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POST OCCUPANCY EVALUATION OF AFFORDABLE HOUSING IN THE USA: TOWARD INDICATORS FOR SUSTAINABLE AFFORDABLE HOUSING

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Abstract: Post Occupancy Evaluation (POE) assesses building performance from the occupants' perspective by exploring the links between satisfaction levels and users' response behavior after they have adjusted to the building. Residents' satisfaction level could be used to identify short- and long-term problems, designate feasible solutions, and provide effective indicators to improve the living environment. This paper uses a POE survey to examine the existing situation of an affordable housing project in the USA and to develop indicators that can lead to sustainable affordable housing for residents. The survey consists of 11 parts that cover aspects of an affordable housing project that are related to the Triple Bottom Line (TBL) pillars for sustainability. The survey respondents were asked to rank their level of satisfaction, resulting in a natural ordering of very dissatisfied to very satisfied. An ordered probit model was used to identify statistically significant indicators that impact a person's probability of reporting a specific level of satisfaction. Responses from 72 residents of Camas Commons affordable housing in Corvallis, Oregon, USA, were modeled, revealing a set of sustainability indicators that could be used to create sustainable affordable housing. Recommendations are presented to highlight the importance of those indicators that influence residents' satisfaction level. Suggestions are made to mitigate the weak points that have led to dissatisfaction among residents and to improve affordable housing.

1 INTRODUCTION

Post Occupancy Evaluation (POE) is a systematic process to assess the performance of a building and the effectiveness of the housing environment by determining the satisfaction level of the occupants after they have adjusted to the building (Preiser et al. 2015). POE provides a viable way to achieve a sustainable outcome; its scope includes building performance as it pertains to its functional, environmental, economic and social aspects. Many studies have elaborated that POE is critical in promoting building performance and evaluating its sustainability by getting feedback from the occupants (Hussein and Jamaludin 2015, Meir et al. 2009). POE provides indicators for what needs to be redone and what needs to be avoided. Many studies have highlighted the importance of housing satisfaction to attain sustainability of the built environment (Forte and Russo 2017, Sanni-Anibire et al. 2016). POE satisfaction surveys provide important indicators that determine the user's perspective regarding their living conditions. Those indicators could be used to solve existing problems or could be applied in future designs.

Indicators are intended to be tools to measure and express important qualitative and quantitative conditions over time (Sinha et at. 2017). Many multi-dimensional sets of indicators have been used to assess affordable housing and its sustainability. The Queensland Department of Public Works (QDPW) coined the term “Triple Bottom Line” (TBL), which defined sustainable housing as housing that is environmentally, socially, and economically sustainable. The TBL concept has been used and adapted by many authors to assess affordability and sustainability outcomes (Ibem and Azuh 2011; Oyebanji et al. 2017).

Several sets of indicators related to the TBL approach have been developed to assess the sustainability of affordable housing (Blair et al. 2004, Ibem and Azuh 2011, Pullen et al. 2010). Indicators related to social sustainability include community participation, sense of community, suitability, social interaction and inclusion, safety and security level, accessibility to public transport services, and good quality education. Indicators related to environmental sustainability include housing quality, comfortable and healthy indoor environment, availability of green public spaces, adaptability and flexibility, and reliability and durability. Economic sustainability indicators include affordable price/renting costs in relation to income, reduced life cycle cost, energy efficiency of housing, and provision of human resource for economic development, such as convenience to employment opportunities for residents. All of these indicators and more were tested in this paper.

These sets of indicators related to TBL have been validated by experts, policy-makers, governmental, non-governmental organizations and housing developers. For instance, Oyebanji et al. (2017) defined eight, four, and nine success indicators related to economic, environmental, and social aspects, respectively, to achieve sustainable social housing. Mulliner and Maliene (2015) used a TBL set that includes 20 indicators to assess housing affordability.

Other scholars have used the resident’s perspective to assess the suitability of affordable housings (Meir et al. 2009; Tapsuwan et al. 2018). For instance, Tapsuwan et al. (2018) evaluated 67 neighborhood and 38 home features to identify preference sustainable characteristics of housing and neighborhood from the residents’ perspective. Although previous studies have identified indicators of residents’ satisfaction, a statistical relationship and the magnitude of their effects have not been provided. Therefore, the current study utilizes a methodology (the ordered probit model) to determine statistical significance of these indicators and their effects on residents’ reporting a specific level of satisfaction.
This paper uses a POE survey to evaluate the current situation of the Camas Commons affordable housing in Corvallis, Oregon, USA. The objective is to determine a significant set of indicators from the residents’ perception that can lead to the creation of sustainable affordable housing that meets its users’ expectations.

2 PROJECT DESCRIPTION

The Camas Commons project, located in Corvallis, OR, contains 56 units, including one, two, three, and four-bedroom units (Figures 1 and 2). It is developed and owned by Willamette Neighborhood Housing Services (WNHS) and managed by Linn-Benton Housing Authority (LBHA). WNHS is a private, non-profit community development corporation whose goal is to enhance lives and promote communities by providing affordable housing that meets its residents’ needs and enhances their sense of community.

Figure1: The Camas Commons community center and play area

Figure 2: A view of typical housing in the Camas Commons project

3 RESEARCH METHODOLOGY

3.1 Survey and Data

The survey consists of 11 parts covering a large spectrum of different aspects of public housing (PH) projects that are related to residents' satisfaction. The characteristics that are used to measure residents' satisfaction level are divided in four categories: resident characteristics, social characteristics, environmental characteristics, and economic characteristics. Resident characteristics incorporate variables such as household size, age, and educational level. Social characteristics include variables such as accessibility, suitability and on-site services, community participation and sense of community. Environmental characteristics encompass variables such as comfortable and healthy indoor environment, effective maintenance and management of properties, and increased consciousness of environmental protection. Finally, economic characteristics include variables such as cost effectiveness and reduced costs throughout the life cycle.

The first step in the survey process was to develop the survey instrument. Data collection included administering the survey, conducting a semi-structured interview, and walking through a sample of residences. The process took place from April 2018 to September 2018 as to reach a population size from which statistical inferences can be made with a high level of confidence. The study sample size is 72, which is larger than the required sample size of 68 for a 90% confidence level based on Eq. (1) (Anderson et al. 2018, Smith 2013):

[1] $$N = \frac{(\text{z} - \text{score})^2\ (\sigma)(1 - \sigma)}{(\text{Margin of Error})}$$

where N is the sample size needed, the z-score is equal to 1.645 (the value associated with 90% confidence), the confidence interval (or the margin of error that is acceptable) is the difference between 1 and 0.90, and σ is a standard deviation of 0.5 (the most conservative number that is used to ensure the sample size is large enough).

For the current study, the satisfaction level of residents was determined by a survey question in which respondents were asked to rank their level of satisfaction with a 6-point Likert scale (1 = not applicable; 2 = very dissatisfied; 3 = dissatisfied; 4 = fair; 5 = satisfied; 6 = very satisfied). However, a "non-applicable" option response is removed from the analysis.

3.2 Best Fit Model for Camas Commons Project

Because the variable is ordered, an ordered econometric modeling framework, the ordered probit model, was used. This study applies the model to identify the significant indicators in terms of probable satisfaction level based on the residents' point of view. The ordered probit model begins by defining an unobservable variable y* as a linear function:

[2] $$y^* = \boldsymbol{\beta X} + \varepsilon$$

where X is a vector of explanatory variables related to previously discussed characteristics (e.g., resident, social, environmental, and economic), β is a vector of estimable parameters that correspond to X, and ε is an independently randomly distributed disturbance term with a mean of 0 and variance of 1. From Eq. (2), each considered response can now be represented as observable:

[3] $$\begin{aligned} y &= 0 \ \text{ if } \ y^* \le 0 \\ y &= 1 \ \text{ if } \ 0 < y^* \le \mu_1 \\ y &= 2 \ \text{ if } \ \mu_1 < y^* \le \mu_2 \\ &\vdots \\ y &= J \ \text{ if } \ \mu_{J-1} \le y^* \end{aligned}$$

where μ are the thresholds used to define the ranked responses provided by the surveyed residents. In this analysis, μ is estimated simultaneously with β. By estimating μ simultaneously with β, integer ordering is conducted, in which J is the highest ranking (i.e., very satisfied).

Upon defining the unobservable and observable ordered probit functions, the probabilities of J are estimated. This is accomplished by assuming ε to be normally distributed (i.e., mean of 0 and variance of 1), where the ranked selection probabilities are as follows (Anderson et al. 2018, Greene 2012):

[4]
$$\begin{aligned}&\text{Prob}(y=0\mid \boldsymbol{X})=\Phi(-\boldsymbol{\beta X})\\&\text{Prob}(y=1\mid \boldsymbol{X})=\Phi(\mu_1-\boldsymbol{\beta X})-\Phi(-\boldsymbol{\beta X})\\&\text{Prob}(y=2\mid \boldsymbol{X})=\Phi(\mu_2-\boldsymbol{\beta X})-\Phi(\mu_1-\boldsymbol{\beta X})\\&\text{Prob}(y=3\mid \boldsymbol{X})=1-\Phi(\mu_3-\boldsymbol{\beta X})\end{aligned}$$

with:

[5] $$0<\mu_1<\mu_2<\mu_3$$

where $y=3$ is the highest satisfaction level (very satisfied) $y=0$ is the lowest satisfaction level (dissatisfied), and Eq. (5) shows the required relationship among rankings to ensure all probabilities are positive.

Finally, to assess the impact of explanatory variable X, marginal effects are computed. For the ordered probit model, there is difficulty in interpreting the interior rankings (i.e., rankings 1 and 2). That is to say, the analyst does not know for certain what magnitude of impact a positive or negative estimate has on the probability of an interior ranking, only that it is positive or negative (Anderson et al. 2018, Washington et al. 2011). In an attempt to account for this, marginal effects are interpreted at the extremes (very satisfied and dissatisfied (Washington et al. 2011). For this work, where all explanatory variables are indicator variables, marginal effects are computed as the difference in probability when an indicator variable changes from zero to one (Anderson et al. 2018, Greene 2012, Washington et al 2011):

[6] $$ME_{X_k}=\Pr\left[y\mid \ddot{\boldsymbol{X}}_{X_k}, X_k=1\right]-\Pr\left[y\mid \ddot{\boldsymbol{X}}_{X_k}, X_k=0\right]$$

where $\ddot{\boldsymbol{X}}_{X_k}$ is the mean of all other variables (i.e., variables are held constant) while the indicator variable X_k changes from 0-1.

3.3 Analysis of Best Fit Model for Camas Commons Project

Nine variables were identified as statistically significant by the best fit model and are presented in Table 1. The distribution of these nine variables consists of one resident's characteristic indicator, four social sustainability indicators, three environmental sustainability indicators, and one economic sustainability indicator. Specifications for best fit model are log-likelihood at convergence of -33.30 and a McFadden Pseudo R-Squared of 0.65 (Table 2). The marginal effects computed at the means are shown in Table 3.

4 KEY FINDINGS AND DISCUSSION OF SIGNIFICANT VARIABLES

4.1 Resident Characteristics Indicator

The final model included one statistically significant resident characteristic indicator, the number of people living in the house. Marginal effects show that increasing the number of people living in the household by one person results in a 0.017 decrease in the probability of reporting being very satisfied with their living conditions (Table 3). Thus, this study found that an increase in household size reduces satisfaction level, which is congruent with the study by Ibem et al. (2013).

4.2 Social Sustainability Indicators

The four social sustainability indicators found to be significant are (1) adequate measures against crime, (2) a moderate level of recurrent thievery, (3) being within walking distance to a ballfield (e.g., soccer,

Table 1: Descriptive Statistics of Significant Variables for Camas Common

Variable	Mean	SD
Residents Characteristics Indicator		
Number of people living in house	4.97	1.52
Social Sustainability Indicators		
Adequate measures against crime (1 if Dissatisfied, 0 Otherwise)	0.19	0.39
The project displays moderate level of recurrent thievery (1 if fair, 0 Otherwise)	0.87	0.33
It is important to be within walking distance to ballfield (1 if Important, 0 Otherwise)	0.43	0.49
I think of community planning in my neighborhood as a "we", not a "they", activity (1 if True, 0 Otherwise)	0.40	0.49
Environmental Sustainability Indicators		
Adequacy of daylight (1 if Satisfied, 0 Otherwise)	0.59	0 .49
Adequate parking at the residence (1 if Dissatisfied, 0 Otherwise)	0.23	0.42
clear separation between guest areas and family areas (1 if Satisfied, 0 Otherwise)	0.56	0.49
Economic Sustainability Indicators		
Average use of the electrical heater in winter is 6-12 hours (1 if Yes, Otherwise 0)	0.06	0.25

Table 2: Best Fit Ordered Probit Model Specifications for Camas Common

Variable	Coef.	Std. Err.	*t*-stat
Residents Characteristics indicator			
Number of people living in house	-0.99	0.20	-4.80
Social Sustainability Indicators			
Adequate measures against crime (1 if Dissatisfied, 0 Otherwise)	-1.24	0.49	-2.49
The project displays moderate level of recurrent thievery (1 if fair, 0 Otherwise)	-1.43	0.64	-2.25
It is important to be within walking distance to ballfield (1 if Important, 0 Otherwise)	2.71	0.59	4.58
I think of community planning in my neighborhood as a "we", not a "they", activity (1 if True, 0 Otherwise)	2.00	0.56	3.56
Environmental Sustainability Indicators			
Adequacy of daylight (1 if Satisfied, 0 Otherwise)	2.41	0.56	4.32
Adequate parking at the residence (1 if Dissatisfied, 0 Otherwise)	-2.39	0.65	-3.66
clear separation between guest areas and family areas (1 if Satisfied, 0 Otherwise)	1.30	0. 50	2.56
Economic Sustainability Indicators			
Average use of the electrical heater in winter is 6-12 hours (1 if Yes, 0 Otherwise)	-1.55	0.76	-2.03
Threshold 1	2.55	0.47	5.42
Threshold 2	5.94	0.90	6.60
Model Statistics			
Number of Observations	72		
Log-Likelihood at Zero	-95.73		
Log-Likelihood at Convergence	-33.30		
McFadden Pseudo R^2	0.65		

Table 3: Ordered Probit Marginal Effects at Camas Commons

Variable	Marginal Effects at Parameter Means			
	Dissatisfied =0	Fair =1	Satisfied=2	Very Satisfied =3
Residents Characteristics indicator				
Number of people living in house	0.00103	0.26450	-0.24758	-0.01794
Social Sustainability Indicators				
Adequate measures against crime (1 if Dissatisfied, 0 Otherwise)	0.00702	0.40730	-0.40224	-0.01209
The project displays moderate level of recurrent thievery (1 if fair, 0 Otherwise)	0.00053	0.22073	-0.11547	-0.10579
It is important to be within walking distance to ballfield (1 if Important, 0 Otherwise)	-0.01121	-0.58881	0.42717	0.17285
I think of community planning in my neighborhood as a "we", not a "they", activity (1 if True, 0 Otherwise)	-0.00410	-0.44283	0.34878	0.09815
Environmental Sustainability Indicators				
Adequacy of daylight (1 if Satisfied, 0 Otherwise)	-0.02230	-0.65489	0.61232	0.06488
Adequate parking at the residence (1 if Dissatisfied, 0 Otherwise)	0.05242	0.70063	-0.72580	-0.02725
Clear separation between guest areas and family areas (1 if Satisfied, 0 Otherwise)	-0.00334	-0.36323	0.34019	0.02639
Economic Sustainability Indicators				
Average use of the electric heater in winter is 6-12 hours (1 if Yes, 0 Otherwise)	0.02207	0.52790	-0.54137	-0.00859

basketball, volleyball), and (4) thinking of community planning in the neighborhood as a "we", not a "they," activity.

Safety level and measures to prevent crime in the PH project have a huge effect on the resident satisfaction. This study found that inadequate measures against crime and a moderate level of recurrent thievery have lowered the residents' satisfaction. Marginal effects show that dissatisfaction with measures against crime in the neighborhood results in a 0.012 decrease in probability of reporting being very satisfied with the neighborhood living conditions. In addition, marginal effects show that answering "moderate" for levels of recurrent thievery in the project results in a 0.105 decrease in probability of reporting being very satisfied with living environment conditions. This finding supports previous study conducted by Ziama and Li (2018). Providing a high level of safety and adequate protection against crime is a key component to attain successful PH that satisfies its users' needs.

Accessibility to recreational areas as part of the neighborhood has an effective impact on the residents' satisfaction (Figure 3). Marginal effects show that access to a ballfield in the neighborhood results in a 0.172 increase in probability of reporting being very satisfied with living environment conditions. This result is supported by previous studies (Ibem et al. 2015, Mohit and Azim 2018).

Social cohesion is about creating connection among residents with their built environment and its people (Atanda 2019). Social cohesion is considered a leading concept for achieving satisfactory PH. It has short- and long-term benefits to the residents, community, and society. For instance, short-term benefits are related to increased security levels in the project, reduced stress, and a higher quality of life of the residents (Oyebanji et al. 2017). Long-term benefits are pertinent to "achieving 'social integration', lower health costs, and increased performance and productivity" (Oyebanji et al. 2017). In this study thinking of community as a "we," results in a 0.098 increase in probability of reporting being very satisfied with built environment living conditions (Table 3). This result agrees with Mohit and Azim (2012).

Figure 3: Basketball court in Camas Commons

Figure 4 (left: office -right: children bed room): Daylight inside the unit

4.3 Environmental Sustainability Indicators

Three environmental indicators were found to be significant: (1) adequacy of daylight, (2) adequate parking at the residence, and (3) clear separation between guest areas and family areas.

Daylight entering the space of the resident is one of the primary factors that affect housing performance and the residents' satisfaction (Figure 4). In this study, being satisfied with adequate daylight inside the unit results in a 0.064 increase in probability of reporting being very satisfied with living condition (Table 3). This result is supported by other studies (Ibem et al. 2015; Xue et al. 2014).

Parking type in the residential project influences the residents' satisfaction. Marginal effects show that being dissatisfied with the adequacy of parking at the residence results in a 0.052 increase in the probability of reporting being dissatisfied with living conditions (Table 3). In the light of this finding, it is important to have good design for parking to achieve residents' satisfaction. This result agrees with previous studies (Ibem 2013; Ziama and Li 2018). However, the study finding is contrary to those of Mohit and Azim (2012) and Reid (2018).

The special arrangement of interior built environments is considered as primary factors that influence residents' satisfaction. The privacy level influences resident's perception of living conditions. According to Ibem and Aduwo (2015), privacy is one of the psychological needs of healthy housing, based on the Committee on Hygiene of Housing of the American Public Health Association. Consideration of the privacy in housing sector is a common need across all cultures. However, the way it affects housing special arrangements differs from one culture to another (Mulliner and Algrnas 2018).

In this study, marginal effects show that being satisfied with clear separation in the design of residence between guest areas and family areas results in 0.026 increase in the probability of reporting being very satisfied with the built environment conditions. Many studies supported this finding (Ibem et al. 2015, Ziama and Li 2018). Dissatisfaction with the privacy level has been shown to negatively impact overall satisfaction level (Moolla et al. 2011).

4.4 Economic Sustainability Indicators

Only one economic indicator was significant: the average use of the electrical heater in winter.Thermal comfort in the residence is a key factor influencing satisfaction, as it is related to behavior and the physiological and psychological comfort of the residents. At the same time, it provides general information pertaining to efficiency and operational costs of the residence. Ibem et al. (2015) found that thermal comfort was important factor in determining residents' satisfaction in their study. Marginal effects found in this study show that when the average use of an electrical heater in winter is 6-12 hours per day, there is a 0.022 increase in probability of reporting being dissatisfied with the living conditions, and an 0.008 decrease in the probability of reporting being very satisfied with living conditions.

Dissatisfaction level is usually related to thermal discomfort, which can result from low energy efficiency, high energy costs, low household income or physiological and psychological traits of the residents. In general, residents spend much of their income on energy consumption; thus, applying energy efficiency to existing projects has many economic and environmental benefits for both residents and society. Accordingly, it is imperative that policy-makers consider reducing energy expenses in affordable housing by applying energy-efficient building codes (Chegut et al. 2016). The operating costs involved in providing thermal comfort should be strongly considered for existing and future affordable housing projects. Deficient buildings could be sustainably retrofit to lower energy expenses, and for future projects, applying passive techniques, choosing appropriate construction materials, and using alternative renewable energy resources are considered better solution to achieve reduction of operation cost.

5 CONCLUSION

This study has identified a set of significant indicators related to TBL indicators from the residents of Camas Commons. Attention to these indicators could lead to the creation of sustainable affordable housing that meets its users' needs. Residents in this project were satisfied with the following social and environmental sustainability indicators: accessing the ballfield as part of neighborhood services, cohesion and sense of community among the residents, as the social sustainability indicators, and natural daylight penetrating the unit and the privacy level between family and guest spaces inside the unit as the environmental sustainability indicators. Enhancing such indicators in affordable housing will improve living conditions and promote resident satisfaction.

With respect to social sustainability indicators, proximity to a ballfield was very important in influencing residents' satisfaction. Thus, this study recommends improving access to social amenities for existing PH, so the residents have a safe place to exercise, in addition to considering the provision of such neighborhood facilities for new projects. With respect to social indicators regarding social cohesion and sense of community, other studies have recommended the involvement of urban sociologists to allocate structure for the mix in multi-ethnic projects and engage neighborhood community in the design and planning stages in order to enhance social interaction within building and common spaces (Atanda 2019). In addition, this study suggests conducting a broad social study with emphasis on the cultural values of anticipated residents in order to promote the 'sense of place' and respect privacy.

With respect to environmental sustainability indicators, we recommend that policymakers consider daylight as a primary factor of the sustainable environment that contributes to satisfactory affordable housing and reduces operational costs. Planners and architects should pay attention to light availability during the developmental stages of projects (Mulliner and Algrnas 2018, Xue et al. 2014). They also should consider providing a privacy level within the house that is compatible with the socio-cultural states of prospective residents. A broad sociocultural study to determine desired levels of privacy would help to achieve this.

Dissatisfaction indicators require more attention in order to improve the built environment. In this study, dissatisfaction indicators included the following: larger family size, adequate measures against crime, a moderate level of recurrent thievery, adequate parking, and usage of electric heater in winter. With regard to social indicators, we recommend conducting a broad social study to provide realistic design that is compatible with the family size and other social requirements. Affordable housing projects should include different unit designs for different family sizes. With respect to social indicators, we suggest applying strategies to prevent crime and increase safety levels throughout the project's life cycle. For instance, making the right decisions at the beginning pertaining to project size, location and proximity to other residential and non-residential facilities is important to prevent crime. After occupancy, provision of sufficient supervision for public and semi-public areas by the residents has had a positive impact (Morgan et al. 2018).

With respect to environmental indicators, we recommend integrating sufficient and sustainable parking into the project. Such parking has social, environmental, and economic feasibility. It is socially feasible because it allows creating more green areas that could promote social interaction. It also has benefits for health by promoting walkability and encouraging the use of alternative transportation, such as bicycles. Plants and trees in a sustainable parking area have environmental benefits, reducing noise and pollution while providing shade. Sustainable surface materials, such as porous pavement, also provide a way to reach sustainability. Additionally, it is important to provide easy access for elderly and disabled residents (Wiesel et al. 2012).

Finally, with respect to economic indicators, we advocate the consideration of energy efficiency in order to reduce operation cost and enhance environmental quality. Introducing alternative renewable energy sources in such projects would also enhance environmental quality.

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