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Decision Making Method based on Function and Performance Matrix Assessment Considering Design Change

Youngsuk Oh, Jaeyoul Chun and Jaeho Cho
Department of Architectural Engineering, Dankook University, Master, Korea
Department of Architectural Engineering, Dankook University, Research Prof. Korea
Department of Architectural Engineering, Dankook University, Prof. Korea

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Abstract A comprehensive understanding of functions and performances enables a selection of appropriate alternatives to the existing design and can prevent defective design. A performance-based design quality management can ensure successful project completion. This study proposes a new model for design quality management in order to prevent defective design and to minimize design change. The new quality management model defines the requirement about function and performance based on technical characteristic, and assesses suitability for design alternatives. This study attempts to propose a quality matrix assessment method that can compare the alternative design and requirements defined with the new quality management model. This method can judge conformity and suitability of design quality in accordance with the requirements configured.

Keywords: Decision-making, Design plan, Function, Performance, Requirement

1. INTRODUCTION

Defining project requirements and executing design based on that criteria are the key concept for the design quality management. A precise and clear definition of quality is as follows: "Quality is conformance to requirements". Philip Crosby explained this concept in his book 'Quality Is Free: The Art of Making Quality Certain.

The requirements can be classified into the definitions of functions and performance criteria. In case of design of structures, the selection problem of alternatives needs a comprehensive assessment review of the multiple functions and relative performances in relation to adjacent systems.

Cooperative design techniques, solution to interferences among construction types, and management of design change in a complex building system etc are becoming main issues as various methods of design quality management.

Corresponding Author: Jongwook Kwon,
Department of Architectural Engineering,
Dankook University, Prof. Korea
e-mail: cjhace@naver.com

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Design Change is a phenomenon which occurs inevitably in the design process. However, effort for good quality management should be made in order to minimize design change. The reasons of occurrences of design change are various including the ordering entity's additional demands or change requests, design errors made by the designer, missing functions, and wrong selection of alternatives, etc.

According to a survey conducted by Public Procurement Service, one of the major national facility design ordering institution in Korea, occurrence of defective design and design change due to insufficient design review could be an extremely negative factor in facility constructions (Public Procurement Service, 2004).

Kwak (2011) has investigated the frequency of flaws inside the design review report of apartment houses and office buildings and discovered that the most frequently occurred ones were wrong decision of alternatives and omitted functions. Then, the next frequently occurred ones were, in order of insufficient review of usability by the user, missing of descriptions on the drawing, and discordance of information among special work classification.

Another study points out that main causes of design change are inadequate definition of project requirement, and lack of information sharing among project stakeholders (Isacc, 2008).

These factors all lead to the design change and most of them are derived from inadequate quality management. Therefore, an effective quality management technique is required to minimize the design change and improve the defective design.

There are some traditional conventional tools for design quality management. The most representative ones are quality assessment, adjustment of constructability, review of interferences among construction types, review of conformity between design and requirement, and peer review method among participants.

The basic quality management process in building design is as follows: The first step is to understand the general functions in the design agenda. The next step is to set the performance criteria required. The precise definition of functions and performances is the preparatory process for quality management to analyze whether the various requirements in the design process are satisfied and to verify the problem os interferences. In the last step, a review of the conformity between the planned performance criteria and the design alternatives is performed.

This is not a temporary process that takes place at a specific time during the design stage. Quality management efforts in the design stage should be made frequently when needed, and should be monitored continuously. The monitoring of the design process for the review of the conformity is the key concept for the quality management described above.

Since various elements and various systems of the architecture are combined complexly, one function can have more than 2 complex functions or the required performance criteria are contradictory due to the different definition of functions. Furthermore, the design of a building (due to the unique characteristics of the project) has different importance level of functions, and thus decision makers should consider which function they should consider more carefully. Therefore, the definition of functions and performances criteria should reflect the criteria which has been decided and adjusted by way of the professional opinions of the project participants.

A new approach to quality management needs to be made based on functions and performances in order to minimize occurrences of design change and improve design quality. In order to reduce the design change and improve the defective design, the basic design management process described above should be abided by. Definition of participants-based function and performance and review of conformity of quality is needed based on the basic process.

2. METHODOLOGY AND SCOPE

This study proposes a design quality management model for minimizing design change and a required function-based decision making method that can actually perform such model. This study is performed by way of the following procedure.

First, the status of the existing literature will be examined. The topic of such literature is divided into the study of 'minimization of design change' and the study of 'decision making methods for quality management'.

Second, causes of design change will be identified and main factors required to improve quality control method will be proposed.

Third, a new quality control model will be proposed through definition of required performance value.

Fourthly, function and required performance-based quality matrix method will be proposed.

Fifthly, the usefulness will be verified through a case comparison of the assessment methods of this study and the conventional decision making methods.

Sixthly, a conclusion will be drawn for this study regarding the quality management model and the quality assessment method.

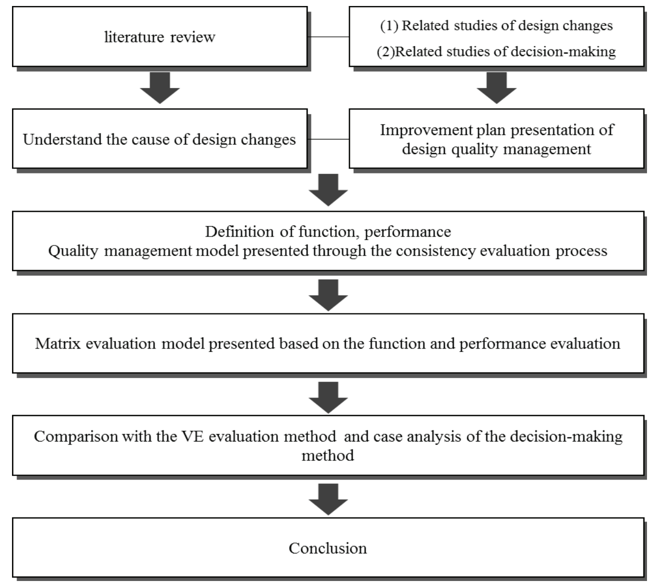

Figure 1. Methodology and scope

3. LITERATURE REVIEW

This chapter proposes a technique and concept to minimize design change by investigating the current status of the existing studies. And also, it will investigate and various techniques as decision making methods for quality control and their advantages and disadvantages

(1) Studies on Design Change

Studies regarding design change have been actively conducted domestically and internationally. In domestic research, the studies were performed regarding status analysis of the design change, systematic problems regarding design change, cooperative design for the design change management and design quality management for prevention, etc.

Ahmed and Sang (2003) utilized a QFD (Quality Function Deployment) model as an assessment tool for alternatives for design change and kept track of the requirements ordered by ordering entity. Moreover, they proposed information management and communication scheme about the requirements of the ordering entity when design change occurs.

Oh Byeong-Seok(2006) analyzed the factors that could cause the design change in construction projects performed in the same site, and proposed the improvement schemes.

Isaac and Navon (2008) understood the causes of system collisions which occur due to functional change when a design change occurs.

They also proposed an automated design change tool that allows users to trace relationships between the requirements and the design and verify the interference items beforehand.

Nam (2009) has analyzed the design change cases in construction work, presented the main causes of the design change, and proposed the process model which supports the design change.

Lee (2010) also focused on design change and proposed a quantitative assessment method of design alternative and design change process in perspective of cost, performances, and constructability.

(2) Studies on decision making methods

Designers play an important role in decision making regarding the project planning, designing, and construction process. Decisions must be made cautiously in the design stage, since they can directly influence the later stages. In particular, any wrong decision making in the planning stage and early design stage could lead to design change in the design development stage or construction stage, and causes loss of productivity of various types.

The following Table 1 is a summary of representative decision making methods focusing on selection of design alternatives.

The most representative decision making methods are the VE matrix method and QFD method.

Prasad (2013) evaluated product quality in terms of performance for each design alternative by using QFD.

Quality evaluation system proposed by Prasad (2013) is a representative case which uses QFD.

Li et al. (2014) proposed a new multi criteria decision- making method by combining QFD and TOPSIS evaluation models. Many other studies on the QFD method have been presented, and case studies of specific applications are continuously in progress.

Each decision making method has its advantages and disadvantages as follows.

The VE matrix assessment method enables users to set weighted values, in accordance with the importance of the functions and to evaluate the performances objectively. However, it is difficult to apply the concept of assessment of suitability and conformity of the design alternative through required performance criteria. One of the disadvantages of the VE matrix is that when the decision maker does not consider the required performance value, higher performance value of the design alternative receives better assessment. In other words, the process of determining the required performance value is not formalized in the VE-matrix technique.

The QFD technique is the most commonly used quality assessment method in the industry. Unlike the VE matrix method, this method has formalized the process of analyzing mutual interferences among construction types.

However, just like the VE-matrix method, the QFD technique does not have the defining process of the required performance values and does not assess their suitability based on the requirements. The main characteristics of this method is that it considers the importance of performance items, creates alternative ideas, and focuses on quality improvement.

(3) Summary of review

The reviewing the studies that dealt with decision making methods, it can be argued that there are few studies that discuss function and required performance-based decision making techniques. In particular, the subjects on the assessment methods of the conformity with and suitability for the required standard were scarce while the quantitative assessment method regarding information on performance was proposed.

Table 1. Decision making methods utilized in the design stages

Section	Summary of decision-making techniques
AHP method	The method of breaking up the components into easy-understand hierarchy about the decision making problems which are complexly entangled and analyzing based on that hierarch and making decisions. (evaluates in 9-point scale, to calculate the final importance)
	Related studies : Jung (2006), Park (2005), Chun (2006)
FD, IWDM method (Functional importance assessment method)	Evaluate and assess the level of importance between functions
	Related studies : Kim (2012), Jang (2009)
VE Matrix assessment method	A detailed assessment method for design alternative and is the method where the user decides the assessment items like functional satisfaction level, constructability and economic feasibility, etc and calculate the weighed value of the assessment items and select the final alternative (Assessment by each design alternative is easy.)
	Related literature : VE theory and practice of architecture (2010)
Weighted Comparison Matrix	Caltran VA: Uses linguistic evaluation (Caltrans). For example, 10 points for excellence, 9 points for very good, 5 points for small problems, 2 points for important problems and 0 points for fatal problems as the assessment criteria.
	Related literature : Value Analysis Report Guide (2013)
QFD method (functional quality deployment)	It converts the design requirements of the clients into design quality, and is a method of analyzing the functions that make up the quality. Quality function deployment method is composed of the survey of the order's demand, deduction of quality elements of the investigated requirements, calculation of importance level of the required quality and conversion of weighed value (Invented by Mitsubishi in 1972)
	Related studies : Kwak (2010), Yu (2005), Yang (2005)

4. CAUSE OF DEFECTIVE DESIGNS AND DESIGN CHANGE

Design change is a phenomenon which occurs due to the characteristic of the architecture design being hard to be standardized. The causes of design change exist through the whole construction project like change of requirements of the ordering entity, change of the law and system, diversification of techniques and method etc. Thus, there is a limit in preventing and minimizing design change even if the design was perfectly made in the early and intermediate stages. Design change is caused by a design plan that is not suitable for the project schedule, costs, and quality. From the perspective of quality control, the problem of improving defective designs and minimizing design changes start with defining the functions and performances and suitable quality assessment method.

Changes in the schematic plan, increases or decreases of the amount of the material quantity, and changes in the requirement made by the clients all occur due to uncertain characteristics of design work. To improve such uncertainty, a new approach needs to be involved. However, 'unclear designs and missing functions' are the types of insufficient design quality management. This is caused by the failure of the project participants to define the requirements clearly. The item ,'discordance between the design documentations and the site condition' as another cause of the design change is closely associated with 'functional interferences among systems', 'functional errors', and 'disconformities of performances' etc. To reduce these factors, the following issues needs to be reviewed. First, whether the design alternative is consistent with the required performance criteria. Second, interferences or contradiction with the neighboring system due to the performance of the configured design alternative needs to be checked. Figure 2 illustrates main causes of defective designs and design changes.

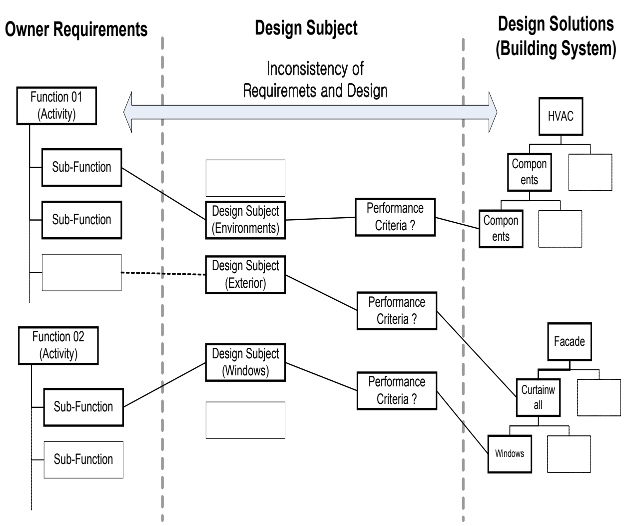

Figure 2. The main cause of the design changes

5. DESIGN QUALITY CONTROL MODEL

Wrong decision makings generate poor design quality and design changes. To make appropriate decisions, a sufficient preparation stage is needed. Detailed levels of requirements should be defined and updates for the change demands need to be managed.

Furthermore, designers can define the suitable requirements for the site condition by communicating technically with professionals from each specialist construction works. Designers should also take into account the comprehensive performance by way of connections of interfaces among different design themes and complex composition of the system.

The general design process performs the decision making by each design subject. This method can, however, omit or miss any possibility of contradiction among the neighboring systems, and thus the design change may occur more frequently with this method.

On the other hand, the integrated design process considers more than two design subjects simultaneously. Integrated design selects the optimal alternative through comprehensive required performance of the design alternative. Here, the concept of optimal designs refer to the assessment of the conformity, suitability and interference of the design alternative based on required performance criteria. Thus, the following three stages should be involved for effective quality management.

(1) Determining the importance of functions and required performance agreed by the project participants.
(2) Analyzing the performance of the design alternative which are interfered mutually by way of the function
(3) Analyzing the conformity and suitability of the alternative designs

A clear definition of the requirements could be extremely useful in assessing the design alternative, since buildings have their own unique characteristics in each project. By defining the functions and the performances in detail, wrong choices of system and construction methods can be reduced.

Moreover, by sharing the information about the functions and performances among the participants, defective designs caused by omitted functions, collisions among required performances, and discordance between the design documentation and the site condition could be prevented fundamentally. Figure 3 below demonstrates the concept of a design quality control model. The proposed quality control model defines the requirements based on the functions and performances. And then, it reviews the conformity and suitability of alternative designs according to the predetermined requirements.

Chapter 6 proposes a quality matrix assessment technique based on this quality control model.

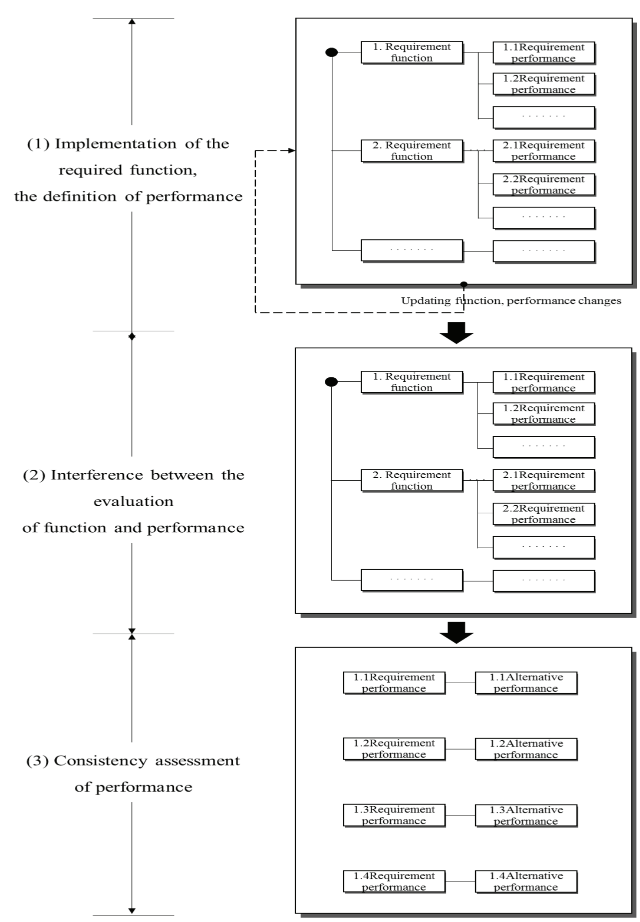

Figure 3. Design quality control model and quality assessment process

6. PROPOSAL OF QUALITY MATRIX ASSESSMENT METHOD(FPMA)

This chapter proposes a quality matrix assessment method based on the functions and performances.

This term will be referred to as the FPMA (Function and Performance Matrix Assessment) technique hereinafter. The 'FPMA' technique utilizes Caltran's linguistic assessment principle (2001). The importance of functions is determined by the Likert 5 point Scale. However, the difference from the QFD technique is that it configures the minimum standard or recommended performance values for performance item. The minimum performance or recommended performance values associated with the functions are utilized in assessing the conformity and suitability of the alternative designs in alternative assessment process.

Figure 4 below shows a concept diagram of a quality measurement after defining the recommended performances or minimum performance values for each performance item. One function element can have more than one performance element. Likewise, one performance element can have more than one function element.

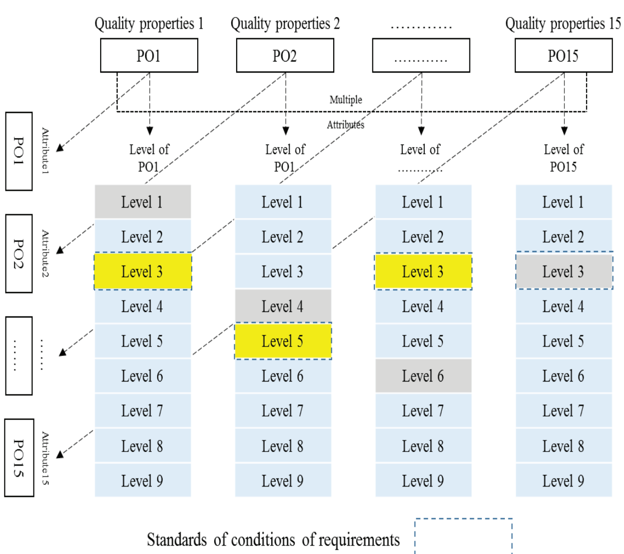

Figure 4. Conceptual diagram of the quality assessment by the required performance criteria

The suitability scale is '3' when the required performance criteria are the same as the performance value of the alternatives; and the '3' value is used for strict conformity. For example: if the performance value of the alternative is higher than the RPC by a score of 2 in the performance ratings, then the suitability score is 5. If the performance value of the alternative is higher than the RPC by a score of 1, then the suitability score is 4, if the performance value of the alternative is equivalent to the minimum performance, then the suitability score is 3, if the performance value of the alternative is lower than the RPC by a score of 1, then the suitability score is 2, and if the performance value of the alternative is lower than the RPC by a score of 2, then the suitability score is 1, etc.

Figure 5 is a diagram of the basic composition and each component of the 'FPMA' technique.

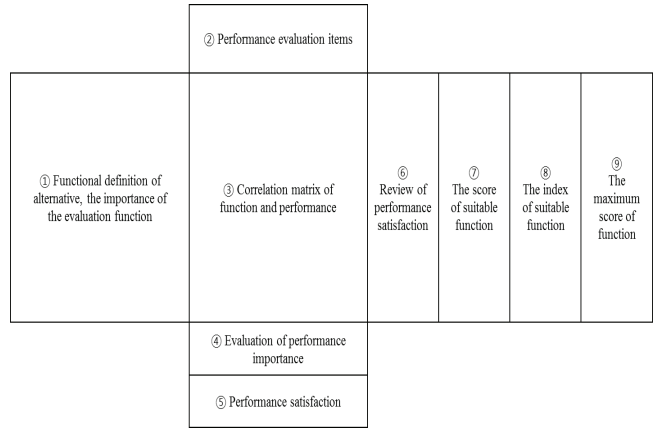

Figure 5. Basic type of (FPMA) evaluation method for function and performance matrix

[1] Definition of functions and configuration of importance of functions : The process of defining the functions is being proposed in the 'Fast Diagram' technique in the VE field as well as VE-related literature. Therefore, the FPMA technique defines the major elements of the functions and expresses them in the relevant parts. The method of determining the importance of functions is to determine the importance level using the 5-point Likert Scale. Example of the scale : 5 points for very important, 4 points for relatively important, 3 points for intermediate, 2 points for relatively not important and 1 points for little important.

[2] Assessment of performance elements in alternative designs : The performances are assessed in 5 grades. For instance, Grade 5 is given 5 points, Grade 4 four points, Grade 3 three points, Grade 2 two points, and Grade 1 one point. If the performance is assessed by binary grading, the method for assessing the performances should use the same criteria.

[3] Analysis of correlation between functions and performances : The relationship between functions and performances are assessed. For example, a high correlation is given one point (■), a moderate correlation 0.66 (●), and a low correlation 0.33(▲). The obtained values are used to analyze the importance of functions and performances.

[4] Importance of performance element related to function : Importance of the related performance is assessed through assessment of importance of function.

[5] Assessment of satisfaction of performance elements : The suitability is assessed by comparing the minimum performance value of the design guide and the performance value of product alternative.

[6] Review of function satisfaction : The suitability is reviewed based on the required performance value related to functions.

[7] Function suitability score : The function suitability score is the same method as the assessment of the importance of function and uses the 5-point Likert scale. Users can freely choose the utilization standard of a 5-point, 7-point, or 9-point scale considering the characteristics of the alternative being assessed. The suitability assessment method compares the performance value of the product and

minimum performance value and provides the score For instance, 5 points will be assigned if the performance value of the alternative is higher by more than 2 grades than the minimum performance value; 4 points if the performance value of the alternative is 1 grade higher than the minimum performance value; 3 points if the performance value of the alternative is equivalent to the minimum performance value; 2 points if the performance value of the alternative is 1 grade lower than the minimum performance value; and 1 point if the performance value of the alternative is lower than the minimum performance value by more than 2 grades lower.

[8] Function suitability index : The function suitability index is calculated by using the ratio of the function suitability score to the maximum function score.

[9] Maximum function score : The maximum function score is calculated by adding 5 points to the elements of the importance of functions.

7. COMPARISON OF DECISION MAKING METHODS

(1) Case analysis method

The FPMA technique will be applied to an analysis of a window design. To verify the validity of the FPMA technique, the comparison and analysis with the existing VE Matrix method will be performed.

Various factors should be considered complexly like the exterior design, energy efficiency, habitability, illumination operating method, technical performance and cost etc in order to select appropriate windows for the architecture space.

The representative performances of windows are complexly related including insulation performance (heat transmittance: U Value), shading coefficient (SC), solar heat gain coefficient (SHGC), air-leakage (AL), visible light transmittance (VT), etc. The thermal comfort(required function) is determined by the complex performance of these functions. The windows for case analysis are summarized below in Table 2.

Table 2. Performance Value of the Alternative Design Solutions

Solutions	U-Value	SHGC	VT	AL	CR	OITC
Alt-(1)	0.49 (Gr.3)	0.33 (Gr.4)	0.55, (Gr.3)	0.20 (Gr.4)	71 (Gr.4)	32 (Gr.4)
Alt-(2)	0.38 (Gr.4)	0.48 (Gr.3)	0.35, (Gr.2)	0.25 (Gr.3)	30 (Gr.2)	27 (Gr.2)
Alt-(3)	0.47 (Gr.3)	0.52 (Gr.2)	0.50, (Gr.3)	0.24 (Gr.3)	58 (Gr.3)	27 (Gr.2)
Alt-(4)	0.31 (Gr.4)	0.46, (Gr.3)	0.55, (Gr.3)	0.36 (Gr.2)	49 (Gr.3)	35 (Gr.4)

The definition of the required performance utilizes the design guideline regulations for the characteristics of windows designed basically for heating in the north-central United States which have similar climates and altitude to Korea (mixed hot and cold climates):

[1]. Heat Transmittance (U-factor) : Not more than 0.60 for skylights

[2]. Solar Heat Gain Coefficient (SHGC) : Not more than 0.40 for skylights

[3]. If the air-conditioning cost is high during the summer or the temperature is high due to the radiated heat in the summer, a window whose SHGC is not more than 0.4 should be selected.

[4]. SHGC should be below 0.55 if heating is essential.

[5]. Visible Light Transmittance : if the blinding daylight is not a big issue, a glass whose light transmission is more than 0.5 (50%) can be used to achieve the maximum amount of light.

[6]. There is no stipulated design standard to solve the blinding daylight. A shade or blind can be used or the VT transmission can be set below 0.40.

[7]. Air Leakage (AL) : Select a window whose leakage factor is below 0.30 cfm/sq.

[8]. Condensation Resistance (CR) : There is no stipulated design standard for this, but should be set above 60.

[9]. Outdoor–Indoor Class Transmission: There is no stipulated design standard for this, but should be set above 32.

Although there sis assessment criteria for the performance of windows, there is no formalized grade classification method.

Thus, the interval scale concept was applied and the performance value of the windows has been graded as in the following Table 3.

Table 3 Classification of performance of windows using the interval scale

Table 3. Performance Scale of the Window Solutions

Grade (Score)	5 grade (5 points)	4 grade (4 points)	3 grade (3 points)	2 grade (2 points)	1 grade (1points)
U	0.00~0.20	0.20~0.40	0.40~0.60	0.60~0.80	0.80~1.00
SHGC	0.20~0.30	0.30~0.40	0.40~0.50	0.50~0.60	0.60~0.70
VT	1.00~0.80	0.80~0.060	0.60~0.40	0.40~0.20	0.20~0.00
AL	0.00~0.10	0.10~0.20	0.20~0.30	0.30~0.40	0.40~0.50
CR	100~80	80~60	60~40	40~20	20~0
OICT	40~36	36~32	32~28	28~24	24~20

[1] Heat Transmittance (U-factor) : The penetration ratio quantifies the insulating performance. The heat transfer coefficients of the window system (BTU/hr./sq.ft/°F or W/sqm-°C) include convection current, current and radiant heat. Average window penetration ratio is between the scope of 0.10 and 1.20.

[2] Solar Heat Gain Coefficient (SHGC) : The value of the SHGC is expressed between 0 and 1.00 and higher value represents higher heat acquisition.

[3] Visible Light Transmittance(VT) : The visible light transmittance means the amount of light in the visible scope which comes in through the window. The visible ray penetration ratio of glass is various from the high radiation coating glass of under 0.1(10%) to the transparent glass of around 0.9(90%).

[4] Air Leakage (AL) : Air leakage means that uncontrolled or undesired air comes in. The general window air leakage(cfm/sq ft) is between the value of 0.1 and 0.3.

No.	Primary function	Importance of function	Weighted calue	The original plan									
				Performance		Performance		Performance		Evaluation value	Evaluation of function value	Evaluation of function index	The maximum score of function
1	Cooling load in summer cused by solar radiation energy occurs	4	5	U Value	3	SHGC	4	AL	4	3.7	18.3	0.7	25
2	The view assurance by visible light of the sun	3	2	VT	3					3.0	6.0	0.6	10
3	Conduction and convection generated by the heat	5	10	U Value	3					3.0	30.0	0.6	50
4	The luminance, glare caused by visible light of the sun occurs	4	5	VT	3					3.0	15.0	0.6	25
5	Heating load generation in winter	5	10	U Value	3	SHGC	2	AL	4	3.0	30.0	0.6	50
6	Lighting load generation	3	2	VT	3					3.0	6.0	0.6	10
7	Condensation caused by the temperature difference between inside and outside	3	2	U Value	3	AL	4	CR	4	3.7	7.3	0.7	10
8	Urban noise	4	5	AL	4	OITC	4			4.0	20.0	0.8	25
				Comprehensive evaluation of function and performance							132.7	0.66	205

Figure 6. VE matrix Evaluation (Alternative 1)

			Performance evaluation items	The performance characteristics of alternative									
				U Value	SHGC	VT	AL	CR	OITC				
				0.49	0.33	0.55	0.20	71	32	기능 평가			
No.	Primary function	Importance of function	Important rank	3	4	3	4	4	4	Review of performance satisfaction	The score of suitable function	The index of suitable function	The maximum score of function
1	Cooling load in summer cused by solar radiation energy occurs	4	2	■ 3	■ 4		● 3			○	13.0	0.65	20
2	The view assurance by visible light of the sun	3	3			■ 3				○	9.0	0.60	15
3	Conduction and convection generated by the heat	5	1	■ 3						○	15.0	0.60	25
4	The luminance, glare caused by visible light of the sun occurs	4	2			■ 2				△	8.0	0.40	20
5	Heating load generation in winter	5	1	■ 3	■ 2		● 3			△	12.5	0.50	25
6	Lighting load generation	3	3			● 3				○	9.0	0.60	15
7	Condensation caused by the temperature difference between inside and outside	3	3	● 3			▲ 3	■ 4		○	9.5	0.63	15
8	Urban noise	4	2				■ 3		■ 4	○	14.0	0.70	20
			Evaluation of performance importance	16.4	9.0	9.4	13.0	3.0	4.0	The total score of suitable	90.0	0.59	155
			Review of recommended performancce satisfaction	-	△	-	-	-	-				
			Review of minimum performancce satisfaction	○	-	△	○	○	○				

Figure 7. Function evaluation of Window by FPMA

[5] Condensation resistance(CR) : The measurement of the condensation resistance assesses how much the internal glass resists to the formation of condensation out of moisture. The CR value is expressed between 0 and 100. A higher value means a higer condensation resistance. Most windows show resistance values in the scope of 10~60.

[6] Outdoor–Indoor Class Transmission (OICT) : Minimize the air leakage first to reduce the noise. Also there are various ways for sound-proofing. Since OITC grade deals with low frequency, it relates closely to the noise of the traffic facility. In case of windows, the OITC value is in the scope of 20~40. A higher value means higher noise resistance.

(2) Case analysis of VE matrix concept

The VE matrix technique assesses the importance of functions using a 10-point scale. The weighted values of functions are calculated using this 10-point grading scale. The method of assessing complex performance associated with the functions utilizes the average value of performance scores. Next, the weight performance value and the complex performance score are counted and the assessment value of each function is calculated. Lastly, the assessed values of each functions are added to calculate the comprehensive function assessment value of the design alternative. Figure 6 is an assessment case of alternative (1). The comprehensive performance value the alternative (1) is 132.7.

(3) Case analysis of FPMA technique

Figure 7 is an assessment case of the alternative 1 by way of the FPMA technique. According to the analysis result of the alternative design, the comprehensive suitability score of the performances was estimated to be 90.0. Different function scores can be assigned depending on the performance of the window alternative. As the function suitability score is higher, it can be judged as the design alternative suitable for the required conditions and performance.

(4) Interpretation of the result analysis

The following Figure 8 are the result of the case analysis of the 4 alternatives.

In the case of the VE matrix technique, alternative 4 is chosen to be the most suitable one. On the other hand, in the case of the FPMA technique, alternative 1 seems to be most suitable. Each technique had ranking order difference because of the method for assessing the performances. (Figure 8)

With the FPMA technique, the method of assessing the complex performances uses the 5-point grading scale based on the weighted values of the performances and the minimum performances.

Meanwhile, with the VE matrix technique, the method of assessing the complex performances simply utilizes the average values of the performances.

The FPMA technique allows a more thorough assessment, when the designer takes into account the importance of the performances. If two alternatives do not provide significantly different performances, it might be difficult to select a suitable alternative. Using the FPMA technique, interferences among the performance items can be identified in advance and an optimal alternative can be selected by way of the suitable criteria concept. Also in the case of the FPMA, the applicable alternative can be verified based on the minimum required performance. To accomplish this, the minimum value of the suitable function score shall be set based on the minimum required performance. In this analysis, the lowest value was set to be 80.

Evaluation method	ALT 1	ALT 2	ALT 3	ALT 4
VE Matrix	132.7	126.5	122.2	133.0
FPMA	90.0	86.0	80.5	88.8

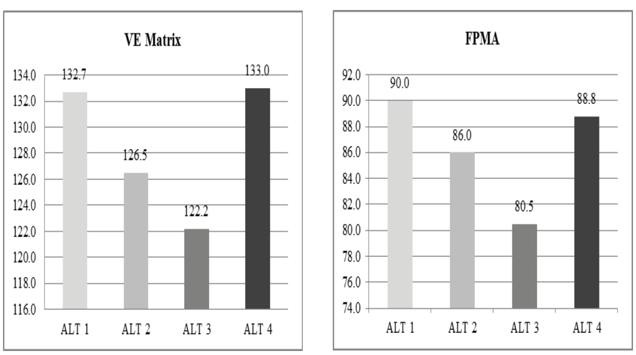

Figure 8. Comparative analysis of the VE and the FPMA

8. CONCLUSION

Defective designs and design change occur due to insufficient quality control. Design quality control requires a thorough preparation phase. The core concept of the design quality management is the review of the conformity and suitability of the design alternative based on the definition of requirements. Understanding the requests clearly and assessing in accordance with the required performance criteria can apparently reduce defective designs and design modifications. Therefore, this study has proposed a new decision making method as a quality control model.

The quality matrix assessment method proposed in this study allows users to objectively analyze the requests and assess alternative designs quantitatively. The suitability assessment concept of the FPMA technique differs from the existing assessment method where the design alternative with high performance value receives a high score unconditionally. The FPMA method has applied improved defining, analyzing and assessing techniques for the requirements, compared to the current decision making techniques.

First, the FPMA technique can define and revise and adjust the requirements made by the participants.

Second, the FPMA technique can assess the priorities of functions and importance of each performance item, and thus verify interferences among the functions.

Third, it also allows an analysis of the conformity and suitability of the alternative design based on the performance assessment.

Fourth, the FPMA technique can set the minimum value of the function score by way of the concept of suitability. The performance of the applicable alternative can be verified through the minimum value.

In future studies, various scales such as a 3-point, 7-point or 9-point scale other than the 5-point scale will need to be applied according to the characteristics of project alternatives. Moreover, a sensitivity analysis should be conducted based on the scale variables and the validity of quality assessment method should be determined. In addition, (in future studies) a web-based computerized decision making model that can be used in the AEC industry needs to be developed.

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