this project. The Minneapolis - St. Paul data were not in such good condition. The socioeconomic and land use data were for a 108 zone system. The highway network data existed only in map form - they had never been set up for model use. A 30 zone version of the highway network had seen some preliminary development, and had been abstracted from the 108 zone system. This was done by a combination of electronic digitizing and hand work. Preliminary tests of this aggregated network to check for discontinuities and other discrepancies were necessary. In addition, the 108 zone areal system had to be aggregated (note that this aggregation work was to keep down computer costs during the project). Finally it was necessary to calibrate the ITLUP submodels for this new 30 zone Minneapolis data set.

On beginning the simulations for Minneapolis a number of further problems appeared. First, the forecast results were bizarre. In checking back through the model system it was found that the problem lay in the parameters for the two location models, EMPAL and DRAM. Next the calibration runs were re-examined. It was found that there were serious problems with the base year employment data. The matter was discussed with the Metropolitan Council of the Twin Cities, from whom the data had originally been obtained some ten years ago, but the issue was not resolved. Finally the aberrant parameter estimates were replaced by estimates extrapolated from calibration results from the dozens of other cities for which EMPAL and DRAM have been calibrated. Immediately thereafter it was discovered that the transit skim-tree file, also obtained over ten years ago was not readable from the source tape. Thus it became necessary to produce a "best estimate" set of transit skims by comparing the automobile skim-trees with maps of the region's transit systems. After some further effort something that appeared to be a reasonable facsimile of a Minneapolis-St. Paul data set was fully assembled.

Even after the data sets were prepared and EMPAL and DRAM calibrated, there still remained the question of sources for the various exogenous inputs such as regional ratios (e.g. unemployment, persons per household, etc.) and regional employment and population forecasts. These were prepared, as best as was possible, from published data describing the two regions, San Francisco and Minneapolis-St. Paul. These data sources included various regional agency reports as well as supplementary material obtained by mail and telephone. There was, however, no time to "fine tune" the model system and to attempt to produce the rather specifically accurate forecasts of which these models are capable. This left a question as to how the project simulation results were to be interpreted.

If this was a new model package there would have been no choice but to attempt further fine tuning and forecast verification. Fortunately, the Integrated transportation and Land Use Model Package - ITLUP, has seen continuous development and application since 1971. Much of the initial development was done using a data base from the San Francisco, California region in the U.S., the same data as was being used for this project. Subsequent research and development efforts, as well as applications, have utilized data from many metropolitan regions around the world.

One of the earliest practical applications was the use of portions of ITLUP to prepare location forecasts for the Pike's Peak Area Council of Governments in Colorado Springs, Colorado in the early to middle 1970's. In the late 1970's and early 1980's there was a more extensive application effort by the Mid-America Regional Council in Kansas City. This project resulted in a series of projections for input to subsequent policy analyses.

There are several ongoing projects using ITLUP both in the U.S. and abroad. Since the early 1980's the Puget Sound Council of Governments in Seattle, Washington has been using various versions of EMPAL and DRAM for both forecasting and policy analysis. Currently the models are being used in evaluation of Seattle transit investment alternatives. The alternatives being evaluated include various combinations of light rail transit, bus systems, and new tunnel construction. There is also a current project involving the use of the ITLUP package by the Houston-Galveston Area Council for the region of Houston, Texas. Here there are several goals, with the HGAC intending to develop the models for assistance in transportation and land use project analyses and evaluation. In particular there are several highway alternatives and bus transit alternatives which are of current interest. Finally, there are several "pilot project" types of effort where agencies are in the process of evaluating all or parts of the ITLUP package. One such project is being done by the Florida Department of Transportation for the Dade County area. The North Central Texas Council of Governments in the Dallas-Fort Worth, Texas area has also obtained copies of the models for evaluation purposes.

There have also been several policy applications of these models outside the U. S.. The Transportation Planning Board of the Ministry of Communication in Taiwan (ROC) has done several practical policy applications. For the Taipei Metropolitan Area there were
a) evaluations of a rail transit system in specific corridors,
b) evaluations of the Linko new town and the Hsinyi sub-center, and
c) evaluation of the consequences of reducing industrial land use by a zoning policy. For the Kao-hsiung Metropolitan Area the models were used in the evaluation of rapid transit systems. There have also been some research applications in Taiwan involving analysis of a second CBD in Taipei, as well as some more specific analyses of transit station impacts. Finally, the Institute of Architecture, Urbanism and

Regional Planning (I.A.U.P.P.) in Sarajevo, Yugoslavia is using ITLUP in a research project concerning transportation and spatial planning for the Republic of Bosna-Hercegovina (Dugonjić, V., et al, 1985).

With all this background of ITLUP use prior to this project, it was decided not to attempt to deal with absolute values of forecasts, as many of these would not be accurate, absent the fine tuning stage of the model applications. Instead, it was decided simply to analyze the differences between the "with-transit" and "without-transit" computer runs. This procedure obviated the need for further model or data preparation work and allowed work to begin on the simulation runs. Even so, given ITLUP's reliable performance on so many other other projects it was believed that the results here would give a clear sense of the consequences of eliminating transit services in either of the two study regions.

2. San Francisco Tests

Two tests of four iterations each were run. A map of the San Francisco 30 zone system is given in Map 1. The first test run included the public transit system , and thus a mode split procedure, while the second test excluded the transit system and thus the mode split calculations done in the MSPLIT program. For these tests, the initial (i.e. those necessary to start the ITLUP iterations) automobile impedances were exogenously supplied estimates for the afternoon peak hour. The difference between the two simulation tests, i.e. with and without transit, results in different impedances as a consequence of the different levels of congestion on the highway

Map 1: San Francisco Metropolitan Region

Definition of 30 Zone System

system. These in turn affect the relative attractiveness of the 30 zones into which San Francisco is divided. Thus the EMPAL and DRAM models produce different forecasts of the employment and population in each zone in response to the change in impedances.

The employment and population forecast results from the San Francisco tests are presented in Table 4. In the table the total employment and population for each zone in the base year is given. This is followed, for each, by a column containing the calculated percentage difference between the "with transit" simulation result and the "without transit" simulation result. In each case the percentage is calculated by subtracting the "with transit" result from the "without transit" result, and dividing the difference by the "with transit" result after four iterations of the model package, and thus represents the predicted response in a zone's population or employment after approximately 20 years simulation.

Focusing attention first on the population results, the percentage difference between the test with transit and the test without transit show significant responses for specific zones. In Zone 1, downtown San Francisco, the predicted population without transit is almost 15% less than the population with transit. For Zone 2, Oakland, the predicted population is about 2% less without transit. In Zone 30, Marin County, predicted population in the "with transit" run is 25% less than in the "without transit" forecast, while in Zone 12, outer Santa Clara County, predicted population is 13% more without transit. In general, the city of San Francisco and

Table 4: Simulation Test Results - San Francisco Data Set

Percentage Difference Between Fourth Iteration Results

With and Without Transit System

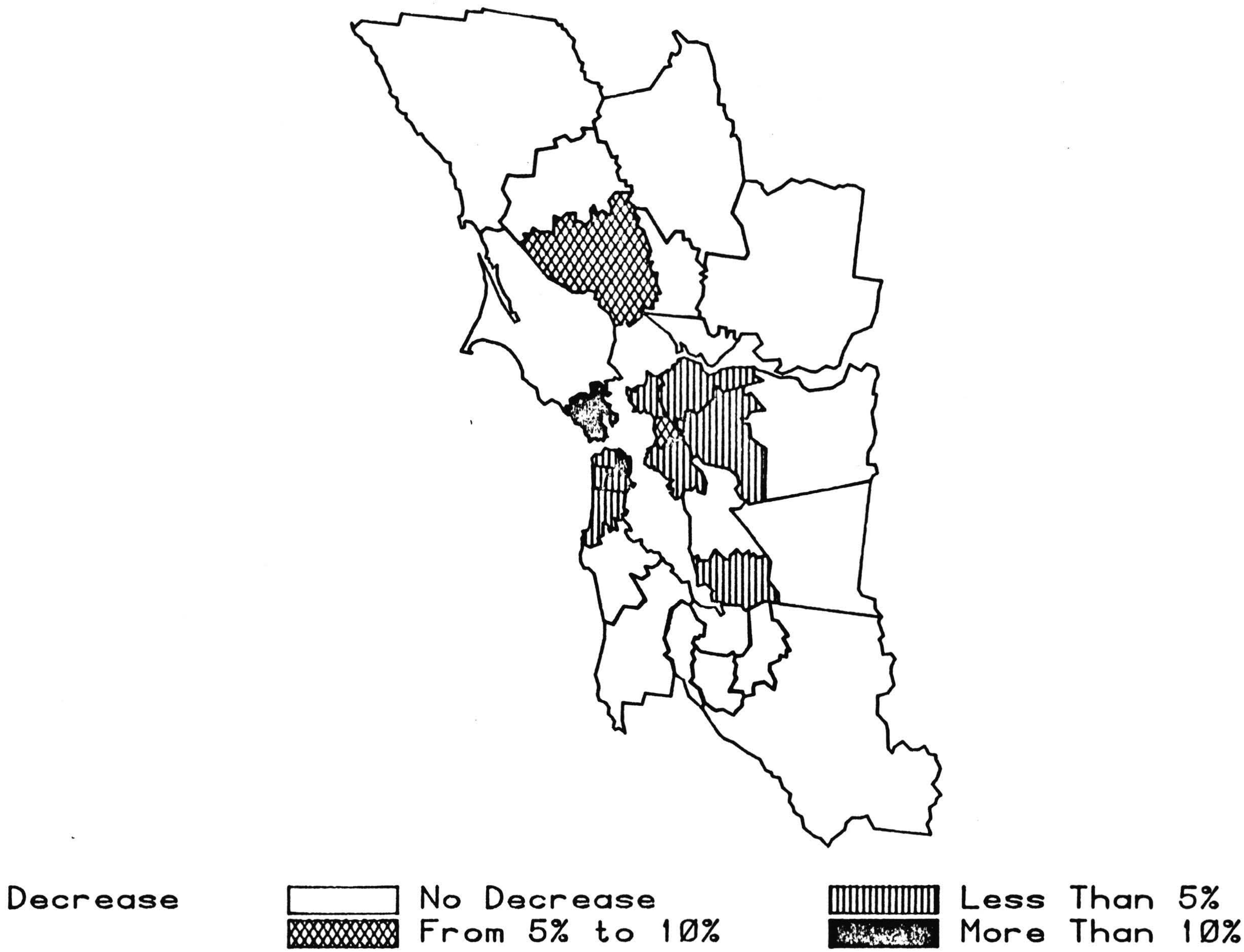
Zone	Base Employment	Percent Difference	Base Population	Percent Difference
1	262,505	- 5.0%	109,131	-14.8%
2	47,032	+ 8.1	200,235	- 2.8
3	87,191	+ 0.8	262,830	- 1.4
4	15,213	- 0.4	166,397	- 2.2
5	65,326	+ 6.8	208,329	- 1.5
6	33,607	- 1.1	123,766	+ 4.4
7	51,024	+ 0.2	158,646	+ 6.7
8	53,159	+ 2.1	126,049	+ 6.0
9	72,955	- 0.8	173,460	+ 6.4
10	24,023	- 0.2	210,780	+ 7.8
11	85,789	+ 2.0	303,551	+ 5.5
12	19,460	- 2.9	63,536	+12.9
13	7,921	- 2.7	50,420	0.0
14	21,542	- 1.1	101,055	- 1.4
15	77,740	- 0.4	285,363	- 1.1
16	148,577	+ 2.1	373,855	- 1.7
17	56,445	- 2.1	150,635	- 6.5
18	37,611	- 0.2	134,512	- 1.4
19	12,655	+ 0.9	52,355	- 4.1
20	33,764	+ 1.2	201,471	- 3.0
21	24,227	- 5.1	67,724	- 0.4
22	17,248	+ 7.1	73,260	+ 2.1
23	14,890	- 2.3	71,031	+ 0.1
24	14,180	+ 1.2	44,462	- 1.2
25	4,950	- 2.2	18,920	+ 1.6
26	10,470	+ 5.6	52,785	- 5.4
27	26,689	- 1.0	82,923	- 0.8
28	10,671	- 3.1	28,466	- 0.8
29	25,427	-21.4	106,617	+ 1.3
30	10,990	+54.5	61,048	-25.4
Total	1,372,706		4,013,612	

Note: Negative values indicate that elimination of transit produces a relative decline.

nearby San Mateo County are predicted to have population declines if transit services are eliminated. Alameda and Contra Costa Counties in the East Bay area, and Sonoma County to the north, also have declines in their populations as a result of eliminating transit facilities in the region. The South Bay area has significant zonal population increases, while Solano County has a slight increase in its population and the remaining areas of the region show minor mixed results. These results are shown in Maps 2 and 3.

The impacts by zone on employment are much more mixed than the population impacts. Again, considering the difference in employment by zone for the fourth iteration case "with transit" versus "without transit", Zone 1 employment, in downtown San Francisco, is predicted to be 5% less without a public transit system than with the system. Oakland is predicted to have a 2% increase in employment with the elimination of transit. The greatest changes occur in Marin County where Zone 30, inner Marin County, is predicted to have more than 50% more employment without the transit system, while outer (northern) Marin County, Zone 29, is predicted to have 21% less employment. Outside of Marin County the impacts are much less significant. The zone with the next greatest increase in employment, 8%, is Zone 2, northwest San Francisco. The next greatest employment loss in response to the elimination of the transit system occurs in Zone 21, outer Contra Costa County, which loses 5% of its employment. In general, the outermost zones lose employment, i.e. zones 12, 13, 21, 23, 25, and 28. Most of the employment gains occur in moderately

Map 2: San Francisco Region – Zones Having a Relative Population Decrease with Elimination of Transit



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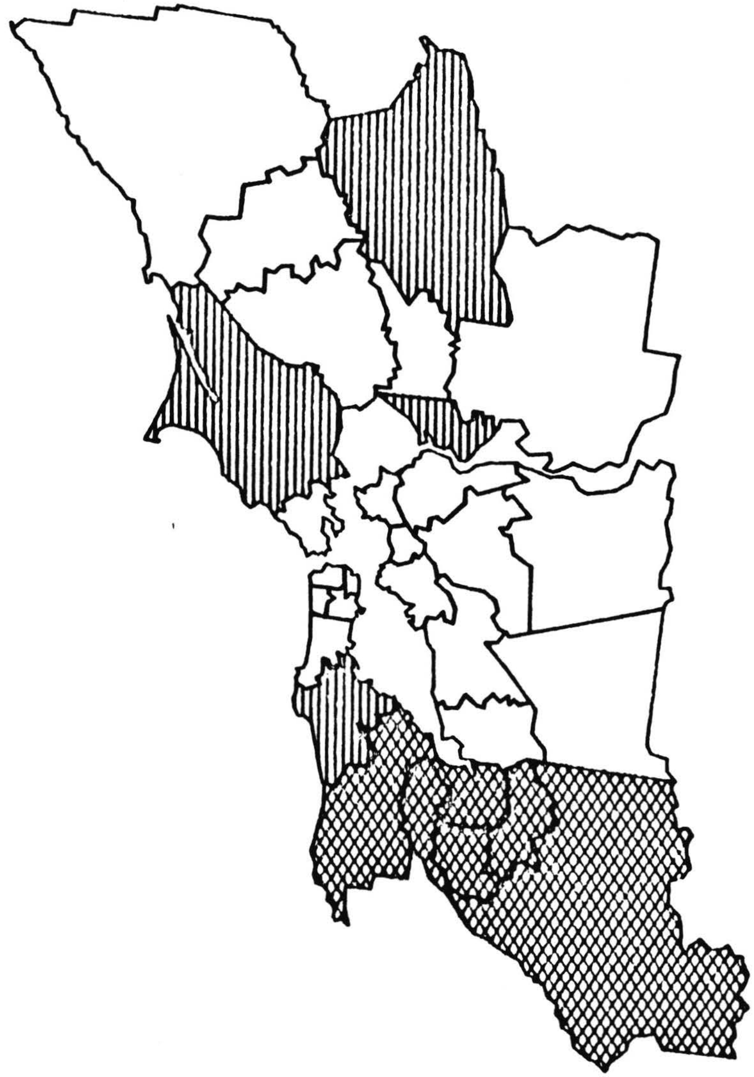
Map 3: San Francisco Region – Zones Having a Relative Population Increase with Elimination of Transit



Decrease

No Decrease	Less Than 5%
From 5% to 10%	More Than 10%

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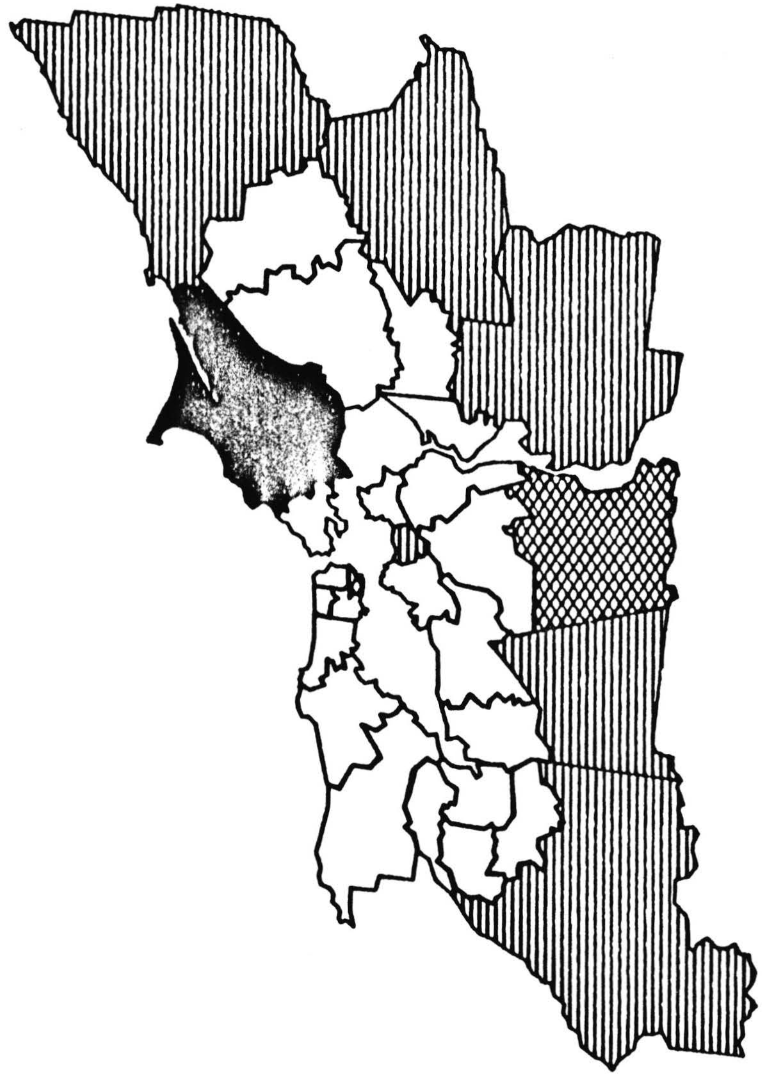
distant (inner) suburban areas. These results are shown in Maps 4 and 5.

It is clear from the above results that the presence or absence of a public transit system can have major impacts on the location of population and employment in the San Francisco metropolitan area. In general, by obviating the need for automobile travel to work for a substantial number of tripmakers, transit facilities have the indirect effect of reducing congestion on the highways of major urban corridors. If these transit facilities were to be permanently discontinued their patrons would be forced to either change their job or residence location, or to switch to using and automobile for work trips. This more likely latter response would add a considerable additional load to what are in many cases already strained highway facilities. An induced effect of this additional highway load would be increased congestion and the types of spatial reallocations discussed above. For the most part this would involve greater centralization of activities around existing concentrations, a rather standard response to higher transport costs.

3. Minneapolis - St. Paul Tests

The second region for which simulation runs were conducted in an attempt to investigate the effects of transit decline by using the ITLUP package, was the Minneapolis - St. Paul metropolitan area. It was hoped that by performing the same set of tests on a second urban region the previously obtained results for the San Francisco area would be confirmed. It also was hoped that these second results would help determine the degree of transferability of the information, Map 4: San Francisco Region – Zones Having a Relative Employment Decrease with Elimination of Transit



Decrease

No Decrease
From 5% to 10%
Less Than 5%
More Than 10%

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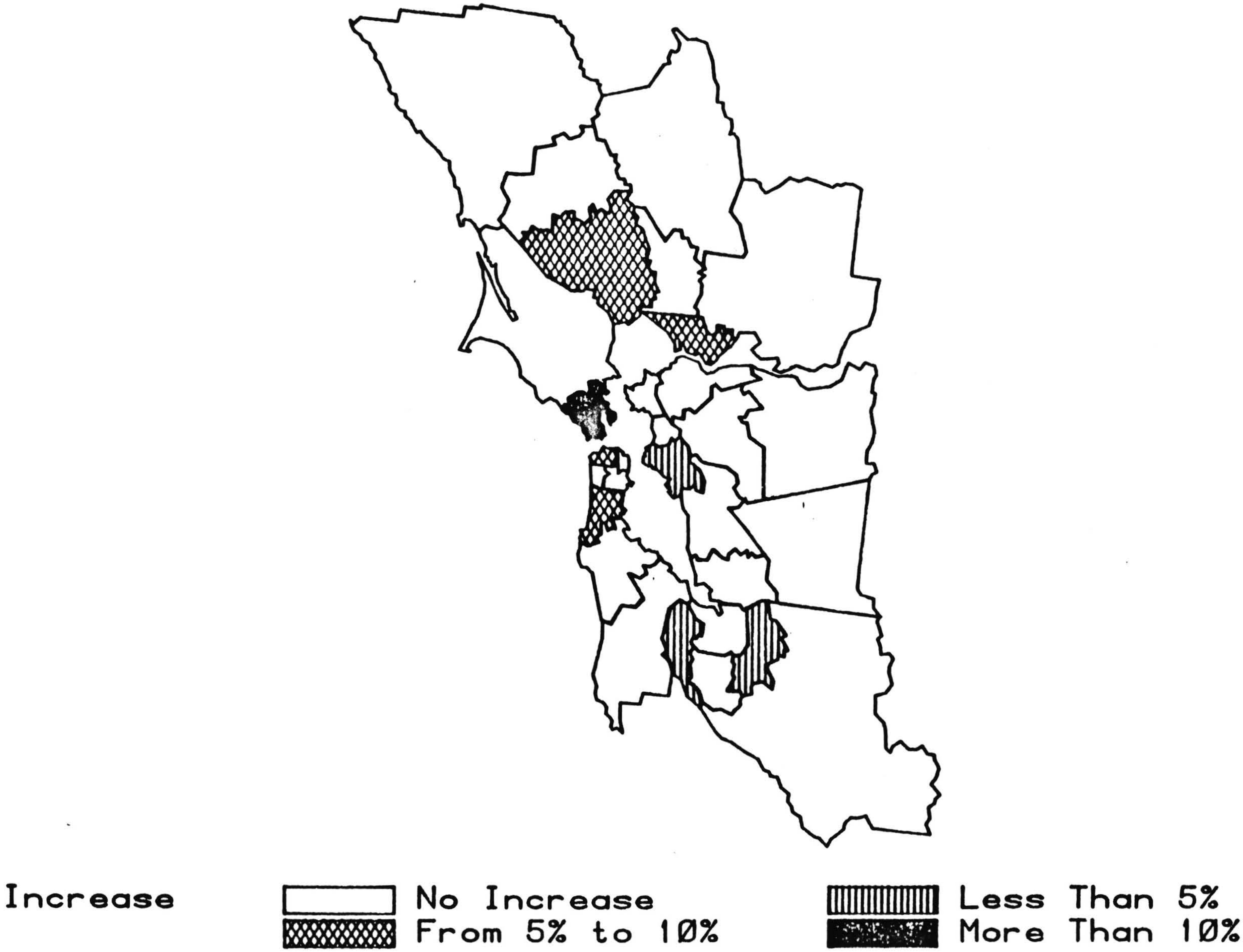
Map 5: San Francisco Region – Zones Having a Relative Employment Increase with Elimination of Transit



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in this case to a region with a much lower percentage of transit ridership, of only 9.5% for 1975 (Bureau of the Census, 1978a).

Although nearly all of the information necessary to run the ITLUP package was available for the Minneapolis - St. Paul region, the MSPLIT model procedure had not previously been run with this data. In addition, the matrix required to transform auto travel times or impedances into transit impedances had not been developed. This matrix of transit factors serves as a crude representation of the relative levels of service of the two types of transportation in the region, automobile and public transit (which in Minneapolis - St. Paul was entirely bus service).

The second major step required to include mode split in the Minneapolis - St. Paul model runs was to calibrate the mode split submodel for the Minneapolis - St. Paul region. This model has a multinomial logit formulation for determining the probability of a tripmaker's choosing either the automobile or the transit mode. The equation structure used (Keith, 1983, p. 38) is:

$$p^1_{ij} = \left[1.0 + \exp(\alpha + \beta_1 x^1_i + \beta_2 x^2_{ij}) \right]^{-1}$$

$$p^2_{ij} = 1.0 - p^1_{ij}$$

where

p^1_{ij} = the probability of choosing mode 1 to travel from i to j

p^2_{ij} = the probability of choosing mode 2 to travel from i to j

x_i^1 = household income in zone i

x_{ij}^2 = difference in line haul travel costs on mode 1 and mode 2 between zones i and j

α, β_1, β_2 = empirically derived parameters.

As neither the data nor the resources were available for the full calibration of a mode split model for Minneapolis - St. Paul, the values obtained from the previous calibration of the model for San Francisco were taken as a starting point. This resulted in a preliminary estimate of transit mode use of 16.4% as the "weighted regional work trip modal share" for transit in Minneapolis - St. Paul. However for 1975, the known percentage of work trips taken on transit was 9.5% for the area. Thus it was necessary to adjust the parameters of the mode split equations. The value of the percentage of trips on transit region-wide proved sensitive to the adjustment in β_2. Indeed, the final, model produced, value of 9.4% transit ridership was obtained by changing β_2 from 0.031 (the San Francisco value) to 0.065 for Minneapolis - St. Paul. This, in effect, implies that the residents of the Minneapolis - St. Paul region are considerably more sensitive to the difference in travel times or costs between transit and automobile than are the residents of the San Francisco region. This effect may also result from the somewhat different natures of the central areas of the two regions, with San Francisco having much more extensive areas of high density development, and more extensive transit service for those areas.

Unfortunately, whether the ITLUP package was run with or without the inclusion of the mode split calculations, the results of the tests were not satisfactory. With or without including mode split, the results were inconsistent and illogical. After the fourth iteration of the model, in either test, population showed a greatly exaggerated tendency to centralize, and employment, to decentralize. Obviously this was contrary to our expectations and the magnitudes of these shifts were quite unrealistic for the known history of American cities.

In one sense these results were not as surprising as they seem given the difficulties encountered in calibrating the models as described above. When this has occurred in previous ITLUP studies, unexpected forecast results similar to those obtained here for Minneapolis - St. Paul have resulted. Also, as mentioned above, the data base used for this series of test showed some obvious inconsistencies, especially in the employment data. Consider for example downtown Minneapolis, Zone 30. According to the data for this zone, the employment decreases over the period from 1960 to 1970 for all the employment types. Total employment for this zone, around 22,000 in 1970 and about 28,000 in 1960, doesn't seem very great for a major American city's downtown area. Indeed, the amount of "finance, insurance, and real estate employment, plus services employment, (Type 4 in this data set) at 715 is simply unbelievable. Many of the other zones (e.g. 19, 25, and 26) exceed Zone 30's employment. There is also a surprisingly large amount of manufacturing employment in this zone (11,697), given that it is a central zone and might be considered to be a part of the area's central business district.

Overall, the Minneapolis - St. Paul results were not directly useful to the final summation of the project. Work is continuing to attempt to unravel the data problem which were discovered. For what it is worth, the percentage differences for both population and employment, with and without transit, are similar to the San Francisco results. Yet, given their absolute distributions, this is not very strong confirmation.

CONCLUSIONS

The conclusions of this preliminary study cannot be stated as generally as was originally hoped, as only one of the two data sets used was acceptable. Thus rather than having the two sets of results be complementary, there is only one set of results. Despite the inadequacy of the Minneapolis - St. Paul results, the San Francisco results alone were adequate to suggest that these preliminary examinations of the topic be considerably expanded. In particular, the non-user costs of transit abandonment may be quite high. This being the case, the public discussion regarding justification, or its lack, for further subsidies to transit systems may be both uninformed and in error. Any analysis which fails to take into account the kinds of non-user costs implied in the increased congestion and induced spatial reallocations shown in these simulations may be seriously underestimating the full value of the transit system to a region. Much of this type of discussion, including that which proposes to sell off transit systems to private organizations, uses regional percentage rates (of transit trips compared to total trips) to state that transit users are a small percentage of the tripmaking population. Yet in specific CBD oriented corridors the transit shares of tripmakers may be several times greater than the regional share. If transit were eliminated by public decision or by the bankruptcy of a private organization which had taken over the system, the transit users in the corridor would have rather little choice. Either they change place-of-work or place-of-residence, or they change mode -- to a private vehicle. In the U.S. there has been rather little enthusiasm for car-pooling, so most mode changing tripmakers would wind up on the highways in their automobiles at 1.5 persons (approximately) per vehicle. Even though they make a small percentage of the region's tripmakers, they would cause a considerable increase in the congestion on the highways leading into the region's center. Enough congestion for a long enough period of time would, almost inevitably, result in center city decline (or further decline for regions where the center city has already been experiencing decline). The societal cost of this decline, along with the cost of increased travel time for all automobile tripmakers (not just those newly transferred from transit), are costs not normally included in transit system evaluation. Not to do so seriously misstates-states the case.

This, of course, was only a small preliminary investigation. The implications of these results are, however quite significant, and surely warrant further investigation.

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