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Integrated Evaluation for Environmental Comfort in Interior Space of Korean Traditional Residence

[Mu-Jin Jo and Seung-Hoon Han]

***Abstract*— The purpose of this study is to assess indoor environmental quality using physical and psychological analysis presented on the consideration of the traditional houses, called Hanok in Korea. In addition, this paper is to build a diversified, integrated assessment system considering traditional, aesthetic and psychological values. For this study, the degree of integrative indoor environmental quality was analyzed and indoor environmental quality 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 assessing psychological indoor environmental quality. Existing relevant studies about indoor environmental quality assessment system were driven to reveal the quantitative elements of the suggested classification system.**

This study also contains a qualitative in-depth analysis of the indoor environmental quality factor and will examine the effect of those elements. This study has finally proposed an integrated indoor environmental quality assessment system that can assess 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 & Psychological Environment, Physical & Psychological Comfort, Integrated Comfort Evaluation System, Hanok(Korea Traditional Residence), Indoor Environment Quality

I. Introduction

Currently, there are 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 important.

These physical assessment systems and analysis skills have continuously been evolved. However, the way of life for the residents became more complex and complicated, and their requirements are being increased. This is why assessing only physical indoor environmental quality factor is not enough. Therefore, the purpose of this study is to suggest an integrated indoor environmental quality assessment system through combines of psychological comfort factors.

Mu-Jin Jo and Seung-Hoon Han*
School of Architecture, Chonnam National University, Korea

II. Method of Research

A. *Research Process*

This study analyzed indoor environmental quality 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 through the following three stages as shown in Figure 1.

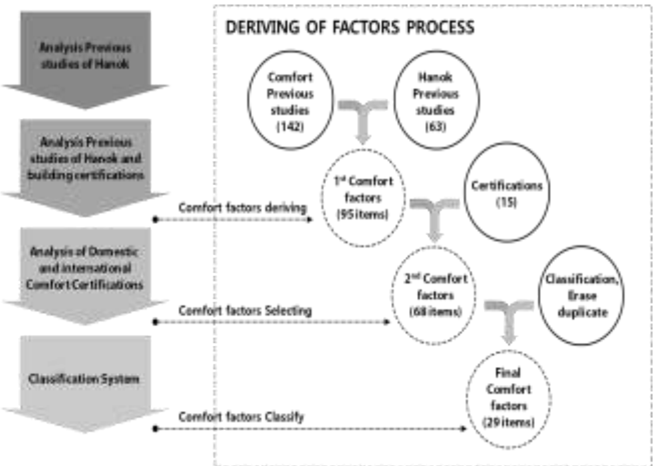

Figure 1. Deriving Process for Comfort Factors

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 reclassifying 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.

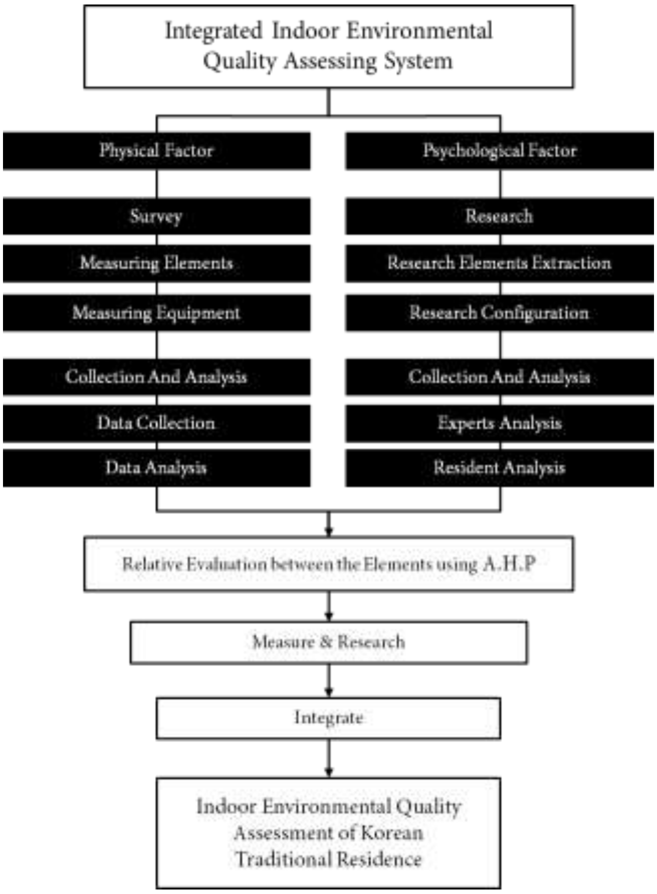

Figure 2. Process of Integrative Comfort Analysis

Then, measured physical and psychological factors were calculated according to the relative importance and by integrating the physical and psychological factors to calculate the overall comfort.

Comfort elements have been classified as shown in the above diagram used to evaluate the relative importance of the AHP. Relative importance of the evaluation could be carried out by a survey of experts. With using the AHP to determine the relative importance of the comfort factor, the respective factor have been measured. Physical factors such as temperature, humidity, air quality are measured by sensors associated in the machine equipment. And psychological factors are primarily assessed through a survey of residents and professionals.

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:

- **Thermal Sensation:** A thermal sensation felt by occupants in the room, the amount of clothing, and the parameters of metabolism, temperature, refers to the result, including the moisture MRT value.
- **Aesthetics:** Within the building as a traditional construction, says the aesthetics of the psychological satisfaction that comes from the outside of the building itself.
- **Visual Fatigue:** Proper combination of artificial and natural light considering the appropriate brightness distribution. Refers to the visual satisfaction felt by the installation location.
- **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.

TABLE I. WEIGHT SETS OBTAINED BY 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

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 (Analytic Hierarchy Process) to determine the weights of qualitative elements. Through this process, the weights between the elements could be set. Weights found by analysis are as the following.

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 different style such as newly-built and traditional. Simplified data measurements have been performed and the results analyzed by a series of simulations.

TABLE II. SITE & SUMMARY OF PILOT TEST

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

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.

Table III is a list of sensor used in the pilot test. The sensor is consists of two environmental sensors and five eco sensors, although the pilot test does not measure all physical comfort factors. Accordingly, the purpose of this pilot test is to collect the database from simple measurements. Then, collected data are sent to rate sensors and relay nodes that can transfer information to analyzable data, and set as one module placed in each room for getting indoor-generated data. Other eco-sensors became classified by a module that each sensor was modularized by collected data type. Modularized sensors are also placed in the rooms.

TABLE III. LIST OF SENSOR UTILIZED FOR THE PILOT TEST

Utilized Sensors		*Specification*	*Apply Factor*
Environmental Sensor	Temperature	Range: -40℃ ~ 120%℃ (max) Accuracy: ± 0.3℃ Response Time: <4 Sec Power Consumption: 30μW	Heat Insulation Property
	Mean Radiant Temperature (MRT)	Range: -55℃ ~ 125%℃ Accuracy: ± 0.5℃ Response Time: 750ms (max) Supply Voltage: 3 ~ 5.5V	Heat Insulation Property
	Relative Humidity	Range: 0 ~ 100% RH Accuracy: ± 1.8% RH Reproducibility: ± 0.1% RH Response Time: <4 Sec Power Consumption: 30μW	Humidity Control
	Anemometer	Range: 0~30m/s, 0~50℃, 0~10,000m^3/h Resolution: 0.01m/s Unit: m/s, fpm, ℃, ℉, m^3/h, L/s, cfm Output: 2×4-20mA, 2×0-10V Omni-directional Flow Measurement	Air Tightness
Air-Quality Sensor	CO	* Analog Sensor: Range: 0 ~ 500ppm Supply Voltage: DC 12V ~ 30V Output Voltage: 4mA (Zero gas) 20mA (Full scale) * Digital Sensor: Supply Voltage : DC5V Output Voltage : TTL (3V Level)	Air Cleanliness
	CO_2	Range: 400 ~ 2000ppm Accuracy: 500ppm = ± 35ppm 800ppm = ± 60ppm 1000ppm = ± 75ppm 1200ppm = ± 90ppm Response time: < 2 min, < 10 min Supply Voltage: 5VDC (±5%) Non-Dispersive Infrared	Air Cleanliness
	Dust	Range (Density): 0 ~ 2.0mg/m3 Range (Particle Size): 1μm more Detection method: Optical detection Supply Voltage: DC 5V Output Type: Negative Logic Pulse Operation Range: 10 ~ 45%, 95%RH less	Air Cleanliness
	VOCs	Range: Toluene 0 ~ 75 (max) Formaldehyde 0 ~ 75 (max) Accuracy: ±7% Detection of the Target: Formaldehyde, Toluene, Benzene, Xylene, ect. Supply Voltage: DC 5V (±1%)	Harmless
	NOx	Range: 200ppm (max) Accuracy: ±10% Supply Voltage: DC 5V (±1%) Output Voltage: 0.5 ~ 5.0V	Harmless

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.

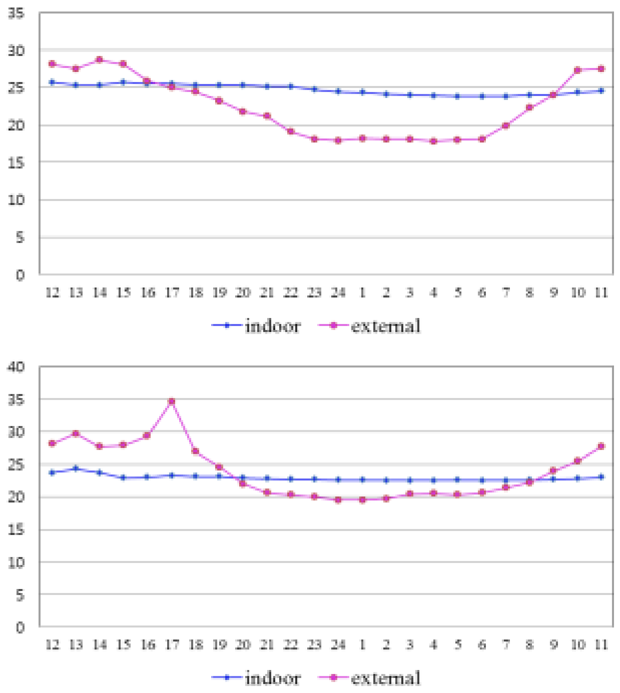

Figure 3. Temperature Distrubution (Up: Do-Rae, Down : Sin-Gwang)

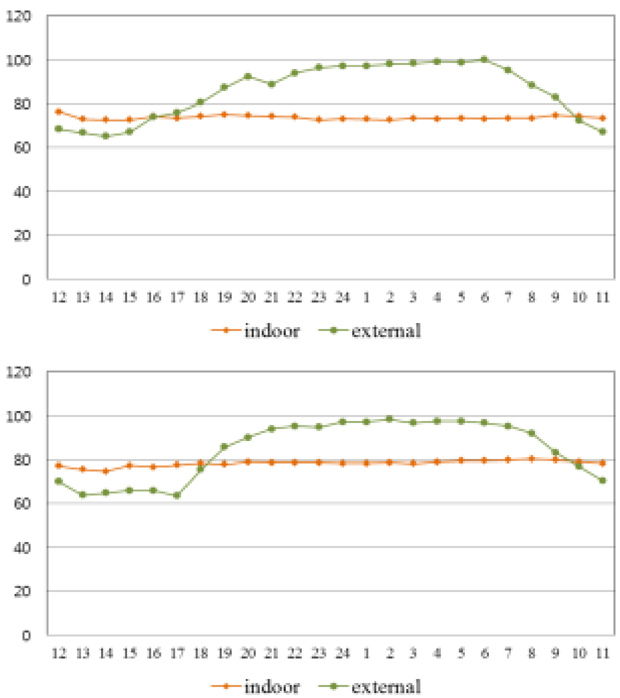

Figure 4. Humidity Distrubution (Up: Do-Rae, Down : Sin-Gwang)

TABLE IV. AIR QUALITY DATA (UP : DO-RAE, DOWN : SIN-GWANG)

Name	***figures***	***Name***	***figures***
Dust	0	Smell	5
VOCs	619	NOX	0
CO2	840	CO	9
Noise	60	-	-

Name	***figures***	***Name***	***figures***
Dust	0	Smell	1~120
VOCs	1~5	NOX	30~60
CO2	460~560	CO	3~12
Noise	39	-	-

The above table is categorizing collected data for dust, smell, air quality such as VOCs, NOX, CO_2 and CO, and noise measure data. The first table is for the data measured at the Do-Rae village which is a Korean traditional Hanok, and the second table is for a newly formed Sin-Gwang Hanok village. Thus, a number of differences in aspects of the indoor environment have been found, although both are called the Hanok in accordance with the material, structure and arrangement.

Measured data, then, could be converted to the score chosen from reliable references such as domestic and international certifications like ASHRAE (American Society of Heating, Refrigerating and Air-conditioning Engineers) standards or LQI (Living Quality Indicators) by WHO (World Health Organization).

Interior noise suitability for use outside noise	$L \leq 30$	5(100)
	$30 < L \leq 35$	4(80)
	$35 < L \leq 40$	3(60)
	$40 < L \leq 45$	2(40)

TABLE V. CRITERIA OF NOISE ABSORPTION SUGGESTED BY WHO

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. This certified way is also to be applied for acquiring the scores of other comfort factors, and finally, integrated comfort rating can be decided from analyzing the whole physical and psychological factors.

C. *The measurement timing and methods*

Determining the integrated comfort factors and comparing Do-Rae traditional village and Sin-Gwang neo-Hanok village fall into the ongoing research, and a series of data for the following factors are being collected by the mentioned settings currently:

- **Insulation:** Heat Perfusion and Thermal Imaging Cameras (to be completed at the winter solstice)

- **Air Tightness:** Blow Door Test (to be completed after construction)
- **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)
- **Ventilation**: Air Circulation Measurement (to be completed after construction)
- **Maintenance:** Checklist from the Maintenance Manual for Hanok (to be completed after construction)
- **Psychological Factors (14 Entries):** Survey (after residency by both residents and professionals)

IV. Conclusion

The purpose of this study is to suggest a new method of indoor environmental quality assessment 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. Then, integrated comfort scores were to be obtained using the weights.

As a result, newly suggested comfort evaluation method 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 before.

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About Author (s):

Mu-Jin Jo
- Master's Program, School of Architecture, Chonnam National University, Korea.
- Research Interests: Architectural Planning Integrative Design, Building Sustainability and Performance Engineering

Seung-Hoon Han
- Professor, School of Architecture, Chonnam National University in Korea.
- Research Interests: Architectural Design, Urban Planning, Building Information Modeling and Performance Engineering