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Space puzzle in a concrete box: finding design competence that generates the modern apartment houses in Seoul

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Abstract. In the planning of the apartment houses in Seoul, it is typical that the stereotyped building form strongly regulates the spatial arrangement of the interior. This research therefore attempts to combine two different approaches, namely the formal approach and the spatial approach, for the comprehensive understanding of the architectural grammar. To bridge the technical gap between these two approaches, a new graph-theoretical method is introduced by which configurational information is linked to a shape generation model. From a series of analyses, it is found that there exist clear principles that generate all the typical house plans in the city.

Form as a mould for space

Just as the body-mind duality that deals with human beings, the form-space dichotomy has pervaded for a long time in the discipline of architecture. In recent decades, this conceptual division has been more concretised as more refined theories exclusively focusing on one of these two aspects have been developed. The space syntax theory (Hillier and Hanson, 1984) effectively captures topological relations of space by means of graph theoretic techniques, but discards original shapes and sizes that are essential for formal understanding. This type of spatial approach, in its effort to illuminate the social consequences of spatial configuration, concentrates mainly on permeability in space, i.e. the access relationship between spatial units. In shape grammars (Stiny, 1980), conversely, since defining final forms becomes an ultimate goal, relational meanings between consisting parts are given a minor concern. In this formal approach, thus, each space is treated separately as a broken piece during the generation process before it is connected to others at later stages. In both approaches, an effort to highlight one dimension inevitably sacrifices the other and, as a result, no compromise has been made between the two.

In a normal design environment, however, the initial action of design tends to start from conceiving approximate forms out of unrefined candidate configurations. In this way, topology and form interplay from the beginning to achieve the intended building function (Brown and Steadman, 1991, p. 278). Hence, Boast concludes that topological and formal measures “cannot be defined without reference to the other and they are, therefore, separable only in analysis and not in practice” (Boast, 1987, p. 451). Furthermore, at the end of the spectrum, there could be some cases where the two measures can never be separated even in analysis. This happens particularly for the building which is designed by setting geometry first and seeking suitable spatial layouts afterwards (Steadman 1983, p. 134). In this type of design, layout patterns are seriously affected by the geometric constraints, as best exemplified by the narrow fronted English houses in seventeenth century London (see Brown, 1990). In a broad sense, most of modern multi-unit houses fall into this type of design category since their plan configurations are inevitably subject to the higher-level geometry, i.e. the form of the building block. For these houses, the approximate building form tends to be determined at an earlier stage of design in relation with the design strategy, and suitable configuration is accommodated at the later stage. Therefore, to find out the grammar used in the design, the analysis should be based on both the formal and spatial approaches.

Focusing on this particular context, this paper attempts to reveal the design mechanism that generates the apartment houses in Seoul. Two phases of analytical propositions are made. In the first phase, a new graph-theoretic representation that can retain the geometric information of the apartment plan is proposed; thus the dimension of form comes into play within the topological expression. In the second phase, the design generation mechanism is modelled using the graph proposed in the first phase; thus the dimension of topology comes into play within the system of formal operations. By combining both the formal and spatial approaches, this study aims to expose the real competence in the designer's mind in which the ideas of space and form go hand in hand from the beginning to the end. The attempt below, then, can be seen as a way of modelling the real design world from the designer's point of view.

The apartment houses in Seoul

What has become the most prominent feature in the landscape of Seoul in the second half of the twentieth century is the fast-growing number of apartment houses. First introduced in 1958, it became the fittest amongst all housing types in the city and its ratio amongst new housing construction kept growing to reach 90% in 1999. In the year 2000, there were more than one million apartment units in the city, occupying 51% of the total housing stock.

Two types of building block dominate the apartment housing market in Seoul: the staircase access type and the balcony access type. In this paper, only the former, which is more prevalent and getting more popular, is chosen for analysis. Figure 1 shows the typical block plan of the staircase access type apartment in which each pair of units are accessed from a public staircase in the middle.

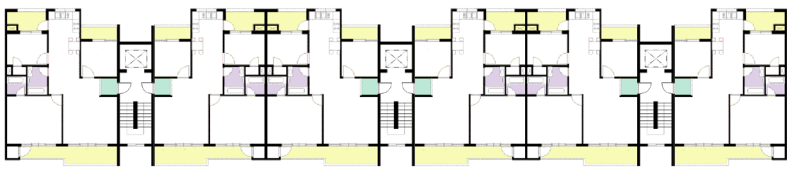


Figure 1. Typical staircase access type block plan

As pairs of units are attached side by side, the building shape becomes a thin slab form. The domination of this shape is due to two major reasons: first, for providers, considering the high value of real estate in the city, this slab shape can be more efficient in achieving high density, and second, for Korean consumers, who strongly prefer the south orientation, it can equally provide good orientation to all the units in it. However, since the external building shape is almost pre-fixed, the internal spatial configuration has to be restricted; each unit is forced to maintain a roughly rectangular format which has two blank walls on the sides and is open to the front and back. As described earlier, this is the typical morphological condition of modern multi-unit housing of which the design should be investigated in terms of the interaction between space and form.

For the analysis of this research, all three bedroom units, which are the most dominant plan type in Seoul, were collected from Gangam-gu, one of the twenty-five administrative districts in the city. The housing development of this area began along with the boom of the 70s' apartment construction and since then new apartment communities were continuously built. Therefore, it is believed that this district can best represent the city of Seoul with a variety of plan types from the early period until today. A total of 75 unit plans were collected from Gangnam-gu: 11 from the 70s, 30 from the 80s, and 34 from the 90s. These include the earlier plans that were already demolished for re-development as well as the existing ones.

Graph-theoretic representation of the plan

As discussed in the beginning, in analysis, the formal approach and the spatial approach have been treated in an unrelated way. The graph-theoretic approach effectively illustrates topology but as soon as real plans turn to graphs, all the information on shape is stripped away. Graphs enable the reading of deep structure blurred by shape, but it is not self-evident what consequences each node and line in them has on the shape. To overcome these limits, a new graph representation is proposed (figure 2).

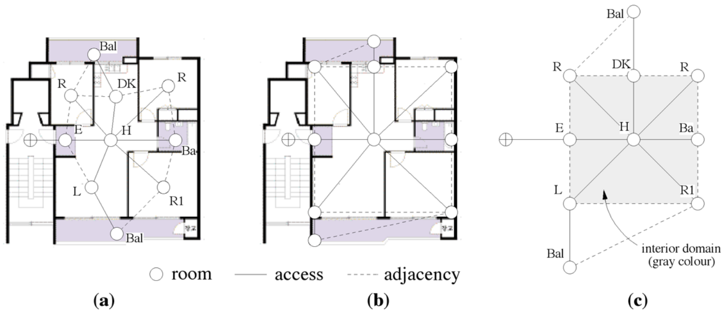


Figure 2. Access-adjacency graph mapped on a plan and its transformation to represent the morphology (R:bedroom, R1:main bedroom, L:living room, E:ent hall, H:central hall, DK:dining-kitchen, Bal:balcony, Ba: bathroom)

In figure 2(a), nodes are placed in the centre of each space and they are connected by continuous and dotted lines to represent access and adjacency respectively. Small spaces like a wall closet are ignored, and when two rooms are adjacent by the length shorter than a door opening, they are not regarded as adjacent in the graph. Next, the nodes facing the exterior boundary are stretched and aligned to render the form of the graph as a rectangle [figure 2(b)]. This rectangularisation is to represent the simplified shape of the boundary geometry. Finally, in figure 2(c), the irregular lengths of the lines are modularised to render the graph a dimensionless format. Here, balconies are placed outside the interior domain of the graph which is marked by a gray colour. This modularisation is an essential part of the graph formulation. As different sized plans can be enclosed within the pre-fixed graph module, the comparative analysis of a large number of sample plans becomes much easier. Now, the final form of the graph contains three types of information, i.e., access, adjacency, and boundary geometry. Access lines preserve syntactic information of permeability while adjacency lines help structuring the rectangularised geometry of the graph by which relative coordinates of each space within the unit plan can be readily exposed. Thus, by storing syntactic and geometric data in a single format, this graph representation can effectively visualise how the topology of a unit corresponds to the building morphology.

A sample of apartment house plans in Seoul is analysed using the graph-theoretic representation suggested above. Through the process of transformation, a total of 75 plans could be represented by 43 graphs. On average, there are 1.74 plans per graph, but it is found that some types of graphs were more heavily used than others, which means that a small number of typical topologies are embedded in many geometrically different plans. In figure 3 are the four most frequently used graphs with one of the corresponding plans on the top of each graph.

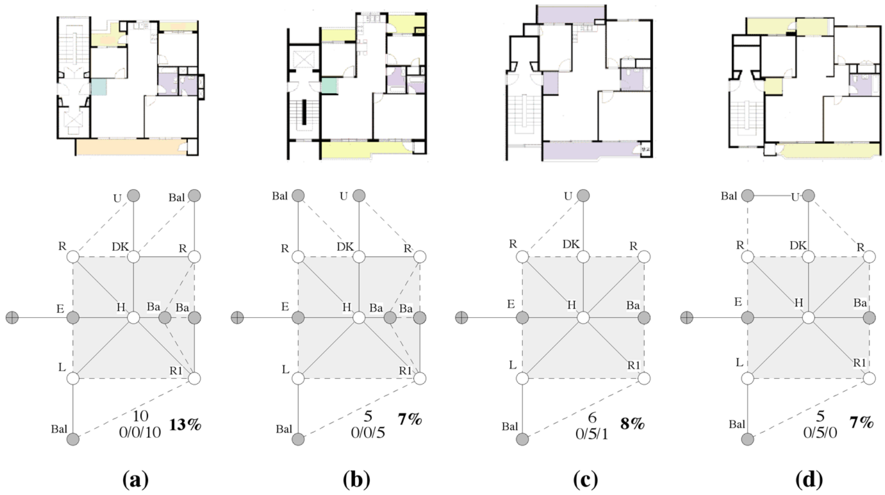


Figure 3. The four most frequently used graphs and corresponding plans
(for clear distinction between rooms, entrances, bathrooms, and balconies are marked dark)

Graph (a) is the most repeatedly used topology for the 3 bedroom staircase access apartment houses in Ghangnam-gu area; the numbers on the bottom of the graph indicate the total number of apartments that adopted this topology and their distribution in each decade from the 70s to the 90s. In the case of graph (a), it was used in 10 different apartment schemes and that exclusively in the 90s. In the case of graph (c), 6 plans can be represented by it, with 5 of them from the 80s and 1 from the 90s. Out of 75 sample plans, 26 plans (34.7%) are following these four dominant patterns. Relating these four graphs to one another, one can notice that graph (a) and (b) are exactly the same except they have different arrangement of the north balconies. Similarly, (c) and (d) share the same topology of rooms except for the variation in the north balcony side.

Finding shared morphology in the sample

Now, from the similarities of the graphs, it is expected that if some of those additive features outside the interior domain are deleted, then a more inclusive pattern can emerge. Following this idea, it is possible to generate sub-graphs that are shared by a multiple number of original graphs (figure 4).

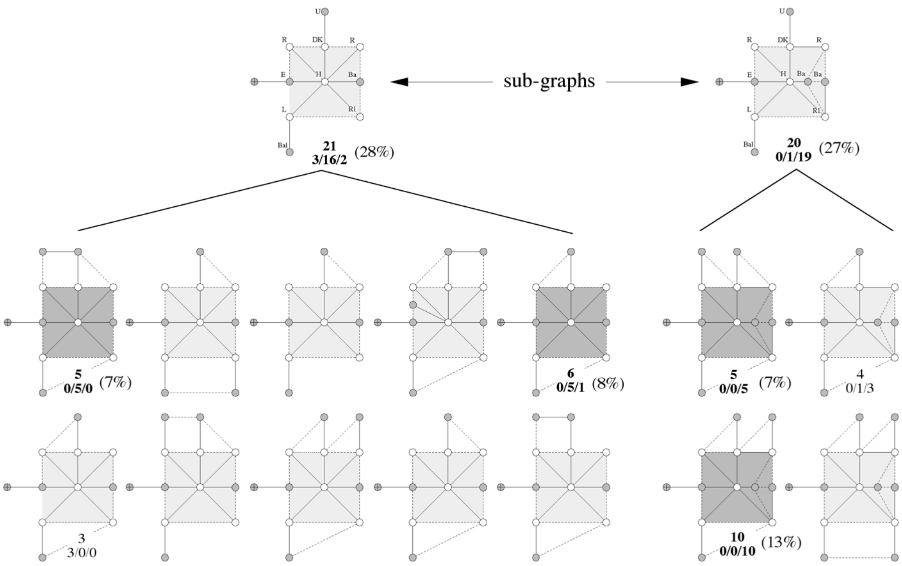


Figure 4. Process of making sub-graphs from the original plan graphs
(darker ones are the four most frequently used graphs in figure 3)

The sub-graphs on the top of figure 4 are the common denominators of many original graphs below including the four most frequently used ones which are coloured darker.

Masked by the variations in the balcony zone, these original graphs looked very different but it turned out that they have exactly the same arrangement of interior rooms. Out of 75 sample plans, 21 plans share the sub-graph on the top-left as an identical part and 20 the one on the top-right. In other words, more than half (54.7%) the 3 bedroom staircase access plans in Ghangnam-gu area in Seoul are following these two types of interior morphology, and this exactly matches with other studies that pointed out the dominance of these two in metropolitan Seoul (see, for example, Kim and Park 1992). These two dominant sub-graphs are generally known as a two-bathroom type and a one-bathroom type, as the number of the bathroom is the only major difference between them. Interestingly, by looking at the plans-per-decade counter under the graphs, it is found that the former appeared mainly in the 80s and the latter in the 90s. As will be dealt with later, this reflects the trend where consumers and providers both seek more luxurious plans as time passes.

As examined above, by extracting the same elements from a plural number of graphs, a new sub-graph as a common denominator can be generated. Through successive application of this process, graphs are converted from direct translation of real plans to more inclusive sub-graphs, and finally arrive at a single sub-graph that is the universal part of the whole sample (figure 5). This is a pyramid-shape bottom-up process where the wide-ranging types of graphs below are recursively converging to a smaller number of sub-sets above. During the construction of the tree, the principle of simplicity is applied since this could lead to a formulation of a more economical and logical tree structure. Within the final form of the tree, it is found that the first phase of sub-graph generation shown in figure 4 now becomes a small part – those four most dominant original graphs are still coloured darker.

It is crucial in this process that any sub-graph generated be a single unbroken topology; each spatial node, in its isolation, cannot function as a design component. This is what distinguishes the generative process of this tree from other formal approaches. Here, spatial sequence, be it partial or whole, becomes the elementary component in design, just as in real practice where designers treat each required space not in isolation but in relation to others. Hence, by adding the topological meaning to the formal generative process, the tree structure in figure 5 suggests a new way of finding shared morphology, which reveals more about the real design mechanism.

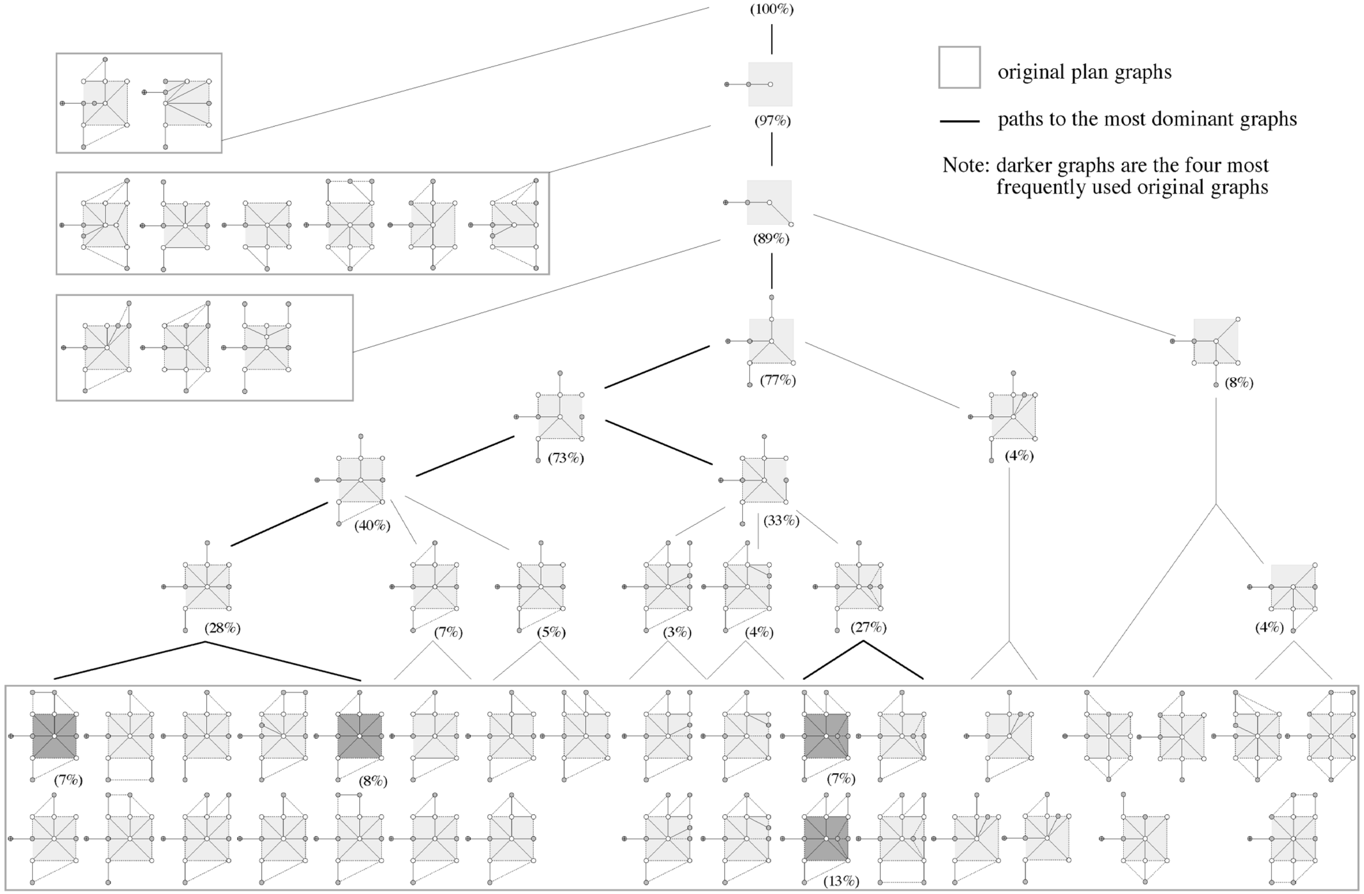


Figure 5. Tree structure showing the process of finding more common subsets from the 75 plans

In the tree structure, the graphs connected by thicker lines are the most dominant ones in each phase of the sub-graph generation. In figure 6 are some of them taken from the final five phases.

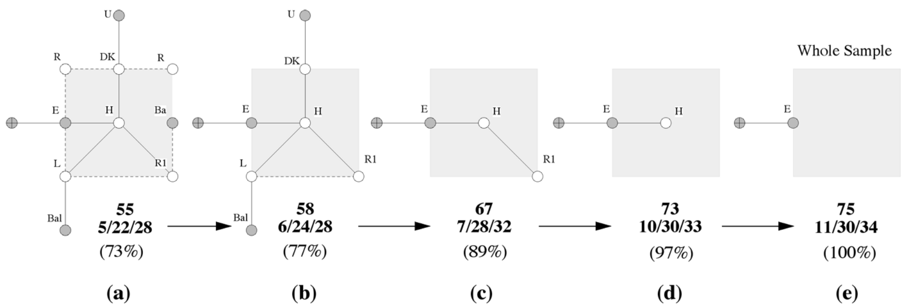


Figure 6. Five dominant sub-graphs taken from each of the final five phases

The graph on the left side is gradually transformed to the simplified sub-graphs on the right side to produce more inclusive common denominators within the morphology of the 75 plans. The first graph (a) is the most important of all in the tree structure. Since the following ones have only a partial structure of room layout, it could be regarded as the most informative sub-graph that suggests the 'most widely accepted' layout pattern. Given the sample area could adequately represent the whole city, a generalisation can be made that 73% of the 3 bedroom plans in Seoul could be generated based on this pattern. Graph (b) further reveals that, amongst all the topological links in the previous graph, some displays a higher percentage of usage (77% of the plans). These are the access links connected to the three major spaces, i.e. the dining-kitchen, the living room, and the main bedroom. Having bigger sizes with more functions, it is assumed that these spaces are considered before others in finding favourable positions. Next, in graph (c), only the route to the main bedroom remains; overwhelming 89% of the plans take the typical access pattern that connects the entrance, the central hall, and the main bedroom at the south corner. Syntactically speaking, this main bedroom is equally deep from the exterior as the other bedrooms and living spaces, but the rectangular representation of the graph enables the reading that it is located in the “best” south spot on the deepest side. The main bedroom disappears in graph (d) and only the connection between the entrance and the central hall remains. Thus, the formulation of the most of the plans (97%), excluding only 2 plans, begins by putting this initial pattern on an empty rectangular box. This spatial connection leads the outdoor space towards the very centre of the plan, dividing the plan into the upper and bottom halves. The central hall, therefore, can be regarded as one of the most fundamental aspects which characterises the morphology of the staircase type apartments in Seoul. Finally in graph (e), only the entrance hall is placed on the entire domestic area. This final graph is a universal element of the whole sample, and thus placed on the very top of the tree structure. This means that the staircase type 3 bedroom plans in Ghangnam-gu are all accessed from the side without exception.

Design competence reflected in plan morphology

Previously, the tree structure was constructed by recursively generating the common sub-sets from the original graphs. It is a bottom-up process where the graphs above are generated from the ones below. Now, when this process is reversed, it is found that the tree structure resembles a design generation process where an empty rectangular box is gradually filled in by a topological structure that is growing from a simpler form to a more complex one. In fact, it is uncertain whether the tree structure epitomises a real design process or not; and it is unlikely that design always proceeds sequentially in a top-down fashion. However, utilising the existing building stock as a material proof, it seems to be a reliable structure that reflects designers’ “competence” rather than their “performace” in Chomskian sense (Chomsky, 1965). If a particular pattern appears in every sample plan, it is safe to say that it is a taken-for-granted pattern instilled in all the designers’ competence. Thus, they consciously or unconsciously carry this pattern in their minds from the very beginning of the project, even if its actual appearance in the drawing might happen at the later stage of the design performance. Likewise, a dominantly used pattern could be the one that is conceived earlier in the design process as an optimum solution by many designers. In this regard, the tree structure which was built up in such a way to find more statistically important spatial patterns can be thought of as a hierarchy of socially accepted plan configurations. Even though the tree may not perfectly portray the real design performance, it can be at least defined as a retrospective modelling of the design competence in Seoul.

The action of design proceeds first by utilising the pre-structured knowledge of "solution types" that has been accumulated from the designer's experience and learning (Darke, 1984; Hillier et al, 1984). Obviously, it is more efficient and productive to work with well-defined knowledge of types rather than relying entirely on abstract intuition. Then, it can be thought that all the abstract variations of syntax in the tree are actually based on the knowledge of clear solution types in the designers' minds. Following this line of thought, an effort is made to reveal these types hidden behind the complex format of sub-graphs. Figure 7 is derived from the tree structure in figure 5 by translating the morphological information of the graphs into classifying types. From each sub-graph, the principal morphological information is picked up and labelled in the box. With no conflict, the whole tree structure can be neatly converted to this hierarchical classification. Now the tree loses mathematical information of design generation mechanism but it provides an insightful brief of the design strategy within which the designers are working. In this respect, this classification tree can be seen as a flowchart of design operations. In the diagram, each choice is explained by one most influential driving force (written in italicised words above each box). From this, one can get a macro-scale perspective on what major forces have leaded the generation mechanism towards the final product.

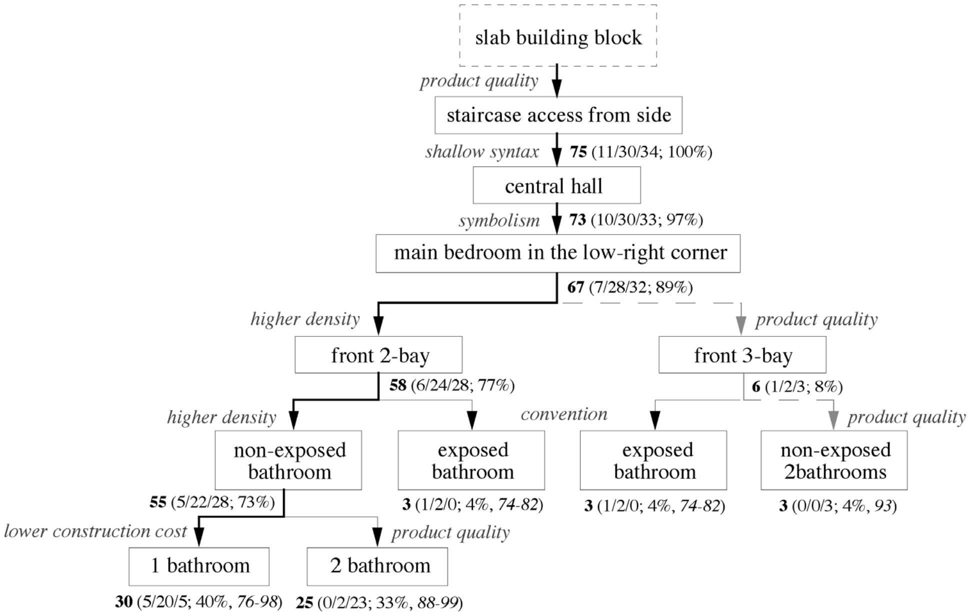


Figure 7. A hierarchical classification diagram derived from the tree in figure 5

Note: (1) The numbers below each box shows the statistics of that plan type. For example, "**25**(0/2/23; 33%, 88-99)" means that 25 plans, consisting 33% of the sample, appeared 0, 2, 23 times in the 70s, 80s, and 90s respectively and the first case appeared in 1988 and the last in 1999**.** (2) Thick black arrows follow the most dominant types and dotted arrows the ideal types for consumers.

One way to look at this hierarchical classification diagram is to regard the total number of the sample plans as the total number of designers participating in design. This translation is based on the idea that the percentage of each solution type can be a reliable index that demonstrates the designers' preference for it. At the top of the tree, let us assume that 75 designers are given a slab-block building shape which has been accepted as most effective for decades. Facing this task, their role is diminished to arranging the interior layout. First, all the designers choose, for building circulation, the staircase access type which is more popular than the balcony access pattern from the 80s on. Compared to the balcony access pattern, which has a long public balcony running along the building in each floor, this circulation type can provide a better design environment and protect the privacy of each unit. Thus, in a broad sense, the driving force for this choice can be described as 'product quality' of the plan.

In the next phase, overwhelming 73 designers (97%) make a decision that the central hall placed in the middle for internal circulation and connected directly from the entrance hall. The driving force for this choice is ‘shallow syntax’ by which the topological distance of each room in the house becomes shorter. Excluding the design patterns that have been caused by the building shape, this can be said to be the most distinguishing spatial feature of the apartment house in Seoul. A majority of the designers (67 designers, 89%) then begin to consider, above all, the position of the main bedroom. They place this most important private space in the farthest south corner from the entrance and connect it directly from the central hall. Although this spot is not deeper than the other living spaces in terms of topology, it is certain that the designers’ intention is to give inhabitants and visitors a feeling that the room is in the deepest position and to ensure that the room receives a good amount of sunlight. The driving force for this choice can be defined as ‘symbolism’ in which the traditional image of this room persists; even though its role as the best living space for the whole family is now diminished, the main bedroom is still regarded as the most prestigious space. Figure 8 shows the typical layout of the traditional courtyard house built for the middle class family until the 1960s in Seoul. It is recognised that, except for the living space (L), the main bedroom (R1) is the biggest in size than the other rooms, reflecting its role as the most important multi-functional space in the house. Almost without exception, the position of the room is at the corner of the so-called “L shaped block”, and this certainly gives the feeling that the room is at the deepest part of the house (for details, see Seo, 2003).

The 67 designers above, who selected the spatial link where the main bedroom is at the farthest south corner from the entrance, now have to choose between the two types: front 2 bay and front 3 bay. In the open front side, front 2 bay typically has a main bedroom and a living room, and front 3 bay has a main bedroom, a living room and another bedroom. Many studies argue that the latter arrangement of R1-L-R has been derived from the same adjacency relation of the rooms in the traditional courtyard house and, as a result, has been preferred in the market than the former (see figure 8).

Figure 8. The middle class courtyard house in Seoul and two types of apartment houses

When the front side has three bays, however, the front width of the unit gets longer and thus the whole building length becomes longer proportionally. As the site planning strategy in Seoul is, in a normal situation, aiming at higher density for profit, the front 3 bay type can hardly be regarded as an ideal choice for the developers. Thus, it seems natural that 58 designers (77%) choose the front 2 bay type. The front 3 bay type is chosen only 6 times (8%), but interestingly it is found that its appearance is concentrated in two periods – 3 of them appear between 1974 and 1982, and the other 3 in 1993 – and there is no appearance between these periods. Since density was not the most crucial issue at least until the early 80s, this wide fronted type was tested quite often. During the 80s, however, as the land value represents a greater proportion of the housing construction cost, the front 3 bay type was actively avoided. In the 90s, however, another turn was made; after a steady growth in the housing stock, stronger competition arose between the providers in the housing market. Thus, they tried to enhance the quality of their products and, within this effort, the front 3 bay type was re-introduced (Kang et al., 1999, pp. 342-346). In sum, it can be generalised that the driving force for the front 3 bay type is ‘product quality’ and that for the front 2 bay type is ‘higher density’. Each of these acts as a promotive force for one type but as a repressive force for the other. The choice between the two types is decided through the interaction of these two heterogeneous forces. When the weight of ‘higher density’ becomes greater, then the design decision tends to flow towards the front 2 bay type; but the opposite movement can occur when ‘product quality’ becomes a more significant factor.

In the next phase, amongst 6 designers who chose the front 3 bay type, 3 designers now choose the exposed bathroom type and the other 3 the non-exposed 2 bathroom type. As noted above, the appearance of these show a chronological split; the former appears in the early period and the latter in the nineties. It is probable that the designers of the early plans simply used the exposed bathroom by ‘convention’ without considering the advantages they could have in unit planning when its position is internalised. Through the 80s, however, the non-exposed bathroom became a single standard while the exposed bathroom became almost extinct. Consequently, when the front 3 bay type re-appeared in the 90s, it was not the designers concern to consider the long-ago-extinct exposed bathroom. Instead, they focused on the generation of a more consumer friendly plan with a wider facade and an additional bathroom to improve ‘product quality’ – thus, all the front 3 bay plans in the 90s are equipped with 2 non-exposed bathrooms.

Moving back to the front 2 bay type in figure 7, there are 58 designers (77%) who choose this dominant type. They now have the same choices the front 3 bay choosers had: installing the exposed bathroom or the non-exposed bathroom. The exposed bathroom was adopted simply by convention until the early 80s; it appears only three times and its last appearance is in 1982. All the other 55 designers adopt the non-exposed bathroom. In this case, the designers’ intention is to minimise the width of the unit by removing the bathroom from the rear edge, thus eventually increasing the housing density of the site. Therefore, the driving force for the selection of the non-exposed bathroom is ‘higher density’ while that of the exposed bathroom is ‘convention’.

In the last phase, after choosing the non-exposed bathroom type, two more choices are awaiting: the one bathroom type and the two bathroom type. Out of 55 designers, 30 choose the former and 25 the latter and their choices are clearly divided by year periods. Until the

80s, the one bathroom type was dominantly chosen but from the beginning of the 90s, conversely, the two bathroom type takes the dominant position. It can be said that those designers who select the one bathroom type are driven by the driving force, ‘lower construction cost’ and those who select the two bathroom type are motivated by ‘product quality’.

Overviewing the whole hierarchical tree, some meaningful patterns are detected. First, if the design follows this branching-out pattern, the final product can be reached by taking single morphological options at the higher levels and through the successive choices between two contrasted morphologies at the lower levels. At the higher levels, the positions of essential spaces, i.e. the entrance, the central hall, and the main bedroom, are determined. At the lower levels, the classifying features, i.e. the number of bays and the number of bathrooms and their exposure to the exterior, are determined. Hence, most of the morphological variations of the staircase access type plan are made at the lower levels. Second, the most dominant final plan, ‘the front 2 bay non-exposed 1 bathroom type’ on the bottom-left, can be reached by following the most dominant types in each phase (those connected by thick black arrows). Interestingly, this design flow is guided by the driving forces, ‘high density’ and ‘lower housing cost’ that only benefit the developers, not the consumers. In contrast, following the other force, ‘product quality’ which benefits the consumers, one can find at the lower-right corner the ‘front 3 bay non-exposed 2 bathroom type’ which appeared only three times in the sample area. This unbalanced distribution of the sample plans testifies that until recently, though there is a marked turn in the 90s towards ‘product quality’, the apartment housing market in Seoul has been controlled more actively by the suppliers.

Synthesis and evaluation

The morphological characteristics analysed in this paper are based on three bedroom plans. Since the apartment housing is the most dominant type in Seoul and three bedroom plans are the majority, it can be justified that the analysis can portray the housing culture in Seoul. However, it is also worth knowing how influential this design tendency is to other types. If different types other than 3 bedroom plans are composed by means of the same architectural approach suggested here, the argument of this study can be expanded to a larger portion of the housing stock in Seoul and thus obtains increased objectivity.

Figure 9 shows five staircase access plans with different number of bedrooms and their corresponding graph representations. They are the most widely used plans in Metropolitan Seoul between 1962 and 1990 according to Kim and Park's study (1992). Pointing out that in Seoul a small number of typical plans are repeatedly produced, they argued that these plans are designed in the same manner regardless of their sizes.

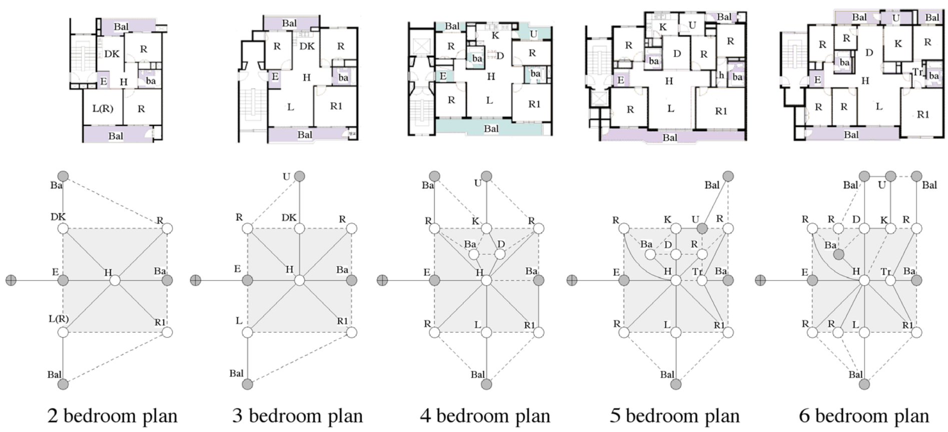
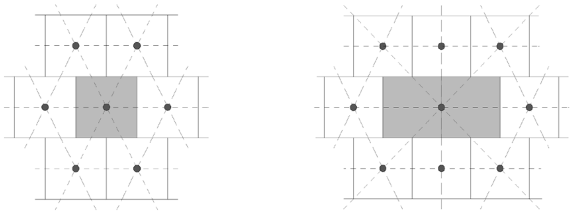


Figure 9. The most popular staircase type plans in metropolitan Seoul between 1962-1990

In figure 9, moving from the left to the right, it is obvious that the spatial system is getting more complex as the number of rooms increases. Both from the plans and the graphs, however, it can be recognised that all of them possess some features in common; they all show the typical design patterns of the three bedroom sample plans. First, they all put the central hall in the middle so that the major living spaces can be directly linked to it, making the system as shallow as possible. Second, the positions of rooms also show the same deterministic characteristics of the three bedroom plan; the main bedroom is always located in the farthest south corner from the entrance and other spaces also seem to follow this tendency.

In addition, the comparison of different sized systems corroborates the existence of other culture-specific layout patterns that were not self-evident in the three bedroom plan analysis. First, when the plan has more than two bays in the front side, the living room unexceptionally comes in the middle between the main bedroom and another bedroom. Thus, it is confirmed that this R1-L-R arrangement, arguably derived from the traditional spatial structure, is regarded as the best solution for Korean consumers. Second, regardless of the sizes, the dining room and the kitchen remain in the central zone of the upper half of the plan so as to be best connected to the living room in the south. When the morphological condition allows, therefore, the overall design patterns conspire to let the bedrooms surround the open public zone of LDK. Finally, this comparison reveals what consequences the central hall has on the generation mechanism of different sized plans. Apart from the role of linking surrounding spaces for shallow syntax, the central hall also acts as a crucial axis for the growth of the system. From figure 9, it is visually clear that as the size of the unit gets bigger, the central hall is gradually stretched out linearly to become a corridor-like space.

Steadman (1983, p.184) illustrates that close packing of rooms tends towards a hexagonal shape to maximise the potential connection between rooms [figure 10(a)]. In the diagram, if the rectangle in the middle is taken as a central hall, six connections can be made from it. Interestingly, the 2 bedroom plan in figure 9, which is the most compact one, has a comparable layout in which the central hall has six access links to other surrounding spaces.



(**a**) hexagonal room-packing (**b**) central cell stretched

Figure 10. Hexagonal packing of rooms and its variation
(reproduced from Steadman, 1983, p.184)

Now, if this central cell in the diagram is elongated, the metric distance of its perimeter is increased, and as a result it can have contact with more surrounding cells as in figure 10(b). In this way, the central hall remains as an integrating core regardless of the plan size. This is how different sized systems are generated from a single design approach; after all, all the plans in figure 9 are the variations of the same spatial structure. Therefore, it can be said that the hall lies at the focal point of the whole unit-planning process and it is from this that the particularity of the apartment plans in Seoul is formulated.

In this paper, the morphological principles that generate the apartment plans in Seoul have been investigated. In the beginning, a new graph-theoretic representation was proposed to overcome the limits of the spatial approach that exclusively values spatial permeability and disregards formal geometry. With its rectangularised format, this spatial representation could take the advantage of formal representation; thus, each spatial node in the graph could have its relative coordinate in relation to the boundary geometry of the plan. This new graph representation, then, was used to build a tree structure in a mathematical bottom-up fashion by recursively finding the common topologies from the 75 sample plans. In this process, the elementary component was not a single detached space but a spatial link between a plural number of spaces; thus this seemingly formal approach could retain in its core the very characteristics of the spatial approach. The tree was then converted to a classification diagram to extrapolate the design process and its related strategies. Since the hierarchical ranking of each design strategy in it came directly from the tree, the diagram reflects the designer's actual decision flow that is constantly guided by the inseparable ideas of form and space. At the end, synthesis and evaluation were made by mirroring the findings from the three bedroom sample plans to the morphology of other popular plan types in Seoul. Through the examinations of this research, it was revealed that within the formal constraints of the building, some morphological principles strongly set up an initial condition from which a few dominant plans are generated.

When a new housing type is introduced, designers tend to explore the possible solutions based on their local design language; but after a trial-and-error period, there comes a time where its formal varieties would eventually converge to a reduced number of socially agreed solutions. This is what Glassie calls the state of "new balance" which is arrived at after the changing process of "disequilibrium, expansion, and synthesis" (Glassie, 1975, p.112). Through the testing period in the 60s and 70s, the apartment house in Seoul is now believed to have arrived at this new balance in which some typical plan types are steadily reproduced. The optimal compromise between the new building form and the old spatial pattern has engendered a new housing prototype in Seoul at the end of the twentieth century.

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