# A SIMPLIFIED URBAN HOUSING INVENTORY MODEL - WITH PRACTICAL APPLICATIONS

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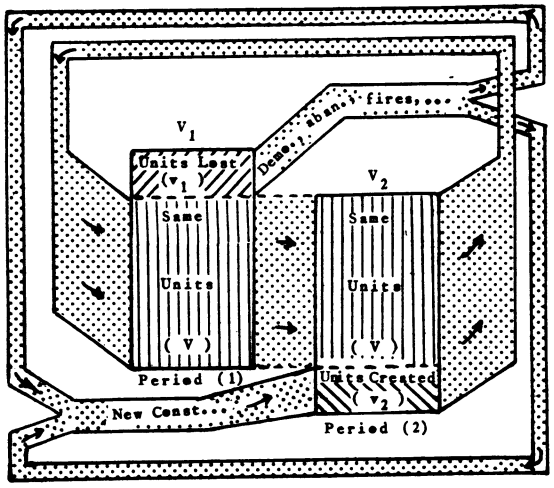
## I. Introduction

Since 1950, the Bureau of the Census has established a standard procedure for measuring the changes of housing inventory components for any given place in the United States (1). In the early 1960's, the economic staff of the Federal Housing Administration utilized the Census Bureau's procedure extensively as part of the FHA's official housing market analysis techniques (2), and applied them to many housing market areas throughout the nation.

## II. A Macro-model

Housing inventory can be modeled as in Figure 1:

Figure 1. A Macro-model of Housing Inventory - General View




In this model, housing units are distributed into three basic components:

- V - those units that are common to both time periods 1 and 2
- $v_1$ - those units that were lost or removed between the last and the current inventory counts
- $v_2$ - those units that were added or created between the last and the current inventory counts

Aggregately, the total housing inventory of the current period is

$$V_2 = ( V_1 - v_1 ) + v_2 \quad (1)$$

or equivalently,

$$V_2 = V_1 + ( v_2 - v_1 ) \quad (2)$$

$(v_2 - v_1)$ is the net inventory change between the two time periods, and the rate of net inventory change is

$$g = \frac{( v_2 - v_1 )}{( v_2 + v_1 )} \quad (3)$$

The value of g ranges from $-1 \leq g \leq +1$.

Between January 1, 1970 and December 30, 1976, Chicago lost about 21,900 housing units per year and built only 5,500 new units annually (3,4). Thus, at the end of 1976, Chicago had a g value of -0.60. In the same seven-year period, Schaumburg, a new community in suburban Cook County, Illinois, issued about 1,500 building permits annually and lost only about 50 units per year (5), so Schaumburg had a g value of +0.93.

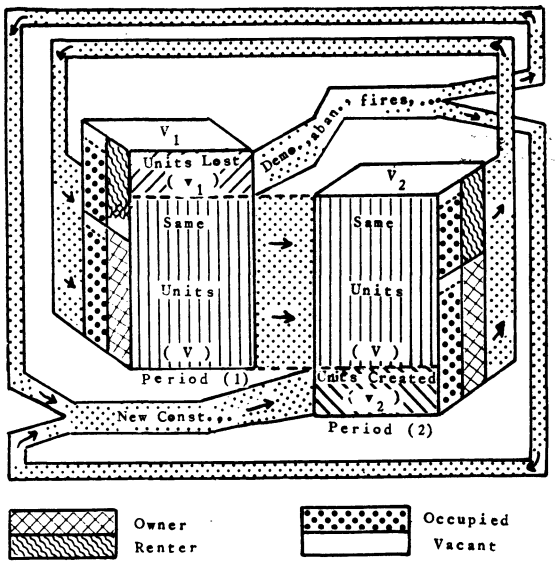
For the estimation of $V_2$ for a rapidly growing place, the critical stratum is $v_2$; for a declining central city, the critical stratum is $v_1$; the critical estimator in both cases is g.

For most urban place in the United States, the value of g ranges from -0.25 to +0.25. Thus, the study of the characteristics of V, which constitutes the major components of both $V_1$ and $V_2$, must be carried out in order to yield an unbiased estimate of $V_2$.

## III. A Multidimensional View

The macro-model of the housing inventory is multidimensional. Figure 2 shows the model segmented in terms of tenure and occupancy status.

Figure 2. A Macro-model of Housing Inventory - Tenure and Occupancy Status




The above model can be described by four equations:

$$V = V_o + V_c \tag{4}$$

$$v_2 = v_{2,o} + v_{2,c} \tag{5}$$

$$V_2 = [(V_{ow} + V_{or}) + (V_{cw} + V_{cr})] + [(v_{2,ow} + v_{2,or}) + (v_{2,cw} + v_{2,cr})] \tag{6}$$

$$V_2 = [(V_{ow} + v_{2,ow}) + (V_{cw} + v_{2,cw})] + [(V_{or} + v_{2,or}) + (V_{cr} + v_{2,cr})] \tag{7}$$

where

$V_o$ ≡ occupied units
$V_{ow}$ ≡ owner occupied units
$V_{or}$ ≡ renter occupied units
$V_c$ ≡ vacant units
$V_{cw}$ ≡ vacant units available for sale
$V_{cr}$ ≡ vacant units available for rent
$v_{2,o}$ ≡ new units occupied
$v_{2,c}$ ≡ new units vacant
$v_{2,ow}$ ≡ new sales units occupied by owners
$v_{2,or}$ ≡ new rental units occupied by renters
$v_{2,cw}$ ≡ new sales units available for sale
$v_{2,cr}$ ≡ new rental units available for rent

$(V_{ow} + v_{2,ow})$ is the approximate number of current homeowners, and $(V_{or} + v_{2,or})$ is the estimated current number of renters. The current number of residential households, $H_2$, is

$$H_2 = (V_{ow} + v_{2,ow}) + (V_{or} + v_{2,or}) \tag{8}$$

For a given place, the average size of a household could be estimated by a small stratified survey as defined by equation (8), or by the least squares method if time series data is available.

The current aggregate population could also be easily estimated by

$$P_2 = \alpha H_2 \tag{9}$$

where $\alpha$ is the estimated size of a residential household. The rate of new household formation is

$$h = \frac{v_{2,ow} + v_{2,or}}{(V_{ow} + v_{2,ow}) + (V_{or} + v_{2,or})} \tag{10}$$

h is a critical estimator for projecting the number of residential households and the total residential population, particularly for a rapidly growing place.

$[(V_{ow} + v_{2,ow}) + (V_{cw} + v_{2,cw})]$ is the homeowner inventory, and the homeowner vacancy rate is

$$c_w = \frac{(V_{cw} + v_{2,cw})}{(V_{ow} + v_{2,ow}) + (v_{cw} + v_{2,cw})} \tag{11}$$

Accordingly, three additional equations may be deduced:

$$v_{2,u} = \frac{v_{2,cw}}{(v_{2,ow} + v_{2,cw})} \tag{12}$$

$$c_r = \frac{(V_{cr} + v_{2,cr})}{(V_{or} + v_{2,or}) + (V_{cr} + v_{2,cr})} \tag{13}$$

$$y = 1 - c_r \tag{14}$$

where

$v_{2,u}$ ≡ unsold new home inventory ratio
$c_r$ ≡ rental vacancy rate
$y$ ≡ rental occupancy factor

In many larger urban areas in the United States, most of the new single-family sales units are concentrated in new subdivisions. The FHA and local homebuilder organizations survey these unsold new units annually. Thus for the estimation of vacant sales housing, the critical strata are new subdivisions, and the critical estimator is the unsold inventory ratio.

In large urbanized areas, many of the rental units are concentrated in garden type projects or high-rise complexes; all of these larger rental projects are managed by specialized firms who usually compute monthly occupancy factors. Thus for the estimation of the rental vacancy rate, the critical strata are those neighborhoods or blocks with high concentrations of multifamily rental structures, $J_m$, and the critical estimator is $y$.

A series of equations for each dimension of the macro-model could be written. Following are a series for the assessment of housing quality (6) :

$$a = \frac{v_{1,a}}{v_1} \tag{15}$$

$$q = f(t, m) \tag{16}$$

$$q_s = 1 - \sum_j \Delta q_j \tag{17}$$

$$r = \frac{\partial f}{\partial t} \tag{18}$$

where

$a$ ≡ abandonment ratio

$v_{1,a}$ ≡ aggregate units abandoned in previous period

$q$ ≡ quality coefficient of a housing structure as a function of time t and maintenance level m

$q_s$ ≡ quality coefficient of housing inventory at substandard point s

$r$ ≡ rate of substandardization

## IV. Critical Strata and Estimators

Statistically, each dimension of the macro-model consists of one or more critical strata and corresponding critical estimators. For the purpose of generating the most reliable estimates of various urban variables, these critical strata must be identified and controlled during the development of a sampling frame, the establishment of a data system, the execution of multistage stratified probability sampling, and during the control of sampling and non-sampling errors. Critical strata and estimators are summarized in Table 1.

Table 1. Summary of Selected Critical Strata and Estimators

| Variable | Critical Strata | Critical Estimator |
|---|---|---|
| $V_2$ | $v_2$, $v_1$ | g |
| $c_w$ | $J_n$ | $v_{2,u}$ |
| $c_r$ | $J_m$ | y |
| $H_2$ | $v_2$, $v_1$ | g |
| $P_2$ | $v_2$, $v_1$ | $\alpha$ |
| a | $J_{v_1}$ | g |
| $q_s$ | $J_{v_1}$ | r |

where

$J_n$ ≡ new subdivisions

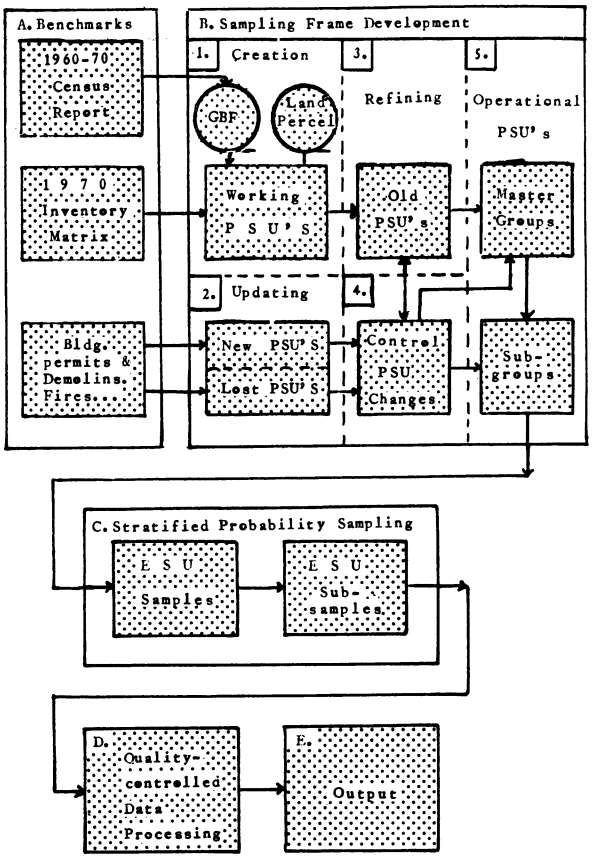
$J_m$ ≡ neighborhoods with concentrations of large multifamily structures

$J_{v_1}$ ≡ neighborhoods with concentrations of inventory loss

## V. A Data System

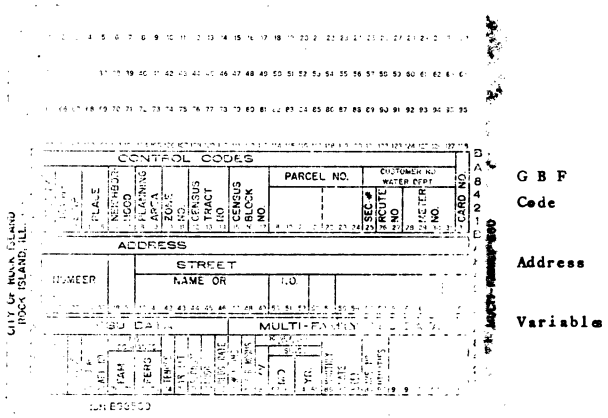
From the statistician's point of view, an efficient data system must be capable of stratifying PSU's into desirable groups and subgroups which can be operated either independently or jointly in order to maximize sampling efficiency. A condensed version of a simplified housing inventory data system is shown in figure 3 (7).

Figure 3. A Simplified Housing Inventory System




The data system is adaptable to any level of automation. Figure 4 shows an example of a PSU unit record for the Rock Island, Illinois system.

Figure 4. PSU Unit Record, Rock Island, Illinois System




The system consists of five components:

A. Benchmarks -- benchmarks insure that the final output is statistically comparable with the latest available Census inventory matrix. Many urban places with a population of 5000 or more are in the Census Bureau's samples of permit-issuing and demolition surveys. Thus with some data collection on fire and other losses, a time series of g values could be estimated. Most communities in the U.S. have a building department that issues permits for new construction, demolition, and conversions. This is the main source for $v_1$ and $v_2$ data. A standard unit record input device such as the one shown in Figure 4 (8) is the updating subsystem for the development of a comprehensive sampling frame.

B. Development of a Sampling Frame -- the sampling frame is the key component of the system. The objective in the development of the sampling frame was to maintain operational flexibility and high reliability. Based on a geographical base file (GBF) or an existing land-use parcel file, or any directory of buildings, a working PSU for existing housing structures could be created. Using a predetermined sampling ratio and procedure, working PSU's were selected on a rotating basis over a fixed time period. They were then stratified into subgroups for refinement and analysis. Refined PSU's were then regrouped into a predetermined number of operational PSU's and sub-PSU's.

C. Multistage Stratified Probability Sampling-- ESU's were randomly selected in several stages from either refined PSU's or sub-PSU's. In practice, the size and other features of ESU's are determined by the requirements of the output matrix and their prescribed confidence levels.

D. Quality Control -- critical estimators play a significant role in this component.

E. Output -- a variety of output matrices are available, including the computed sampling error tables.

The primary features of the data system are

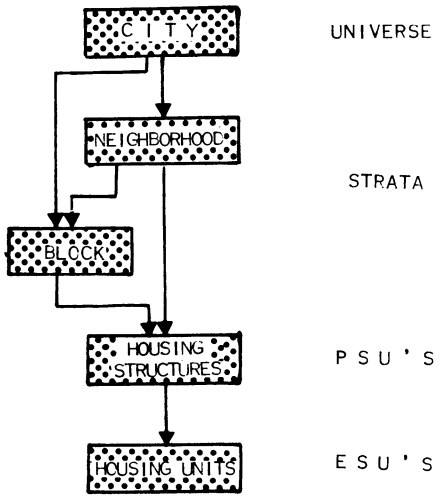
- staged development of a series of desirable PSU's
- refined treatment of the developed PSU's

- dynamic maintenance of a series of independent sub-PSU's
- Flexibility of multistage stratified probability samplings and control
- high reliability at a relatively low cost
- a multitude of applications because of the interchangability of ESU's and households

## VI. Procedures

A. Sampling Process -- the successive elements involved in the sampling process are shown in Figure 5.

Figure 5. Elements of the Sampling Process




In certain special cases, city blocks are used as strata even though only a small sample is required. For example in Chicago, Illinois, the absorption rate of high-rise condominums is estimated using city blocks as strata because most units are concentrated along the lake shore.

B. Sampling Plan -- In many urban areas, the distribution of PSU's in terms of the size of structure is quite significant. Therefore disproportionate cut-off sampling is the method of choice.

C. Control of Non-sampling Errors -- because of the extensive refinement and stratification of PSU's, non-response recall, survey control, and quality control editing of questionaire returns could be efficiently executed. Non-sampling errors are therefore controlled, and costs may be reduced.

E. Quality of Output -- since most of the critical estimators are known, the quality of output will be comparatively high and statistically acceptable.

## VII. Potential Applications

In urban areas, housing constitutes the most significant sector of land use. A comprehensive housing inventory model is therefore the major component of a total urban planning model. It generally covers most of the variables involved in the measurement of urban planning and programming adequacies, cost-benefit analyses, allocation of limited resources, projection of transportation and community facility requirements, and the development and implementation of urban socioeconomic models. The Rock Island, Illinois, Total Housing Inventory System (8) was developed with these long term objectives in mind.

The Rock Island data base covers every piece of land in the city, including vacant parcels. Thus the system can generate much desirable time series data on a broad spectrum of urban variables in addition to serving the requirements of a housing inventory system. It is considered to be a comprehensive version of an urban housing inventory model.

Alternatively, a simplified housing inventory model could be developed based on almost any acceptable data base as shown in Figure 3, and be maintained at comparably less cost with some advantageous features.

The federal, state, and local governments have collectively spent a large sum on a variety of urban programs. Many of these programs were adopted with little or no testing or empirical data, mainly because of the lack of a current dynamic sampling frame. If a series of simplified housing inventory models were developed and maintained at strategic locations, many of the hypotheses of urban programs could be tested on short notice. A significant contribution to the decision-making process could result.

In addition, if a network of such housing inventory models is maintained, not only will the communities involved benefit in their daily operations, but the system could be utilized as an urban research laboratory. Urban planners, researchers, and governmental and non-governmental agencies could utilize the lab for

- testing of hypotheses of proposed new urban programs
- testing of significance of differences between competing program proposals
- evaluation of the performance of existing programs
- simulation or testing of developed urban models
- testing new survey questionnaires and procedures

## VIII. References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6. Ko Ching Shih, "Measuring the Quality of Housing, " Proceedings of Social Statistics Section, American Statistical Association, 358-363 (1971)

7. A detailed description of the data system is too large for publication. Limited copies are available upon written request to the author

8. City of Rock Island, Illinois, Total Housing Inventory System, Rock Island, Illinois (1971)