A Typology of Korean Housing Units: In Search of Spatial Configuration

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Abstract
Space analysis aims to identify the relations between society and space. Space analysis results let us identify the characteristics of the targeted space and subsequent human activities based on the notion of social relationship. The reason authors try to understand spatial structure lies in that it is the intrinsic attribute of physical built environment. This research looks into apartment houses, a widespread form of housing in Korea, in an attempt to investigate the social logic lying in its domestic space by measuring the spatial configuration. This research is based on empirical data and uses a quantitative methodology; Space Syntax. Characteristics of spatial structure in apartment units and their meanings were identified through this research. The implication of the living room-centered layout type most common in Korean apartments was discussed from the viewpoint of the domestic space genotype.

Keywords: unit plan; spatial configuration; space syntax; cluster analysis; genotype

1. Introduction
1.1 Background and Purpose of the Research
Lifestyles, behaviors, values, and beliefs of a society develop under the mutual influence of the physical environment, and are thus revealed through the structural organization of space. This results from the fact that human behaviors are basically shaped within space and displayed through space. Thus conversely, if authors identify the structural properties of space, authors can reveal human behaviors, predict lifestyles, and further discuss social phenomena from spatial structures. Studies on domestic space, on the other hand, can be extended to diverse cultural studies through microscopic approaches. This is enabled by the fact that housing can be explained as a society's cultural phenomenon which exposes the features and meanings of the time. In other words, housing is the product primarily of socio-cultural factors of the society (Rapoport, 2001). In this respect, Korean apartments are no doubt an interesting research topic. Korea, with its collectivist and homogeneous cultures, has achieved rapid economic growth, during which it has also undergone many changes in housing, both cultural and physical, in a short period of time. Apartments came to be the most prevailing housing type in a relatively short time in Korea, and at the same time, have been preferred by many people. Thus, this research focuses on the apartment housing type and the spatial structure of its domestic space. This research is based on the premise that dominant apartment types in Korea will display certain structural features of space. The purpose of this research is to identify, from an objective viewpoint, the socio-cultural implication of the apartment's domestic space by looking into the structural properties of space.

1.2 Scope and Method of the Research
This research started from the question of whether the typical spaces of Korean modern housing have any topological characteristic, and was further developed by applying the following research scope and methods. The spatial scope of this research is restricted to an apartment's interior domestic space. The bounds of domestic enclosure can be extended from internal to external bounds if authors consider the residents' movement tracks. Also, there exist boundary spaces in between. Interior domestic space, however, holds an important place in residents' living patterns in that it must serve as a home, as well as meeting the basic functional needs as a shelter. The structure of interior domestic space within an apartment is determined by its spatial configuration. Planar spatial configuration is exposed through the floor plan. Thus, spatial configuration will be addressed in this research, the determinants for the spatial structure in an apartment unit plan.

Space Syntax theory was applied to domestic spaces. Also, precedent researches were reviewed relating to Korean apartment units, through which a space analysis methodology was developed for identifying...
the structural properties of space. This study consists of two parts: a quantitative analysis on spatial configuration and exploration of the domestic space genotype of Korean apartments. The first relates to data analysis and results, the latter to the interpretation of the analysis results.

2. Literature Review

2.1 Spatial Configuration of Domestic Space

The advantage of representing topological relations of spatial features is that it allows clear understanding of spatial structure by simplifying the connections between spaces. There can be differences in the degree of integration or segregation among domestic spaces with seemingly similar configurations. In other words, plans with similar layouts can still have spaces with different structural features depending on how they are connected with one another. Apartment units can have similar plan layouts, which particularly makes it difficult to quickly and directly grasp the connections between spaces. This is because the 'structure' of space is not immediately apparent on the surface. Many researchers have examined spatial layout patterns of domestic space. The methodology used most often is to identify and draw integration or segregation patterns of space out of spatial layout properties based on plan design. Hillier et al.'s thesis (1987) was the first to apply this research methodology. It confirmed the genotype based on the spatial layout patterns by analyzing seventeen farmhouses from the Normandy region of France. The genotype was determined by the common characteristics drawn from identifying each space's order of integration within a plan and structuralizing them into a graph.

Then how will the genotype be defined here? Genotype is broadly defined as features or phenomena that persist over time. It is cloned from generation to generation, and repeatedly expressed in multiple cases. In a similar vein as the precedent research, the genotype of domestic space can be defined as the spatial layout patterns that commonly emerge from multiple cases.

2.2 Apartment Unit Plans in Korea

Precedent studies concerning Korean apartment units can be divided into (a) ones that analyzed spatial structure to investigate changes in plan or the evolutionary process of Korean traditional houses and (b) ones relating to plan archetypes and typologies. If we look at the researches analyzing the spatial structure of traditional versus modern houses to interpret its implications, one significant study (Choi, 1990) confirmed that the apartment living room assumes the role of the Korean traditional courtyard, which was brought indoor in modern apartments and persists as a focal space for family life. It proved Korean traditional spatial activities can successfully be reenacted in modern apartments. Other studies (Choi, 1996a and 1996b) investigated apartments located in the Seoul metropolitan area to analyze changes in plan and lifestyle and interpret its implications by tracking topological changes of each space in a unit plan. These works are significant in that they practically proved that Korea's socio-economic changes have been clearly reflected in apartment unit plans.

Otherwise, the evolution of domestic space was explained as a topological transformation process of adapting to new housing types by differentiating floor levels for separate spaces (Seo, 2003). Seo argues that the Korean traditional courtyard has been transformed into modern apartments' lower floor level spaces, such as entrances, balconies, bathrooms, storages, etc., based on the notion of 'spatial activities' and the distinction between lower and higher floor level spaces. Seo's research suggested a new possibility for interpreting the genotype which can differ depending on hypotheses and viewpoints for analyzing the evolutionary process of a certain space.
Other studies (Kim et al., 1992) on the plan typology developed general patterns for plan based on the number of rooms, spatial layout for living room, dining room and kitchen, doorways, and the number of front bays. Looking at studies concerning the archetypal elements of plan, a set of archetypal spatial elements were suggested as a conceptual framework for explaining changes in Korean house plans. These elements were defined as 'ondol', 'maru', and the service area 'bueok' which have emerged anywhere, at any time in Korea, and their grouping and integration patterns were presented (Jeon et al. 2008).

The literature review suggests that this research has significance with respect to research scope, analysis data, and methodology. This research limited the time period of analysis from 2001 to 2013. Precedent studies set the time period to the early 2000s, whereas this study concentrated on spatial configuration patterns for plans from 2000 and includes the latest cases where various spatial layouts were attempted. While the years from 2001 to 2005 had witnessed the beginning of the branding and gentrification of apartments, such phenomena intensified and specialized designs appeared during the period from 2006 to 2013. In the early 2000s, apartment brands started to gain recognition in place of construction companies' brands themselves. In 2002, Green Building Certification Criteria (GBCC) was implemented in the public housing sector. The construction law was revised in 2005 to legalize balcony extension. Other changes included more concern about the quality of life and social activities which mirrored the introduction of a five-day workweek. Public awareness on the importance of green lifestyle practice also started to grow in households. If authors look at the period from 2006 to 2013, the notion of green building became popular and the sustainability paradigm, covering the green building issues, spread. The gentrification of apartments brought further specialized plan designs. Specialized apartment designs for vertical extension, low-rise terrace types, multi-home types, etc., were developed, with the related patents being applied for. This research is distinctive in that a complete enumeration survey was done for data collection, not just a randomly sampled dataset. The overall research framework for this study is based on Space Syntax theory. However, statistical analysis was conducted in addition to the existing space analysis methodology.

3. Material and Method
3.1 Data Collection

Unit plans for apartments built in the city of Seoul from 2001 to April 2013 were collected for analysis. Of those collected, only three-bedroom and four-bedroom types were used for the research. Data collection was done in two parts: the compiling of lists of unit plans, and the collecting of plan images. As this research aimed for a complete enumeration survey, a complete listing of the population was quite important. Apartment Encyclopedia: Seoul was referred to for the preliminary listing. The book has a complete list of apartment complexes located in Seoul, with basic information including titles, locations, the number of units, etc., and unit plan images. For data since 2006, the web portal "Naver Real Estate" was used for search by administrative region. Data collected from the web were cross-checked against the preliminary listing and complemented to complete the final list. The final list included a total of 2,500 plans. Plans for three-bedroom types amounted to 1,757, those for four-bedroom types to 743. If authors look at the years 2001 to 2005, collected plans amount to 1,277, 842 for three-bedroom types and 435 for four-bedroom types. For the period 2006 to 2013, plans amount to 1,223, 915 for three-bedroom types and 308 for four-bedroom types.

3.2 Analysis Method

Spatial structure analysis of unit plans was carried out in three phases: first, the setting of unit space and representation of spatial structure; second, selecting analysis indexes and tools; and third, statistical analysis for the space analysis results. Methodologies developed for each phase are as follows.

First of all, spatial structure within a unit plan is represented as a series of convex spaces. This is done by creating a convex map. One convex space corresponds to one unit space. Representation scope for spatial structure of a unit plan includes all the rooms defined by walls within the unit: entrances, living rooms, kitchen and dining, master bedrooms, other bedrooms, bathrooms, master bathrooms, closets, powder rooms, balconies, storages, etc. While every room will be included in the spatial structure representation, for the result analysis, we will only focus on the following spaces: the outdoor (of an entrance), entrances, living rooms, kitchen and dining, master bedrooms, other bedrooms, and living room balconies. Bathrooms, corridors, family rooms, other balconies, and storages were excluded from the analysis.

Next, authors selected integration as the analysis index for examining spatial structure properties. Space analysis methodology uses several indexes that quantitatively represent various spatial structure properties, such as connectivity, control value,
legibility, etc. Integration index, representing the topological centrality of a space within the plan, is the principal measure of spatial structure properties. The most integrated and segregated spaces within a unit plan can be located using the integration value of each unit space. The overall spatial layout pattern will be mapped and its characteristics will be examined. 'S-cube Convex Analyzer v 2.1' was used for the space analysis. Using this tool, convex maps created in AutoCAD were imported and after running the analysis, integration data for each unit space were exported into an Excel spreadsheet.

Lastly, the analysis results were statistically processed. Analysis results for each test case—the integration values for each space within the plan—are used as raw data for statistical processing. The statistical techniques employed are factor analysis and cluster analysis. The varimax rotating method was applied for factor analysis out of principal component analysis and orthogonal rotation methods. After examining accountability and reliability of the data, spaces with high accountability are identified by period and plan type. Also, factor values gained from it are inputted as independent variables for the cluster analysis.

The K-means method used most often for nonhierarchical cluster analysis was applied for extracting the clusters. The number of clusters was set from two to nine. After the analysis run, cases for each cluster were examined. Three groups were finally selected, whose characteristics were distinct and the clustering patterns were significant. Cases within each cluster and their spatial layout features were examined and after that, the level of centrality for some specific spaces was compared to one another to discover differences between clusters. SPSS 20 was utilized for the statistical analysis.

4. Result Analysis
4.1 Factor Analysis Results

Factor analysis results revealed that all KMO values were over 0.6. For the period 2001 to 2005, the three-bedroom type accounted for 83.9% of the total dispersion, and the four-bedroom type accounted for 73.8%. For the period 2006 to 2013, the three-bedroom type accounted for 59.9%, and the four-bedroom type accounted for 69.6%. Factors demonstrating high accountability as overall cumulative accountability reached over 60%. However, both types showed lower accountability than before during the period 2006 to 2013. The reason for this should be specifically addressed in further analysis, because it means that the overall data's accountability became lower. For the two periods, unit spaces with only the same functions are selected and applied as variables. Unit space variables are reduced to two to three factors to show different results from one another, and cumulative dispersion also became lower, requiring interpretation in multiple aspects based on factor analysis results. Looking at each unit space's grouping pattern, entrance loaded on factor 1, a major factor, whereas living room was included into factor 2. Other spaces, however, displayed different patterns depending on the period and the number of rooms. This implies their accountabilities were affected by different factors. A closer look at factors for each floor plan by period is presented below.

The period 2001-2005 witnessed extraction of three factors for both the three-bedroom and four-bedroom types, but unit spaces loading on each factor differed. Entrance/bedrooms, living room, and kitchen-dining room loaded on each of the three factors for the three-bedroom type. Entrance, living room/kitchen-dining room, and bedrooms loaded on each of the three factors for the four-bedroom type. It is notable that living room and kitchen-dining room loaded on separate factors for the three-bedroom type, whereas both loaded on the same factor for the four-bedroom type. In other words, living room and kitchen-dining room can be said to demonstrate different accountability from each other, as they were grouped into different factors for the three-bedroom and four-bedroom types respectively.

The period 2006-2013 witnessed the selection of two factors for the three-bedroom type, and three factors for the four-bedroom type. Entrance, bedrooms, and kitchen-dining room all loaded on factor 1, while living room loaded on factor 2 for the three-bedroom type. One can assume changes in kitchen-dining room as it loaded on a major factor compared to the period before. For the four-bedroom type, entrance, kitchen-dining room, and bedrooms loaded on factor 1, living room on factor 2, and master bedroom on factor 3. Changes in relations between bedrooms and other spaces can be detected, compared to the previous periods. Unit spaces loaded on different factors from one another, and their accountability of variance showed difference. The degree of spatial integration or segregation mostly affected the factor loading pattern, as the integration index was used as variables for factor analysis.

4.2 Cluster Analysis Results

The results of the cluster analysis are provided in a table format, where A, B, and C denote the order of clusters from the highest number of cases to the lowest. The same cluster label does not necessarily indicate the same spatial structure properties. The rank order indicates the order of mean integration for each space within the cluster. Plans within each cluster were extracted conversely from the rank order and then tracking the raw data.

The result has showed that in many cases, living room demonstrated high centrality. This means that the spatial layouts tend to be living room-centered in general. There were differences, however, in the degree and order of centrality between living room and other spaces. Also, there were a few cases where kitchen-
In the period 2001-2005, cluster A and B of the three-bedroom type showed the rank order of centrality as follows: living room, kitchen-dining room, master bedroom, and entrance. Cluster C had the lowest case rate, where kitchen-dining room displayed the highest centrality. The deviation between kitchen-dining room and other spaces was quite large. Cluster A of the four-bedroom type had the highest case rate of 89%, where living room showed the highest centrality. Next to living room, living room balcony and kitchen-dining room were ranked in the order of their integration value. Cluster B and C showed a very low deviation of centrality for each of the spaces.

The three-bedroom type in the period 2006 to 2013 had balconies with increased centrality and master bedroom with lowered centrality compared to the previous period. Kitchen-dining room was ranked higher than for the four-bedroom type. As living room balconies are placed adjacent to the living room, their dining room displayed high centrality. Notable trends from the cluster analysis results are presented below by period and number of bedrooms.

### Table 1. Factor Analysis Results (2001-2005)

<table>
<thead>
<tr>
<th>Unit</th>
<th>Variable</th>
<th>Communality</th>
<th>Initial Eigenvalues</th>
<th>Rotation Sums of Squared Loadings (Cumulative %)</th>
<th>Rotated Component Matrix*</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Factor 1</td>
</tr>
<tr>
<td><strong>3R</strong></td>
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<td></td>
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<tr>
<td>Outdoor</td>
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<td>3.369</td>
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<td>.735</td>
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<td>Bedrooms</td>
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<td>.782</td>
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<td>.156</td>
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<td>2.832</td>
<td>27.134</td>
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<td>.932</td>
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<td><strong>4R</strong></td>
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<td></td>
</tr>
<tr>
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<td></td>
<td>-.022</td>
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<tr>
<td>Kitchen/dining</td>
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<td></td>
<td></td>
<td></td>
<td>.032</td>
</tr>
<tr>
<td>Master bedroom</td>
<td>.725</td>
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<td></td>
<td></td>
<td>.143</td>
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<tr>
<td>Bedrooms</td>
<td>.747</td>
<td></td>
<td>.941</td>
<td>73.801</td>
<td>.279</td>
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</table>

Kaiser-Meyer-Olkin Measure of Sampling Adequacy: .727(3R), .657(4R)
Bartlett’s Test of Sphericity: p-value .000(3R, 4R)
Extraction Method: Principal Component Analysis
Rotation Method: Varimax with Kaiser Normalization

*Rotation converged in 4 iterations (3R), Rotation converged in 5 iterations (4R)

### Table 2. Factor Analysis Results (2006-2013)

<table>
<thead>
<tr>
<th>Unit</th>
<th>Variable</th>
<th>Communality</th>
<th>Initial Eigenvalues</th>
<th>Rotation Sums of Squared Loadings (Cumulative %)</th>
<th>Rotated Component Matrix*</th>
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<td>Factor 1</td>
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<td>.857</td>
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<td>.581</td>
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<tr>
<td>Master bedrooms</td>
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<td></td>
<td>.068</td>
<td>73.801</td>
<td>.469</td>
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<td>Kitchen/dining</td>
<td>.480</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Living room</td>
<td>.630</td>
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<td>1.544</td>
<td>.061</td>
<td>.791</td>
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<td>Living room</td>
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<td>Master bedroom</td>
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<td>.122</td>
<td>.045</td>
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</table>

Kaiser-Meyer-Olkin Measure of Sampling Adequacy: .690(3R), .652(4R)
Bartlett’s Test of Sphericity: p-value .000(3R, 4R)
Extraction Method: Principal Component Analysis
Rotation Method: Varimax with Kaiser Normalization

*Rotation converged in 3 iterations (3R), Rotation converged in 4 iterations (4R)
rank order can be interpreted as the living room being relatively centralized. Master bedroom displayed a more segregated pattern than before. Changes in spatial layout pattern also directly relate to changes in spatial functions and roles. Cluster A and B showed the rank order of centrality to living room, kitchen-dining room, and living room balcony. Living room balcony displayed increased centrality than before. However, entrance became segregated. Cluster C had the rank order of centrality as kitchen-dining room, master bedroom, and living room.

A number of four-bedroom type cases turned out to have living rooms with high centrality. However, the percentage has declined compared to the previous period, which is notable. It shows a clear difference from the three-bedroom type in terms of spatial configuration. Cluster A showed the rank order to be living room, living room balcony, and kitchen-dining room. This demonstrates a typical spatial layout where the living room’s centrality is emphasized. Kitchen-dining room turned out to have high centrality in cluster B, whereas the difference with that of living room was minimal.

The case rate of each cluster was identified from the cluster analysis results. The cluster with the highest case rate can be seen as a meaningful archetype. It was also demonstrated that a difference exists in spatial layout properties among clusters. That is, from 2001 to 2003, living rooms were placed in the topological center within a unit plan. This is the feature that has been identified through a number of cases. This living room-centered spatial layout was extracted as a common feature, but differences existed in the inside.

5. Spatial Configuration and Society

5.1 Why Living Room?

As can be seen from the analysis results above, the rate of living room-centered plans was overwhelming from the 2000s until recently. The three-bedroom type showed strong tendency of the living room-centered layout, while layouts for spaces other than living room—master bedroom, entrance, balconies, etc. —varied. The four-bedroom type also showed
the tendency of the living room-centered layout, but the rate somewhat declined during 2006 to 2013. This weakening of living room-centered layout implies that there have been changes in connectivity among the other spaces, although the tendency was still significant. However, many cases still exhibit the living room-centered layout pattern, where the living room's centrality is high.

Then what is the background for this prevalence of living room-centered layout in apartment unit plans? This can be understood in a twofold way: from the viewpoint of structural properties resulting from spatial configuration; and the acceptance of life style.

First, authors will examine the spatial structure properties of living room. This can be explained by spatial layout principles applied to traditional houses and apartment unit plans. A living room represents the center of a house plan. A living room does not simply support only public functions in household life. It provides passages for movement to other spaces. This has been identified in a spatial structural viewpoint. An apartment living room assumes the role of the courtyard in Korean traditional houses, 'Hanok', in a topological sense. Also, the living room serves as a focal place in household life which is visually integrated within a housing unit (Choi, 1990). This research confirmed that this is still true at the present time, when apartments have become pervasive.

The courtyard that once served an important role in traditional life came to reappear as the form of living room in an apartment, and as a result, our traditional life style could successfully continue… Unlike in other countries, Korean apartments were successfully introduced and settled as one of our housing types, the reason for which is it symbolizes modernization on the external side and at the same time, fully accepts our own life style on the internal side (Choi, 1990).

Thus, the second viewpoint will be that the spatial layout properties of the living room within apartments and the spatial functions formed from them conform to Korean life style. This is because the apartment housing type started to accept life style in a Korean context from the beginning. Apartments have experienced many changes since the 1960s when they were first built. The living room-centered plan was not the only type attempted, however. A so-called western type of plan layout that clearly separates public and private spaces was once attempted, but it didn't last (Kang et al., 1999).

Thus, the living room-centered spatial layout identified by the analysis results of this research proves that the spatial functions provided by the living room are still of importance in a household space. Also, the research results demonstrate that this type of spatial layout principle easily accepts nowadays diverse and complicated life styles. To put it differently, the function and layout properties of the living room have resulted from the fact that they conform to Korean people's way of living. Domestic space has been partly changed or unchanged according to the times, socio-cultural factors, family structures, etc. Spatial configuration of the unit plan can also be explained through its parts that have changed and parts that have not changed. The unchanged part would be the living room-centered spatial layout, while the changed part would be the degree to which living room is integrated within the whole spatial configuration. In the living room-centered spatial configuration, the deviation of centrality between the living room and the other spaces depends on the connectivities between spaces other than the living room. That is, while the living room's status as a topological center within the plan is still maintained, it is suggested that the spectrum inside it can be interpreted in various ways. This is enabled by the fact social changes in Korea are reflected in domestic space, the physical substance itself.

5.2 Genotype and Social Logic of Domestic Space

Apartments became the dominant housing type in Korea in a relatively short period of time. Although it first started from the west, it was accepted and developed in a Korean context. This can be explained as the 'social logic' inherent in space. The fact that socio-cultural concepts are reflected in the physical substance can be discussed with the issue of the genotype which can be raised for the structural properties of space. Earlier studies that extracted genotypes by using Space Syntax have drawn the genotypes based on unit spaces' integration or segregation patterns. Identifying these patterns would be the most objective methodology that can extract and interpret the common attributes of spatial structure, as well as reveal its properties.

However, the genotype of unit plan can be criticized as being a standardized, uniform one in terms of architectural planning. These criticisms do not only point out plans, which result from the planning practice, but are more like pointing out the assembly of plans, layout of buildings, or even the site planning. Also, structure of space is not visible on the surface, but is an intrinsic property that is a totally different matter of discussion apart from the shape of space. Thus, one must be aware that the genotype of spatial structure is a fundamentally different issue apart from these criticisms. The genotype in terms of spatial structure is a commonly emerging spatial configuration pattern from a number of cases. This research looked into unit plans from 2001 to early 2013 to find out that plan cases implementing the living room-centered spatial layout had higher ratios.
Today's apartment does not exist in the West, nor in China, nor in Japan, nowhere except in Korea. It is a housing typology unique to Korea, and the possibility for globalization lies here (Jeon et al., 2008).

This result implies that the living room-centered spatial layout can be interpreted as the genotype of spatial structure emerging in the unit plans of Korean apartments. First of all, it can be discussed in terms of life style. The genotype for unit plan can widely accept life styles from Korean traditional household life to modern household life, and is still being maintained. In other words, it has significance in that it compromises life styles before the introduction of apartments and at the same time, accepts today's changing life styles. Next, the genotype can be discussed from a socio-cultural perspective, further to the housing culture. Spatial structure of housing enables the interpretation of family structures, housing culture, socio-culture, and even the times. Thus, the genotype of unit plan needs to be considered in terms of structural properties of space within a comprehensive framework and its internal changes. The comprehensive framework will possibly relate to Korea's socio-cultural distinctiveness such as homogeneity, and inside it can reflect social changes or the current of the times.

6. Conclusion

This research attempted to objectively identify the implication of apartment housing from a Korean socio-cultural point of view, by searching the structural properties of space. Through a literature review, the research scope was set to the period from the 2000s and the spatial structures of the cases were analyzed. The analysis results revealed high case rates of the living room-centered spatial layout type. This supports the fact that spatial configuration found in Korean traditional housing is still present as a modified form in modern housing, and accepts the modern household life as well. The research results particularly suggest that it can be reinterpreted as the genotype of spatial structure which is inherited from generation to generation. This research utilized a quantitative methodology; Space Syntax, to draw principles for the spatial layout of apartment unit plans. This research is significant in that it clearly identified the analysis results from an objective perspective. However, it only addressed cases built after the 2000s and only apartment cases were treated out of all existing housing types. Follow-up studies will be complementary to this study, in which the periods after the introduction of apartments until recently will be examined, and changes in spatial structure properties will be identified in detail.

Acknowledgement

Chapter two and three of this research are based upon results from the doctoral dissertation of the first author, appearing first in the reference list. Chapter four and five are the main chapters of this research, which are newly added.

References

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