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THE RELATIONS IN THE PLANAR AND SECTIONAL SCALES AND KAN COMPOSITION OF TRADITIONAL KOREAN ARCHITECTURE

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ABSTRACT: In traditional architecture of East Asia, a distinct feature is the clustering of multiple buildings to form a single-unit. Therefore, the expansion of a single-unit building has not been given as much consideration as in Western architecture. This study aims to examine the planar and sectional scales in the Kan composition of traditional Korean architecture and to identify the limitations of scale expansion. Although previous studies have focused on the characteristics of the plan and section, this study is the first to conduct a comprehensive survey of all nationally designated cultural properties and derive statistical significance. The typical plan configuration consists of three bays for both the front and side, which emphasizes the facade. However, a plan with a side of five bays is relatively uncommon, and there are no examples of buildings in Korea exceeding five bays. This can be attributed to the structural characteristics of East Asian wooden architecture, where expansion to the side is difficult and the desire for depth and height is not prominent. In contrast, China and Japan have buildings with a side length of six and seven bays, respectively, allowing for a more expandable limit of scale.

KEYWORDS: traditional Korean wooden buildings, Kan Composition, scale of Kan, limitations of scale expansion

1 INTRODUCTION

Traditional wooden architecture in East Asia is comprised into three main components: the foundation, body, and roof. These three parts are constructed into a single building through the joining method of the structural members. This study focuses on the planning and scale of the body section. In the process of constructing wooden architecture, the initial consideration is to establish a floor plan, which subsequently informs the creation of a section plan and elevation plan. The floor plan plays a crucial role in determining the overall size of the building. [1]

In traditional East Asian architecture, the floor plan is divided into units called "Kan" (bay). Kan is a term with a wide range of meanings, including length, width, the width between columns, or the unit area where four columns are placed. [2] This is due to the development of East Asian architecture based on the post and lintel structure. The length of one Kan, or the distance between columns, must be determined on the floor plan [1]. A standard Kan is approximately 8ja (about 2.4m), but the size may vary depending on the dimensions of other wooden components such as purlins and the distance between the body and the bracket set (gongpo) that connects the body and the roof. [2]

In traditional wooden architecture, a single building is constructed using a combination of bays. Therefore, the number of Kans is a vital measure in determining the size of the architecture [1]. The single building is composed of the Purlin-Direction, which makes up the façade, and the Beam-Direction, which makes up the side. The arrangement of bays is achieved by combining the number of bays in the Purlin-Direction and the Beam-Direction. This study aims to examine the scale of the façade, side, and height, based on the configuration of the bays, and to understand the characteristics and relationship between the plan and section in Korean traditional wooden-structure buildings. Although some studies have investigated the characteristics of the plan and section in the past, this study is significant as it conducts a comprehensive survey of representative cultural assets throughout the country and statistically processes them, thereby providing a more accurate understanding of the characteristics of Korean traditional architecture.

In traditional architecture across Korea and other parts of East Asia, it is common for individual buildings to be clustered together, leading to less emphasis being placed on the expansion of a single building's scale when compared to Western architecture. The objective of this study is to investigate the extent of the expansion of scale achieved in traditional Korean architecture. The evolution of Korean architecture has moved towards dispersing functions across multiple buildings to form clusters. As a result, the depth of space cannot be fully appreciated from the entry point of a single building or house (chae) alone. Since the chae is composed of several kan and differentiates, [3] the investigation of kan is crucial for understanding traditional Korean space. Similarly, the scale of individual buildings in traditional Chinese architecture is also limited in terms of expansion due to

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the fact that its units are based on a cluster composed of "number".[4]

2 METHODS

The Korean government manages a total of 489 buildings constructed using the traditional-timber structure that are of historical or archaeological significance. Among these buildings, 238 excluding residential buildings and clusters of multiple buildings have been selected and classified into categories based on their function, which includes Buddhist temples, Confucian schools, royal halls (palace), pavilions, shrines, government-managed buildings, residential buildings, and others. The exclusion of residential buildings was due to their high frequency of practical use, resulting in a wide range of styles that do not preserve traditional forms. This study aims to investigate the characteristics and limitations of the floor plan and height of the 238 buildings, including the number of bays, scale, relationship between the core bay (jeongkan) and side bay (hyeopkan), and external and internal heights, as well as to classify them by their function. In traditional Korean architecture, the function of a building plays a crucial role. During the traditional era, buildings were differentiated based on their formality and scale depending on one's social class, [2] which applied not only to residential buildings but also to public buildings such as temples and schools. Previous studies have suggested that the internal spatial structures were modified according to the building's function, not only in terms of scale but also in terms of the arrangement of internal columns to create appropriate spaces. [5]

Upon classifying the floor plans according to their architectural type, the findings revealed that Buddhist temples comprised approximately 45% of the total number of buildings, followed by Confucian schools at 20%, palaces at 10%, pavilions at 11%, shrines at 7%, government-managed buildings at 6%, and others at 1%. These results suggest that Buddhist-related facilities represent a significant portion of the traditional timber-structured buildings in Korea, comprising almost half of the total number of structures examined

3 SCALE OF KOREAN WOODEN TRADITIONAL ARCHITURE

3.1 Composition of Kan

Upon examination of the layout of 238 buildings, it was determined that 92.0% (219 buildings) of the structures adhered to a rectangular shape with perpendicular columns. In analyzing the size of the kan (bay) within these structures, a 3x3 structure with Purin-Direction 3-bay type (front) and Beam-Direction 3-bay type (side) was identified as the most frequent, accounting for 26.0% (57 buildings) of the surveyed structures. The subsequent most common layout was a 3-bay front and 2-bay side structure, which constituted 18.3% (40 buildings). A layout with a 5-bay front and 3-bay side was found in 15.5% (34 buildings), whereas a 5-bay front and 4-bay side layout was present in 8.2% (17 buildings). Structures with a 5-bay front and 2-bay side were discovered in 4.1% (9 buildings). The remaining bay configurations were scarce, with only 1-3 structures per configuration. In summary, the layout with 3 bays along the front was the most commonly found in the survey. [6]

Table 1: Classification of Research Subjects by Composition of Kan/Building Type

Bay		Number of Buildings							
P	B	BT	C	R	P	S	G	E	Total
1	1	2							2
	2	1				2			3
2	2						1		1
3	0	1							1
	1	3	3						6
	2	21	3	5	6	2	3		40
	3	44	7	1	1	2	2		57
	4	4	1				1		6
4	2		2						2
	3	1	1		1				3
	4				1				1
5	1		2			1			3
	2		2	1	1	2	3		9
	3	17	12	2	1		1	1	34
	4	4	3	3	4	2	2		18
	5	2		1	1				4
6	2					1			1
	4						1		1
7	2		1						1
	3	1			1				2
	4	1		1					2
	5	1		1					2
9	1		1						1
	2	1							1
	4			2					2
	5						1		1
10	2		2						2
	4			1				1	2
11	1		1						1
	2		3						3
	5			1					1
12	1		2						2
15	2	1							1
	5						1		1
16	4					1			1
19	4					1			1
		105	46	19	17	14	16	2	219

P: Purlin-direction, B: Beam-direction, BT: Buddhist temple, C: Confucian school, R: Royal hall(Palace), P: Pavillion, S: Shrines, G: government-managed, E: etc

In a prior study, the predominant occurrence of a 3-unit front width (Purin-Direction 3kan) and 3-unit side width (Beam-Direction 3kan) in traditional Korean architecture was attributed to several factors. First, the front width of 3 units was determined to be the minimum unit capable of achieving centrality and serving as the entrance facade of the building [5]. Thus, having centrality was deemed significant. Second, a survey of buildings in 219-dong found that all structures, with the exception of two, had a front width that was either longer or equal to the side width. In the two buildings with a greater side width, the

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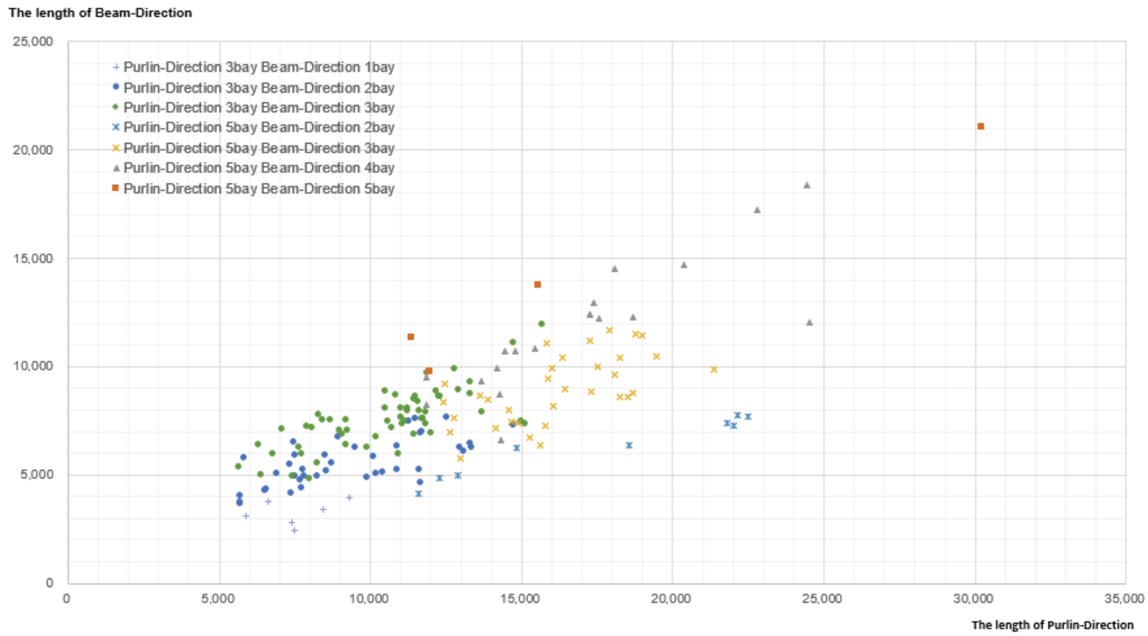

Figure 1 : Kan composition and the length

front-to-side ratio was 0.94 and 0.99, signifying no significant variance in side width. Furthermore, when comparing the widths of the core and side bays in 110 buildings with a front width of 3 units, it was found that the widths of the core and side bay were almost equal in 46% of the cases.[6] In a 3-unit configuration, the core bay (jeongkan) refers to the middle bay, while the side bays (hyeopkan) are located on either side.

In addition, it has been established through previous research that the 3-bay façade represents a fundamental structure in traditional wooden architecture not only in Korea but also across East Asia [5]. The recognition of this structural element has been preserved through generations and continues to be employed in contemporary design. For instance, the Korean pavilion at the Montreal Expo '67 was designed with the intention of linking tradition and modernity through the use of this architectural feature [8]. Notably, this fundamental structure has remained steadfast in its traditional essence.

In Chinese architecture, the importance of frontality has also been widely recognized. This can be observed in the design of the great hall (大殿) at the Foguang Temple (佛光寺) during the Tang Dynasty, where the core bay (當心間) was enlarged by widening the gap between the columns relative to the other bays [4].

In traditional East Asian architecture, the standardized wooden structures require joints that restrict the expansion of space in the beam direction due to the size of the wooden components. As a result, the scale and structure of buildings are limited. The longitudinal direction, on the other hand, represents 44% (94 buildings) of the total, with the majority consisting of three bays. The maximum number of bays found in the longitudinal direction is five, with nine buildings exhibiting five bays on the side. All of these are classified as the highest level of Korea's traditional cultural heritage classification system, as national treasures or treasures, indicating their high hierarchy and scale.

3.2 Scale of Kan

Research was conducted on the relationship between the length of the purin-direction and the beam-direction in various bay configurations, including 3X1 Bay(purin-direction 3bay and the beam- direction 1bay), 3X2 Bay, 3X3 Bay, 5X2 Bay, 5X3 Bay, 5X4 Bay, and 5X5 Bay. The most commonly utilized floor plan, the 3X3 Bay configuration, exhibited a purin-direction length ranging from 5.6m to 15.7m (with a median value of 11.2m) and a beam-direction length ranging from 4.8m to 11.9m (with a median value of 7.5m). It was observed that for small-scale planning, the kan were combined in 3X2 Bay due to the shorter length in both directions compared to the 3X3 Bay configuration. For even smaller-scale planning, while the number of cases was limited, it was found that the 3X1 Bay configuration was combined.

In cases where there was a demand to expand beyond the 3X3 Bay configuration, it was observed that the 5X3 Bay configuration was commonly utilized. For the 5X3 Bay configuration, the purin-direction length ranged from 12.4m to 21.4m (with a median value of 15.9m) and the beam-direction length ranged from 5.8m to 11.7m (with a median value of 8.8m). As the front bays expand in size, it is expected that the overall scale of the structure will increase. However, it is noteworthy that even with only 3 bays in the side, the resulting structure can still possess a significant length.

In matters for significant increase in scale, 5X4 Bay was adopted. Even compared to 5X3 Bay, which had the same 5 cells in the front, it is evident that a rapid expansion of the scale was achieved in both the purin and beam directions. The purin-direction length ranges from 11.9m to 24.5m (with a median of 17.3m) and the beam-direction length ranges from 8.3m to 18.4m (with a median of 12.1m).

The 5X2 Bay floor plan exhibited a variety of front length distributions, while the 5X5 Bay floor plan had a unique combination of longitudinal and latitudinal lengths similar to the Geunjeongjeon Hall in Gyeongbokgung Palace. However, compared to floor plans with 3 or 4 bays in the side, no significant expansion of the scale was observed.

3.3 Distribution of Heights by Kan Composition and Building Function

The height of buildings has been classified into three categories and measured accordingly. Initially, the height perceived from the outside of the building, which includes both the body and roof, was determined. The measurement criteria were based on the distance from the stylobate (gidan) to the roof ridge (yongmaru). Subsequently, the interior height of the building was measured, taking into account whether a ceiling was present or not. In cases where no ceiling was present, the height was quantified from the floor to the top purlin, which is typically perceived as the maximum height of the building. Conversely, where a ceiling was present, the height was measured from the floor to the ceiling, which is assumed to be the element that people perceive as the maximum height of the building and detect the sense of space. In cases where multiple ceilings are present, the height was determined based on the highest ceiling.

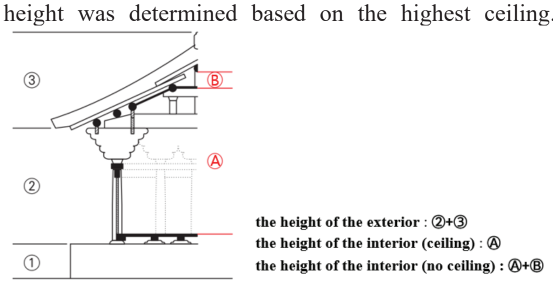

Figure 2. Standard for determining the height of a building.

The relationship between the height of the building and the use of the building was examined. The numerical values were analyzed using the median. For the height outside the building, the values were recorded in the order of shrine, Confucian academies, Buddhist temples, palaces, and governmental buildings. In terms of internal height, in cases where there was no ceiling, ancestral shrine buildings (3,666mm) and school buildings (4,753mm) exhibited a height of approximately 4 meters, while government buildings (5,411mm), Buddhist buildings (6,425mm), and residential buildings for noble families (6,898mm) showed a height of 6m. The palace recorded the highest value of 8 meters. For cases where there was a ceiling, the internal height was recorded as follows in descending order: residential buildings for noble families (3,034mm), school buildings (4,132mm), ancestral shrine buildings (4,452mm), the palace (4,978m), Buddhist buildings (5,635mm), and government buildings (6,788mm).

The median of the palace, which had the highest recorded values for outside height and inside height without a ceiling, was unexpectedly smaller than anticipated. This can be attributed to the significant difference between the minimum (4,413mm) and maximum (8,483mm) values. Among various types, palace buildings recorded the highest value for inside height with a ceiling, with the Deoksugung Junghwajeon (8,483mm) being the maximum recorded value. Conversely, the Sunwonjeon, a shrine building dedicated to ancestral worship located within the Changdeokgung Palace compound, has been recorded to have the minimum interior height. Despite being classified as a palace, its use as a sacrificial space within the palace accounts for its limited vertical elevation. Notably, shrine buildings tend to exhibit comparatively lower height values when classified by function.[9]

The composition of the kan and the distribution of heights by building function suggest that higher-ranked palaces and Buddhist buildings tend to have taller structures. Specifically, in the case of purin-direction 3 kan, Buddhist buildings displayed the highest heights irrespective of the type of beam-direction. For the most prevalent form of 3x3 kan, the heights of Buddhist buildings ranged from 9.2m to 20m, with an average height of 15 meters. Meanwhile, in the case of purin-direction 5 kan, both Buddhist and palace buildings demonstrated higher values for height compared to other building types. For a 5x4 kan, which is typically employed for large-scale expansion, the increase in height was significantly greater compared to a 3x3 kan. The average height of Buddhist buildings was 18.8m, whereas the average height of palaces was 17.7m. This represents an increase of approximately 3-4m in comparison to the 15m average height of a 3x3 Buddhist building.

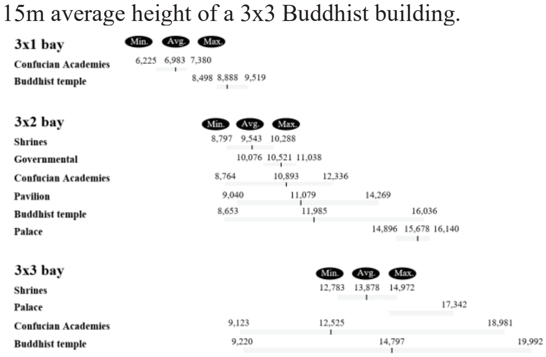

Figure 3: Height Distribution by Building Function with purin-direction 3 kan

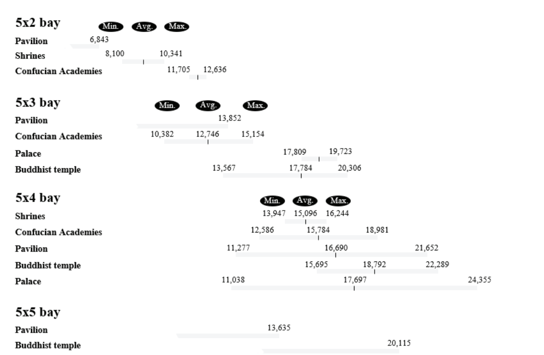

Figure 4. Height Distribution by Building Function with purin-direction 5 kan

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We analyzed the relationship between composition and scale of kan and heights as a key element of the floor plan and section plan in traditional wooden architecture.

Considering the characteristic of purin-direction kan with a strong symbolic meaning and the side bay with a strong structural meaning, [5] the relationship between the height and purin-direction kan, height and beam-direction kan were analyzed respectively.

Upon data analysis, in the case of purin-direction kan, when the scale increases from 3 to 5 kans, the median showed a difference of about 3.8-6.6m. However, the difference in height is narrower, ranging from 3.8-4.7m.

In contrast, for beam-direction kan, an increase in size from 2 to 3 kans resulted in a difference of 2.2-3.6m, and when increased from 3 to 4 kans, the numerical difference was recorded to be 1.9-3.3m, indicating that the range of numerical values was not significantly large. Thus, it can be concluded that while purin-direction kan exhibits greater flexibility in scale expansion, there are limitations to the expansion of height and beam-direction kan.

4 Limitations of Planar Structures and Expansion

4.1 Scale and expansion of plan

Traditional East Asian architecture employs standardized wooden structures, which allows for expansion in the purlin direction by connecting wooden pieces. However, expansion in the direction is limited due to the standard size of wooden beams, resulting in limitations on the structure and size of the building. In Korean traditional architecture, expansion in purin-direction(front) can extend up to 19 kan, while expansion in the beam-direction(side) is limited to a maximum of 5 kan.

The existence of large-scale expansion in the front direction in Korean architecture may be attributed to the pursuit of frontality, despite its cluster-like characteristics. Moreover, expansion may occur for functional reasons when a large space is required even for a single building. An example of such expansion can be seen in the Jeongjeon building at the Jongmyo Shrine, a national treasure that exhibits an overwhelming front length of 70m and side length of 14m with 19 kan in the front and 4 kan in the side. This large space was created to accommodate the functional space required for the addition of royal funeral tablets.

Figure 5. the façade of Jongmyo

On the other hand, the expansion of buildings in the side direction is limited to a maximum of 5 kan, resulting in a total of 9 buildings in Korean traditional architecture with such a design feature. Of these, the buildings with five bays on the front are the Bulguksa Temple Daeungjeon Hall in Gyeongju(cultural assets designated as treasures), the Kangnung Gyeongpodae Pavilion (Treasure), and the Geunjeongjeon Hall in Gyeongbok Palace (National Treasure). The buildings with seven bays on the front are the Gyeonghoeru Pavilion in Gyeongbok Palace (National Treasure) and the Gakhwangjeon Hall in Gu-rye Hwaeomsa Temple (National Treasure), both of which are main halls in Buddhist temples. Next, the buildings with five bays on the side and nine bays on the front are the Sebyeonggwan Guest House in Tongyeong (National Treasure), and the buildings with eleven bays on the front are the Huwonjeong Hall in Changdeok Palace (Treasure). Finally, one building has fifteen bays on the front, which is Guest House in Yeosu (National Treasure).

The lateral span of the beams in the beam-direction, consisting of five kan, is characterized by a broad distribution ranging from a minimum of 9.8m at Gangneung Gwanryongnu Pavilion to a maximum of 28.2m at Gyeonghoeru Pavilion in Gyeongbokgung Palace, with an average length of 16m. The column-beam construction method exhibits a structural limitation in terms of extending the length of the beams. Furthermore, the employment of wooden beams is subject to constraints on the maximum length, as even the most massive trees fail to exceed 20m in length. Typically, the beam spans in the beam direction do not surpass 10m, with a majority of structures being limited to lengths of 5-6m. [10]

4.2 Scale and expansion of height

When examining the utilization of large-scale buildings, it can be deduced that practical necessities, such as the requirement to accommodate numerous individuals and the inclusion of guest quarters, prompted the construction of sizable structures rather than a desire for scaling up a singular building. The dimensions and elevation of the lateral bays are contingent upon the number of rafters and the limitations of the beams. The purlin framework, referred to as ryangga, was analyzed to ascertain the height of the edifice based on the dimensions of the ryangga. Concerning the external height of the building, the average height of 3 ryang was 7,955m, 5 ryang was 14,170mm, 7 ryang was 17,907mm, and 9 ryang was 18,675mm, illustrating a correlation between an increasing height and an expanding size of the ryangga. Nevertheless, it was observed that the height discrepancy between 7 ryang and 9 ryang was merely around 0.8m, which is an insignificant difference. In the case of buildings without an interior ceiling, the height also increased proportionate to the dimensions of the ryangga, and the gap in height between 7 ryang (8,439mm) and 9 ryang (9,447mm) was approximately 1m, but the disparity between 5 ryang (6,474mm) and 7 ryang was approximately 2m, signifying an increase in the magnitude of the difference. The height of structures with an internal ceiling followed the same pattern. In conclusion, a substantial association between the size and height of the ryangga is apparent, and the relatively minimal height difference between 7 ryang and 9 ryang suggests that the dimensions of the ryangga were not a significant consideration when designing the furniture structure.

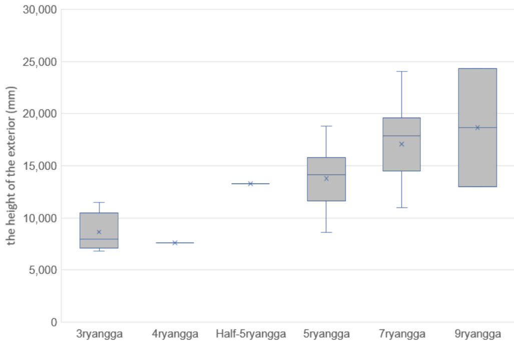

Figure 6. The relationship between the ryangga structure and height

Regarding the limitations of column components, the expansion of building height is also subject to such constraints. When assessing building height across different historical periods, the median height was found to be highest during the late Chosun era, measuring 13,947mm, followed by the Goryeo period at 13,234mm. During the Chosun period, building height tended to increase progressively from the early to the middle to the late period. The difference in height between the middle (13,843mm) and late (13,947mm) periods of the Chosun era was minimal, whereas the transition from the early period (11,008mm) to the middle period resulted in a substantial increase in height. Over time, the column component played a critical role in determining building height, and efforts to raise height through bracket sets (gongpo) became evident. An analysis was conducted on the trend in the height of columns and bracket sets (gongpo) over time. When examining the median height trend of the interior height of buildings without ceilings, there was no notable change in the absolute height of the column. However, the height of bracket sets (gongpo) component exhibited an increasing trend during the late Chosun period.

Concerning the interior height of buildings with ceilings, the column height displayed a declining trend during the late Joseon period, while the height of bracket sets (gongpo) component showed an upward trend as the Chosun era progressed from the early to the middle to the late period. In conclusion, it can be deduced that, as the Chosun period advanced into the later periods, the adjustment of bracket sets (gongpo) for height became a more significant consideration than column height.

5 CONCLUSION

Traditional Korean wooden architecture permits unrestricted expansion along the purlin-direction, enabling buildings to extend up to 19 kan (approximately 32 meters) in length. However, the expansion in the beam-direction is constrained to a maximum of 5 kan (approximately 8.5-23 meters) due to the structural limitations of the side walls. Many traditional Korean cultural properties reflect this maximum length of 5 kan. Similarly, the height is also restricted to around 19 meters due to the length of the column and their connection with the side walls. While attempts were made to increase the height to some extent as time progressed, owing to the addition of columns and bracket sets, it can be surmised that there was limited interest in expansion, as evidenced by the minor differences in height between the 7 and 9 kan structures.

In traditional Korean wooden architecture, similar to Chinese and Japanese architecture, there were clear limitations on the scale of buildings, particularly in terms of lateral expansion, with a maximum length of 5 kan. In China, traditional architecture never expanded beyond a certain point and remained at a consistent level, with the maximum front length in Tang-era architecture being only 11-13 kan and depth limited to 5-6 kan. The Taehwajeon of the Qing palace is the largest surviving single-story wooden structure with a front length of 11 kan and depth of 5 kan [4]. In Japan, there was a period when lateral kan counting was not present, indicating a lack of concept for depth in ancient Japanese architecture [7]. Unlike China and Korea, which recognized maximum lengths of 6 and 5 kan, respectively, Japanese architecture shows many examples of traditional buildings with a maximum lateral length of 7 kan, including the Kondo of Todai-ji Temple. This can be attributed to not only differences in recognition, but also differences in the sophisticated wooden structures required to achieve larger scales and heights in the three East Asian countries. A detailed comparison of these differences requires further research.

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