MEASURING THE QUALITY OF HOUSING

Ko Ching Shih, U.S. Department of Housing & Urban Development*

I. BACKGROUND

In the decennial censuses of 1940, 1950 and 1960, the Bureau of the Census had collected information on the structural condition of housing by direct observation and overall rating. A post-census evaluation study (16) in 1967, however, resulted in the rejection of much of this data on statistical grounds; the collection of this type of data was discontinued starting with the 1970 Census (17).

In 1968, the National Commission on Urban Problems found that both the definitions and the supporting data relating to substandard housing in most Federal urban programs were inadequate and in many cases inconsistent. The Commission recommended the following definition of a substandard unit:

> "... any dwelling unit in which there is a substantial departure from accepted minimum housing code provisions..." (12).

Various U.S. Housing Acts have required local communities who undertook Federal urban programs to provide decent, safe and sanitary housing (18,20).

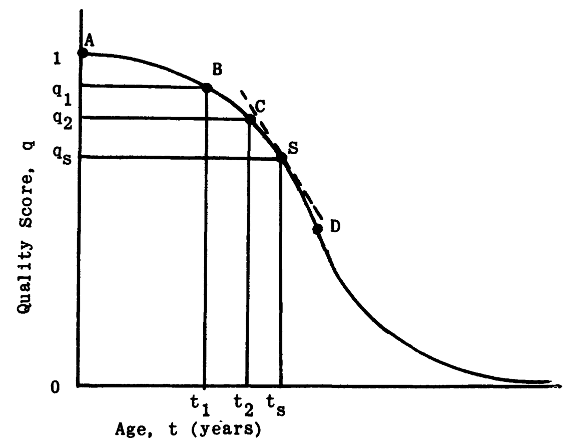
A study of any local housing code would show that there are actually many elements and variables involved in a quality measurement. Not only many variables of the housing structure must be considered, but also the number of residents, and neighborhood environmental factors. Because of the complex nature of such measurements, the task would be simplified if data collection facilities already in existence in a community could be utilized.

It is the purpose of this paper to present some theoretical concepts and the appropriate methods and procedures for measuring the quality of housing as a by-product of a local community's established housing inspection program.

II. THE HYPOTHESIS - A MICRO-MODEL

A micro-model of the deterioration process of a housing structure is shown in Figure 1:

Figure 1 A Micro-Model of the Deterioration Process of a Housing Structure with m Constant



With all other variables constant, a quality score q can be defined as a function of age t and maintenance m, i.e.

$$q = f(t,m) \tag{1}$$

where q ranges from zero to one.

For new structures with all aspects in good order, q at t = 0 is one, or perfect.

At a point B after a time t_1, assuming a constant level of maintenance, the quality score q has declined to q_1 or $1 - \Delta q_1$, where Δq_1 is a penalty score. This could be called the point of minor deficiency. Similarly, C could be called the point of major deficiency, D the point of critical deficiency, and so on.

Point S could be set as the substandard point, that is, the critical point in terms of housing code. Then all housing units with quality scores falling below S would be classified as substandard.

Looking again at the micro-model curve, it can be seen that a tangent at point S is easily drawn. That is to say, if time-series data were collected at pre-determined intervals, the rate of change of the quality coefficient at S can be estimated by taking the partial differential of f with respect to t, i.e.

$$r = \frac{\partial f}{\partial t} \tag{2}$$

* The methods and precedures presented here are not necessarily official interpretations of regulations of the U.S. Department of Housing & Urban Development. The author is solely responsible for any errors made.

r is truly the rate of substandardization, the critical statistic for the estimation of the level of substandard housing in a given stratum of a community.

In practice, the quality score at the substandard point S is computed by means of the following equation:

$$q_s = 1 - \sum_{i=1}^{s} \Delta q_i \qquad (3)$$

The quality score can be readily converted to a quality coefficient which can be interpreted flexibly and meaningfully.

Coefficients for crowdedness, environment, transportation, and other factors can also be computed with appropriate variables.

III. A MACRO-MODEL

Let us employ the following notation:

- j stratum number
- V aggregate total housing inventory $= V' + V''$
- V' aggregate standard inventory
- V'' aggregate substandard inventory
- N number of new housing units completed or remodeled
- S number of units with deficiencies rated as slight
- M number of units with deficiencies rated as minor
- J aggregate number of units with deficiencies rated as major $= J' + J''$
- J' number of units with deficiencies rated as major, but above the substandard level
- J'' number of units with deficiencies rated as major that are below the substandard level
- C number of units with deficiencies rated as critical
- D number of units scheduled to be demolished or in the process of demolition

The macro-model can then be expressed by the following equations:

$$V_{ij} = \sum_j [V'_{ij} + V''_{ij}] \qquad (4)$$

or

$$V_{ij} = \sum_j [(N_{ij} + S_{ij} + M_{ij} + J'_{ij}) + (J''_{ij} + C_{ij} + D_{ij})] \qquad (5)$$

or

$$V_{ij} = \sum_j [N_{ij} + V_{(i-1)j} - D_{(i-1)j} + D_{ij}] \qquad (6)$$

And

$$V_{(i-1)j} = \sum_j [N_{(i-1)j} + S_{(i-1)j} + M_{(i-1)j} + J'_{(i-1)j}] + [J''_{(i-1)j} + C_{(i-1)j} + D_{(i-1)j}] \qquad (7)$$

$$V'_{ij} = \sum_j [N_{ij} + S_{ij} + M_{ij} + J'_{ij}],$$ but is not necessarily equal to

$$\sum_j [N_{ij} + N_{(i-1)j} + S_{(i-1)j} + M_{(i-1)j} + J'_{(i-1)j}],$$

because the coefficient of each individual housing unit depends greatly on the maintenance efforts. In other words,

$$M_{(i-1)j} \neq M_{ij} \text{ and } J'_{(i-1)j} \neq J_{ij}.$$

For this reason,

$$V''_{ij} = \sum_j [V'_{(i-1)j} - D_{(i-1)j}] + rV'_{(i-1)j} \qquad (8)$$

$rV'_{(i-1)j}$ is the portion of $V'_{(i-1)j}$ which fell below the substandard level during the time period between (i-1) and i.

Since $V'_{(i-1)j} = \sum_j [N_{(i-1)j} + M_{(i-1)j} + J'_{(i-1)j}]$,

thus $$rV'_{(i-1)j} = r \sum_j [N_{(i-1)j} + M_{(i-1)j} + J'_{(i-1)j}] \qquad (9)$$

In the short run, $rN_{(i-1)j} \simeq N_{ij}$, i.e. it is unlikely any unit of $N_{(i-1)j}$ became substandard during a relatively short period of time; it is also true that $rM_{(i-1)j} \simeq M_{ij}$.

In other words, it is likely that most new substandard units came from $J'_{(i-1)j}$.

Approximately,

$$V''_{ij} = V''_{(i-1)j} - D_{(i-1)j} + rJ'_{(i-1)j} \qquad (10)$$

Thus, $J'_{(i-1)j}$ is the critical stratum in estimating the parameters of the current substandard housing inventory (V''_{ij}), and r is a critical estimator.

IV. PROCEDURES

Based on the Housing Code of the City of Rock Island, Illinois (14), quality conditions of a housing structure are classified as either sound, minor, major, or critical. Definitions of each of the four conditions together with the codes and penalty score weightings are shown in Table 1.

Table 1 Definition, Code and Penalty Score Weighting, Rock Island, Ill.

CODE	QUALITY CONDITION	PENALTY SCORE WEIGHTING	DEFINITION
1	SOUND	0	ELEMENT SOUND, NO REPAIRS NEEDED
2	MINOR	1	TO A MINOR DEGREE, DEFECTS THAT CAN ORDINARILY BE CORRECTED IN THE COURSE OF NORMAL MAINTENANCE.
3	MAJOR	4	TO A MAJOR DEGREE, DEFECTS THAT REQUIRE SUBSTANTIAL REPAIR OR REPLACEMENT BUT WHICH ARE NOT SERIOUS STRUCTURAL FAILURES.
4	CRITICAL	16	TO A CRITICAL DEGREE, DEFECTS OF THE PRIMARY STRUCTURAL COMPONENTS ONLY AND ARE SERIOUS STRUCTURAL FAILURES.

Twenty-one variables in five structural elements (primary components, secondary components, related components, system components and availability of plumbing facilities) were selected for computing the housing structural quality coefficient q. Two variables (persons per room and persons per block) were selected for computing the crowdedness coefficient c, and modified quality coefficient q'. Fifteen variables in five environmental factors (space, street conditions, utilities, atmospheric conditions and general conditions) were selected for computing the environmental coefficient v and modified quality coefficient q''.

Table 2 shows the classification of quality rating variables and penalty scores for computing quality coefficients q, q' and q''.

Table 3 shows the overall quality rating of a housing structure together with the range of penalty scores and structural quality coefficients q.

Table 3 Overall Quality Rating of A Housing Structure, Rock Island, Ill.

OVERALL QUALITY RATING	RANGE OF PENALTY SCORES p	RANGE OF QUALITY COEFFICIENT q
N	0	1.00
S	0 - 14	1.00 - 0.90
M	14 - 22	0.90 - 0.85
J	22 - 46	0.85 - 0.68
J'	22 - 32	0.85 - 0.78
J''	32 - 46	0.78 - 0.68
C	46 - 72	0.68 - 0.50
D	72 - 144	0.50 - 0.00

The computing equation for q, using the simplified questionnaire, is

$$q = 1 - \frac{1}{144}\left[\sum_{k=1}^{5} A_k + \sum_{k=6}^{21} B_k\right] \qquad (11)$$

where 144 is the maximum penalty score, A_k is one of the primary components, and B_k is one of the other components as listed in Table 2.

The first modified quality coefficient q' is simply the average of q and the crowdedness coefficient c. The second modified quality coefficient q'' is found by averaging in v, the environmental coefficient given by:

$$v_j = 1 - \frac{1}{56}\sum_{i=1}^{14} v_i \qquad (12)$$

where 56 is the maximum penalty score.

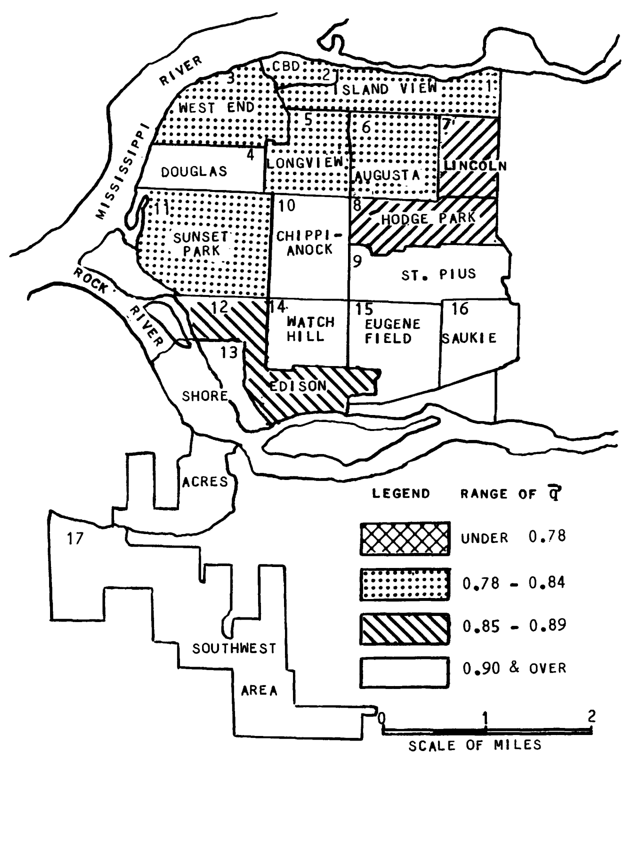
By means of a series of one-page precoded questionnaires and a low-cost, simple to operate portable data terminal - the IBM Information Recorder, all of the measurable variables can be logically recorded during the course of a housing inspector's daily routine. The inspectors are highly trained, and they can observe and record the appropriate scores for each variable according to predetermined standards.

V. EMPIRICAL RESULTS

These are some of the highlights of the empirical results:

(1) According to the urban growth theory, many American cities have grown concentrically or on a neighborhood by neighborhood basis. The origin is usually called the central business district, and growth spreads out to the peripheries - the new neighborhoods. Statistically, these neighborhoods are ideal strata. Figure 2 shows the distribution of modified quality coefficient $\bar{q}'$ by neighborhood.

Figure 2 Distribution of Modified Quality Coefficient $\bar{q}'$ by Neighborhood Rock Island, Ill.



In conducting housing quality surveys, stratification of sampling units by neighborhood is essential in order to allocate the samples efficiently. These statistics are certainly useful for code enforcement and urban renewal programs.

(2) The survey also shows that $\bar{q}'$ of owner-occupied housing (0.91) is significantly higher than for renter-occupied units (0.82) and low rent housing (0.74), and that the variances of the quality coefficients and their distribution patterns are valuable indicators when used in the decision-making process of housing planning.

(3) The elementary sampling units (ESU's) of the environmental survey are block faces. In conjunction with the transportation study which the city is planning to conduct in the near future and a law enforcement study which is in progress, the end results of the quality measurement can be more effectively utilized and expanded.

(4) In the June 1970 JASA, Kain and Quigley concluded that "the quality of a bundle of residential services has at least as much effect on its price as such quantitative aspects as number of rooms, number of bathrooms, and lot size. . ." (7). In actual practice in the determination of the market price of a housing structure, the element of quality is one of the independent variables (16). Specifically,

$$P_k = f\ (q_k, C_k) \tag{13}$$

where P_k is the price of house k;

q_k is the quality coefficient of house k;

C_k are the characteristic variables of house K.

C_k is given by a regression equation developed by Musgrave (11).

Hence, Musgrave's equation may be modified as:

$$P_k = q_k\ [\ b_o + b_1C_{1k} + b_2C_{2k} + \ldots + b_{21}C_{21k} + e_k\ ] \qquad (k=1,\ 2,\ \ldots\ n) \tag{14}$$

or:

$$P_k = q_k\ [\ b_o + \sum_{j=1}^{21} b_kC_{jk} + e_k\ ] \qquad (k=1,\ 2,\ 3,\ \ldots\ n) \tag{15}$$

where b_o is the constant term in the regression; b_1, b_2,... b_{21} are the regression coefficients corresponding to C_{jk} = 1 if house k is in category j and = 0 otherwise; e_k is the "error" or "residual" term in the regression equation. If a house is brand new, q=1, thus,

$$P_k = b_o + \sum_{k=1}^{n} b_kC_{jk} + e_k \tag{16}$$

The quality coefficient of each characteristic variable may vary significantly. Thus, equation (14) many be written as

$$P_k = b_o + q_1b_1C_{1k} + q_2b_2C_{2k} + \ldots + q_{21}b_{21}C_{21k} + e_k \tag{17}$$

or

$$P_k = b_o + \sum_{j=1}^{21} q_jb_jC_{jk} + e_k \qquad (k=1,\ 2,\ 3,\ \ldots n) \tag{18}$$

If a house is occupied or was previously occupied, its quality coefficient q will be a significant independent variable for its price determination.

(5) By means of a Total Housing Information System (THIS), Rock Island, Illinois, currently maintains a nearly perfect sampling frame of PSU's in terms of local real property units. Thus, housing inspection samples are ideally stratified and randomly selected. One stratum consists of non-residential structures, which, however, do contain living quarters, for example, housing units above a grocery store. This stratum is the missing inventory component that usually does not show up in many reports. The quality coefficients of this missing component, in combination with other statistics such as vacancy rates, are significant values for urban relocation applications.

VI. CONCLUSIONS

(1) For the time being, it is not feasible to measure the quality of housing on a national scale. There are several reasons: 1) Not many communities are ready to operate a continuous program of this kind. 2) The enumerators must be trained housing inspectors. 3) Many local housing codes are far from standardized. 4) Local needs and capabilities vary too greatly. 5) Too often politics is involved.

(2) For the purposes of maximum benefit and generality, measuring the quality of housing must be a basic subsystem of an integrated total housing inventory system. In other words, the project should be dynamically operated on a long-term basis.

(3) For HUD and the Census Bureau, it is ideal to select several communities of various sizes in each region of the nation, and develop various types of housing inventory systems, including housing inspection as a basic subsystem. Thus a relatively small number of samples can be used to determine certain basic variables for the purposes of estimation, projection, and further development.

Table 2 Classification of Quality Rating Variables and Penalty Scores

Quality Coefficient	*Target Population*	*Element Variable*	*Penalty Scores* 1 (0)	2 (1)	3 (4)	4 (16)	*Maximum Penalty Scores*
q	Housing Structure	All Structural Variables	0	21	84	80	144
		a. Primary Components:	0	5	20	80	80
		1. Foundation Walls	0	1	4	16	16
	[PSU]	2. Exterior Walls	0	1	4	16	16
		3. Roof & Roof Structure	0	1	4	16	16
		4. Floor & Floor Structure	0	1	4	16	16
		5. Bearing Walls & Columns	0	1	4	16	16
		b. Secondary Components:	0	6	24	-	24
		6. Nonbearing Walls	0	1	4	-	4
		7. Interior Stairs & Railings	0	1	4	-	4
		8. Porch & Steps	0	1	4	-	4
		9. Windows & Window Units	0	1	4	-	4
		10. Doors & Door Units	0	1	4	-	4
		11. Chimney & Cornices	0	1	4	-	4
		c. Related Components:	0	4	16	-	16
		12. Lighting & Ventilation	0	1	4	-	4
		13. Adequacy of Floor Space	0	1	4	-	4
		14. Entrances & Exits	0	1	4	-	4
		15. Grounds	0	1	4	-	4
		d. System Components:	0	3	12	-	12
		16. Plumbing System	0	1	4	-	4
		17. Electrical System	0	1	4	-	4
		18. Heating System	0	1	4	-	4
	Housing Unit [ESU]	e. Availability of Plumbing Facilities:	0	3	12	-	12
		19. Kitchen Sink	0	1	4	-	4
		20. Flush Toilet	0	1	4	-	4
		21. Bathtub or Shower	0	1	4	-	4
q'	Persons & Households	1. Persons per Room	NA	NA	NA	NA	NA
		2. Persons per Block	NA	NA	NA	NA	NA
q"	Block-face	All Environmental Factors	0	14	42	-	56
		a. Space	0	1	4	-	4
		1. Open Space	0	1	4	-	4
		b. Street Conditions:	0	5	20	-	20
		2. Street Pavement	0	1	4	-	4
		3. Street Width	0	1	4	-	4
		4. Sidewalk	0	1	4	-	4
		5. Street Lighting	0	1	4	-	4
		6. Offstreet Parking	0	1	4	-	4
		c. Utilities:	0	3	12	-	12
		7. Water Supply	0	1	4	-	4
		8. Sewage Disposal	0	1	4	-	4
		9. Drainage	0	1	4	-	4
		d. Atmospheric Conditions:	0	3	12	-	12
		10. Noise	0	1	4	-	4
		11. Air Pollution	0	1	4	-	4
		12. Odor	0	1	4	-	4
		e. General Conditions:	0	2	8	-	8
		13. Safety	0	1	4	-	4
		14. General Conditions	0	1	4	-	4

PENALTY SCORE CODES: HOUSING STRUCTURE - 1 - SOUND, 2 - MINOR DEFECT, 3 - MAJOR DEFECT, 4 - CRITICAL DEFECT, PLUMBING FACILITIES - 1 - COMPLETE, 2 - PARTIAL, 3 - NONE. ENVIRONMENTAL FACTORS - 1 - ADEQUATE OR NORMAL, 2 - MARGINAL OR ACCEPTABLE,, 3 - NEGLECTED OR UNACCEPTABLE. NA - NOT APPLICABLE

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