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Space syntax analysis of urban housing transformation in Indonesia
Case study: Jatiwaringin Asri, Bekasi

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ABSTRACT

Previous researches on urban housing transformation in Indonesia focused on the privacy and observable morphological changes of the house. This study aims to compare the spatial configuration between the original and transformed plan of the urban houses in Indonesia. Six houses in Jatiwaringin Asri, Bekasi were investigated as part of the case study. The original plan and transformed plan of the houses are obtained through the interviews with the occupants of the houses. The plans were analyzed graphically and mathematically using space syntax. The results show that the open plan space is central in both original and transformed plan. There is strong segregation between public and private area but the interior of the houses maintains low hierarchical organization.

Introduction

User-initiated housing transformation in developing countries has been the subject of study by housing researchers. Tipple (1999) observed that housing transformation is common in developing countries to accommodate the social changes within the household. These transformations also demonstrated the social identity of the families that were not accommodated by the provision of mass-built housing (Tipple 2000). Thus, changes in the physical environment could help us understand the social value that motivates the housing transformation by the user. Indonesia is no exception to the user-initiated housing transformation. Although the number is never documented, several studies have been conducted to study self-initiated housing transformation in Indonesia focusing on the subject of privacy and morpohological changes (Sjaifoel 2008; Agnes 2017; Aryani, Wahyuningsih, and Mulyadi 2017).

While previous researches focused on the observable morphological changes and privacy issues of the house, this research objective is to compare the spatial configuration between the original and transformed plan of the Indonesian urban houses. Through the comparison, it aims to describe the differences in generative rules of the original and transformed spatial configurations. Space syntax is mainly used as the analytical technique. This case study proposes the wider use of space syntax to study the spatial configuration in Indonesian architecture and promotes the scientific study of the domestic architecture in Indonesia.

The case study took place in Jatiwaringin Asri housing estate. It is located in Bekasi, fourth most populated cities in Indonesia with 2.932 million people, which is a satellite city of Jakarta

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Metropolitan Area (figure 1). Jatiwaringin Asri was developed from 1980 by PT. Runa Ikana, a granddaughter company of PT. Pertamina – a state-owned oil company of Indonesia. The houses were initially sold exclusively to the employers of Pertamina and its subsidiaries. By choosing Jatiwaringin Asri as the case study, it helps to eliminate economic factor when transforming the houses because the family comes from relatively similar income level.

Figure 1. The case study is located at Jatiwaringin Asri (red dot) in Bekasi. Inset: The housing block with the cases numbered by interview order

Understanding society through space

Lawrence and Low (1990) stated that spatial ordering in a built environment is a reproduction of the social ordering of a society. Social relations of the society is responsible for creating the network of spatial relationships (Asif et al. 2018; Netto 2016). It means that the configuration of spaces represents social value, which results from a collective understanding of the society (Hillier 2007). Hence, we can understand the social pattern of a society by studying the spatial configuration in their built environment (Peponis and Wineman 2002).

Hillier and Hanson (1984) introduces space syntax analysis based on the idea that social organization is embodied within spatial organization. Hillier (2007) believed that space is a cultural artifact that is configured by following certain principles that govern the social interaction of the cultural group. Space syntax is an analytical tool that is rooted in graph theory to evaluate the spaces and analyze its hierarchies through which spatial organization is reduced into diagrammatic representation. The results can be used to study the social ordering of the society (Hillier 2005). In space syntax, the study of space is separated from form. While form reflects client's or architect's intent, the spatial structures reflect social orders and hierarchies that exist in the wider community (Ostwald 2011a; Ostwald and Dawes 2018). Hence, space syntax focuses on the topological qualities of space by ignoring the form from the architectural analysis.

There are two topological qualities that are considered in space syntax analysis: spatial structure and connective permeability (Ostwald 2011b). The spatial structure refers to the delineation of spaces, which can be defined through the presence of boundaries such as walls. Next, connective permeability refers to the connection between the spaces. Connection can be defined through openings, doors, or stairs that creates linkage between clearly defined spaces.

Space syntax does not provide normative judgement over architectural spaces. The analytical process of space syntax does not by any means dictate the rules of the design process. It rather tries to explain a system of possibilities that provide the structure and limitation to the design of the building. Space syntax can give insights to the practice by architects behind the arrangements of spatial structure (Amorim 1997; Ostwald 2011b; Dettlaff 2014). It can also help researchers understand the value upheld by society (Shapiro 2005).

Method

The cases in this study were houses in Jatiwaringin Asri housing estates. The houses were originally built as single-story houses with floor area of 45 – 54 m^2. Currently, all houses have been transformed into double-story house. There were other criterias for the selection of case study. First, the houses were occupied by the first owner. Second, the houses were occupied in 20 years or more so that substantial transformations are done to the house. Third, the occupants are married with children to reflect the life of Indonesian family.

The data was gathered through interview with six families. The interview was conducted to obtain information about the custom in the houses and measure the floor plan. Measured floor plans were drawn in CAD programs, which provides the base for convex map analysis in DepthmapX software. Convex map was drawn based on the programmatically-defined boundaries (Bafna 1999; Hanson 1999). This technique allows spaces with open plan and no clear threshold markers (such as walls or partitions that separate the space) to be treated as a single node. Thus, if the guest area (G), living room (L), and dining room (D) are located in an open space, they will be combined as a single node labelled GLD. Then, the convex maps were translated into a plan graph. Finally, the plan graph was justified by placing the nodes on their depth levels with exterior space as the 'root' or level 0.

After the JPG is created, it is mathematically analyzed following these steps (Ostwald 2011b).

Total depth

The total depth (TD) is defined by the sum of the number of connections in each level. The nodes at the corresponding depth level of the JPG (n_L) are multiplied by its number of depth level (L). Hence, the formula is:

$$TD = \sum_{L=0}^{L} n_L \times L$$

Mean depth

Mean depth MD is calculated by dividing the TD with number of rooms (K) minus one. It is defined as the average degree of depth of a node in JPG. Room with depth level higher than the mean depth is therefore more isolated than the room with depth level lower than the mean depth. The formula is stated as follows.

$$MD = \frac{TD}{K-1}$$

Relative asymmetry and real relative asymmetry

Once the TD and MD for the given house is calculated, the relative asymmetry (RA) is calculated next to compare the results with other houses. As the houses have radically different K values, the real relative asymmetry (RRA) is also calculated to find the benchmarked comparisons. The (RA) is stated by the following formula.

$$RA = \frac{2(MD-1)}{K-2}$$

To get RRA, we must benchmark the RA against D values. The D values are provided by the table "*D values for K spaces*" by Hillier and Hanson (1984). Thus, the RRA is stated as follows.

$$RRA = \frac{RA}{D}$$

Intergration

Integration is the opposite of the relative asymmetry (RA). If RA denotes segregation value, the integration tells how integrated the space to the whole spatial configuration. The integration (i) values are calculated by dividing 1 with RRA.

$$i = \frac{1}{RRA}$$

Difference factor

The differentiation degree between spaces is calculated to mathematically compare the spatial structure of the house. The differentiation degree between spaces will help us to understand the characters of spatial distribution among our cases. Therefore, we need relative difference factors H^*. The difference factor H^* is a relativized result of H , which provides a useful comparison for different houses with different number of rooms.

The calculation needs the maximum RA (a), the mean RA (b), and the minimum A (c). The sum of a, b, and c defines t, which is also required in the calculation. The unrelativized difference factor H can be calculated by this formula.

$$H = -\sum\left[\frac{a}{t}\ln\left(\frac{a}{t}\right)\right] + \left[\frac{b}{t}\ln\left(\frac{b}{t}\right)\right] + \left[\frac{c}{t}\ln\left(\frac{c}{t}\right)\right]$$

The relativized difference factor H^* can be calculated by normalizes the H into a scale between $ln2$ and $ln3$.

$$H^* = \frac{(H-ln2)}{(H-ln3)}$$

It is important to note that TD, MD, RA, RRA, H, and H^* are calculated according to their carrier. Traditionally the calculation must be repeated accordingly until every space has become a carrier. However, DepthmapX allows us to generate the TD values automatically from the convex map.

Result and discussion

Preliminary analysis

There are six cases that were studied in this research. The occupancy period ranges from 20 years to 32 years. The land size varies: 8 x 12 m (Case No. 4), 8 x 15 m (Case No. 3), 10 x 17 m (Case No. 1,2, and 7), and 12 x 17 m (Case No. 5 and 6). The original building sizes are 45 m2 (Case No. 4 and 6), and 54 m2 (Case No. 1, 3, 5, and 6). The transformed building sizes varied by cases (table 1).

Table 1. The occupancy period of the houses with its respective original and transformed building size

Case No.	Occupancy period	Land size	Original building size	Transformed building size
1	28 yrs	10x17 m	54 m^2	280 m^2
2	23 yrs	10x17 m	45 m^2	198 m^2
3	24 yrs	8x15 m	54 m^2	160 m^2
4	31 yrs	8x12 m	45 m^2	140 m^2
5	32 yrs	12x17 m	54 m^2	265 m^2
6	26 yrs	12x17 m	54 m^2	167 m^2

The characteristics of the houses in this case study will be explained in the following paragraphs.

Access

Before space syntax analysis was conducted, a preliminary analysis was done to the floor plan. It is noticeable that the houses have multiple entrances from the yard/ front yard into the house. The entrances provide two types of access. The first type is formal access. It is designated for occasional guests or business colleagues. The second type is informal access. It is designated for occupants, relatives, and close friends. The second type of access is more frequently used than the first type.

Multiple entrances are not always available in the original floor plan. When it is available, the first entrance provides access to the guest area (G), while the second entrance provides access to the living room (L). This can be seen in case no. 1, 2, and 3. In case no 4,5, and 6 there is only one entrance available to the guest area. In the renovated plan, multiple entrances are available in every house. The first entrance always provides access to the guest area. However, the second entrance varied by cases.

Rooms

In this study, the yard and backyard are treated as part of the house interior. These spaces are well-segregated with fences from the street and part of the private properties of the house. In the original plan, the yard is one big space covering the front to the back of the house. In the renovated plan the yard can be clearly divided into front and backyard. To simplify the study, the front yard is simply written as the yard.

The common feature of the houses in this case study is the existence of open plan space as the central part of the house. In the original plan, there is only single open plan space at the ground floor (OP-GF). Whereas in the renovated plan, there is an additional open plan space at the upper floor (OP-UF). The OP-UF has no dedicated functional properties. It flexibly adapts to the occupant’s needs, while the OP-GF might contain a combination or separation of guest, living, and dining room in the original plan. In the renovated plan, the pantry is also part of the OP-GF.

Rooms like bedrooms and toilets grow in number when the house is renovated. The number of bedrooms will depend on the number of children, although there can be more bedrooms than the family needs. The extra bedroom is provided for the guest lodging. Other rooms that may be available are praying room, drying area, laundry, maid room, storage, and balcony. The complete rooms list with its abbreviation is written below (table 2).

Table 2. The list of rooms with its abbreviations and apperances in the original and transformed plan (O = Original, T = Transformed)

Rooms	Abbr.	O	T
Yard/front yard	Y	•	•
Garage	Ga		•
Guest	G	•	•
Living	L	•	•
Dining	D	•	•
Pantry	P		•
Open plan ground floor	OP-UF	•	•
Kitchen	K	•	•
Back yard	BY	•	•
Side yard	SY		•
Open plan upper floor	OP-UF		•
Toilet/bathroom	T	•	•
Bedroom	BR	•	•
Praying room	Pr		•
Drying area	dr		•
Laundry	la		•
Maid room	ma	•	•
Storage	st		•

Rooms	Abbr.	O	T
Balcony	ba		•

Space syntax analysis

While the preliminary analysis provides some insights about the houses, space syntax helps us to reveal the underlying spatial structure of the house. A visual analysis of the JPG for the original and renovated plan reveals a relatively similar and arborescent structure. In the original plan, the OP-GF provides a point of connection for the compartmentalized private spaces (toilet and bedroom) and service spaces (kitchen and maid room). In the renovated plan, there are two points of connections, OP-GF and OP-UF, that provide a point of connection into other rooms in the houses (figure 1).

If we simplify the plan graph of the original plan by grouping the guest area, living room, and dining room into OP-GF, then we can discover a pattern. Root - Yard - OP-GF is the backbone of the houses. Furthermore, OP-GF in the original plan provides points of connection to the kitchen, bedroom, toilet, and few service areas. The simplification of the transformed plan by grouping the guest area, living room, dining room, and pantry into OP-GF allow us to discover Root - Yard- OP-GF- OP-UF as the backbone of the houses.

In the transformed plan, OP-GF provides points of connection to the kitchen, bedroom, toilet, backyard, side yard, and praying room. The OP-UF provides points of connection to the bedrooms, toilets, balcony, and service spaces (laundry, drying area, maid rooms, and storage). Another discovery is that the deepest level of the branch from the OP-GF or OP-UF is three levels. The graph analysis also shows that the kitchen is not always existent in the original plan, but it is always existent in the transformed plan. Kitchen is consistently connected to OP-GF, either through the dining room or pantry.

The JPG also shows how the entrances from the yard transformed. In the original plan, the yard provides entrances not only to OP-GF but also to many service-related areas such as storage, maid room, kitchen, and toilet. However, in the transformed plan the yard only serves as entrances to OP-GF, kitchen, and garage. The number of rooms accessible from the yard is reduced.

The next step is to identify the primary spatial structure through mathematical analysis, particularly to find its integration (*i*) values (table 3). In all of these cases, the OP-GF becomes the most integrated space in the house of the original plan and five cases of the renovated plan. In the renovated plan, the OP-UF becomes the most integrated space in case no. 3. If the OP-GF becomes the most integrated space, then OP-UF follows as the second most integrated space. Whereas if OP-UF becomes the most integrated space, the OP-GF follows as the second most integrated space. Root (⊕) is the least integrated space in five cases of the original plan and among the least integrated space in only two cases of the renovated plan. In the renovated plan, the toilet dominates as the least integrated space in four cases, which is part of the bedroom or laundry area.

It is clear that not every house has similar types of rooms. In order to seek a clear pattern, an analysis was conducted to spaces that always present in every case. In the original plan, the spaces are ⊕, Y, OP-GF, BR and T. Whereas in the renovated plan, the spaces are ⊕, FY, OP-GF, OP-UF, BR, T, and K. When the analysis focuses on the rooms that always present in every case, then a pattern starts to emerge. The *i* value of those rooms are presented in the following box plot graph (figure 2).

Table 3. The order of the rooms by their *i* values

Case No.	Type	Room rank
1	Original	OP-GF =Y (1.75) > ⊕ = St = BR = T (0.58)
	Renovated	OP-GF (3.66) > OP-UF (2.66) > FY (1.46) > K = BR2 (1.39) > Pr = BR1 = BY = T1 (1.27) > dr = BR3 = BR4 = BR5 = T3 = ba (1.13) > ⊕ (0.84) > T2 (0.81)
2	Original	OP-GF (2.96) > Y (2.22) > T1 = BR1= BR2 = K (0.89) > ⊕ = T2 = ma (0.81)
	Renovated	OP-GF (3.25) > OP-UF (2.09) > FY = BR2 = BR3 (1.33) > BR1 = BY = T1 = K (1.22) > BR4 (1.08) > T4 = St = dr (1.01) > ⊕ = T2 = T3 (0.79) > ba (0.7)
3	Original	OP-GF (3.44) > Y = K (1.15) > BR1 = BR2 = T2 (0.86) > T1 = ⊕ (0.57)
	Renovated	OP-UF (2.60) > OP-GF (2.08) > dr (1.30) > Y = BR2 = BR3 = T1 = ba (1.04) > BR1 = T1 = K (0.95) > ma = T2 (0.74) > ⊕ (0.65)
4	Original	OP-GF (2.55) > Y = K (1.02) > BR1 = BR2 (0.73) > T = ⊕ (0.51)

Case No.	Type	Room rank
	Renovated	OP-GF (2.36) > OP-UF (2.14) > FY = CS (1.12) > BR4 = la (1.07) > Pr = BR1 = K (1.02) > BR2 = BR2 (0.98) > T1 = ⊕ (0.69) > ba = T2 (0.67)
5	Original	OP-GF (3.49) > Y (1.75) > D (1.16) > BR = T (0.7) > ⊕ (0.58)
	Renovated	OP-GF (2.41) > OP-UF (2.30) > Ga (1.38) > P (1.34) > G = Pr (1.30) > dr (1.27) > BR5 (1.21) > T1 = SY (1.18) > BR2 = BR3 = BR4 = ba = T3 (1.15) > FY (0.93) > BR1 (0.86) > K (0.85) > T5 = St (0.82) > T4 (0.79) > ⊕ (0.66 > T2 (0.63)
6	Original	OP-GF = Y (1.72) > K (0.86) > BR1 =T1 = BR2 = ⊕ (0.69) > T2 (0.49)
	Renovated	OP-GF (2.31) > OP-UF (1.60) > FY = BR1 (1.16) > K = Pr (1.10) > T2 = BR2 = ma (0.99) > dr (0.83) > T1 = ⊕ (0.69) > la (0.67) > T3 (0.48)

The box plot graph provides insight to the order of spaces. In the original plan, we can see the order from the most integrated space to the least integrated space as follows.

OP-GF > Y > BR > T > ⊕

Whereas in the transformed plan, the order of the spaces are as follows (figure 3).

OP-GF > OP-UF > FY > BR > K > T > ⊕

The order between the original and renovated plan is almost identical. The only difference is the presence of OP-UF (open plan space at the upper floor), which follows after OP-GF as the second most integrated space in the house.

The boxplot graph shows that the root (exterior) is within the lowest *i* values in both original and transformed plan. This mathematical analysis gives a hint about public-private domain relationship in the floor plan. It could indicate that there is strong segregation between the interior (private) and exterior (public) of the house.

It is also possible to compare the six houses mathematically through their relative difference factor (H^*). H^* value shows degree of differentiation of the spaces. Because the H^* value is a relativized factor, it is possible to compare different houses with different number of rooms. The interpretation follows the theory outlined by Hanson (1999): “the closer to 0 the difference factor, the more differentiate and structure the spaces ...; the closer to 1, the more homogenised the spaces … “It means that if the H^* value is closer to 1, the spaces can accommodate various activities with little functional differentiation between the spaces. When the H* values are compared between the original and renovated plans, an almost consistent H* value is obtained.

The H* values of the original plans are: case no. 1 H^* = 0.79, case no. 2 H^* = 0.72, case no. 3 H^* = 0.54, case no. 4 H^* = 0.61, case no. 5 H^* = 0.54, and case no. 6 H^* = 0.73. All houses have spatial configuration that fall into the category of “homogenised” or “weak genotypes” because the H^* value is close to 1. The number is almost consistent with the H^* values of the transformed plans: case no. 1 H^* = 0.65, case no. 2 H^* = 0.63, case no. 3 H^* = 0.69, case no. 4 H^* = 0.74, case no. 5 H^* = 0.69, and case no. 6 H^* = 0.60. Although the numbers are slightly closer to the middle range, it still falls into the category of “homogenised” or “weak genotypes”. Hence, the spaces are not strict to particular functions.

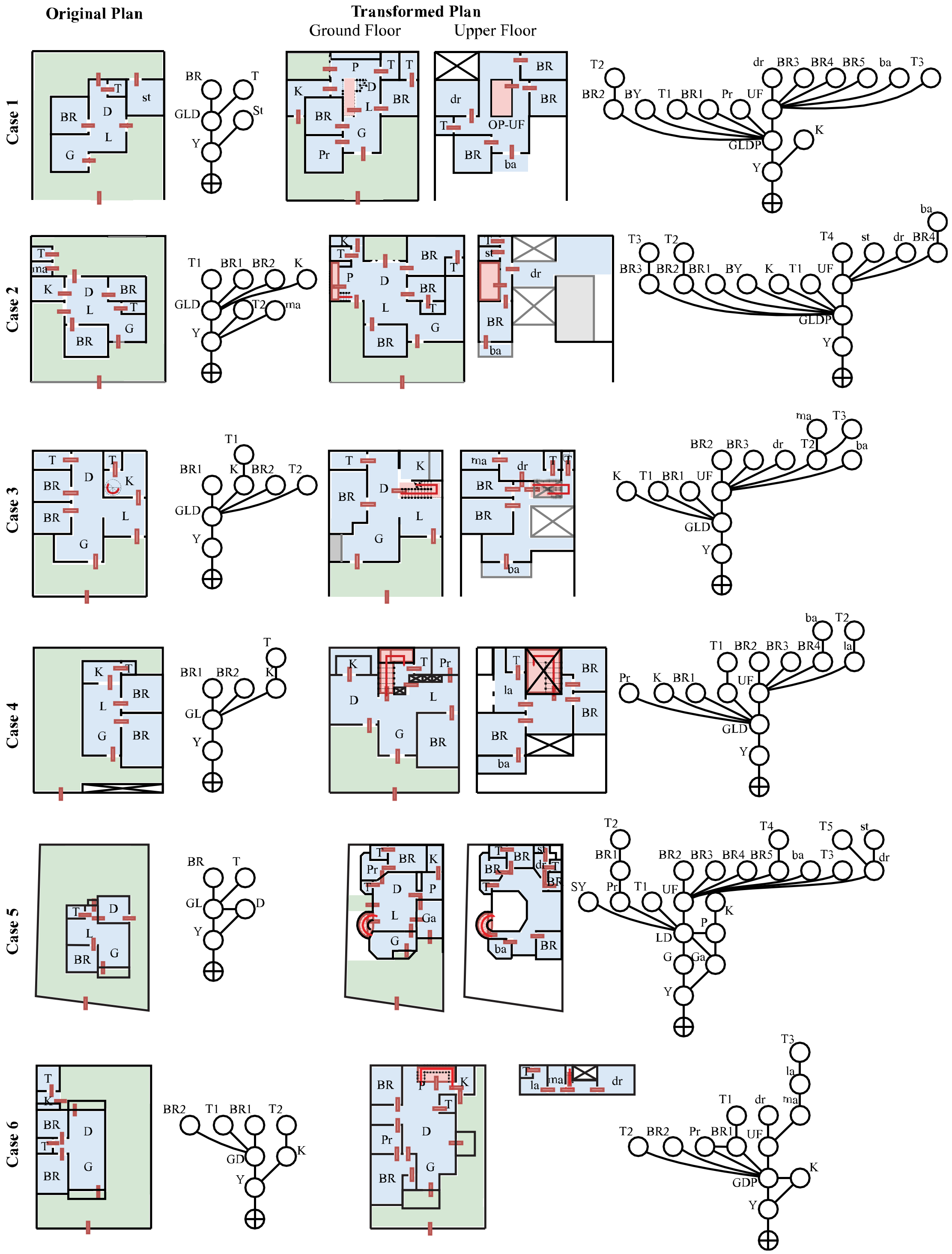


Figure 2. The summary of convex mapping and its respective JPG

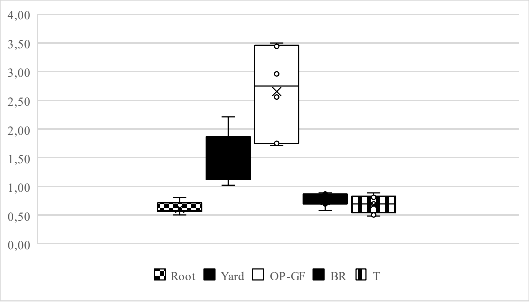


Figure 3. The *i* values of the original plan

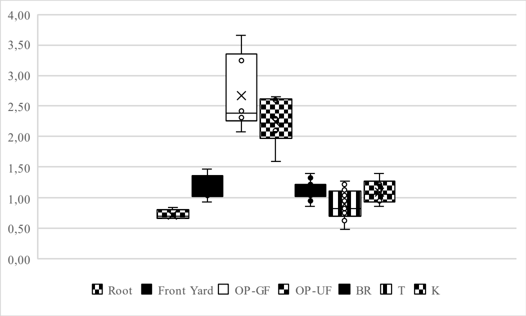


Figure 4. The *i* values of the transformed plan

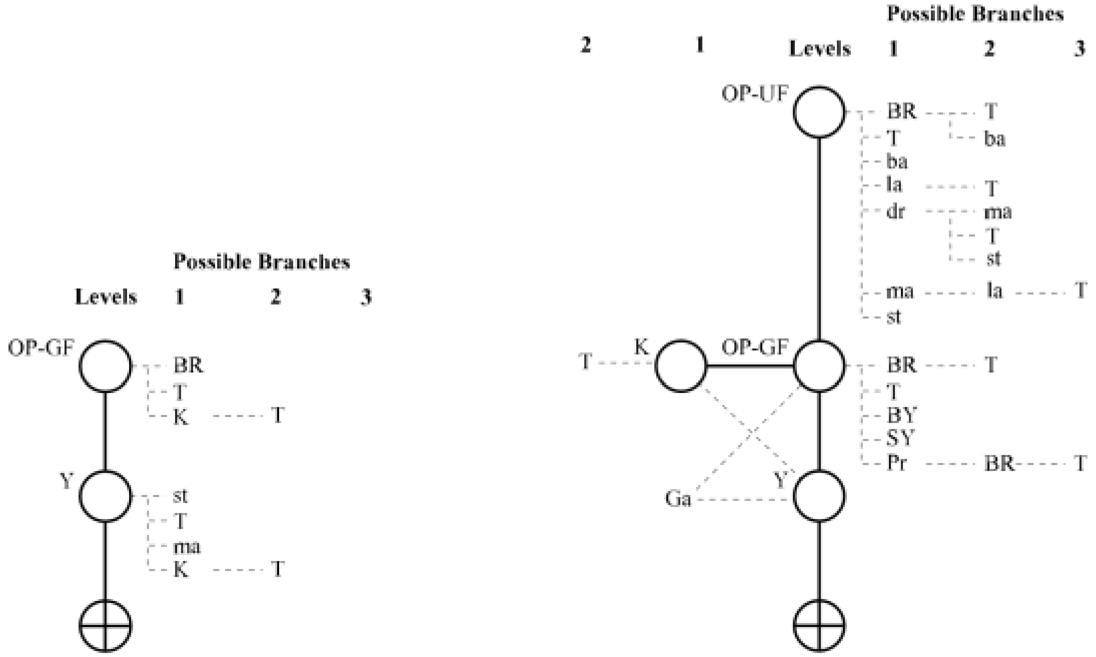
Conclusion

The open plan space, in both original and transformed plan is central to the urban houses in this case study. It is also the most integrated space of the houses. The open plan space provides a point of connection to other rooms in the houses. Transformation is done to the house to add more open plan space at the upper floor, providing more points of connections for the rooms at the upper floor. Although the addition of rooms seem to add more complexities to the floor plan, the relativized difference factor proved otherwise.

The analysis also discovers following generative rules. (1) Multiple entrances are always available in the transformed plan to allow access to rooms in the open plan space and or to kitchen; (2) In the original plan, OP-GF might contain a combination or separation of G, L, and D. In the renovated plan, P is also part of the OP-GF; (3) Root - Yard - OP-GF is the backbone of the original plan. Root - Yard - OP-GF - OP-UF is the backbone of the transformed plan; (4) In the original plan, the Yard provides access to OP-GF and many service-related areas, while in the transformed plan, the yard only provides access to OP-GF, kitchen, and garage; (5) Kitchen is consistently connected to the OP-GF through dining room or pantry in the transformed plan; (6) The possible branches for OP-GF (original plan) are kitchen, bedroom, toilet, and service spaces; for OP-GF (transformed plan) are bedroom, toilet, backyard, side yard, and praying room. The possible branches for OP-UF are bedroom, balcony, toilet, balcony, and service space (laundry, drying area, maid rooms, and storage); (7) The deepest level of branches from OP-GF or OP-UF is 3 level. The generative rules of the transformed plan also can be summarized in the following diagram (figure 4).

The H^* value shows that the houses are “homogenised” in the original plan. It reflects that the urban society is less hierarchical with weak organizational order. Surprisingly the hierarchy was not affected by the transformation of the plan, despite addition of rooms. However, low i value of the root space (exterior; public street) indicates strong segregation of the private and public domain. This is also indicated with separation between public and private access into the house. Therefore, private (occupants) and public (outsiders) separation is needed but the interior space should maintain low hierarchical organization.

Of course, the cases from this case study cannot generalize the result. The number is too few and the criteria is limited to a particular type of family. However, this research discovers the possibilities to describe spatial structure of Indonesian urban houses and the generative rules in the production of the spatial configuration. With a larger number of samples and different types of family, it will be possible to discover patterns which can be used to generate floor plans that represent the spatial structure of Indonesian urban houses. Further study is needed to collect larger samples of data.



(a) (b)

Figure 5. The generative rules of the houses (a) the original plan and (b) is the transformed plan. The shapes in bold shows the backbone of the houses, with dotted lines show possible branches of rooms

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