International Journal of Environmental Engineering– IJEE
Volume 3 : Issue 1 *[ISSN : 2374-1724]*
Publication Date: 18 April, 2016

A Standardized Assessment System for Integrative Comfort Factors of the Korean Traditional Housing

[Mu-Jin Jo, Mihyang Lee and Seung-Hoon Han]

Abstract— **Intention of this study is to evaluate indoor environmental quality system using physical and psychological analysis presented on the consideration of the traditional houses in Korea, called Hanok. In addition, this paper is to build a diversified, integrative evaluation system considering traditional, aesthetic and psychological values. For this study, the degree of integrative indoor environmental (IEQ) quality was analyzed and IEQ performance has been classified. Indoor environmental quality performance was divided into two large performance categories: physical and psychological. For this research, survey data from residents were collected for evaluating psychological indoor environmental quality. Existing relevant studies about IEQ evaluation system were driven to reveal the quantitative elements of the suggested classification system. This study also contains a qualitative in-depth analysis of the IEQ factor and will examine the effect of those elements. This study has finally proposed an integrated IEQ evaluation system that can evaluate over inhabitants of the interior environmental conditions and surveys. As a result, the proposed system will have to be turned on quite good applicability in the field.**

Keywords— **Physical Environment, Psychological Comfort, Integrated Comfort Evaluation System, Indoor Environment Quality, Insulation Evaluation Method, TDRi, Simulation for Solar Performance**

I. Introduction

Previously, there have been standards and regulations related to the indoor environmental quality assessment of physical (quantitative) environment. However, the integrated assessment of the emotional and psychological indoor environmental quality is not presented successfully, although physical living environment such as temperature, humidity, noise and lighting conditions is very momentous.

These physical evaluation systems and analysis skills have continuously been evolved. However, the way of life for the residents became more complexed and convoluted and their requirements are being increased. This is why evaluating only physical IEQ factor is not sufficient. Therefore, the purpose of this study is to suggest an integrated indoor environmental quality evaluation system through combinations of psychological comfort factors.

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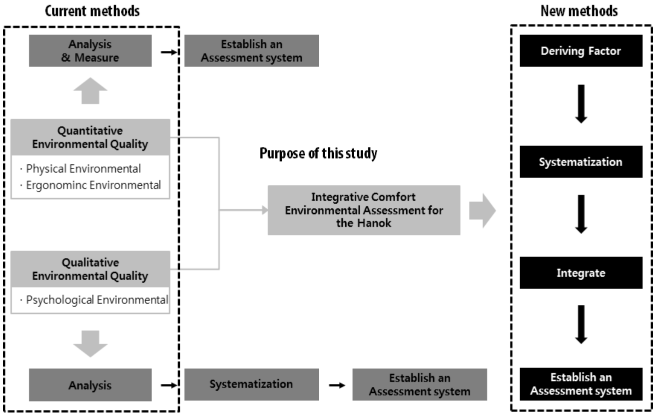


Figure 1. Process of Integrative Comfort Analysis

II. Method of Research

A. *Research Process*

This study has analyzed IEQ factors, and as a result, it was confirmed that both physical (quantitative) and psychological (qualitative) comfort zones could be separated by two areas, reconstructed and listed with indoor environmental quality factors with examining existing researches. Comfort factors of Hanok classification was made by the following three stages as shown in Figure 1.

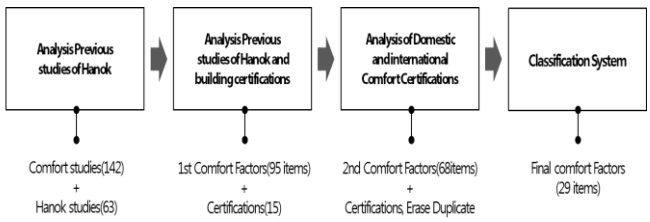


Figure 2. Deriving Process for Comfort Factors

1) **First step**: analyzing the previous studies for hanok with 63 cases and categorizing 93 pleasant elements from 142 previous studies and cases.
2) **Second step**: comparing the above 93 comfort factors to the 15 national and international certifications and reclassifing 69 comfort factors.
3) **Third step**: deleting the duplicate factors, adding the necessary factors from 69 comfort factors, and extracting the final 29 comfort factors to be utilized for evaluation.

Results are listed through the number of elements with preceding analysis, and it was possible to find a common sense classification between psychological and physical indoor environmental areas. Most of the physical and psychological environmental factors can be sensed through vision, auditory, tactility and smell. This survey has been put together by a systematic, objective comfort configuration using five sensory systems in the physical and psychological comfort zones. After classifying and organizing comfort factors by investigating the definitions, AHP (Analytic Hierarchy Process) program has been utilized and set the weights.

B. *Vocabulary Reorganization of the Combined Assessment Factors*

The vocabulary of a comprehensive evaluation factors were reconstructed. This allows professionals and residents to grasp the meaning of comfort factors and get accurate surveys. Vocabularies found by assessment are as the following:

- **Insulation:** The heat transfer performance generated in the walls, windows, floors, roofs, etc.
- **Solar Performance:** The performance of the solar relate with the visual environment and the air-conditioning performance of buildings..
- **Aesthetics:** Within the building as a traditional construction, says the aesthetics of the psychological satisfaction that comes from the outside of the building itself.
- **Sound Absorption:** Reduce sound energy through the use of a sound absorption materials and noise insulation materials.
- **Availability:** Refers to the satisfaction use in everyday life though the appropriate design of such a public corridor, flexible space structure and door.
- **Psychological Harmless:** Refers to the psychological satisfaction of residents appears when using eco-friendly materials.

By the weighted analyses, it was possible to identify the important psychological comfort factors by the expert and professor groups. Auditory convenience showed the highest result, followed by flavor, calm, thermal sensation, and aesthetics.

C. *Weight Set Using AHP*

Through the above process, the fill-out questionnaire and survey were selected by a representative expert. Selected experts consist of researchers and professors, practitioners in the field of architecture. Then, this study utilizes the AHP to determine the weights of qualitative elements. Through this process, the weights between the elements could be enshrine. Weights found by analysis are as the following:

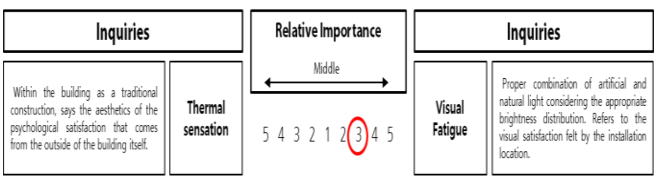


Figure 3. Survey Paper of Weight Set using AHP

Category		Weight Results of Comfort Factors		
		Factor Name	*Weight Group(%)*	*Final Weight (%)*
Psychological (64.46%)	Tactile	Tactile Convenience	30.90	4.44
		Texture	27.18	3.91
		Thermal Sensation	41.91	6.03
	Auditory	Auditory Convenience	38.92	4.02
		Calm	61.08	6.31
	Visual	Visual Convenience	16.25	3.47
		Fatigue	16.96	3.62
		Opening Performance	22.41	4.78
		Aesthetics	27.88	5.95
		High Sense	16.50	3.52
	Olfactory	Olfactory Convenience	38.45	4.06
		Flavor	61.55	6.51
	Non -Sense	Availability	46.38	3.64
		Publicity	23.69	1.86
		Psychological Harmless	29.93	2.35
Physical (35.54%)	Tactile	Humidity	14.44	1.58
		Insulation	41.46	4.54
		Air Tightness	19.20	2.10
		Solar Performance	24.90	2.73
	Auditory	Sound Absorption	28.61	1.65
		Noise Absorption	71.39	4.13
	Visual	Artificial Lighting	21.04	1.78
		Day Lighting	78.96	6.67
	Olfactory	Air Cleanness	38.32	2.34
		Deodorization	17.53	1.07
		Ventilation	44.15	2.70
	Non -Sense	Maintenance	40.01	1.69
		Security	26.89	1.14
		Harmless	33.10	1.40
TOTAL				99.99

TABLE I. WEIGHT SETS OBTAINED BY AHP

III. Pilot Test of Integrate Comfort Assessment Systems

A. *Pilot Test*

Two locations have been selected in order to simulate Hanok village. Each location has each divergent style such as newly-built and traditional. Simplified data measurements have been performed and the results analyzed by a series of simulations.

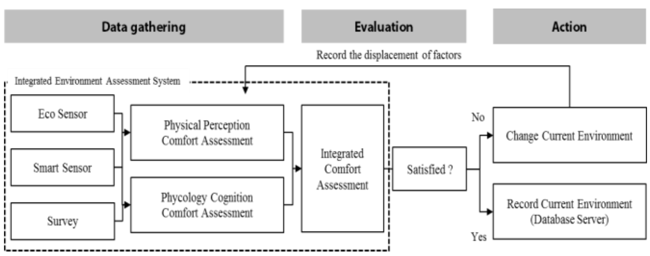


Figure 4. Process Pilot Test of Integrate Comfort Evaluation System

Measurement factors include temperature, humidity, wind, illumination, MRT, dust, smell, VOCs, NOX, CO2, CO, and Noise. Physical factors have been obtained in way of sensing those factors, and psychological factors obtained through surveys of residents and professionals. Since then, final score has been obtained by multiplying the weights collected from both methods.

	
Site : Do-Rae Traditional Village (Naju, Chonnam, Korea)	**Site** : Sin-Gwang New Hanok Village (Naju, Chonnam, Korea)
Date : 6.22 (Summer Solstice), 8.19 - 8.20	**Date** : 6.22 (Summer Solstice), 8.19 – 8.20
Measuring Equipment : Smart Sensor (Temp, MRT, Humidity, Wind, Illumination) Eco Sensor (Dust, Smell, VOCs, NOX, CO2, CO, Noise)	**Measuring Equipment** : Smart Sensor (Temp, MRT, Humidity, Wind, Illumination) Eco Sensor (Dust, Smell, VOCs, NOX, CO2, CO, Noise)

TABLE II. SITE & SUMMARY OF PILOT TEST

B. *Measuring Results of Pilot Test*

In pilot test insulation, moisture control performance and indoor air quality were evaluated. By analyzing the internal and external difference of temperature, humidity, lighting, CO_2, CO and wind, the figure below shows the difference of exterior temperature and humidity in the displayed continuous period time.

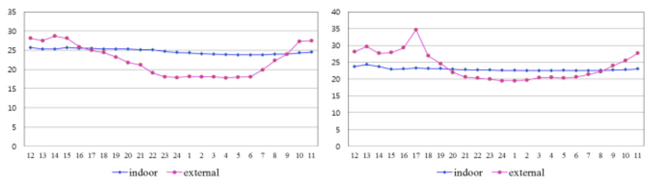


Figure 5. Temperature Distrubution (Left: Do-Rae, Right : Sin-Gwang)

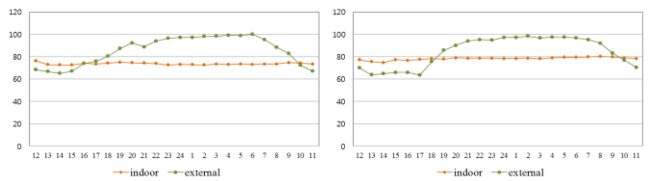


Figure 6. Humidity Distrubution (Left: Do-Rae, Right : Sin-Gwang)

According to the criteria of WHO, the measured value of the sound absorption at the Sin-Gwang village could be translated and converted to 60 points. Its final score seemed pleasant and consistent, after multiplying the weights of sound absorption (4.13). In other words, 60 points in aspects of sound absorption at the Sin-Gwang village can be represented to a point of 2.48 in the overall comfort quality.

C. *The measurement timing and methods*

We were divided for the top five weight elements. For evaluation of the physical elements were analyzed intensively. In view of the fact that psychological factors are evaluate through expert surveys. The top five elements of the physical are day lighting, thermal insulation, noise absorption, solar performance, air cleanness.

- **Insulation:** Heat Perfusion and Thermal Imaging Cameras (to be completed at the winter solstice)
- **Solar Performance:** Simulation and Regulations (to be calculated for two consecutive hours, over a total of 4 hours)
- **Sound Absorption:** Sound Absorption Materials (with drawing creation) by Decibel measurements (to be completed after construction)
- **Daylighting:** Roughness Measurement and Evaluation Mining Rate (to be completed after construction)
- **Air Cleanness**: Pollution Measurements (to be completed after construction)

TDRi is indicated by the ratio of the difference between the room temperature and the room surface temperature. If the insulation state is superior to the result value is converged to 0, because the room surface temperature becomes closer to the room temperature. On the contrary, if poor insulation state is converged to 1, since the room surface temperature becomes closer to the outside temperature.

$$\frac{T\,i - T\,is}{T\,i - T\,o} = TDRi$$

T i = Room Temperature (℃)
T o = Outside Temperature (℃)
T is = Room Surface Temperature(℃)

Figure 7. TDR Calculation Formula

As the next graph illustrates thermal performance evaluation using TDRi, part of the 'The Second performance Evaluation for the Trial Eun-Pyeong Hanok' performed by a governmental research in Korea. The thermal performance evaluation as compared to the heat transmission coefficient data obtained the preliminary assessment. Thereafter, it measured using the infrared camera acquires the present certificate. Most comfort elements are composed of the two procedures, pre-authentication and official authentication

Thermal Performance	TDR	The Probability of Occurrence of Condensation
Excellent	< 0.15	Room temperature 20℃, Outside temperature -10℃, relative humidity below 85% in the performance of condensation does not occur
Good	0.15-0.2	Room temperature 20℃, Outside temperature -10℃, relative humidity below 80% in the performance of condensation does not occur
Bad	0.2-0.3	Room temperature 20℃, Outside temperature -10℃, relative humidity below 75% in the performance of condensation does not occur
Very bad	> 0.3	Room temperature 20℃, Outside temperature -10℃, relative humidity below 70% in the performance of condensation does not occur

TABLE III. THERMAL PERFORMANCE EVALUATION TABLE BY TDR

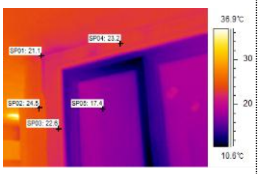
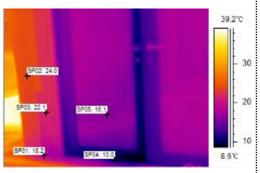
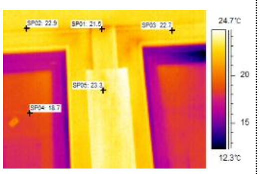
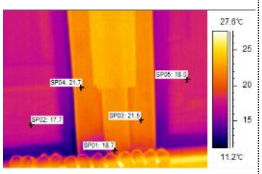
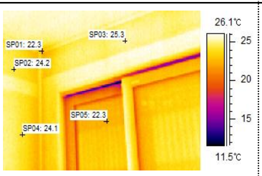
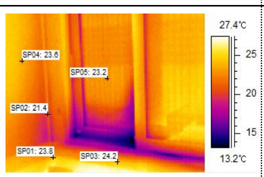
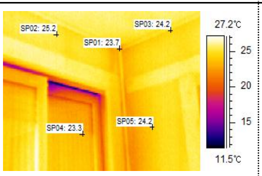
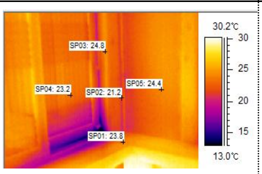
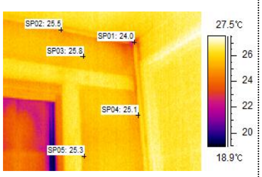
			Temp	TDR
No. 01		SPOT-01	15.9	0.21
		SPOT-02	17.1	0.14
		SPOT-03	17	0.15
		SPOT-04	17.3	0.13
		SPOT-05	15.9	0.21
No. 02		SPOT-01	18.4	0.07
		SPOT-02	17.7	0.11
		SPOT-03	17.2	0.13
		SPOT-04	16.2	0.19
		SPOT-05	16	0.20
No. 03		SPOT-01	15.2	0.25
		SPOT-02	17.9	0.10
		SPOT-03	17.6	0.11
		SPOT-04	16.2	0.19
		SPOT-05	16.5	0.17
No. 04		SPOT-01	14.7	0.27
		SPOT-02	17.3	0.13
		SPOT-03	17.7	0.11
		SPOT-04	17	0.15
		SPOT-05	17.8	0.10
No. 05		SPOT-01	16	0.22
		SPOT-02	16.5	0.20
		SPOT-03	17	0.17
		SPOT-04	16.8	0.18
		SPOT-05	17.3	0.15
No. 06		SPOT-01	13.8	0.34
		SPOT-02	16.5	0.20
		SPOT-03	18	0.11
		SPOT-04	19.2	0.05
		SPOT-05	19	0.06
No. 07		SPOT-01	15.3	0.26
		SPOT-02	16.9	0.17
		SPOT-03	16.8	0.18
		SPOT-04	17.2	0.16
		SPOT-05	19.1	0.05
No. 08		SPOT-01	13.6	0.35
		SPOT-02	16.7	0.19
		SPOT-03	17.2	0.16
		SPOT-04	18.9	0.07
		SPOT-05	19.1	0.05
No. 09		SPOT-01	16.8	0.18
		SPOT-02	18.1	0.11
		SPOT-03	17.1	0.16
		SPOT-04	19	0.06
		SPOT-05	20.6	-0.03
			Temp	TDR

TABLE IV. THERMAL PERFORMANCE EVALUATION USING TDR (SOURCE: J. LEE, 2014)

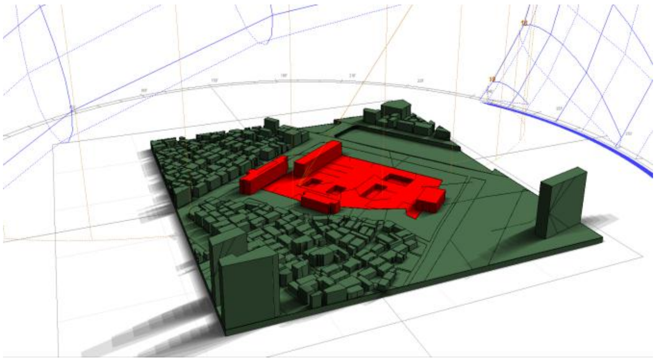


Figure 8. Example for Solor Performance Simulation using Ecotect

In addition, solar performance can be evaluated by simulation analysis using a 3D model. In the case of solar performance it is difficult to evaluate just design books. Therefore it evaluated considering the position information and the surroundings of the building, and evaluation standards are based upon the building raw of Korea (Solar Performance standard of Korea: based on the winter season, consecutive 2 hours in a day, over a total of 4 hours).

The diagram below shows an evaluation time per each comfort factor according to the building production cycle. Preliminary certification is performed in the working design phase and, evaluated through design drawings and 3D modeling, simulation. Final certification is conducted after construction is completed and will vary depending on the method of physical comfort and psychological comfort. First, physical comfort is evaluated by measuring and manual. Psychological comfort is evaluated by expert survey. Current continues being developed for the evaluation method and evaluation time.

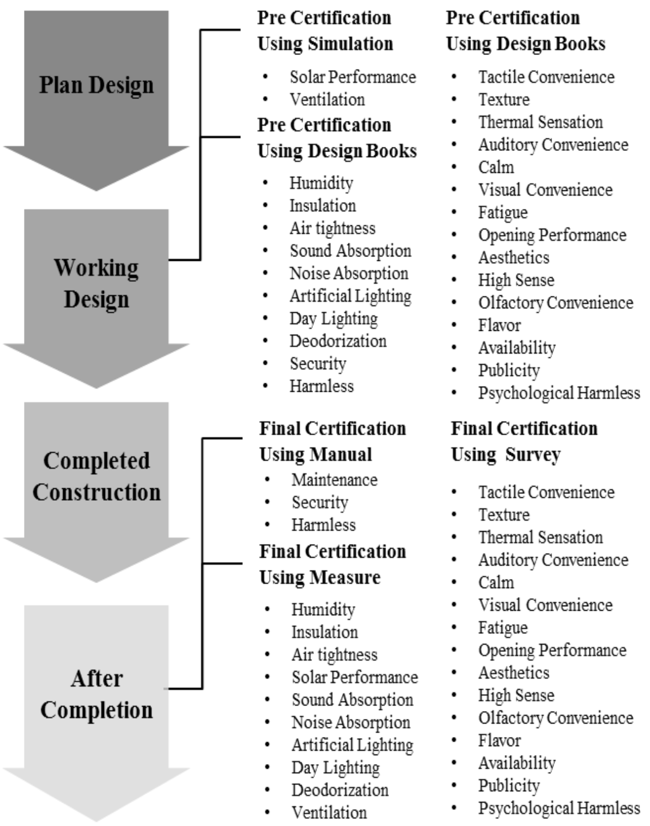


Figure 9. Measurement Timing Diagram

IV. Conclusion

The purpose of this study is to suggest a new assessment method for indoor environmental quality targeting Hanok in Korea. Most quality assessment methods for the indoor environment tend to be performed by only quantitative factors, and relative factors have been analyzed by qualitative evaluation and a method of integrated evaluation has been suggested to resolve this problem. Weights for indoor environment factors were finally established as shown in Table II, after the field survey conducted and the qualitative part of comfort could be assessed by residents.

After a series of measurements for this study, physical comfort elements with the respective equipment have been determined, and psychological comfort factors could be measured through the questionnaire for both residents and professionals. Meanwhile, integrated comfort scores were to be obtained using the weights.

This research has analyzed for and antogonized to the various national and international comfort factors evaluation systems and standards. Based on this analysis, this study suggested the assessment system to be adopted as advantageous accurate evaluation methods. In some comfort factors, heat insulation and solar performance can be seen as materialized.

As a result, a newly suggested comfort evaluation formula is expected to insure high efficiency. The proposed assessment system includes qualitative factors that would show more accurate results. It was turned that the result showed satisfactory records towards the needs of the residents than ever previously.

Acknowledgment

This research was supported by a grant (14AUDP-B070933-02) from Urban Architecture Research Program (Development of Hanok Technology, Phase II) funded by Ministry of Land and Transport Affairs of Korean Government.

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