

*USER SATISFACTION IN A PROTOTYPIC FOURPLEX IN BLACKSBURG,  
VIRGINIA*

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*ABSTRACT*

*A structurally innovative fourplex, designed by Homer T. Hurst, P.E., was one of nineteen award-winning designs in the 1980 design competition "Building Value Into Housing" by the United States Department of Housing and Urban Development. This passive solar unit, The Hillside Fourplex, was constructed in Blacksburg, Virginia and was ready for occupancy in September, 1982. This paper reports the findings of a study conducted to evaluate livability of the unit, as evidenced by user satisfaction with the particular design features.*

*INTRODUCTION*

Because of escalating costs of new construction, there is increased interest in reducing both the initial costs and the life cycle costs of housing. Prototypic housing units designed in response to these concerns, however, often include design features that require adaptation by the resident. In addition, the innovative technologies used in prototypic housing may affect the size, appearance, arrangement and features of the units. This study examines resident acceptance of some innovative features and looks at the livability of a passive solar fourplex in Blacksburg, Virginia.

Livability is the ability of residential space to meet the daily living needs of a household through its design, arrangement and construction (Beamish, 1982). Operation Breakthrough (the United States Department of Housing and Urban Development demonstration program to encourage the volume production of safe, durable quality housing for volume housing markets) recognized that the development of performance standards for evaluating prototypic, innovative and technologically advanced housing systems was a vital part of the program (Pfrang, 1970). The more complex a design is, however, the more difficult it becomes to integrate and synthesize information concerning the design.

Social scientists have a formidable task in attempting to explain human environment relationships. There are at least two types of measurements involved: 1) objective measurement---the actual level of well-being achieved, and 2) subjective measurement---satisfaction with that level (Morris and Winter, 1978). Assessment of the subjective reaction to the objective condition is necessary. Both user requirements and the performance approach evolved to meet this need. Because the user is the starting point in the design process, a successful design is defined as user satisfaction with the end product.

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The performance approach demands a statement of performance in terms of function. Because buildings should serve people, function (i.e. livability) is defined as the attributes necessary to satisfy human occupancy requirements. The means of delivering these features is left open. The philosophy of the performance approach emphasizes the satisfaction of human needs (Wright, 1971).

Brill (1974) characterizes post-occupancy evaluation as a means of determining the success of the plan in practice and the extent to which project goals are achieved. Goals take the form of activities to be performed. The ultimate goal is to design an environment with characteristics that enable the activity to be performed properly.

Previous evaluations concentrate on general attitudes and preferences without adequately specifying design characteristics. It is difficult, therefore, to discover the relationship of response to the building as a whole and response to particular design features (Rubin and Elder, 1980).

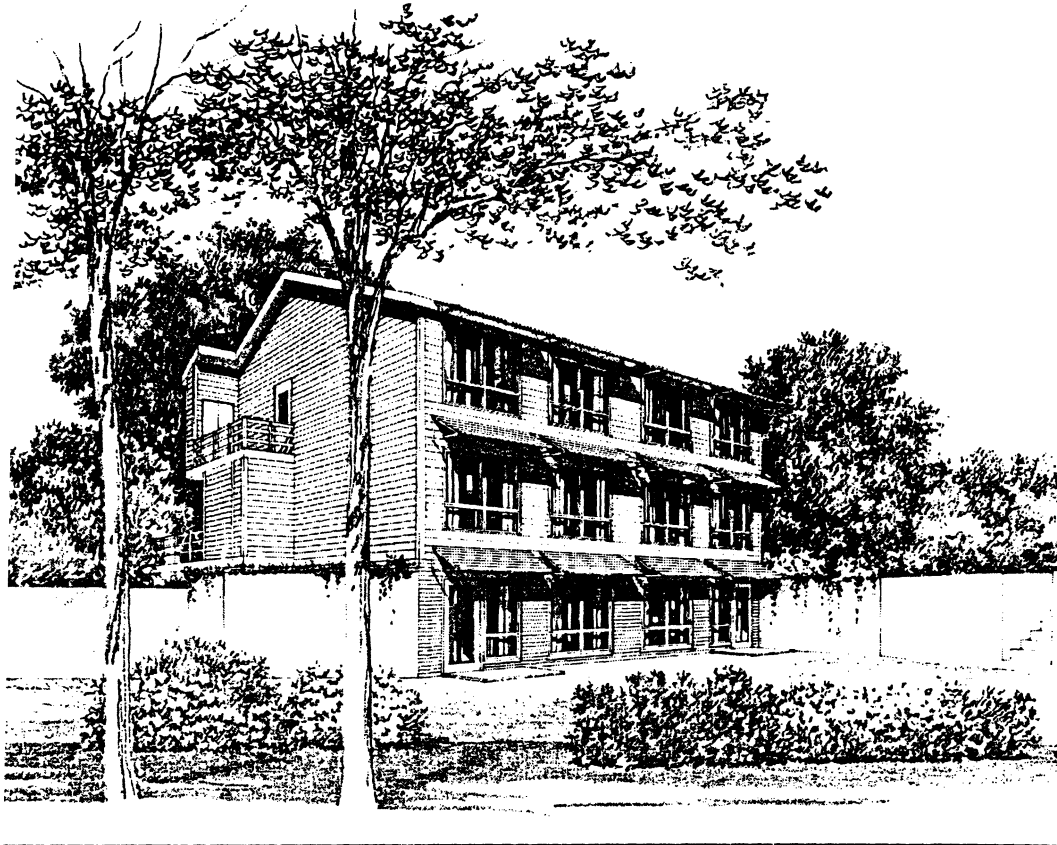
#### *DESCRIPTION OF THE FOURPLEX*

The Hillside Fourplex is an innovative, prototypic housing unit designed to build value into housing (see Figure 1). Units constructed using this design concept are expected to be worth more than their original costs for two reasons: 1) special attention is given to livability and to desirability, and 2) cost-effectiveness is considered as both the initial cost and as the life-cycle cost of the housing unit (Smith and Hurst, 1981).

The floor plan of the fourplex consists of two two-bedroom units on the lower level and two four-bedroom, bilevel units on the middle and upper levels (see Figure 2). Design features include isolated entries for each living unit, adequate indoor and outdoor living space and liberal storage areas. Because the fourplex has a southern exposure, there is maximum heat gain. In addition, the bilevel units have two areas that can be used as either living room or family room areas.

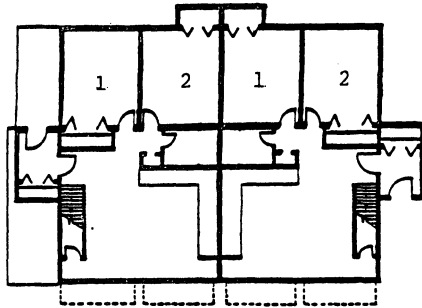
Cost effectiveness is achieved by the compactness of the building and the concentration of plumbing and mechanical parts. It is also achieved through a building system that eliminates over half of the structural materials normally required in conventional construction, while facilitating heat distribution by gravity and convective forces. Each dwelling unit is constructed to conserve energy and each utilizes solar energy to provide 40 percent of the space-heat requirements (U.S. Department of Housing and Urban Development, 1980).

Innovative construction techniques incorporated into the design include: 1) 1-by-10 joists, spliced to form both continuous beams and floor trusses, 2) floors of 3" concrete on steel decking to act as thermal storage, 3) walls constructed of rough-sawn 1-by-6 poplar studs spaced 16" on center, and 4) a corrugated coated steel roof on continuous wooden purlins to eliminate conventional sheathing/rafter/truss systems. The insulation package includes a 2" polyurethane core (R=17) for the foundation wall and fiberglass bats (R=17) for exterior stud walls. The upper units also have fiberglass batts (R=38) in the attic. Energy efficiency is enhanced by setting the lower floor into the sloping site, capitalizing on the earth's insulative properties (see Figure 3). The building's orientation allows passive solar heating using large, south-facing, double-pane windows equipped with exterior shades to control summer heat gain. Windbreaks in the form of evergreen plantings are utilized along the northwest edge of the site to reduce heat losses (Smith, 1982).

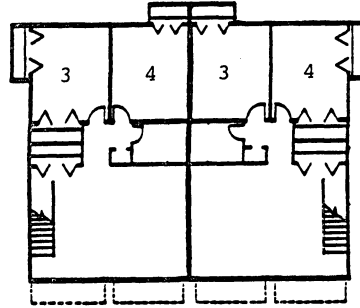


THE HILLSIDE FOURPLEX  
COURTESY OF HOMER HURST  
FIGURE 1

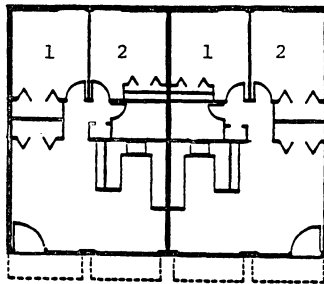
FOUR BEDROOM: 1728 sq. ft.



MID-LEVEL



UPPER LEVEL



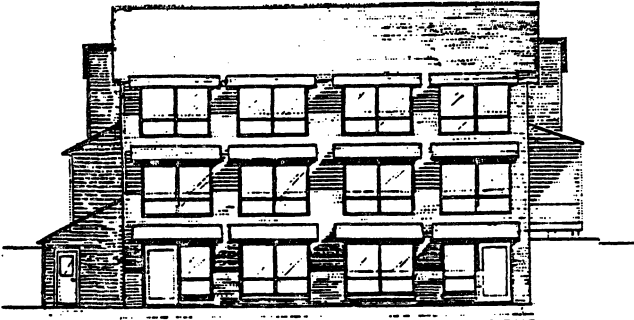
LOWER LEVEL

TWO BEDROOM: 828 sq. ft.

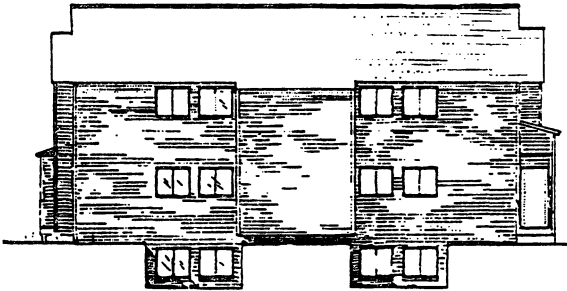
FLOORPLAN FOR THE HILLSIDE FOURPLEX

FIGURE 2

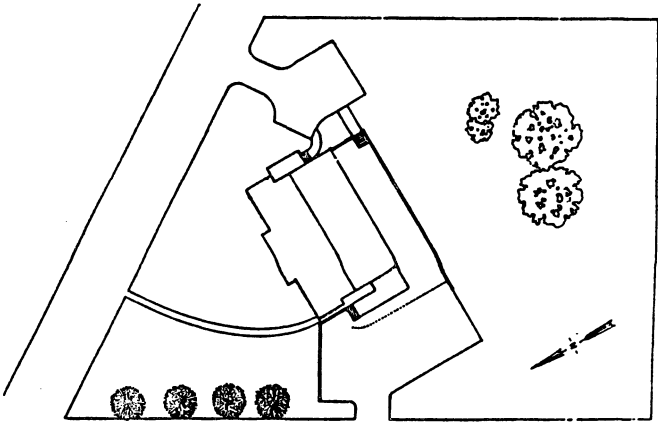
ELEVATIONS FOR THE HILLSIDE FOURPLEX



SOUTH ELEVATION



NORTH ELEVATION



SITE PLAN FOR THE HILLSIDE FOURPLEX

FIGURE 3

The heating system for the fourplex is a passive solar design with a mechanical, forced hot-air auxiliary support system. The solar system consists of a convection loop incorporating a plenum formed by a suspended ceiling hung 12" below the structural system. Ceiling grills above the southern windows admit solar-heated air. The air flows through the plenum to the north wall of the unit where it exits through ceiling grills above the bedroom windows and returns via open bedroom doors to the living area. There, the air is reheated and recirculated. The convection loop system operates on all floors and in all units (a total of six loops). The upper units are independently served by a gas-fired, hot-air furnace with a positive air supply to the ceiling plenum on the entry level. The heated air travels by convection from the entry-level living space to the upper levels. It exits through a central-return duct to the furnace room. A heat-exchange system uses exhaust heat from the gas furnaces serving the upper units to preheat the hot water for all four units and to efficiently supply auxiliary heat to the lower units.

#### *PROCEDURES*

A pretest/post-test survey was used to assess user satisfaction with the design and features of the Hillside Fourplex. All students at Virginia Tech interested in off-campus rental housing were the theoretical population for the study. The working population was obtained by calling all persons who signed leases to the Hillside Fourplex and inviting them to participate in the study. All those who agreed to participate constituted the sample. The test instrument was a questionnaire, modified for use in assessing user satisfaction, that was originally used in assessing public acceptance of the fourplex (Spaid, 1983). The 80-item questionnaire was administered as a pretest. The instrument and a cover letter were mailed to each participant before occupancy of the fourplex occurred. Four weeks after occupancy, the questionnaire was administered as a post-test. It was administered again after 20 weeks of occupancy (after a heating season) as a second post-test. Both "satisfaction with" and "importance of" the design features were assessed using five-point Likert-type scales. The data from the questionnaire were subjected to descriptive and statistical analysis.

The descriptive analysis for this study consisted of frequency distributions and the computation of means as measures of central tendency. Statistical analysis used paired t-tests (.05 alpha level) to test the hypotheses for three test periods: 1) pretest and first post-test, 2) first post-test and second post-test, and 3) pretest and second post-test.

Hypothesis 1. There is no difference in a mean scores between paired tests for satisfaction with the exterior of the unit.

Hypothesis 2. There is no difference in mean scores between paired tests for satisfaction with the interior of the unit.

Hypothesis 3. There is no difference in mean scores between paired tests for satisfaction with innovative features of the unit.

Frequency distributions and mean scores, as well as changes in the means, for each item were used to assess user satisfaction for each design feature. A matrix (see Figure 4) was created to combine the responses to the unimportant/important and the dissatisfied/satisfied rankings (Morris, Winter, and Crull, 1980) using a range of -10 (dissatisfied with an important feature) to +10 (satisfied with an important feature) with 0 being neutral. The procedure involved recoding the dissatisfied/satisfied scores to give a range of -2 to +2, then

multiplying the satisfaction score by the importance score. For example, very satisfied (5 recoded to 2) with an unimportant (1) feature would result in a score of 2 (2x1). A judgement was then made as to livability, evidenced by user satisfaction with the features tested, to evaluate the success of the unit in meeting the housing needs of the occupants.

#### RESULTS AND DISCUSSION

The sample for the pretest consists of ten students at Virginia Tech, ranging in age from 19-21. Occupancy by units shows: upper unit A, three females; upper unit B, three males; lower unit A, two females; and lower unit B, two males. The sample for the first and second post-test includes all those students who participated in the pretest. In addition, questionnaires were completed by two females in upper unit A and one male in upper unit B, for a total of thirteen residents. Closure interviews were obtained with all residents of the fourplex.

User satisfaction is evaluated by dividing residents' responses into three categories: exterior of the fourplex, interior of the fourplex, and innovative features. The data from each of the categories is then combined into the matrix (see Figure 4) and the matrix is zoned (see Figure 6) to further evaluate the fourplex.

*Exterior.* The residents are generally satisfied with the exterior of the fourplex. Statistical analysis for Hypothesis 1 indicates significant differences between pretest and first post-test mean scores and between pretest and second post-test mean scores, indicating users' opinions of the exterior of the units rose over time. This can perhaps be understood since grading and yard work, including parking facilities, were incomplete at the time of the pretest. The matrix, combining responses to the unimportant/important and the dissatisfied/satisfied rankings, indicates that more than 90 percent of the residents produced a score of 0 or above (neutral to satisfied) for overall opinion of the exterior of the units (see Figure 5) in each of the three test periods.

*INTERIOR.* The residents of the fourplex are generally satisfied with the interior of the unit with a few notable exceptions. Satisfaction with the interior features ranges from neutral (3.1) to very satisfied (5) with the exception of painted walls, comfortable temperatures, temperature uniformity in winter, absence of drafts, and workmanship (range: 2.3-2.9). Statistical analysis for Hypothesis 2 indicates no significant differences for users' satisfaction with interior features in any time period. The null hypothesis, therefore, is not rejected. The matrix scores, combining responses to the unimportant/important and the dissatisfied/satisfied rankings, indicates that more than 90 percent of the residents produced a score of 0 or above (neutral to satisfied) for the overall opinion of the interior of the units in each of the three test periods. However, scores decline with each administration of the test (see Figure 5).

The slight decline in the overall opinion of the interior of the unit with each administration of the test may be related to the perception of more problems with the passage of time, to negative feelings associated with perceived heating problems, to a reduction in the excitement of living in a new, experimental housing unit, or an emotional response to reported tenant/landlord tensions (builder leased units to occupants).

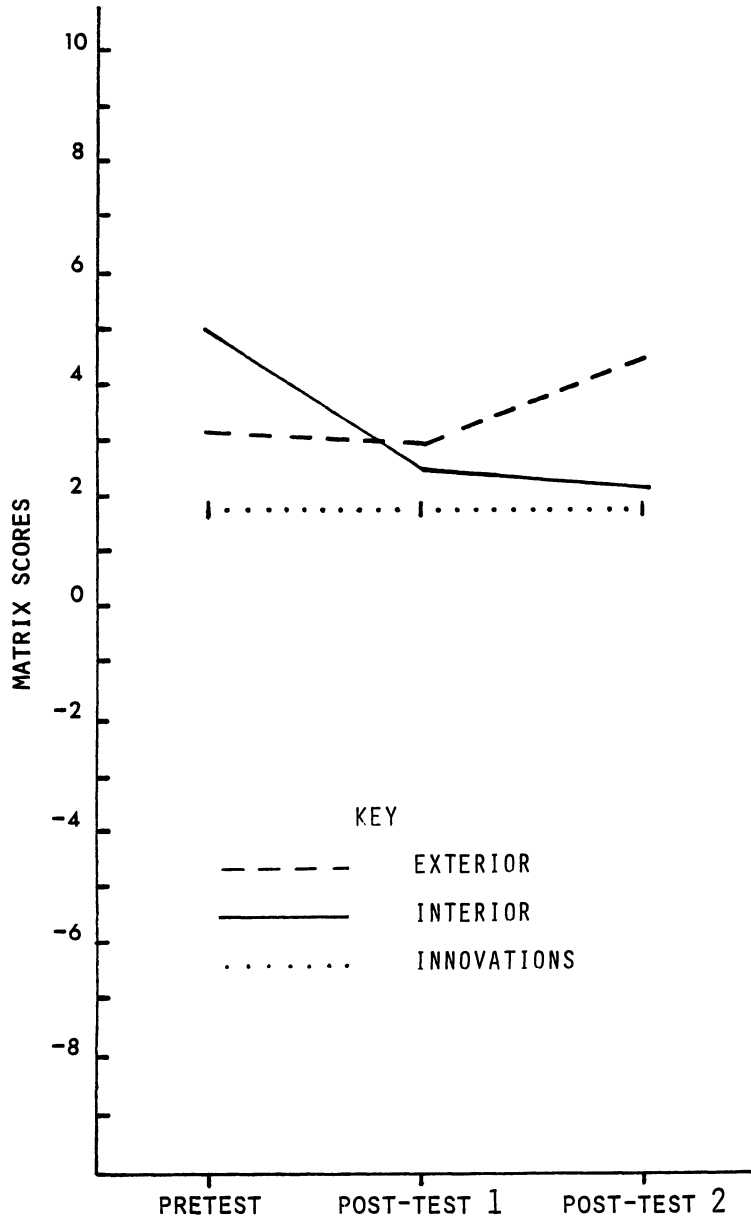
Interviews with the residents revealed several problems with the heating system. These problems are reflected in the declining satisfaction with thermal comfort in winter, temperature uniformity, and absence of drafts. The residents do not feel there is sufficient heat in the bedrooms. This may be due to

		DISSATISFIED			SATISFIED	
		-2	-1	0	1	2
IMPORTANT	5	<b>-10</b>	<b>-5</b>	<b>0</b>	<b>5</b>	<b>10</b>
	4	<b>-8</b>	<b>-4</b>	<b>0</b>	<b>4</b>	<b>8</b>
	3	<b>-6</b>	<b>-3</b>	<b>0</b>	<b>3</b>	<b>6</b>
	2	<b>-4</b>	<b>-2</b>	<b>0</b>	<b>2</b>	<b>4</b>
	1	<b>-2</b>	<b>-1</b>	<b>0</b>	<b>1</b>	<b>2</b>
UNIMPORTANT						

IMPORTANCE/SATISFACTION MATRIX

FIGURE 4

FIGURE 5



RESIDENTS' EVALUATION OF FOURPLEX  
MEAN COMPARISON FOR MATRIX MEASURE

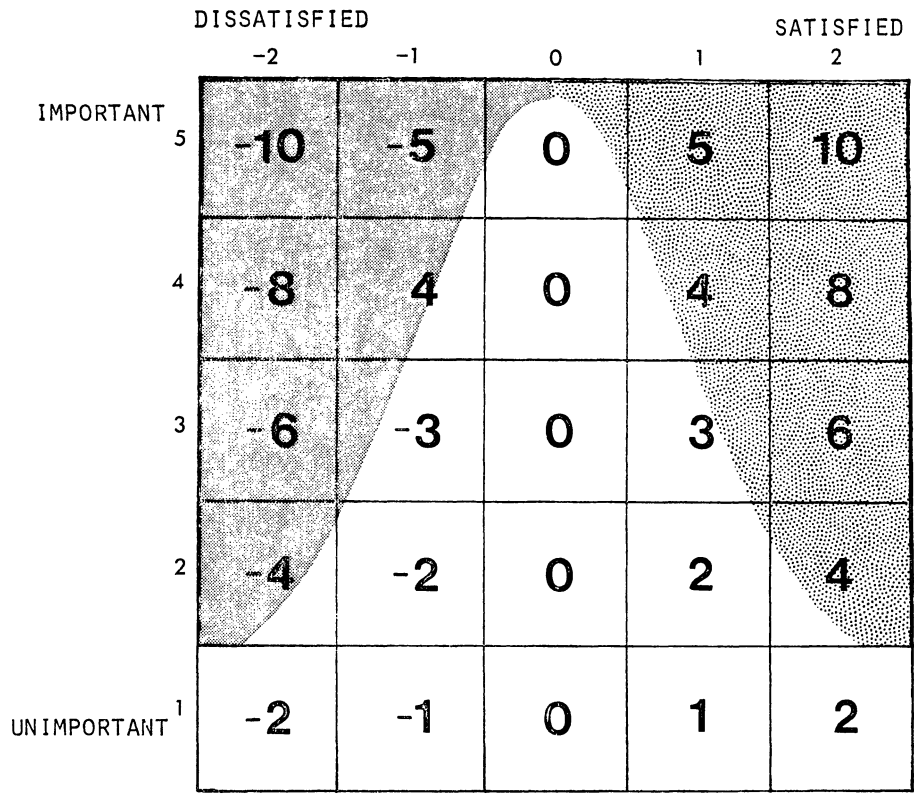
problems with the air flow through the plenum, air infiltration problems around bedroom windows (residents reported movement of the draperies), conduction losses through the glass (no nighttime insulation was utilized), inadequate insulation in the closets (closets are cantilevered beyond the foundation wall) or inadequacies in the circulation path when the mechanical system is in operation. It is also possible that residents close their bedroom doors, interfering with the heat circulation patterns. Residents indicate it is necessary to use auxiliary heat as soon as, if not before, the sun sets---possibly indicating a need for nighttime insulation or inadequate heat storage. Part of the dissatisfaction with the temperature is the result of the residents being without heat for several weeks due to mechanical failure. In addition, the heat exchange system did not function as planned. Electrical baseboard heaters had to be installed in the lower units, increasing heating costs. The problem of unacceptable drafts may have been due to the characteristics of a convection loop system, the characteristics of the duct-return system for the mechanical unit, or problems with air infiltration.

The problems with workmanship are related in part to nail pops and doors that do not close. Some residents believe the unit is shifting on the foundation. It seems more likely to be a problem with humidity. However, user satisfaction is, for the most part, positive. Nine of the 13 students intend to renew their leases.

*INNOVATIVE FEATURES.* Residents also tend to be satisfied, in general, with the innovative features of the fourplex. The score for the overall opinion of innovative features generated by the matrix, combining responses to the unimportant/important and the dissatisfied/satisfied rankings is 0 or above (neutral to satisfied) for 70 percent of the residents (see Figure 5) in each of the three test periods. Satisfaction ranges from neutral (3.2) to very satisfied (4.5) with the exception of the innovative construction techniques that eliminate over half of the structural materials usually required (valued decreased with each test: 3.8 to 3.1 to 2.7). Residents may relate this feature to perceived structural instability of the units. Statistical analysis for Hypothesis 3 indicates no significant differences for users' satisfaction with innovative features of the unit in any time period. The null hypothesis is, therefore, not rejected.

*ZONED MATRIX.* Since the Hillside Fourplex was given an award for "building value into housing", it is important to understand which features contribute to satisfaction and are, therefore, worthy of the cost. It is also important to note problem areas in order to make necessary corrections in design or allocation of funds. The matrix combining the responses to the unimportant/important and dissatisfied/satisfied rankings can be divided into zones. These zones can then be used to determine which features are desirable and which features are potential problems (see Figure 6). Values of -4 to -10 indicate problem areas. These features should be examined before the unit is replicated. Values of +4 to +10 indicate desirable features which should be maintained if the unit is replicated. Zero is a neutral value. Values of -1 to -3 indicate possible problem areas which might require attention. Values of +1 to +3 indicate features which are somewhat desirable and probably should be maintained during replication.

Using the zoned matrix in this way to evaluate responses to the design features, the residents tend to be satisfied with the fourplex. The majority of the features tested received scores of +4 to +10 by more than 50 percent of the residents. However, several factors received a score of -4 to -10 indicating dissatisfaction with a feature considered important by the user. Problems with the heating system caused some discomfort that is particularly evident in the second post-test. Residents consider non-uniform winter temperatures (50



KEY

- 10 to -4 PROBLEM AREA
- 3 to -1 POSSIBLE PROBLEM AREA
- 0 NEUTRAL AREA
- +3 to +1 SOMEWHAT DESIRABLE AREA
- +4 to +1 DESIRABLE AREA

IMPORTANCE/SATISFACTION MATRIX FOR GROUPING DESIGN FEATURES

FIGURE 6

percent of the responses), uncomfortable temperatures (31 percent), and presence of drafts (50 percent) unsatisfactory. Additional features perceived as problem areas by more than 30 percent of the residents are: security and safety, 15 percent and 31 percent (the first percentage is from the first post-test, the second percentage is from the second post-test); privacy for residents from others in the fourplex, 23 percent and 38 percent; amount of light in the bedrooms, 8 percent and 38 percent; adequacy of space of furniture placement in lower living room, 31 percent and 31 percent; workmanship, 23 percent and 38 percent; and assessment of painted walls, 38 percent and 31 percent.

### *CONCLUSION*

User satisfaction indicates the building is successful for the most part in meeting the needs of the residents. With a few exceptions, primarily related to the heating system, livability as evidenced by user satisfaction is relatively high. For most features, including the innovative ones, responses are positive and deviation from the mean is so slight that a factor analysis to isolate factors mediating satisfaction is not advisable. It is not clear if all features are equally important in determining satisfaction (i.e., there is no hierarchy) or if the study only includes those features that are important to the users.

Results of the study suggest several recommendations for the builder if the structure is replicated. The various components of the heating system should be evaluated to determine possible weaknesses, since thermal comfort is a problem. The problem of privacy within the fourplex seemed to be associated with sound transmission. If this is not due to the duct system (residents' belief), it should be addressed as a separate issue. The problem with security and safety seems to be perceived only by the residents of the lower units. They feel the window in the door and inadequacy of the lock are potential problems. Material specification changes could correct this problem. Since the amount of light in the bedrooms is a function of the unit being set into the site, this may be a trade-off with potential energy savings. Residents of the lower units have problems with the space provided for the living room. This area serves as an entry and as access to both the kitchen and private spaces, but has only one wall suitable for conventional furniture placement. An enlargement or rearrangement of the space may be desirable.

Residents of the fourplex do not seem to understand the significance or characteristics of the innovative features employed. Neither are they aware of the structural testing completed prior to construction. An introductory session to help residents understand both the building process and the design characteristics and to encourage a feeling of participation in the innovative process may be beneficial.

Future study is desirable to assess livability of the fourplex over a longer period of time, in different geographical locations, and with different occupant groups. It is not possible to draw conclusions from this study as to livability for non-student singles, nor for families. An evaluation also cannot be made for other geographical areas. Further refinement of the instrument is necessary in order to isolate the particular features that mediate satisfaction with the unit.

In view of the escalating costs of new construction and in terms of both the initial costs and life cycle costs, the Hillside Fourplex seems to be a viable alternative housing unit. Earlier studies show public acceptance for the design concept (Spaid, 1983) and user satisfaction is generally positive. Although there are a few problem areas to be addressed, the units seem worthy of replication and of future study.

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