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A Post-Construction Evaluation of Long-term Success in LEED-certified Residential Communities

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In this study, a post-construction evaluation model was developed to identify the determinants of the long-term success of sustainable residential projects from users' points of view. To do this, a primary model was developed based on the existing theories and models including measures adopted from LEED standards and UC Berkeley's Center for the Built Environment (CBE) tool. The model included four predictor variables investigating the perceived performance of buildings, infrastructure, neighborhood, and economic aspects. The response variable was residential satisfaction as the determinant of long-term success. The data was collected through an online survey from the residents of LEED-certified residential communities in the USA (n=192). After validating the model through confirmatory factor analysis (CFA), the relationships between the independent and dependent variables were evaluated through structural equation modeling (SEM). The results showed that the perceived building performance was the most influential factor in determining satisfaction followed by the perceived neighborhood design while perceived infrastructure performance and perceived cost performance did not show any significant effect in determining satisfaction. The findings benefit researchers by providing a model for the evaluation of the long-term performance of green buildings and providing opportunities for practitioners to determine priorities for future sustainable residential development projects.

Key Words: Green Building, Satisfaction, Perceived Performance, Confirmatory Factor Analysis, Structural Equation Modeling

Introduction

Project success has been the focus of several studies and traditionally, the iron triangle factors (time, cost, and scope) have been the focus in evaluating project success. However recently, the importance of the long-term evaluation of project success has been highlighted, which evaluates the successful performance of the projects at the post-construction stage with a focus on three main aspects of sustainability, satisfaction, and life cycle cost performance (Adabre & Chan, 2019; Dvir et al., 2003). This is even more important when it comes to sustainable residential projects as one of the main focuses of sustainable construction is the long-term performance of the buildings. Therefore, besides technical aspects, a comprehensive assessment of project success in sustainable development projects must include long-term successful performance (Adabre & Chan, 2019).

One factor that is of high importance in determining the long-term successful performance of a project is its accordance with human needs and expectations (Williams et al., 2015). This is even more important in residential projects as the end-users are residents who spend a significant amount of their time in their homes. Therefore, it is crucial to investigate the feedback of users about their living environment to find if it is performing successfully. Perceived project performance compared to the expected performance is an important factor indicating the success of a project (Toor & Ogunlana, 2010). This highlights the role of users' judgments and satisfaction in determining the success of sustainability practices as several experts have suggested that customer satisfaction is a critical dimension of project success (e.g. Heravi & Ilbeigi, 2012; Davis, 2014).

Considering the residents' judgments and perceptions can provide essential ideas for successful housing development and the improvement of design and construction practices (Aliyu & Muhammad, 2016). This can be important both by providing lessons for architects and contractors and by providing a benchmark and a pool of research on the building industry to indicate how the end product meets the expectations and needs of its end users (Enright, 2002). By ensuring that the feedback of users is considered throughout the building design and construction processes, the quality of the built project is protected both during the construction process and later in the operation phase (Preiser & Vischer, 2006).

Although users' satisfaction can be collected in surveys, the analysis of this variable can be challenging. This becomes even more highlighted in evaluating the satisfaction with sustainable residential communities as it depends on the time, place, and evaluation system of the assessors. Reviewing the literature and looking at the factors that have been considered as variables to evaluate the satisfaction of users with residential buildings and communities, satisfaction appears to be a complex and multifaceted subject that demands much more research to provide a better understanding of the relations between the factors. Therefore, it is important to understand the theoretical and empirical aspects of the evaluation of users' satisfaction to determine the variables and successfully develop an evaluation model. This research is an attempt to develop and validate a model to evaluate the associations between the perceived performance and satisfaction of sustainable residential communities and identify the key determinants of satisfaction in sustainable communities.

Developing a conceptual Model

Reviewing the relevant theories regarding users' satisfaction with housing projects (e.g., Housing Needs Theory, Housing Adjustment Theory, and Psychological Construct theory) as well as the developed model for evaluation of user's satisfaction (e.g., Weidemann & Anderson, 1985), an a-priori model for evaluating the relationships between the long-term success factors of sustainable residential projects was developed. The model consists of several components that are measured through one or a few indicators or variables (Figure 1). The model indicates the effect of the perceived performance of the building, neighborhood design, infrastructure, and cost performance on the level of satisfaction of residents with their home and community. Furthermore, the model pictures the way that satisfaction can be evaluated directly by asking a question about satisfaction and indirectly based on the intention of residents to behave in response to their home and neighborhood conditions. The mutual interaction between sustainability and satisfaction is also pictured in this model.

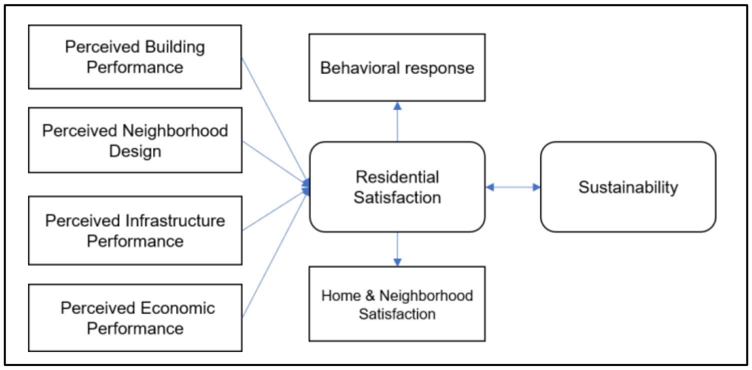

Figure 1. Conceptual model of long-term success factor interactions

Method

Data Collection

To evaluate the long-term success of sustainable residential projects from users' points of view, the data was collected from residents of LEED-certified residential communities, in the USA, through an online survey using a structured questionnaire. Multi-stage sampling was adopted as the sampling method in this research; in the first step, among all of the LEED-ND certified projects (101 projects), 40 projects were selected randomly to survey the residents. Individuals were then randomly sent an email that included a link to the survey. After asking some eligibility questions on the first page of the survey including age, and the duration of the stay in the neighborhood, eligible respondents were directed to the main survey question (those whoe lived in the neighborhood for at least six months and had more than 18 years old).

Research Variables

The attributes of the physical environment that were considered as the predictor variables consisted of three main groups of building features, infrastructure, neighborhood aspects. Building features were features that are mentioned as the criteria for determining individual building sustainability according to LEED certification such as energy efficiency, insulation, water efficiency, etc. Infrastructure attributes were the elements of the built environment that provide a context for the entire neighborhood and are considered as green infrastructure in the LEED certification system. Finally, neighborhood aspects were aspects that were related to the pattern and design of the neighborhood such as density, walkability, the mix of the land use, etc. As the focus of this study was evaluating the successful performance of sustainable residential projects from the users' point of view, only features specific to sustainable communities were considered. A seven-point Likert scale was employed to evaluate the perceived performance of each attribute with 1 being "very poor" and 7 being "very well". The sustainability-specific attributes adopted from LEED-BD+C Multifamily Midrise and LEED-ND standards as well as the UC Berkeley Center for the Built Environment survey tool were considered as measures to evaluate the performance of the physical environment. A set of economic measures was also developed from the literature in order to evaluate the cost performance of the residential communities.

Overall satisfaction with the residential built environment was considered as the dependent variable. Two sets of questions were asked to measure the overall satisfaction. The first set of questions asked the level of satisfaction of the residents with their home and neighborhood and the second set of questions measured the intentions of residents to behave in response to the current condition of their residential built environment (Weidemann & Anderson, 1985). Both measurements used a 7_point Likert scale to evaluate the responses.

Data Analysis

Respondents' Profile

A total of 192 responses was collected including 49% female, 49.5% males, and 1.5% others. The summary of respondents' profiles is presented in Table 1.

Table 1

Summary of sample characteristics

Variable	Number	Percentage	Variable	Number	Percentage
Gender			Education level		
Female	94	49	High school graduate or less	8	4.2
Male	95	49.5	Some College or two-year degree	36	18.8
Other	3	1.5	Four-year degree	59	30.7
			Graduate degree	89	46.4
Age			Income		
18-34	75	39.1	Less than $59,999	30	15.8
35-54	104	54.2	$60,000 - $119,999	101	52.6
55 or above	11	5.7	$120,000 or more	60	31.3
Undefined	2	1	Undefined	1	0.5

Reliability Test

The internal consistency of the entire survey data was tested by conducting a Cronbach's alpha test. The alpha value for the survey data was above 0.7 showing a high internal consistency of the data.

Confirmatory Factor Analysis

In order to validate the model for the data, confirmatory factor analysis (CFA) was conducted. Testing the assumptions for conducting confirmatory factor analysis, the data did not meet the assumption of multivariate normality. Therefore, the maximum likelihood (ML) method, which is the most commonly used method used for this analysis, could not be used (Table 2). As the substitute method, the "robust" ML estimation (Satorra and Bentler, 2001) was used as it is the most appropriate approach to deal with the non-normality of the data. The data was analyzed using JASP version 14.1, which uses Lavaan syntax for the data analysis.

Table 2

Mardia's multivariate skewness and kurtosis

Test	B	z	p-value
Skewness	141.0779	4514.49211	<0.0001
Kurtosis	799.9258	13.05944	<0.0001

Conducting CFA the model was validated and the fittest model representing the variables was achieved. Multicollinearity among the indicators was also addressed using CFA. As shown in Table 3, overall fit indices show that the overall model fits the data and can provide a valid and reliable structural equation model to evaluate the relationships between the latent independent and dependent variables.

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Results of final CFA

Variable/Indicator	Estimate	p	Std. Est. (all)
Factor 1: Perceived Infrastructure Performance			
GI1-Outdoor Lighting	1.176	< .001	0.645
GI2-Recycling Facilities	0.863	< .001	0.522
GI3-Rainwater Collection System	0.851	< .001	0.519
GI4-Public Transit Infrastructure	0.956	< .001	0.571
GI5-Biking Infrastructure	0.897	< .001	0.548
GI6-Road Quality	1.001	< .001	0.578
Factor 2: Perceived Neighborhood Design			
ND1-Walking Infrastructure	1.035	< .001	0.719
ND2-Neighborhood Density	0.712	< .001	0.577
ND3-Mixed Use Neighborhood	1.052	< .001	0.716
ND4-Housing Diversity	0.802	< .001	0.53
ND5-Access to Public Space	0.879	< .001	0.628
Factor3: Perceived Building Performance			
BP1-Thermal Comfort	0.949	< .001	0.726
BP2-Availability of Daylight	0.999	< .001	0.717
BP3-Indoor Water Efficiency	0.90	< .001	0.671
BP4-Quality Views from Window	0.907	< .001	0.601
BP5-Indoor Materials Used	0.96	< .001	0.704
BP6-Building Energy Efficiency	0.901	< .001	0.665
Factor 4: Perceived Cost performance			
EP1-Value/Rent	0.972	< .001	0.73
EP2-Utility Bills	0.918	< .001	0.656
EP3-Travel and Transportation Costs	1.084	< .001	0.723
EP4-Other Fees (HOA/Condo fees, tax, etc.,)	0.811	< .001	0.579
Factor 5: Residential satisfaction			
S1-Plan to Live permanently	1.264	< .001	0.836
S2-Recommend to others	1.18	< .001	0.825
S3-If look back, would move here again	1.02	< .001	0.744
S4-Overall Neighborhood Satisfaction	1.002	< .001	0.702
S5-Overall Home Satisfaction	0.972	< .001	0.77

Fit indices: X^2/df= 1.3, p-value= <.001; CFI= 0.956; RMSEA= .040; SRMR= 0.051

Structural Equation Modeling

After validating the model through conducting CFA, a structural equation modeling (SEM) was performed to provide an understanding of the relationships between the perceived performance of the built environment in residential projects and the level of satisfaction of the users as the determinant of the long-term success of these projects. The results of the SEM are presented graphically in Figure 2 and the key findings are summarized in Table 4. The darker color of the lines in the model shows a stronger relationship between the factors. The relationship between the item with the highest factor loading and the corresponding factor is shown as a dashed line for each factor. The positive relationships in this model are shown by the green color while the negative relationship is shown in red.

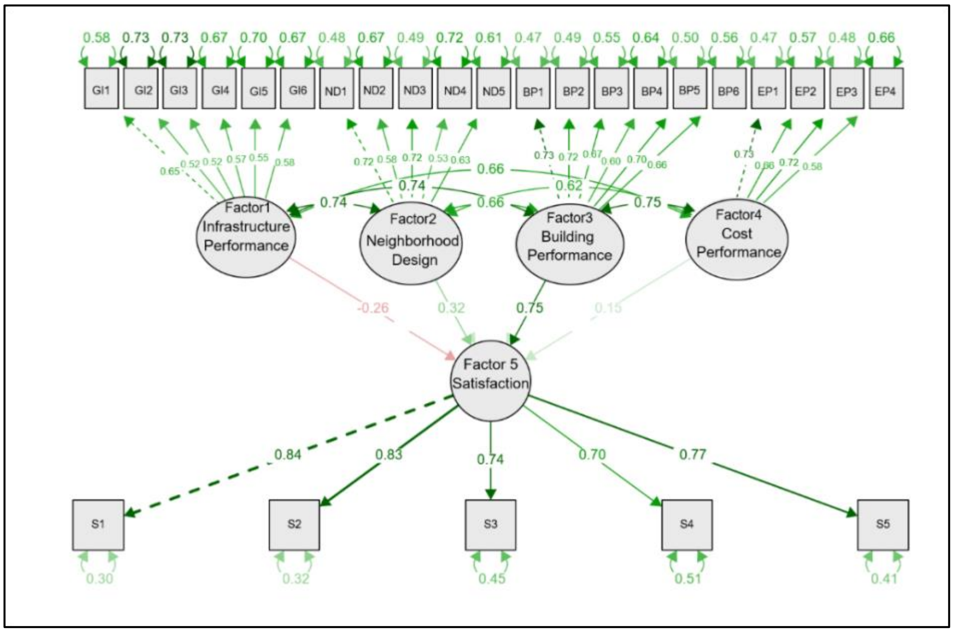

Figure 2. Modeling the effects of the perceived performance on satisfaction; Fit indices: X^2/df= 1.30, p-value < .001: CFI= 0.956; RMSEA= 0.040; SRMR= 0.51

Table 4

Summary of SEM key results: the relationships between IVs and the DV

Latent variables (IVs)	estimate	Std. error	z	p	Standardized estimate
Perceived Infrastructure Performance	-0.281	0.149	-1.883	0.06	-0.261
Perceived Neighborhood Design	0.394	0.157	2.512	**0.012**	0.322
Perceived Building Performance	1	0.203	4.918	< **.001**	0.751
Perceived Cost performance	0.199	0.176	1.132	0.258	0.153

*Dependent Variable: Residential Satisfaction

Results

Figure 2 and Table 4 show that perceived building performance and perceived neighborhood design have significant relationships with satisfaction. Among the two independent variables, perceived building performance is the most influential (coefficient=0.0.751, p<.001) followed by perceived neighborhood design (coefficient= 0.322, p=0.012). Other independent variables including perceived infrastructure performance (p=0.06) and perceived cost performance (p= 0.15) do not bring significant information to explain the influence on satisfaction score meaning these independent variables do not show a statistically significant relationship with residential satisfaction.

Discussion

This study evaluated the long-term success of these projects from the users' points of view by finding the relationship between the perceived performance of the built environment and the satisfaction of the users. The results of the evaluation showed that perceived building performance has the highest influence on overall satisfaction with the residential communities followed by perceived neighborhood pattern and design. On the other hand, cost performance and neighborhood infrastructure did not show any significant relationship with residential satisfaction.

The perceived building performance having the highest influence on residential satisfaction was expected as people spend several hours of their days in their homes, and a positive perception about their immediate living environment will create higher satisfaction. Satisfaction with home can affect the residents' opinions about their neighborhood and provide overall satisfaction as Bonaiuto (2004) suggests that perceived quality of the residential units is a prerequisite of obtaining an environmental and psychological picture of the living environment. Moreover, Ibem et al. (2015) suggested that residents' evaluation of their living environment is mainly influenced by the perceived quality of housing characteristics along with the actual quality of the housing environment.

Furthermore, the influence of perceived neighborhood pattern and design on providing residential satisfaction was also expected as the design factors are tangible factors for people, and they can easily evaluate them visually. The effect of perceived performance of the neighborhood built environment on place attachment and residential satisfaction has been demonstrated by Noriza et al. (2013) highlighting that neighborhood design factors are among the factors that have very important effects on determining residential satisfaction. Factors such as compactness, housing diversity, access to the public spaces, walkability, and land use mix could easily be understood and if the residents are satisfied with these factors, they usually perceive their neighborhood as a satisfactory community.

On the other hand, the relationship between perceived infrastructure performance and residential satisfaction was not found to be significant in this study. This finding was not expected as the infrastructure features that are considered in this study, namely outdoor lighting, rainwater collection systems, recycling facility, public transit, and road quality, are demonstrated to directly affect the quality of life of the people in their living environment. The finding of this research is inconsistent with Bonaiuto (2004) indicating that infrastructure features are influential in determining the satisfaction of residents. However, the findings of Adriaanse (2007) showed that neighborhood infrastructure is not among the most important influential factors in determining residential satisfaction. It is worth mentioning that each of the evaluated infrastructure attributes can potentially be significantly associated with satisfaction but when we look at them as a group, their perceived performances do not have any association with overall satisfaction. This highlights the importance of evaluating the relationship between each infrastructure attribute and the overall satisfaction to understand the influence of each individual infrastructure in predicting residential satisfaction.

This study has another finding that was not expected based on the existing literature. The cost performance of the built environment was found not to have any significant relationship with residential satisfaction while research has demonstrated the economic aspects of the neighborhood as an important predictor of satisfaction (Sirgy & Cornwell, 2002). As the most tangible criteria by residents, perceived cost performance was expected to be a significant predictor of residential satisfaction in this research. This finding can be due to two reasons: first, it may come from the overall high cost of living in the LEED-certified buildings and communities. If this is the case, one of the most highlighted aspects of living in a sustainable community, which is lower post-construction costs would be in doubt. The other possible reason for this finding could be the lower importance of the cost of living in sustainable communities when it comes to comparison with the quality that it is providing for residents. Even if this is the reason for the insignificant relationship between satisfaction and cost performance, still one of the main aspects that are highlighted in LEED-certification and green buildings is not working well in practice.

Conclusion

With an increasing emphasis on the role of users in evaluating the long-term success of sustainable residential projects, it is important to recognize the key factors contributing to users' satisfaction in green residential buildings. This research employed an SEM in order to investigate the relationships between the perceived performance of the built environment in sustainable residential projects and the level of satisfaction of the users with these projects in order to provide an understanding of the long-term success of these projects. The results showed that the perceived performance of the building is the most important factor determining the satisfaction of residents with their residential communities. The second important factor that affected the satisfaction of residents was neighborhood pattern and design while other aspects such as economic aspects and neighborhood infrastructure did not show any impact on providing satisfaction. The findings of this study determined the aspects that could potentially be considered for improving future sustainable community development projects that best meet residents' needs and expectations.

Despite being unique research by addressing one of the most important aspects of long-term project success of sustainable residential projects, this research has some limitations. The small number of responses for conducting CFA is one of the important limitations of this study. Although the minimum requirement for conducting such analysis was met by the number of respondents, the findings were more generalizable if the number of responses was more. Therefore, future research can improve the generalizability of the findings by surveying a higher number of LEED-certified community residents. The findings of this study can benefit researchers by providing a model for the evaluation of the long-term performance of green buildings and providing opportunities for practitioners to determine priorities for future sustainable residential development projects.

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