Utility Value-Based User's Preference Evaluation to Select Design Alternatives for Customized Apartment Housing Remodeling

Eunhwa Hong¹, Jaeho Cho² and Jaeyoul Chun*³

¹ Doctor's Course, Department of Architectural Engineering, Dankook University, Korea
² Research Professor, Department of Architectural Engineering, Dankook University, Korea
³ Professor, Department of Architectural Engineering, Dankook University, Korea

Abstract

As an alternative method for architectural regeneration, remodeling is drawing keen attention. However, it has turned out that post-occupancy satisfaction is quite low. The main reason for the low satisfaction lies in the remodeling method that does not consider functions demanded by users, but carries it out in an expensive and uniform structure. As for architectural function, multiple functions are required to meet resident's demands for performance and functional values are apt to conflict with each other, which means when one function improves, others are limited in terms of value. Therefore, user requirements should be well defined to increase their satisfaction while considering functions in conflict. In this respect, the present study proposes a method for user preference evaluation to define functions that a user requires, and thus for maximizing the values of remodeling by improving user satisfaction and residential performance.

Keywords: customized remodeling; performance; Life Cycle; multi-attribute utility theory; TOPSIS

1. Introduction

Remodeling, which is one of the architectural techniques to regenerate an old building, is drawing keen attention as a means of promoting a pleasant residential environment. However, studies on cases of remodeled apartment houses prove very low residential satisfaction. (Lee et al., 2013)

Remodeling has a structural limitation; there are certain architectural elements and/or areas in nature that cannot be improved by remodeling, which lead to a user's low satisfaction. Besides, it can cost more than expected due to the excessive scope of demolition and structural reinforcement. In many cases, furthermore, improvement after remodeling is not greater enough to compensate the cost spent. Moreover, such remodeling as one done in a uniform way without considering diverse residential functions of an occupant lowers a resident's satisfaction with remodeling also.

Many studies have been conducted to improve a user's satisfaction with remodeling. They propose remodeling preference evaluation based on residential satisfaction with existing housing as part of post-occupancy evaluation. However, it does not clearly define the diverse functions required by residents. Although there were some studies on quality evaluation in the trade-off relation between performance and required functions by using QFD, few have attempted to find a way to maximize net value in consideration of conflicting values.

As resident satisfaction becomes an evaluation indicator for residential quality, it is defined as evaluation to the extent that resident's requirements for residential performance are satisfied (Weidemann, 2000). Therefore, resident satisfaction is based on the concept of general satisfaction.

According to Kim (1988), satisfaction is defined as the difference between the expected performance and actual performance in general. In other words, satisfaction occurs when a user's expected performance is met while dissatisfaction is formed when not. (Roszkowski et al., 2005)

Here, only one function may be required to meet a users satisfaction, but, as for dwellings, multiple functions are involved and some of them conflict with each other. That is, they face value conflict problems; as one function
improves, it limits the other or other functions.

Accordingly, it can be considered important to specifically define functions required by residents and their expectation while solving the functional conflicts in order to improve resident's satisfaction with remodeling.

This study introduces the concept of multi-attribute value, placing antinominal conflict among functions in consideration, and proposes a utility value-based preference evaluation and decision-making process to specifically define the residential functions that users demand. It is when user requirements are reflected in the design of remodeling by priority that it can be helpful in evaluating and selecting economically feasible design alternatives of remodeling. Therefore, this study aims to propose a way to achieve it and thus improve residential satisfaction and performance, which eventually leads to increasing the value of the remodeling business.

2. Research Method

User satisfaction is an evaluation of the extent to which the residential performance meets the requirements of users as an index to evaluate the quality of the residence. Considering the relationship between conflicting functions, the authors' clearly define the various required functions of the user and directly reflect the value of the user to the remodeling design, thereby presenting a customized design alternative that is close to the user's demand, away from the conventional uniform remodeling method and maximizing satisfaction. This study:

1) Conducts a literature review on the performance evaluation and habitability evaluation of remodeling and analyzes the factors by which users have a low satisfaction with existing customized remodeling.

2) Reviews the Kano model and the value tradeoff theory (MAUT) applied to this study to eliminate the factors of dissatisfaction and to specifically define the requirements of users.

3) Examines the QFD and TOPSIS theories, which are used for multi-attribute decision-making, to gain and quantify preference evaluation values through cross analysis between design information and functional requirements.

4) Defines the constructs of the definition of a user's functional requirements based on the theory considered.

5) Proposes a value-utility survey model by applying the multi-attribute utility function method (MAUT) as a tool to concretely collect a user's requirements.

6) With the collected requirements as basic data, presents a QFD-TOPSIS model to conduct cross analysis with design information and user preference analysis on design alternatives so that it can be evaluated in absolute and relative terms by function and alternative.

7) Presents the applicability of this study through a case study.

3. Literature Reviews and Analysis

3.1 Literature Review

1) Remodeling Performance Evaluation

Noh (2015) and Jang et al. (2005) showed in their satisfaction survey of residents living in remodeled houses with shared expense of household allotment that more residents were dissatisfied with it.

In his study on resident's requirements for remodeling, Park (2007) found that they preferred improvement of interior materials to space extension and explained that it was because most respondents were residents living in a house bigger than 99m2 (30 pyung), so they were less dissatisfied with a small space.

With four apartment-housing complexes, Kim (2007) conducted a preference survey on remodeling plans and found that only 20% of the respondents preferred remodeling of inner walls (removal). She pointed out that the low preference was attributed to the high cost and complex process of the demolition work.

Through a literature review on remodeling performance evaluation, it was found that there are some functions that have a great impact on the cost of remodeling. Therefore, it seems necessary to analyze resident preference and consider the risk of cost. In addition, of resident's requirements, there were some remodeling items that did not improve residential performance after work. Therefore, they needed additional improvement even after remodeling.

2) Habitability Evaluation

Han (2003) concluded in her study that some post-occupancy evaluation (POE) items agreed with the design information, but did not completely correspond with each other. She admitted that evaluation items were very important and useful information in the process of design, but analyzed that it was difficult to apply in a practical sense.

Park et al. (2014) found that scattered post-occupancy evaluation information at the designing stage, statistical analysis results of complicated terminology, and inappropriate forms of information kept designers from utilizing post-occupancy evaluation information.

Therefore, it is thought necessary to restructure unstandardized and scattered resident's functional requirements. It is also needed to establish a process in which resident's functional requirements are linked to performance information of remodeling so that resident's requirements can be reflected in designing remodeling, and an index applied to quantify design information.

3) TOPSIS

Hsu-Shih Shih et al. (2007) extended the TOPSIS in "an extension of TOPSIS for group decision making", studied group decision support tools through multi-attribute decision making, and conducted group decision analysis.

Ye Chen et al. (2010) presented a hybrid model using the TOPSIS technique for solving multi-criteria decision problems in "an OWA-TOPSIS method for multiple criteria decision analysis".
TOPSIS has the objectivity and logic that makes it possible to quantify, weigh and normalize evaluation values, and to express a rational choice that considers both the best and worst alternative for many attributes.

3.2 Improvement Plan of This Study

One of the reasons why satisfaction with remolding is lower than demand lies in the high share expense of remolding.

While the construction cost of apartment housing remodeling continues to rise, the remodeling share expense that residents think of varies based on their income level and propensity. (Noh, 2015)

Eventually, the scope of remodeling work should be determined considering the share expense that residents want to pay to improve residential performance.

The second reason for the low satisfaction is unnecessary remodeling work.

According to Kim (2007), residents have the lowest satisfaction with, for example, balcony interior work. Although this work is common for general households, it means residents do not feel it is quite necessary and that the remodeling is inconvenient. Therefore, remodeling needs to be carried out on the necessary functions of a house based on a resident's life pattern and experience, rather than on a one-size-fits-all remodeling method for generally applied parts.

The third reason for the low satisfaction with remodeling has something to do with the design and use of a questionnaire survey.

Jang et al. (2005) showed in their study that, among the items found necessary to improve through a questionnaire survey, only a few items made a difference in performance after remodeling, and the rest did not.

Therefore, they needed additional improvement even after remodeling work. This indicates that the user's requirements were not properly considered at the stage of remodeling design.

To increase the usability of a questionnaire survey, a plan is necessary so that the results of the survey can be directly utilized by a designer so that they can be helpful for the designer to secure design quality and to use it as the basic data for quantitative decision-making.

That is, remodeling forms that residents demand should be reflected in a design to improve user satisfaction. To do so, a process to collect a user's specific requirements is needed more than anything else.

As the purpose of this study is to improve resident's satisfaction with remodeling, (i) it begins with Kano's definition of satisfaction. (ii) it takes the antinomical conflicts among functions into consideration when analyzing remodeling preference, which has not been included before. (iii) it proposes a value-utility survey model to specifically define a user's functional requirements. And (iv) it connects a user's functional requirements with remodeling performance so that it can be applied to improve residential performance and used as design information through cross evaluation with design elements. As an evaluation technique, this study improves and applies QFD and analyzes use's preference for design alternatives. (v) it employs the concept of TOPSIS to quantify the results of preference evaluation. Through this process, the present study aims to help a designer reflect a user's functional requirements in design work specifically by comparing design alternatives, and improving the factors that lower resident's satisfaction.

4. Review of Applied Techniques

(1) Kano Model

Users follow the law of marginal utility by which they take for granted what is enough to some extent and are not satisfied with something new although they have complaints concerning the details of a product. Like this, two aspects work on satisfaction: to be satisfied and to be dissatisfied (subjective) and physical gratification or non-gratification (objective).

There are three quality factors involved with satisfaction. First, is the essential (must-be) quality factor. People can be satisfied only when there is an essential factor concerning quality.

Second, is the functional (performance) factor. Because it is a most commonly perceived quality factor, people are satisfied only when the performance is met and when not, they have a complaint.

Third, is the attraction (Wow) factor. When it is met, people feel satisfied, but even when not, they do not have dissatisfaction with it. Therefore, when customers are given an attraction factor, they become satisfied because they did not expect it or were more satisfied.
than they expected. (Kano, 1984)

This study reinterprets Kano’s definition of satisfaction and defines as ‘recommended requirements’ the factors that can provide satisfaction when given but not dissatisfaction even when not given, and as ‘essential requirements’ the factors that generate dissatisfaction when they do not meet or improve a user’s functional requirements because weight varies by user. That is, essential requirements can be defined as the extent to which a function is required to improve user satisfaction during the process in which improvement of one required function inevitably has to increase or decrease other function or functions.

(2) Multi-Attribute Utility Theory (MAUT)

In general, multi-attribute decision-making deals with selection among alternatives that consist of several attributes. For example, suppose two attributes (economic feasibility and environment) are involved in the decision-making of dam construction. It is possible to achieve the highest level of both attributes, but if they conflict with each other, one can be limited by the other. In this situation, the best solution to the matter is to maximize the utility of the decision-maker with the conflicting attributes. In the process, it is natural to have a trade-off issue because they are in a conflicting relationship. To solve this, a multi-attribute utility theory was developed. It is based on the hypothesis suggested by Neuman and Morgenstern (1947). The key purpose of using this problem-solving method is to help a decision maker correctly evaluate alternatives under in an uncertain situation by expressing his or her preference concerning decision-making.

The term ‘utility’ in multi-attribute utility theory is a concept of distinguishing ‘good’ from ‘bad’ and is an emotional value. It is used as the basis for decision-making upon the evaluation of past behavior and selection for the future. Multi-attribute utility theory is not the integration of intuitive and overall criteria, but a process in which a problem is analyzed, and each attribute of it is evaluated, and each utility is combined into one. (Coner, 1978)

In general, it is ideal that a design is made at minimum cost and performs at maximum function, which is when user satisfaction increases. However, some residential functions are in an antinomical and trade-off relationship: when one function is satisfied, other function or functions are dissatisfied. As shown in a literature review, this study places in consideration the trade-off relationship of cost and its related functions because cost has a great impact on user satisfaction with remodeling, and defines it as a risk factor. Accordingly, when required functions conflict with each other, a user, thinking of them as risk factors, should make a reasonable decision on the level of improvement required, based on the value trade-off of those functions.

(3) QFD-TOPSIS

QFD (Quality Function Deployment) is a total quality management tool widely used in many industries. It converts a consumer’s requirements into the design elements of a product, part features, process features, and into specifications for production. The key of the QFD structure lies in how to design and produce a product and service so as to satisfy customers. That is, it connects the end and the means in a matrix and structures it. Through this, QFD helps reflect a consumer’s requirements fully on a product and service and thus maximize customer satisfaction.

TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) analyzes preference for a product using its multiple attributes. To evaluate preference, TOPSIS divides product quality by entire distance scale and standardizes it to 0 through 1. As it gets close to 1, it means high preference and perceived good quality.

In this study, the final evaluation values by QFD-TOPSIS are the weight of a user’s functional requirements and the values of the functions computed from the design elements that experts evaluate. Because they can evaluate user preference by function and alternative, they can differ from the weight of design elements, which are the computed values by existing QFD.

This study applies the distance-based scale concept of TOPSIS to carrying out QFD as follows.

(1) Experts analyze and draw out design elements from design alternatives.
(2) The design elements in (1) are evaluated on a 5-point scale.
(3) Experts derive residential functions related to design elements in (1) after analyzing design alternatives.
(4) The relationship between residential functions and design elements are analyzed.
(5) While considering (4), they define the value trade-off among design elements.
(6) Find the weight of user’s required functions through a value-utility survey.
(7) Evaluation scores of functions are computed through TOPSIS.
(8) According to (7), preference scores of design alternatives are calculated.
5. Value-utility Survey and Defining User's Requirements

User functional requirements are defined through the following process.

(1) As for general performance, the performance necessary to improve a functional requirement can be called 'feature'. When we call a function that can be selected/unselected to improve performance, among user's functional requirements, "recommended requirements (should)", essential (must-be) requirement is a function for which its interlinked feature with other function or functions must be thought of because the improvement of one function limits or lowers the features of other function or functions. Looking at Kano's definition of satisfaction from a different angle, it can be said that when required functions among user's demands are not satisfied, he or she becomes dissatisfied. And each user has a different level of weight in required function because the functions and level required vary by user.

(2) The multi-attribute value concept has an antinomical characteristic. A user defines his/her required functions as risk factors because construction cost increases to improve the required functions as much as he/she wants or the functions in conflict degrade. As a result, he/she trades off values among design elements based on their risk preference by lowering the level of requirements or accepting high construction cost or degradation and loss of conflicting functions to maintain the level of requirements. Risk preference is determined by a user and in order of value preferred.

Through this, users determine the level at and the extent to which they require functions that lead them to optimal satisfaction.

(3) Based on a literature review, this study composed a residential function system by integrating and analyzing the elements of residential functions used for habitability evaluation. It consists of 56 items and they are divided into 5 areas: improvement of convenience, advancement of interior/exterior, extension of effective area, improvement of eco-friendliness, and increase of economic feasibility.

In addition, it connected the items of residential functions with those of remodeling performance so that the results of a value-utility survey could be used as direct and specific design information.

(4) Value-utility survey is based on the multi-attribute utility theory mentioned in (2). It provides criteria for a reasonable trade-off among related functions and elements such as cost, and improves functions in a way to satisfy the diverse requirements of a user.
The questionnaire survey is conducted on users and ascertains a user's required functions and their weight. And the questions are designed with the items/elements of residential functions mentioned in (3). Therefore, the results of the survey are related to remodeling performance, that is to say, design elements, and thus can be used as design information.

(5) To reflect users' required information of residential functions directly on remodeling design, QFD is used. This method competitively evaluates residential functions, their weight, and design elements. The characteristic values of design alternatives are determined by expert review on a 5-point scale. Through QFD analysis, users' functional evaluation scores are calculated and, in turn, satisfaction, that is performance, is determined by design alternatives.

(6) Precedent habitability evaluations measured the functional satisfaction of the design alternative simply; 3 scales (satisfied, average, dissatisfied) or 5 scales (very satisfied, satisfied average, dissatisfied, very dissatisfied). In addition, the final evaluation scores of existing QFD were calculated with simple multiplication of weight, correlation, and expert's evaluation scores. Therefore, it was possible to make a relative comparison, but impossible to make an absolute and objective evaluation.

In this respect, this study applies the concept of TOPSIS scale and normalizes the evaluation scores made on the performance of alternatives and the multiple attributes of the functions between 0 and 1 so that the design alternatives can be evaluated for preference.

\[
F = \sum_{m=1}^{M} f_m = \frac{\sum_{m=1}^{M} R_m w_m}{\sum_{m=1}^{M} w_m}
\]

\(w_m = \text{weight of residential function}\)
\(f_m = \text{evaluation value of residential function } m \text{ (TOPSIS normalized value)}\)
\(R_m = \text{evaluation value of design feature } n \text{ (TOPSIS normalized value, } R_{max}=1)\)

6. Case Analysis

(1) Summary of Plan Alternatives (R apartment in OO city)

As for remodeling, the architectural elements are divided into 2 types: one that cannot be changed or improved by remodeling due to structural limitation and the other that can be improved by it. In this case study, improvable design alternatives based on users' required functions for a plan were compared to each other, mainly focusing on the plan of an apartment.

It turned out according to KS A3011 (illumination standard) that the plans before remodeling did not have sufficient lighting; the bathroom and the kitchen were narrow; service space such as storage room was needed more, all of which were the factors to lower user residential satisfaction.

To tackle these problems, this study applied 3 types of alternative to the previous plan, expanding space by 11.42 m² (19.66%).

The first alternative (Type A) is to demolish 35% of a bearing wall. This remodeling has the largest rate of demolition and accordingly leads to the highest construction cost. At the same time, it means low economic feasibility. Besides, the balcony is divided per bedroom for multiple use and the kitchen is designed to be an island type in which living room and kitchen have no walls or partitions between them. The existing balcony is expanded to enlarge the size of the living room while the total size of the bedroom, though the number of rooms increases, decreases as a bedroom-annexed bathroom, dressing room, and built-in storage or closet are added.

The second alternative (Type B) is to minimize the demolition of a bearing wall by less than 10%, which can shorten the construction period and allow use of the existing plan as much as possible. Based on this, the size increases with a balcony added per bedroom and the size of the bedroom expands.

The third alternative (Type C) is similar to the first one (Type A) in terms of wall composition, except for the air flow of the kitchen (ventilation), but it separates the kitchen and thus reduces the number of bedrooms, while size per bedroom and living room increase.

(2) Examples of Survey

Kitchen separated from the living room and added with a balcony. The balcony annexed to the kitchen improves the questions of the survey consist of the items of residential functions extracted in the expert's review. And the weight of function was measured by a revised semantic differential scale. Semantic differential scale is often used for a questionnaire survey because it is easy to understand. The weight of function is expressed in language in consideration of those that it conflicts with. It becomes the reference

![Fig. 7. Case of Plan Alternatives](image-url)
for users' to select the weight of function. It is marked
on any of four points whose space is equal on a
horizontally straight line. With these four reference
points, users decide the weight of function. The
linguistic expressions that describe the weight are
determined by experts. The weight of user's residential
function is evaluated on a 10-point scale: 1 for the
lowest and 10 for the highest.

A value-utility survey model is used to analyze
preference, which can differ by user when a user's
required function conflicts with cost or other function(s).
Therefore, construction cost was described in relevant
questions to help the respondents refer to it and
determine the weight of function for cost in the survey.

7. Drawing Up QFD and Evaluation

Based on the structural limitations of remodeling
and the problems of the existing options, the residential
functions that can be improved by remodeling were
selected. The users' weight of residential functions was
computed on the results of a value-utility survey and
by semantic differential scale ((4) in 5). User's required
functions were analyzed by a user and according to
their weight as follows.

User A showed low demand for storage space, but
had much limitation in terms of cost. Therefore, it
proved that User A demanded relatively low household
layout change and functions related to size expansion,
which accompany large demolition cost.

The weight of construction cost reduction of User
2 was 1. Therefore, it means that he or she wanted to
proceed with remodeling without cost limit. Besides,
User 2's demand for remodeling work for the kitchen,
storage space, lighting and ventilation system was great.

User 3 turned out to be relatively less attentive to
the size of cost, but much to storage space. Because the
characteristic values of a plan can differ by subjective
evaluation, the average of 3 experts' evaluation scores
were taken.

Fig.8. shows the performance evaluation analysis
of the plan remodeling alternatives, which were
carried upon (4) and (5) in 5. Users' required functions
according to the results of the case study were
quantitively analyzed. It turned out that User 1 had
the weight of 10 for economic feasibility. Therefore,
he or she showed relatively low demand for change in
household layout (compartment) that largely conflicts
with financial budget, and traded off functional values
among the alternatives. As a result, User A had 0.64 of
value for Type A; 0.82 for Type B; and 0.57 for Type C.
Eventually, User A took Type B, in which the ratio of
bearing wall demolition was lowest, so the construction
cost could be saved, as the optimal choice. User 2 was
the one who did not care about cost. Therefore, his/her
choice was Type C in which the ratio of bearing wall
demolition was highest and characterized by a balcony
annexed to the kitchen and separated for better lighting and ventilation. User 3 chose as optimal Type A in which household layout changed to a great extent while the storage space was rearranged.

8. Conclusion

User requirements have become diverse as demand for remodeling has increased. Therefore, it is expected that evaluation of alternatives based on user preference can increase their satisfaction with remodeling and eventually increase the business value of remodeling. The key findings of this study can be summarized and concluded as follows.

(1) A case study and value-utility survey made it possible to define user-required functions more accurately regarding construction cost and related functions. In QFD-TOPSIS, the cross analysis of the elements of design alternatives and required functions made it possible to compare the scores of function by an alternative, which presented a customized choice, and the scores of the final evaluation can be interpreted as satisfaction with alternatives. This study applied TOPSIS and set the maximum satisfaction to 1, which is a perfect level of satisfaction. With this as a reference, User 1 showed 0.82 or 82% satisfaction with Type B, which was the highest of the alternatives. When we assume the uniform application of Type C without considering a user's required functions, the choice increases a user's satisfaction with remodeling by 25%.

(2) In a literature review, it turned out that studies on the method of systemizing the functions and performance, which is necessary to evaluate the design alternatives of an apartment, have not been sufficiently carried out. In this respect, this study defined the items of residential functions among a user's required functions. They included 56 items and were divided into 5 sectors and connected with those of remodeling performance.

(3) As a result of analyzing the relationship between user satisfaction and remodeling design factors, it was found that the degradation of remodeling satisfaction resulted from the conflict of the many functions required by the users. The authors' have derived a model that applies a multifactorial utility theory that can improve satisfaction through trade-offs of the factors related to the relationship between the two. It is possible to select remodeling alternatives that can increase the satisfaction according to user preference by gathering specific user requirements through constructing and surveying function-oriented questionnaires rather than just grasping the rough requirements of the initial remodeling performed previously.

(4) In the cases of existing remodeling, they have reflected only the rough requirements through interviews and surveys. In addition, evaluation criteria are insufficient and are not directly reflected in the design. Because it was possible to connect the results of a user's required function analysis through a value-utility survey and design elements by the QFD-TOPSIS decision-making process, this study proposed evaluation criteria by which user requirements can be directly reflected in a design. In addition, the analysis of design alternatives by function had a remarkably positive effect on design review and readjustment.

The limitations of this study and direction of future research are as follows.

(1) Research for the utilization and generalization of a wide range of apartment houses, such as main and complex evaluation, is required.

(2) Rather than applying a single optimal design alternative as in the past, research on the main and complex planning that can apply various alternatives customized for each resident group is needed.

(3) User preference evaluation and alternative analysis data are required to be constructed as a knowledge base database for remodeling design information.

Acknowledgments

This work was supported by the "Human Resources Program in Energy Technology" of the Korea Institute of Energy Technology Evaluation and Planning (KETEP) and granted financial resource from the Ministry of Trade, Industry & Energy, Republic of Korea. (No. 20174030201740).

The research was supported by the Basic Science Research Program through the National Research Foundation of Korea (NRF), funded by the Ministry of Science, ICT & Future Planning (No. 2015R1A5A1037548, 2015R1D1A1A09060806).

References