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Utilization of the Evaluation System for Spatial Comfort toward Multi-Layered Public Hanok Facilities

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Abstract: This study aims to present evaluation methods that can evaluate thermal comfort reflecting traditional values of the vernacular architecture in Korea called Hanok, especially focused on modernized public facilities. For this purpose, representative vertically-sectional structures of Hanok has been categorized by the spatial configuration used for public buildings such as school, museum, library and so on. Next, a comfort assessment index was derived to evaluate the spatial comfort performance of Hanok especially with certified domestic standards and indices. Then, predicted mean vote (PMV) has further been selected as the method for the thermal assessment for their interior spaces. As a result, the surrounding conditions showed the least influence on the Hanok comfort and the adjacency type mostly affected the performance of thermal control in the aspects of the habitual sustainability. Finally, Hanok designs could positively be considered and utilized by surroundings and adjacency types that have the most advantages in terms of thermal environment.

Keywords: Hanok; thermal comfort; evaluation system; Korean traditional architecture; residential sustainability; public facilities

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1. Introduction

Recently, various environmental issues caused by the increased use of artificial building materials have emerged, and in the aspect of habitability, health problems such as new-house syndrome and atopy have become a major concern, especially in Korea. This situation has led to the investigation of the original values of Korean traditional buildings called Hanok that are mostly composed of wooden structures with natural building components [1]. Accordingly, the frequency of Hanok construction has gradually increased nationwide, and its dissemination has accelerated through the implementation of public projects.

Cultural identity normally refers to identification with, or sense of belonging to, a particular group based on various cultural categories, including nationality, ethnicity, race, gender, and religion, and it tends to be constructed and maintained through the process of sharing collective knowledge such as traditions, heritage, language, aesthetics, norms and customs [2,3]. Ultimately, all cultures are about the ascription of values and meanings to both tangible and intangible elements of human experiences. As worldwide globalization accelerates, preserving and maintaining cultural identities of a nation is regarded as one of the most important values today.

In this regard, Hanok is a unique architectural type in Korea that retains its own cultural identity as shown in Figure 1. Traditional buildings such as Hanok have had a distinctive shape with such features as roof formation and building materials normally used, depending on the climate, lifestyle, environment and location of the country in which they were built. Each style reveals architectural characteristics and internal meanings associated with actual conditions of each region, including cultural individuality and peculiarity inherent in ethnicity and shapes in forms of the habitability [2].

Figure 1. Hanok as a Korean traditional building.

According to the '2017 Statistical Report of Hanok' by the Architecture Space Research Institute operated as a research unit under the Ministry of Land, Infrastructure and Transport (MOLIT) of the Korean Government, the tentative number of Hanok buildings in Korea is 376,677, accounting for 5% of the total buildings, and it is estimated that 26.2% of Hanok have totally-wooden structures. Their main uses are distributed between housing (46.6%), community facilities (34.4%), religious facilities (9.3%) and so on, which shows that the proportion of building uses in comparison to residential and public purposes is similar. Thus, it can be said that public Hanok facilities are classified as one of major architectural styles that could provide places and spaces for performing traditional sustainability with the category of residential use as well [4].

Nevertheless, the number of traditional Hanok building constructions decreased from 1500 to 770 according to the '2011–2015 Hanok Permit Records' by MOLIT, and it shows a steady decline of 15% in average per year. In contrast to this trend, the number of building permits for wooden and tiled contemporary buildings has increased from 2800 to 3600 at the same period [4]. This might be caused by the fact that the traditional buildings, regarded as old-styled rather than traditional, have certain architectural weaknesses, and as a result, the needs for Hanok are gradually declining which represents a serious problem and a new challenge in the succession of the cultural heritage. Therefore, various new styles of Hanok are being designed and implemented to resolve the above issue, and a series of specimens are being developed and proposed by combining traditional concepts and contemporarily-modified elements such as multi-floored or multi-layered structures, large-spanned forms, use of inside slopes, and many other suggestions.

Therefore, it is necessary to evaluate Hanok buildings comprehensively in consideration of their history, tradition, place, image, memory, and symbolism. In other words, it is necessary to establish a multi-dimensional evaluation model in order to preserve the strengths, values, and spatial performance factors of Hanok. Previous studies, however, show that there is a lack of complex interest in the integrated evaluation system and detailed guidelines in terms of habitability including the spatial comfort. Lee and Park, in this sense, raised the fact that some critical issues have emerged for Hanok in comparison to contemporary buildings, such as narrow space dimensions and the adaptability of the layout for a modern lifestyle, poor insulation, weak fire resistance, expensive construction costs and so on [5].

Jeong et al., on the other hand, raised another issue, that of maintenance and sustainability as a main factor in the habitability of traditional buildings, especially for Hanok. They emphasized that architecture has a duty to society to preserve the past, provide the possibility of retaining the present on the strength of culture and tradition, and keep the performance by sufficient monitoring to see whether Hanok maintains its habitability functions accordingly [6]. Han et al. also stated that Hanok is a settlement space built according to the customs of residents who have lived in the local community since the past, and it is necessary to consider it by expanding its meaning to not only visual and physical characteristics but also the psychological and intrinsic space derived from them [7].

Currently, Hanok research is underway in the investigation of the contemporary configurations and spatial composition by the combination of a new recognition of standardized methods. It is necessary to evaluate thermal factors for actual users or residents living there, and to simultaneously find a unique performance evaluation method that is suitable for Hanok [8,9]. This study tried to confirm the thermal environmental conditions of the interior space of Hanok from the perspective of the spatial design to broaden the scope of their contemporary application and to present its new types that inherit traditional values [10–12]. Specifically, this research attempts to determine the thermal properties of each indoor space by classifying Hanok structures according to the vertical connection type of the multi-story space from an environmental point of view based on the proposed analysis results.

The scope of this research has been limited to public Hanok facilities in the area with the highest occupation frequency by users as the target buildings that were performed with the instrumental monitoring. As the first stage of the investigation, classification conditions were derived to examine the multi-layered Hanok public buildings by the vertical connection type of architectural spaces. Then, previous studies and references about spatial comfort were reviewed to see the most suitable application to be applied to and predicated mean vote (PMV) was chosen for this research [13]. Next, evaluation factors for thermal environment of the main indoor space of target buildings were measured to calculate the PMVs of each space. To induce the tendency of the spatial comfort as a result, the change trend of PMV calculated by the measured environmental factors, the average PMV for each time period according to the building operation schedule, and the range of changes in maximum and minimum PMVs according to the type of activity have been compared and follow-up analyses including the advantages and disadvantages with new challenges of Hanok have been performed.

2. Methods

2.1. Classification of Vertical Connections in the Hanok Space

The general classification of the vertical connection method of the building space is normally based on its spatial arrangements and circulation, and in the study of Lee, it could be divided into four types as shown in Table 1: a surround type in which space exists, an insertion type that is interlocking between spaces, an adjacency type in which spaces are vertically attached but not physically connected, and an interspace type that is indirectly connected through transition spaces. The characteristics of each type would be described by psychological and symbolic values of each space as well [14].

Table 1. Types of vertical space connections.

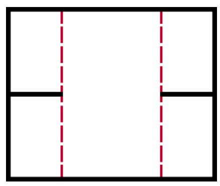
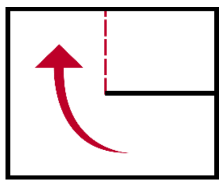
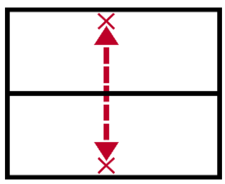
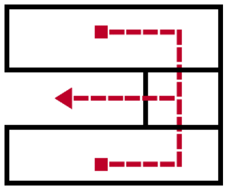
Type	Definition	Composition
Surround	Partitioning a space in another space	
Insertion	Penetrating into another space by expending a specific space	
Adjacency	Arraigning each space vertically	

Table 1. *Cont.*

Type	Definition	Composition
Interspace	Connecting indirectly through interspaces	

Since the surround type penetrates all vertically constructed spaces or floors, it has a strong influence on all connected spaces, and has the characteristic of centrality, hierarchy, openness and contrast. The insertion type can directly feel the psychological changes according to movement through the combination with the vertical circulation system and could be classified as the most dynamic vertical connection type. The adjacency type has universality as the most common connection method and provides continuity in the vertical direction to the space [15]. Finally, in the interspace type, the connection between the inside and the outside is revealed due to the properties of the transition space, and thus the sense of spatial expansion could normally be felt.

2.2. Evaluation of the Thermal Comfort of Hanok

Various evaluation indices of thermal comfort exist as evaluation indicators such as Universal Thermal Climate Index (UTCI), Wet-Bulb Glove Temperature (WBGT), and Standard New Effective Temperature (SET), related to the human perceived temperature. However, these indicators are classified as a derivative concept that corrects limits and errors of the external thermal environment evaluation of PMV developed originally by Professor Fanger of the Danish Institute of Technology. PMV is an official evaluation index used to evaluate for the thermal comfort in a space occurred differently by user's thermal characteristics and environmental factors that could affect the human body temperature [16]. Environmental factors are directly reflected to the calculation of PMV and include dry-bulb temperature, mean radiant temperature (MRT), relative humidity and air speed. There are also clothing level (CLO) and metabolic rate (MET) as human factors that are determined by user conditions in a space. It is possible to calculate official PMVs through the above six factors, and the calculation of predicted percentage of dissatisfaction (PPD) is performed concurrently as the average response rate for spatial comfort.

According to the International Standard Organization ISO 7730 norm (Ergonomics of the Thermal Environment), where the official regulation for PMV is defined, the comfort range of PMV based on 99% PPD is −0.5 to 0.5 depending on the building category, and it can be extended up to level −1 to 1 at reduced 95% PPD [17]. When the calculated value of PMV is distributed within the above-mentioned range, it is determined that the user may feel thermal comfort in the corresponding environment. For this study, among vertical interconnection types of Hanok spaces, the interspace type was regarded as an extensive case that can appear in a multi-layered structure composed of three or more floors. Therefore, three vertical connection types except for the interspace were set to distinguish target buildings to be analyzed for comparisons.

A study performed by Choi et al. reached the conclusion that "*the main factors composing the indoor environment quality (IEQ) are classified into thermal comfort, indoor air quality (IAQ), and visual comfort, and among these factors, the degree of thermal comfort is decided by predicted mean vote (PMV), one of the thermal comfort indices*". However, they insisted that the individual factors like CLO and MET are difficult to measure objectively and accurately due to the real-time rate of change in the heat production of the human body, while physical factors can be measured simply with sensors [18].

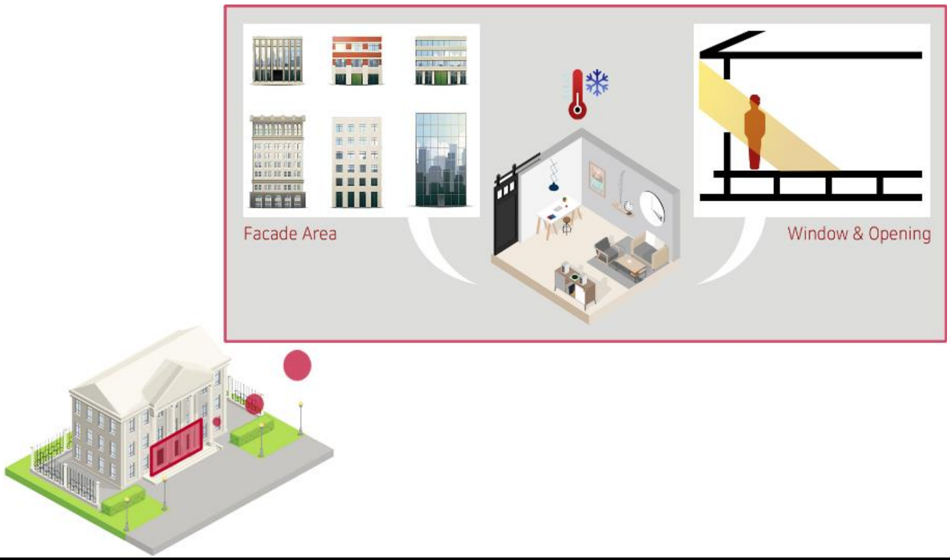
Choe and Han also insisted, in a paper titled 'Applicability of Assessment Indices for Hanok-User Sensory Comfort Based on Visual and Tactile Comfort Evaluation Indicators', that a combined PMV and daylight glare probability (DGP) would be applicable to fix the limitations caused from irregular human environment especially with the sensory factors in a comprehensive thermal and daylighting conditions. This means that an individual comfort factor like PMV would be widely challenged due to its inaccuracy, and a qualitative method like a field survey from people could adjust the problem as suggested by Korean Standard (KS) 6300-1, Examination method for Hanok—Part 1: Comfort [19]. Therefore, it would be necessary to compare the calculation results from the standard and the actual sensations of users and/or residents in target spaces.

Although PMV has a limitation that may induce errors caused by shadows in the process of evaluating the thermal environment from an external space, it is still used as a major evaluation index for assessing spatial thermal comfort currently [20]. In addition, PMV has already accepted institutional recognitions as an international certification standard, and it seems to have a certain advantage to be applied for the analyses. Therefore, PMV has been selected as an evaluation mechanism for performing evaluation for spatial thermal comfort to target Hanok facilities.

3. Analyses

3.1. Measutenent Settings

A set of equipment and loggers have been installed as data collection tools for the PMV calculations to be analyzed at the location where the fluctuations most sensitive to environmental changes can appear in the main space of the selected target buildings. As shown in Figure 2, specific installation conditions of the equipment were defined as the area with an opening in the front elevation of the main space. The opening properties of the front part can be seen as the area in which the environmental conditions of the interior space respond most sensitively to changes in the external environment such as the sun and wind. Then, a series of measurements were carried out at the location with the weakest environmental performance in the space to acquire the maximum range of the environmental change for the indoor space.



Evaluation Index	Measure Value through the Test Method
Thermal Comfort	Average PMV Based on CLO 0.7, MET 1.2

Figure 2. Spatial conditions and measurement settings of target spaces.

The essential environmental factors to be measured for the PMV calculations were dry-bulb temperature, MRT, relative humidity, and air speed. In order to collect accurate data, a Testo 480 device (Testo SE & Co. KGaA, Lenzkirch, Germany) certified according to the European Standard (EN) 12599, ISO 7730 and ISO 7243 has been utilized as a comprehensive environmental logger. The target facilities of the analysis were finally chosen from twenty-nine public Hanok facilities in eight sites built through research projects supported by MOLIT of Korean as presented in Table 2. Haonks in the Gangneung Hanok Village coded C-1 cannot be classified as public facilities because they are currently being used as commercial accommodation properties. Eunpyeong Community Hall (C-3) and Sunchang Kindergarten (C-7) are als, frequently used by specific user groups, and therefore, they were excluded during the selection process due to possible weaknesses in the data that are difficult to regenerate for general public uses. Yongin Modernized-Hanok Testbed (C-4) and Naju Agricultural Hall (C-6) are classified as event spaces for temporal use like festivals and an experiment without regular activities, and so it is hard to provide a proper dataset of indoor environments that meets the purpose of the study.

Table 2. Outlines of candidate target Hanoks.

Code	Candidate Sites	Design Outlines			Main Figures
		Site Area (m^2)	Gross Floor Area (m^2)	Use	
C-1	Gangneung Hanok Village	12,300	1318.5	Accommodation	
C-2	Eunpyeong Literature Museum (Selected to be T-1)	273.9	249.16	Exhibition	
C-3	Eunpyeong Community Hall	361.88	142.2	Convention	
C-4	Yongin Modernized-Hanok Testbed	-	126.18	Residential	
C-5	Suwon Exhibition Center of Hanok Technology (Selected to be T-2)	2661	946.32	Exhibition	
C-6	Naju Agriculture Hall	6615	263.25	Convention	
C-7	Sunchang Kindergarten	900	446.17	Education	
C-8	Seoul Jeungsoo Elementary School (Selected to be T-3)	15,991	3236	Education	

For this reason, among twenty-nine candidate Hanok buildings, Eunpyeong Literature Museum coded C-2 to be T-1, Suwon Exhibition Center of Hanok Technology (C-5 to T-2) classified as exhibition facilities, and Seoul Jeongsoo Elementary School Library (C-8 to T-3) categorized as educational property, were selected for the final analyses. The vertical connection types of each selected space for analysis belong to the surround, insertion, and adjacency classes in order [21,22]. The test schedule was set to regularly measure during time periods with similar climatic conditions for two weeks before and after, centered on the summer solstice with the longest sunshine hours based on the twenty-four solar terms reflecting the seasonal characteristics of the Korean Peninsula. The measurement interval of the data collection by the logger was set to 5 min and carried out for a total of twenty-four hours, and recorded data were converted into an average value of each one-hour period to calculate an average PMV for the time settings.

3.2. Analysis Parameters

Environmental data and user conditions are required for the calculation of PMV for spatial thermal comfort evaluation as mentioned previously. First, environmental factors can identify physical characteristics of a place or a space according to the vertical connection type of the Hanok structure. Therefore, four environment-relative parameters to the calculation of PMV were set as independent variables. Then, user conditions need to be controlled separately, because they are not included in the environmental properties of the building. Therefore, CLO and MET were classified as control variables as presented by ISO 7730 by setting 'Wearing Y-shirts and Trousers to CLO 0.61′ and 'Standing in the Target Space to MET 70′ to be controlled. In addition, according to the type of activity of the building user, the highest MET was set as 'Walking (100)', and the lowest MET was defined as 'Sleep (40)' at CLO 0.96 that were consistent with the set activities in order to compare the analysis ranges of PMV as presented in Table 3.

Table 3. Analysis settings of MET rates and CLO levels.

Category	Metabolic Rate	Clothing Level
Minimum	Sleeping (40)	Sleepwear (0.96)
Average	Standing (70)	Y-Shirt and Trouser (0.61)
Maximum	Walking (100)	

On the other hand, when measuring the climatic conditions of the measurement parameters it turned out that stable controls of the external environment were not practically possible, and therefore, PMV was calculated by securing the data at the time point showing climatic characteristics on a clear day with no precipitation with low total cloud cover within the measurement period. During the measurement, cooling and heating utilities that could affect the thermal environment, were not operated, and it was performed in a range of the main living area in order to prevent data contamination due to the deterioration of human behaviors in spaces.

Finally, all the target buildings to be analyzed are public facilities and have a certain operating schedule. Accordingly, it is possible to set the activity type by the building operation schedule, to calculate the average PMV for each time period, and to understand the range of PMV fluctuations by the activity type. And, a measurement test was planned through a series of variables and condition settings described above, and the final analyses for target spaces were executed as indicated in Table 4. Figure 3 shows the operation schedules of target Hanoks applied to the PMV calculation for each time period.

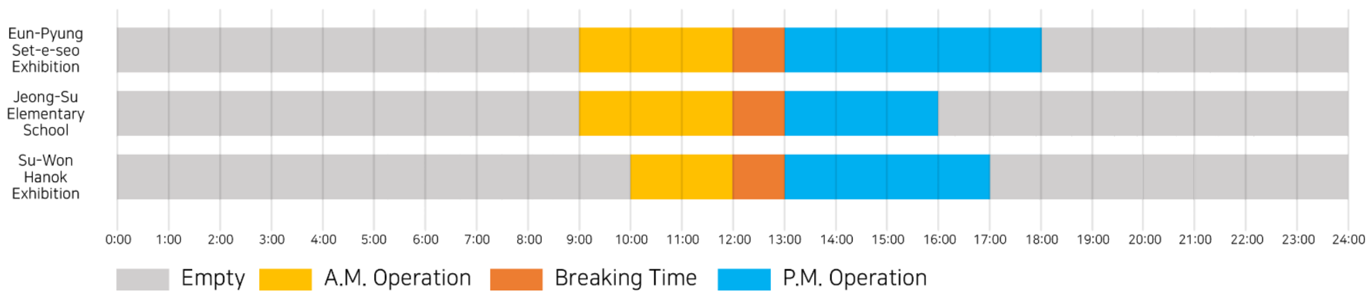
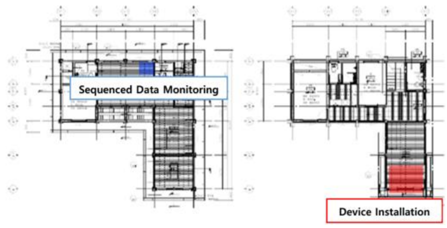
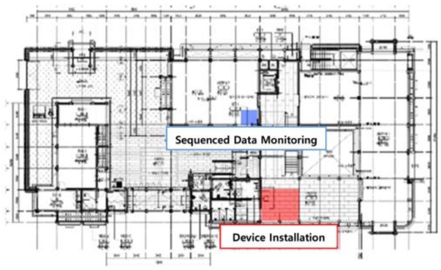
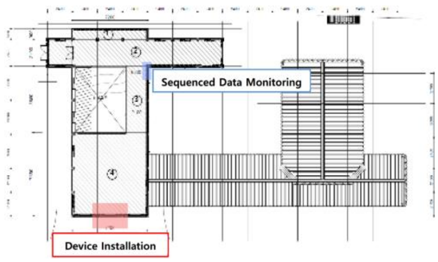


Figure 3. Operation schedules of selected target Hanoks.

Table 4. Plans and measurement scheme of final target Hanoks.

Code	**Target Sites**	**Design Outlines**		**Plans and Measurement Points**
		Location	**Vertical Connection Type**	
T-1	Eunpyeong Literature Museum (C-2)	Seoul	Adjacency	
T-2	Suwon Exhibition Center of Hanok Technology (C-5)	Suwon	Surround	
T-3	Seoul Jeungsoo Elementary School (C-8)	Seoul	Insertion	

4. Results

4.1. Change Tendency of PMV Measured over a Unit Period

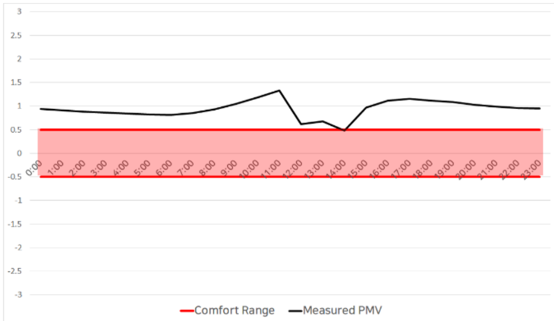
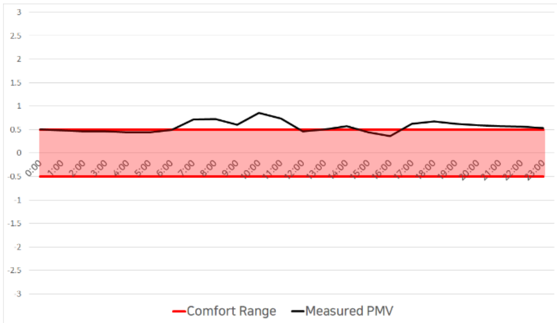
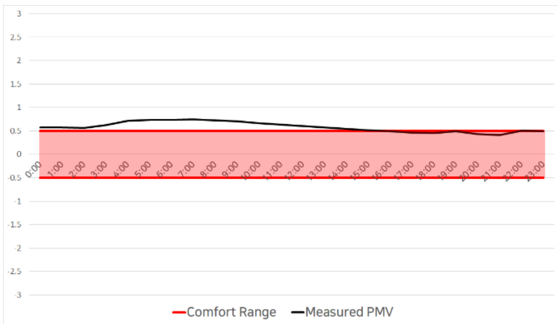
The distribution of PMV calculated by applying environmental data per unit period measured from each building is summarized in Table 5, and CLO and MET rates have been set as control variables. In the case of T-1 classified as an adjacency type, the hourly PMV calculation range was 0.48 to 1.33, indicating the highest type of thermal discomfort among all analysis subjects. In addition, all calculated PMV values are out of the range of −0.5 to 0.5 that means the PPD 99% comfort range suggested by ISO 7730. Therefore, it was found that all users who use the property of T-1 at summer solstice would feel a 'Slightly Hot' or 'Hot' sensation regardless of the usage time.

On the other hand, PMV of T-2 classified as an insert type and T-3 as an insertion type showed that seasonal climatic characteristics did not affect the indoor space relatively compared to T-1. The hourly PMV dataset measured at T-2 was in the range of 0.36 to 0.86, and the time period outside the comfort range based on PPD 99% was fifteen hours in total indicating that the unpleasant section was the shortest. Accordingly, it was analyzed that building users could feel both 'Comfort' and 'Slightly Hot' sensations in the indoor space, and the proportion of a unit period related to 'Slightly Hot' was higher.

The case of T-3 also showed specific thermal environmental characteristics similar to those of T-2 with a PMV level of 0.40 to 0.74, and a total of seventeen hours is classified as an unpleasant section. In addition, the target space T2 is also likely to feel the thermal comfort as 'Comfort' and 'Slightly Hot' sensations inside, and it is analyzed that the time to feel 'Slightly Hot' sensation becomes relatively long. However, it is judged that a close comparison to the surround type is necessary in terms of the thermal environment, since the section where people feel thermal discomfort would be higher than that of T-2.

As a result of comparative investigations about the trend of PMV fluctuations over unit periods for three different types of public Hanok facilities, it was determined that T-1, an adjacency type, has provided the most unpleasant thermal environment and its thermal environment needs to be supplemented. Conversely, the type with the least variation in thermal comfort was found to be an insertion type, T-3. However, T-2, a surround type, is expected to have the most favorable thermal environment, if the indoor thermal environment is evaluated from the viewpoint of the minimum PMV value.

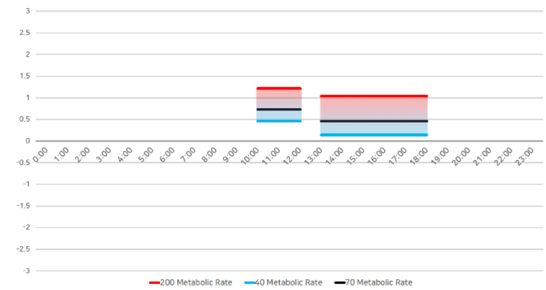
Table 5. Measured hourly PMVs for target Hanoks.

Code	Type	Measured PMV			Analysis Results
		Minimum	Average	Maximum	
T-1	Adjacency	0.48	0.94	1.33	
T-2	Surround	0.86	0.56	0.36	
T-3	Insertion	0.74	0.58	0.40	

4.2. PMV Fluctuation Range per Operation Schedule and Activity Type

A comparative analysis was performed on the average PMV of usage time per operation schedule and the range of changes in PMV according to the activity type among environmental data of the target to be analyzed and as summarized in Table 6. As a result of calculating the average PMV for each morning and afternoon operation hours of T-1, it was found that the morning hours would provide various PMVs ranging from 0.94 to 1.54 and the afternoon hours from 0.59 to 1.34, depending on the user activity type. According to activity type changes in both periods, it was found that users would not feel 'Comfortable' but rather 'Slightly Hot' or 'Hot' inside the space. In addition, PMV is also 1.17 and 0.89 when the user is standing in an indoor space, and it indicates that users feel 'Slightly Hot' or 'Hot' in the indoor space, despite not taking a specific action.

Table 6. Calculated PMV ranges per operation schedule for target Hanoks.

Code	Schedule	Measured PMV			Analysis Results
		Met 40	Met 70	Met 100	
T-1	A.M.	0.94	1.17	1.54	
	P.M.	0.59	0.89	1.34	
T-2	A.M.	0.46	0.73	1.22	
	P.M.	0.14	0.46	1.04	
T-3	A.M.	−0.18	0.91	1.34	
	P.M.	−0.39	0.78	1.24	

On the other hand, in the case of T-2 and T-3, they were similar to T-1 in terms of evaluation criteria of spatial sensations, but relatively less thermal discomfort was derived. The morning and afternoon PMV fluctuations of T-2 were 0.46 to 1.22 and 0.14 to 1.04 respectively, and the PMV level of 0.73 and 0.46 was calculated when the user stood still in the indoor space. If the user does not take any action, there is a possibility that the user does not feel thermal discomfort in the indoor space or senses relatively less heat, and this tendency becomes clear over time.

This tendency is similarly observed from T-3, but the distribution range of the indoor thermal environment shows the widest change according to the user behavior type. In fact, the range of PMV fluctuations at T-3 is −0.18 to 1.34 and −0.39 to 1.24 depending on the morning and afternoon hours respectively, showing the widest range of PMV fluctuations. Based on these results, in terms of creating an indoor thermal environment by mechanical utilities, T-3 can be classified as the most difficult type to control the thermal environment by the activity type. Nevertheless, it is judged that T-3 users would still feel a sense of 'Comfort' or 'Hot'.

As a result of our comparative analyses for the average PMV by operating hours of three target spaces categorized by the vertical connection type, the most effective case by climate characteristics for to the season is judged to be the adjacency type, and relatively, the surround type is appeared to be least affected by seasonality. However, it can be classified as the easiest to control and maintain thermal environment of the indoor space, since the adjacency type has the narrowest range of fluctuations in PMV according to the user activity type. The type with the largest fluctuation has been investigated to be the insertion type that showed the measurement result in which the fluctuation range of PMV was mostly changed by the user activity type in the indoor space. To verify the accuracy of the result, an additional survey for the actual user sensations has been performed and the following is an example of the comparative investigation, although it could not cover the entire period due to the difficulty of COVID-19. The right half of Figure 4 shows the similarity of the tendency between the calculated results and the sensory responses, while the left half indicates a gap due to insufficient data due to the pandemic situation.

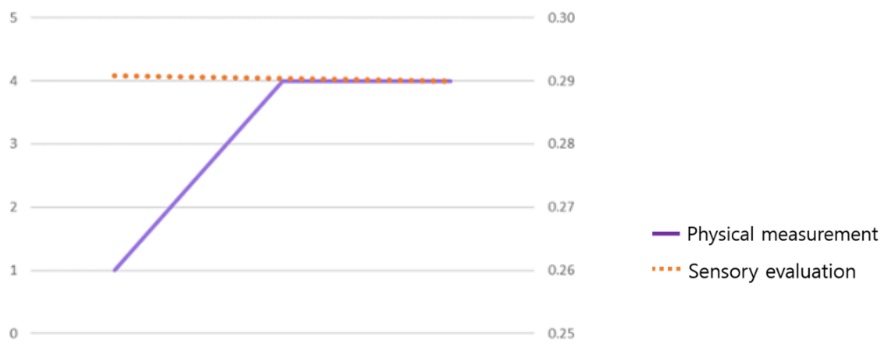


Figure 4. Exemplar comparison of physical measurements and sensory evaluation for a target Hanok.

In sum, the type related to the most seasonal influence was the adjacency type, and the least influence was shown by the insertion type. When considering the vertical connection type of Hanok in environmental aspects of the building, it is more advantageous to design in the direction of forming a vertical connection by constructing a transition space on the exterior wall or intermediary space together as an indoor space, and a thermal environment can simply be controlled in this way.

In addition, when considering the use of active facilities, the type with the biggest advantage in creating an optimized indoor thermal environment appears to be an adjacency type, and it is judged that a close examination of the active facility is necessary, if the space is composed of an insertion type. For target public properties, the operation of active facilities could also be regarded as an essential parameter, not optional. Therefore, it would be possible to create the most advantageous environment in terms of indoor thermal comfort by dividing the space in an adjacency type rather than vertical space connection by the insertion type, when using a Hanok building as a public facility.

5. Conclusions

Hanok is a unique architectural style with a cultural identity in Korea. Hanok facilities are traditionally used as a public place and/or a private space that can control the physical environment and subjective psychological state at the same time, and it is necessary to comprehensively evaluate the psychology of the residents living there, as well as the quantitative evaluation such as measurement and/or monitoring in a technological sense for instance. Finally, this study aimed at proposing an evaluation system that can assess spatial comfort with retaining the cultural values of public Hanok facilities. This study tried to confirm the thermal environment conditions of the indoor space of Hanoks from the perspective of the spatial design to broaden the scope of various contemporary utilization and to suggest new types that inherit traditional values in public. In addition, this study has attempted to reveal thermal properties of Hanok spaces by classifying the vertical connection type of the multi-layered structure from an environmental point of view.

This study also aimed to present a design direction for public Hanok buildings, and therefore, the vertical connection type of Hanok space and evaluation indices of thermal environment were derived through previous references, and they were applied to three target buildings that were selected by detailed research requirements. As a result, it was found that the type with the least influence shielding from the external environment was the surround type, and the type with the easiest thermal environment control was found to be the adjacency type. On the other hand, in the case of the insertion type, the effectiveness was relatively low in terms of blocking the external environment with the most weakness in terms of controlling the thermal environment. It was also derived that building designs applying adjacency and surround type layouts rather than an insertion type would have the most advantages in terms of thermal environment, when planning multi-layered Hanoks, especially in the context of the design process of public buildings.

However, the fact that it was impossible to control the external climatic characteristics completely and that environmental conditions affective to the thermal comfort were not controlled in more detailed aspects, such as the space size and the user occupancy of the selected building, would be the most notable points of view for further study. It could also be pointed out as a limitation, in addition, even though the use of the building is similar, it could also be happened that operating hours for each building do not match due to the detailed characteristics of the facility.

Nevertheless, this study has meaningful value as a source of practical data for the spatial planning stage of Hanok facilities in the process of establishing guidelines for the design direction of public buildings especially. In addition, if it is possible to suggest an optimized evaluation system for determining comprehensive environmental comfort performance values, then public Hanok buildings will be more reasonable structures in terms of sustainability for the future, and a series of studies could be followed and conducted with more diverse environmental points of view in mind.

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