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# Bay Area Simulation Study

## INTRODUCTION

THE BASS MODEL under review was initiated at the Center for Real Estate and Urban Economics, University of California, Berkeley in 1962. Some of the goals of this study—"analysis of the probable impact of changes in employment on future land uses in the San Francisco Bay Area" and "analysis of the impact of major transportation investment on the structure and distribution of urban land uses in the San Francisco Bay Area"[1]—led to the construction of models similar to those constructed for the Bay Area Transportation Study. Discussions of both the BASS and BATS models are included here in order to illustrate two attempts at a land-use model for the same area (the discussion of the BATS model follows in Chapter 8).

In the BASS model, two employment submodels and one population submodel generate the overall area projections of employment and population for five-year iterations projecting to the year 2020. The two employment forecasts are averaged to get labor demand, which is then compared with labor supply generated by the population model. Demand and supply are reconciled, and employment forecasts for the twenty-one industry groups, as well as a population forecast for the year 2020, are obtained for the thirteen-county Bay Area.

BASS differentiates between the locational determinants of different groups of industries, making use of six different employment location submodels. The employment forecasts are inputs to the employment location submodels.

[1] Institute of Urban Regional Development, *Jobs, People and Land: Bay Area Simulation Study Special Report*, 6, Berkeley, 1968.

A residential location submodel reconciles housing supply and usable land with the housing demand generated by the population forecasts. The submodel uses six housing unit groups based on two structure types (single-family and multifamily) and three values (high, medium, and low). The submodel incorporates approximations of housing filtering and demolition.

Employment locations, with the exception of those for educational services, construction, and agriculture, are determined prior to residential locations. The assumption implicit in this sequence is that retail employment adjusts to the population distribution, both homesite and worksite, that existed at the beginning of a five-year period, while residential location adjusts to changes in the distribution of employment during that period.

## METHODOLOGY

The methods for locating employment for the six industry classifications are described briefly as follows:

1. Retail employment—allocated with a combination of a gravity potential model and an attractiveness measure derived from regression analysis.
2. Manufacturing, trucking and warehousing, and wholesaling—allocated by means of an attractiveness measure derived for subareas.
3. Finance, insurance and real estate, education and government—allocated to counties and important subareas of counties on the basis of a simple extrapolation of historical trends, modified judgmentally; residual allocated to other subareas on the basis of population.
4. Services—assigned with a regression model in which employment is a function of density and accessibility.
5. Construction—allocated to subareas as a function of the amount of their new employment and new housing.
6. Agriculture, mining, transportation, communication, and military—total employment from the projection model is allocated to the subareas in the same proportion as at present.

The first four of these models will be discussed in greater detail below; the last two are self-explanatory. Construction is assumed to be related to new housing and new employment, and allocated to subareas on the basis of the proportion of these two activities now being undertaken. The level of agricultural activity is a residual, and agricultural employment is reduced in each subarea in proportion to the removal of agricultural land from the subarea.

### *Retail Trade*

The proportion of new retail trade employment locating in any tract, *j*, is a function of the percentage of the region's new employment locating in *j*, the percentage of the area's total population in *j*, and the relative attractiveness of *j*. The equation is written as:

$$ALLOC_j^r = \frac{[(\alpha NE_j/\sum_j NE_j) + (\beta POP_j/\sum_j POP_j) + RAI_j]}{2} \Delta EMP^r$$

where $ALLOC_j^r$ is new retail employment in *j*, $NE_j$ is total new employment in *j*, $POP_j$ is total population in *j*, $RAI_j$ is relative attractiveness index of *j*, $\Delta EMP^r$ is areawide new retail employment, and $\alpha$, $\beta$ are exogenous constants summing to 1.

Of the above, only *RAI* needs further explanation. The *RAI* is a function of the potential demand for retail trade in the tract and the tract's commercial site suitability. Potential demand is the difference between actual demand (employees) already in the tract and expected demand. Expected demand is determined by a gravity model. Commercial site suitability is obtained from a regression equation relating the amount of retail employment to population accessibility, commercial accessibility, industrial accessibility, tract density, and the amounts and location of other types of employment. The two measures are combined as follows:[2]

$$RAI_j = \sqrt{DP_j}\,[1 + 0.5(CSS_j/\textstyle\sum_k CSS_k)] \div \textstyle\sum_i \sqrt{DP_i}\,[1 + 0.5(CSS_i/\textstyle\sum_k CSS_k)]$$

where $DP_j$ is potential demand and $CSS_j$ is commercial site suitability.

### *Industrial Land-Use Model: Manufacturing, Trucking and Warehousing, Wholesale Trade*

Increases in employment are spatially located by means of weighted indexes of tract locational factors calculated separately for eleven industry groupings. The tract with the highest score for one industrial

[2] The square root and 0.5 were introduced to make the model fit the data better. The form of this function, and many others in the BASS model, is entirely judgmental. There is no attempt to justify it other than to say that it fits the data. These equations are identities and are not estimated.

group receives one average size firm of that industrial group. If more employees are to be located, the indexes are recalculated, taking into account changes from the first allocation. Again, the tract with the highest score receives one firm. This process continues until all employment is located. Allocated employment is converted into land use by means of land absorption coefficients.

The tract scores ($S_j^k$) are calculated as follows:

$$S_j^k = \sum_i W_i^k I_j^i$$

where $k$ is the industrial group number, $j$ denotes tracts, $i$ is location factors important to industrial group $k$, $S_j^k$ is the tract score for industry group $k$, $W_i^k$ is the weight of the $i$ factor for group $k$, and $I_j^i$ is index of factor $i$ for tract $j$.

Regression analysis was used to determine weights for the $i$th factors for each of the eleven employment groups. Among the variables considered were the location of the other industrial firms in the area, rail access, freeway access, vacant land, restaurants, libraries, and tract density. "Industrial location experts" altered the weights judgmentally when they thought it necessary. An index for the $i$th factor in tract $j$ is calculated by means of the following:

$$I_j^i = (X_j^i - MIN^i)/(MAX^i - MIN^i)$$

where $I_j^i$ = index for factor $i$ in tract $j$, $X_j^i$ = actual magnitude of the $i$ factor for subarea $j$, $MIN^i$ = minimum value of $X$ for all $j$, and $MAX^i$ = maximum value of $X$ for all $j$.

In the BASS model intra-area industrial migration is recognized and incorporated into the model. The rate at which employment migrates from a tract is a function of the density of the tract. Density is defined as the sum of population and employment per acre. If the density of a tract is greater than ten, some industry migrates from the area. For example, on the basis of historical data, if density per acre is thirty or greater, 10 per cent of all industrial employment in the tract migrates; if density per acre is twenty, then 5 per cent migrates. Migrating employees are added to the pool of new employees to be allocated for each industry. Land released by migration is added to the stock of vacant land in that tract.

When an areawide decline in employment in some industrial group is projected, a different technique is used to determine where employment should be decreased. Instead of reversing the procedure used for growing industries (i.e., decreasing employment in those tracts with the lowest score), BASS introduces a new procedure. The percentage of an industry's total decline to be allocated to each tract is calculated by

$$PLDECL_j^k = (EMP_j^k \times DEN_j^{1/2}) \div \sum_m (EMP_m^k \times DEN_m^{1/2}).$$

The number of employees lost from tract $j$ is determined by

$$EMPLOS_j^k = PLDECL_j^k \cdot (1.2\ \Delta EMP^k)$$

where $EMPLOS_j^k$ is number of employees of type $k$ lost in tract $j$, $PLDECL_j^k$ is percentage decline in industry $k$ in tract $j$, is $\Delta EMP^k$ is projected decline in employees of type $k$, $DEN$ is density.

It is clear that $\Sigma_j\ EMPLOS_j^k$ will be 120 per cent of the areawide decline of industry $k$ projected in the regional economic projections. BASS allocates an amount equal to this excess decline of 20 per cent by using the growing industry algorithm. This approach to industry decline is introduced in order to take account of the fact that industry decline is a complex occurrence, involving intraregional migration of employment in declining industries.

### *Finance, Insurance and Real Estate, Education and Government*

The geographical breakdown for this locational algorithm is (1) counties, (2) important subareas of counties, and (3) residual subareas. F.I.R.E. and government employment are allocated to counties according to the present proportions, with judgmental modifications. This same combination of history and judgment is used to allocate employment to important subareas within counties. Remaining employment is distributed to the other subareas on the basis of population.

### *Services*

Service employment location is determined in a manner similar to that used for retail employment. Employment is distributed to tracts as a function of a relative attractiveness index and population. The allocating formula is

$$ALLOC_j^s = \left(\alpha RAI_j + \beta \frac{POP_j}{\sum_i POP_i}\right) \Delta EMP^s$$

where $ALLOC_j^s$ is new service employment located in tract $j$, $RAI_j$ is relative attractiveness index, $POP_j$ is population in tract $j$, $\Delta EMP^s$ is new service employment in area, and $\alpha$, $\beta$ are exogenous constants summing to 1.

The $RAI$ is obtained from an equation determined by regression analysis. Different *RAI* equations, including different independent variables, are estimated for (1) eating, drinking and lodging services, (2) personal services, (3) miscellaneous services, and (4) medical and other health services.

### *Residential Housing Location*

The residential allocation simulation can be viewed as a step toward an explicit replication of the housing market. The model separates the treatment of supply and demand. On the supply side the BASS model introduces important but often neglected aspects of the market. These innovations include both housing demolition and filtering.

An exogenously determined overall rate of demolition of existing housing is assumed for the whole area. On the basis of the findings of other independent studies and some BASS investigations of the demolition rate in San Francisco in recent years, demolition is assumed to be 4 per cent of the existing housing per five years. The rate of demolition is not constant for all types of houses. Bureau of Census data show that, in California, demolitions in the sixties could be distributed among housing types in the following ratios:

| | High Value | Medium Value | Low Value |
|---|---|---|---|
| Single-family type | 1 | 2 | 4 |
| Multifamily type | 2 | 4 | 8 |

Demolitions in the first five-year period are distributed among the housing types in the assumed ratios, that is, demolitions of low-value multifamily dwellings are eight times those of high-value single-family dwellings. However, because multiple family units have changed in nature from subdivided single-family units and low-quality post-World War II construction to more durable and high-rise types, the rates of demolition of multifamily units are adjusted down 10 per cent in each succeeding period.

The distribution of the demolitions depends on the value of the tract's housing units, the portion of its units representing the multifamily type, and the density of tract development. For single-family dwellings, the tract's proportion of new demolitions is determined as follows:

$$DR_j^s = (DD_j)^{1/4} \cdot (PM_j^{1/2} / HV_j)$$

where $DR_j^s$ is proportion of single-family unit demolition in tract $j$, $DD_j$ is density of development in tract $j$, $PM_j$ denotes multiple units as percentage of total housing in tract $j$, and $HV_j$ is housing values in $j$, or (2 · high value + middle value)/total housing units.

A tract's share of multifamly unit demolition depends on the single-family proportion:

$$DR_j^m = (DR_j^s)^{1/2}.$$

Demolition affects both supply (by changing the number of houses available) and demand (by altering the number of households looking for housing). The effect on housing demand will be considered below.

Filtering of the housing stock does not alter the number of housing units available, but it does change their value distribution. The model assumes that, in each time period, 20 per cent of all high-value housing becomes medium value-housing and 20 per cent of all medium-value becomes low-value housing. No distinction is made here between single-family and multifamily housing units. The conversion of single-family housing units to multifamily units is assumed negligible.

The rate of filtering differs between tracts. The filtering rate on single-family units in tract $j$ depends on the percentage of multifamily units in $j$ and the value of housing in $j$:

$$FIL_j^k = S^k(PM_j^{1/2} \cdot HV_j)(H_j^k)$$

where $FIL_j^k$ denotes net units filtered from housing of type $k$ in $j$, $S^k$ is scalar factor for housing of type $k$, $PM_j$ is per cent of multifamily units in $j$, $HV_j$ is housing values in $j$, or (2·high value + middle value)/total housing units, and $H^k{}_j$ is number of housing units of type $k$ in $j$. The rate of multifamily unit filtering in a tract depends only on housing values:

$$FIL_j^k = S^k(1/HV_j)(H_j^k).$$

The total potential supply of new housing construction in a tract depends on the land supply, slope of the land, attractiveness, housing value distribution, proportion of single-family units, and density. Land supply is the sum of agricultural acreage, usable vacant land, and land freed by migration and demolition. Tract density is defined as the average of the density (defined above) of the tract and of the surrounding tracts.

Potential new housing construction is partitioned into potential single-family and multifamily units, and then into high-value, medium-value, and low-value units. The first partition is made by averaging two ratios: the present percentage of single-family units and the potential percentage. The potential percentage is determined by the density of development in the tract. The second partition depends on three proportions: existing value partition, the density of development, and the slope of the land. The land absorption coefficients used to determine the number of potential new housing units vary with housing type and housing value, and between tracts.

The total demand for new housing is the sum of families forced to move because of demolition and the increase in families projected by the population projection model. The demand is judgmentally partitioned into housing type; a secular decline in the proportion of single-family units is assumed. The proportion of demand for each of the three value classes for single-family units is assumed to be as follows: 36 per cent, high value units; 52 per cent, medium value units; and 12 per cent, low value units. For multifamily units, it is 19 per cent, 51 per cent, and 31 per cent, respectively.

The last step in the residential allocation model is the determination of the location of new housing construction. The proportion of potential new housing construction developed in a tract depends on access to employment.

## OVERVIEW

The most interesting innovation in the Bay Area Simulation Study is the introduction of filtering and demolition into the model of the residential housing market. It is commonplace to observe that changes in the stock of housing have major implications for urban form, yet these changes usually are omitted from urban models. BASS makes no attempt to model the behavior behind filtering and demolition but does attempt to simulate the results.

BASS allocates households on the basis of overall access to employment. An alternative approach is to allocate employees of a particular worksite on the basis of access to that worksite. This second methodology is used by the Bay Area Transportation Study. Differences in the resulting population distribution estimates could be very interesting.

The most disturbing feature of BASS is the repeated use of arbitrary equations for allocating employment and households. These equations are not estimated via statistical techniques, but are defined judgmentally. The reason for the particular form (e.g., square root) is never clear. Nor is it clear how significant the resultant relationships are. While this methodology can give good predictions, it probably adds very little to an understanding of the behavioral determinants of the spatial form of urban areas.