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EVOLUTION OF SPATIAL CONFIGURATIONS IN GHANA'S HOUSING DEVELOPMENT: THE CASE OF PRIVATE APARTMENT BUILDINGS IN GHANA

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ABSTRACT

In architectural application, activity spaces in the spatial system must follow a thought through process in order to harness its full benefits. Amidst current developments, modernization and innovative technology in the recent contemporary development of private apartment buildings, high consumption of energy and poor functional efficiencies of spatial configurations coupled with defects in activity performances have become prevalent issues. This study is aimed at evaluating the functional efficiency of spatial configuration of selected apartment buildings in Ghana to aid improvement as much as adding to the body of knowledge. The objective was to assess the impact of spatial configuration parameters on the functional performance of apartment spatial layouts. Using the space syntax methodology (Mean Depth, Mean Integration, Space factor, Space-link ratio and Space type) 30 apartment layouts spanning over a 30 (divided into 3 periods) year period was examined (1980-2010). Mean depth for bedrooms and washrooms (bathroom and toilet) was high across all the periods. This gives an indication of how private these spaces have been and continue to be. Mean Integration values showed the kitchen in the 3rd and the living spaces in the 2nd and 3rd periods being very efficient and less segregated. The results show the 3rd period layout (more recent) offer better solutions in terms of privacy but the negative effects (depression, marginalization, loneliness) of the drive for privacy and shunning away from communal living, even within nuclei family structures and spaces ought to be considered. The study thus provides scientific evidence of the progress made in the development of spatial configuration in the Ghanaian housing sector. It also unearths the possible dangers that this progression is fraught with. The data collected is of immense benefit in the design process of future house layouts in Ghana as to the way forward towards developing a congenial environment.

Keywords: Spatial Configuration, Functional Efficiency, Spatial Performance, Apartment Layout, Space Syntax.

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1.0 INTRODUCTION

Sustainability and efficiency in all facets of human development has become imperative in the 21st century. All over the world, city styles and layout of communities have had great influence on the lives of the inhabitants. Nopadon (2001) reiterate that the configurational approach of spatial arrangement is based on the theoretical concept that if built space is composed of organizational units, it is because they are responding to precise living patterns. Oftentimes, these patterns are also based culture predominantly which include factors ranging from religious beliefs, family structure, gender, privacy etc. Rarely do environmental factors such as thermal comfort and lighting considered. According to Mustafa, Hassan & Baper, (2010), one of the most important objectives of sustainable architecture is upgrading the performance and the efficiency of interior spaces within buildings. These spaces eventually gives the form of the design architecturally. Hillier (2007), emphasizes the importance of developing the form and space into configuration, because the latter represents the key to the solution, not only with regard to the nature of the buildings, but also on how architecture can be emerged through the building spaces. How spaces come together in the formation of a housing unit is one area that has not been explored in Ghana as a country. In Ghana, the provision of housing has always been left to individuals whose taste and economic capacity to develop dictates the whole process. The study of Agyefi-Mensah (2013) concluded that architects depend largely on professional training, experience and ontological local content knowledge of Ghanaian socio-cultural habitation to determine user requirements with no empirical basis or direct participation of end users at the design stage. Various Governments have tried many affordable housing projects but eventually there has been little success. In more recent years, the real estate sector has been very vibrant, developing various typologies with different configurations and selling or renting it out to the populace. Spatial configuration is seen as an abstract term which has different aspects in the formulation of buildings and usually the last factor to consider in Ghana. The aim of the paper is to find out the functional efficiency of spatial configuration of selected apartment buildings in Ghana to aid improvement in residential designs as much as adding to the body of knowledge.

2.0 SPATIAL CONFIGURATION STUDIES

Spatial Configuration studies have been conducted around the world since the development of the space syntax model and the syntactic approach has been commendable. Brkanić, Stober, & Mihić, (2018); Mzoori, (2014); Mustafa and Hassan (2010); Dursun and Saglamer (2003); Nopadon (2001) are just but a few of such studies. Mustafa and Hassan (2010) assess that the relations between the various domestic spaces in a home have an influential role on the nature of spatial configuration of the house layout in general. The study of Brkanić, Stober, & Mihić, (2018) which sought to identify the spatial configurations that dominated apartment designs from 1930 to 2015 in the city of Osijek in Croatia made some stunning revelations. The authors used space syntax approach with parameters of integration degrees, mean depth, difference factor, space link ratio and space type indicators as the approach. The authors concluded that changes in the apartment layout can be seen in different time periods in terms of

1) Design according to zones versus design according to rooms;

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2) Internal communication between rooms as mostly direct or mostly indirect;

3) The appearance of specific room functions (living room, dining room, bedroom, built-in closet, etc.) versus integration of room functions (living room, dining room, and kitchen all within a single space); and

4) Growth of net flor area (outdoor spaces, toilet, pantry) versus the decline of net floor area (kitchen, bedroom, storage).

The period from 1960 to 1975 stands out as the period with the smallest total net floor area of apartments, mostly influenced by the small net floor area of the living room and bathroom. Nahyang & Jaepil (2016) utilized a quantitative methodology; Space Syntax, to draw principles for the spatial layout of apartment unit plans through the use of syntactic spatial structure analysis carried out on sample unit plans in the city of Seoul, South Korea. The authors established that the living room centered spatial layout typology can be interpreted as the genotype of spatial structure emerging from the old unit plans of Korean houses, in addition, for lifestyle, the genotype for unit plan layouts could largely accept both Korean traditional domestic livelihood and modern domestic lifestyles, which is however still being maintained. Meanwhile, Mustafa and Hassan, (2010) elucidates that in order to achieve efficiency from building layouts by indicators such as the availability of interior spaces for individual and communal use, and the openness or closeness of physical partitions, two components are important: The psychological efficiency which deals with the extent a building 'invite' the potential user or visitor to come in, makes use of the building and of the activities going on inside. Relevant spatial aspects include: a recognizable entrance; clear transitions and circulation from public to private; syntactical characteristics which facilitate spatial - functional orientation, such as a clear outline of a building layout, visual axes, points of recognition, differentiation in the use of spaces etc. The other is the physical efficiency which deals with the ease with which users and visitors can reach, enter and move through a building, thus being able to use its various spaces. A focal point in particular is the integral accessibility, which means that people with physical disabilities can also enter and move through the building independently, just like others. Mustafa et al. (2010), in their study using the syntactic parameters of space syntax methods (mean depth, mean integration, difference factor, space link-ratio and space type) as their methodology surveyed samples of spaces to evaluate the functional efficiency of traditional and Modern House Layouts in Erbil City, Iraq from 1900 to 2010. The authors commented that spatial configurations reflects effectively the degree of functional efficiency of based on each indicator and benchmark adopted in the study. Towards spatial depth, there was an upward projection which indicated the prominence of the spaces moving on unto the newest periods from the old, and spatial integration varied across the all periods signifying the least value as the best cohesion-link integration from the differentiation values of the spatial layouts. Nopadon (2001) adopted the space syntax methodology with field research strategies to investigate the differences in spatial configuration among vernacular houses built during various periods of construction in upper northeast of Thailand, with the key variable being the floor plan. The writer found out that the change in the characteristics and physical features influences the configurational properties of the houses, more so the modifications of spatial arrangements from different sources of design reveal the change of spatial patterns among vernacular houses. From a socio-cultural viewpoint in housing culture, a spatial arrangement of housing layout configurations supports the

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interpretation of family units, cultural activities and social connections relating to its uniqueness which reflects homogeneousness and social changes in modern times.
In Africa and Ghana as a country, very few of these studies have been undertaken. With its diverse cultural content and lack of housing infrastructure and a growing population rates, people will still live irrespective of spatial layouts seeking where to lay their heads. Chokor (2005) revealed that people adapt to spaces to live but gradually make changes to suit their activity patterns and more functional and efficient once their economic situations improve. Agyefi- Mensah (2013) in his study in some apartments in Ghana revealed that there exist functional inefficiencies in residential flats and recommended objective approaches to evaluate functional performance of mass housing design as a solution for flexibility and longevity, providing a suitable set of design prerequisites.

Considering the above, this study is aimed at evaluating the functional efficiency of spatial configuration of selected apartment buildings in Ghana to add to the body of knowledge. The objective was to assess the impact of spatial configuration parameters on the functional performance of apartment spatial layouts.

3.0 METHODOLOGY

The space syntax methodology is used in the study. This methodology combines physical and social indicators to explain the spatial-functional systems in order to identify their configurations in terms of differences and similarities. This paves the way to diagnose the strengths and weaknesses in the structures of house layouts functionally (Mustafa and Hassan, 2010). The methodology aims at describing spatial models (house layouts) and representing these models in a numerical and graphical form (to interpret them on a scientific basis) according to Manum (2009); Dursun (2007) and Hanson (2003). Implementation of the syntactic process was carried out through the application of a licensed software Programme (A-Graph). The process of measuring and calculating was based on the following steps:

- Preparing the scheme of spatial depth (justified – graph/ gamma map) for each house layout of the sample, considering the space outside the house as a carrier root space.
- Through equations and formulas, values of the indicators: Real Relative Asymmetry-(R.R.A.), Mean Depth (MD), the Difference Factor of space (H*), Space-Link Ratio of the spatial system, and Space type were achieved by applying the software programme (A-Graph).

Mustafa and Hassan (2010) gives an elaborate explanation of the various indicators as summarized below.

In calculating the Mean Depth of space (MD), a justified graph is created by putting the intended space to measure its relative depth at the base of the house layout as a key space (root space) usually the entrance; the other spaces are then aligned above it in levels according to how many spaces one must walk through in order to arrive at each space from the root space. Each space in the system is represented by a small circle, while the permeability between spaces are represented by linked lines.

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The integration value of space (Relative Asymmetry – R.A.) expresses the relative depth of that space from all others in the graph through a formula.

The difference factor is used to quantify how much a space is interchangeable with others as a proportion of the sum of integration values of spaces under consideration (Bellal, 2007). Low values for (H*) would indicate the existence of a 'strong' genotype whiles values close to 1 would designate 'weak' genotypes, that means there is no functional differentiation and weakness in the functional efficiency of space. According to Zako (2006), these simple measures are able to express culturally significant typological differences among various house layouts over time, because the concepts on which they are based, have in themselves a kind of intrinsic 'social logic'.

Space-link ratio assess the distributedness and non-distributedness properties. Distributedness reflects the existence of more than one non-intersecting route from a given point in a system to another point. If there is only one route for any two points in the system, then the system is said to be non-distributed; Measuring the degree of 'ringiness' of a spatial system, or the space-link ratio, represents the extent of the permeability of spatial system. It is a ratio between the number of links that is located between spaces plus one, and the number of spaces in a spatial system of the house. Its values vary around the number (1). Where the values are more than (1), then there is a high degree of 'ringiness' of a spatial system (ringy structures), and therefore its tendency of distributedness; this in turn refers to a high degree of flexibility (functional efficiency) in using the space enabling the user to change the layouts to adapt to different circumstances, either by closing or opening doors.

The methodology (space syntax) provides a way to categorize the types of spaces on the topological characteristics of the building's spaces that meet functional requirements of occupation and movement through it. In Space Syntax terminology, there are four different topological types of space (space type or degree of spaceness): a-type space which has one link; b-type space which has more than one connection and lies on a tree; c-type space which has more than one connection and lies on a ring; and d-type space with more than two connections and lies on at least two rings. To calculate the degree of a-ness of a house layout the number of a-type spaces is divided by the total number of spaces minus one, since the maximum number of a-type spaces can be found in a shallow bush graph with a-type nodes all connected to a b-type single node. For calculating the degree of b-ness, divide the number of b-type spaces in a house layout by the total number of spaces minus two; since the b-type spaces, is always a way to another space. According to Guney (2005), the degree of c-ness and d-ness is calculated by dividing the number of c- or d-type spaces by the total number of spaces in the layout as a whole.

Results were presented on Tables, charts, and graphs, to facilitate the process of interpretation and evaluation. The spaces being examined under the various indicators include Kitchen, Bedroom, and Living Room, Washroom (bathroom and toilet).

3.1 Object Description

Nine (9) multi-storey apartment buildings (averaging 30 different spatial layout configurations) from three different time periods of developments in Accra (1980-2010) were selected for the study. The sampled layouts were divided into three periods of a decade each for the analysis. The buildings are; Premier Place Apartments (P.P.A.), Kaiser Apartments (K.A.), Segeco Apartments

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(S.A), Villagio Vista Towers Apartments (V.V.T.A), Sakaman Apartments (SK.A), Harmony Apartments (H.A), Royale Apartments (R.A), Tema SSNIT Apartments (TS.A) and Adenta Housing Apartments (AH.A). The buildings were chosen because they are a representative of the design trends in Ghana's high-tech, mass private apartment housing system through the time under consideration. Figure 1 illustrates samples of spatial configuration layouts and the corresponding justified permeability graphs for the various periods.

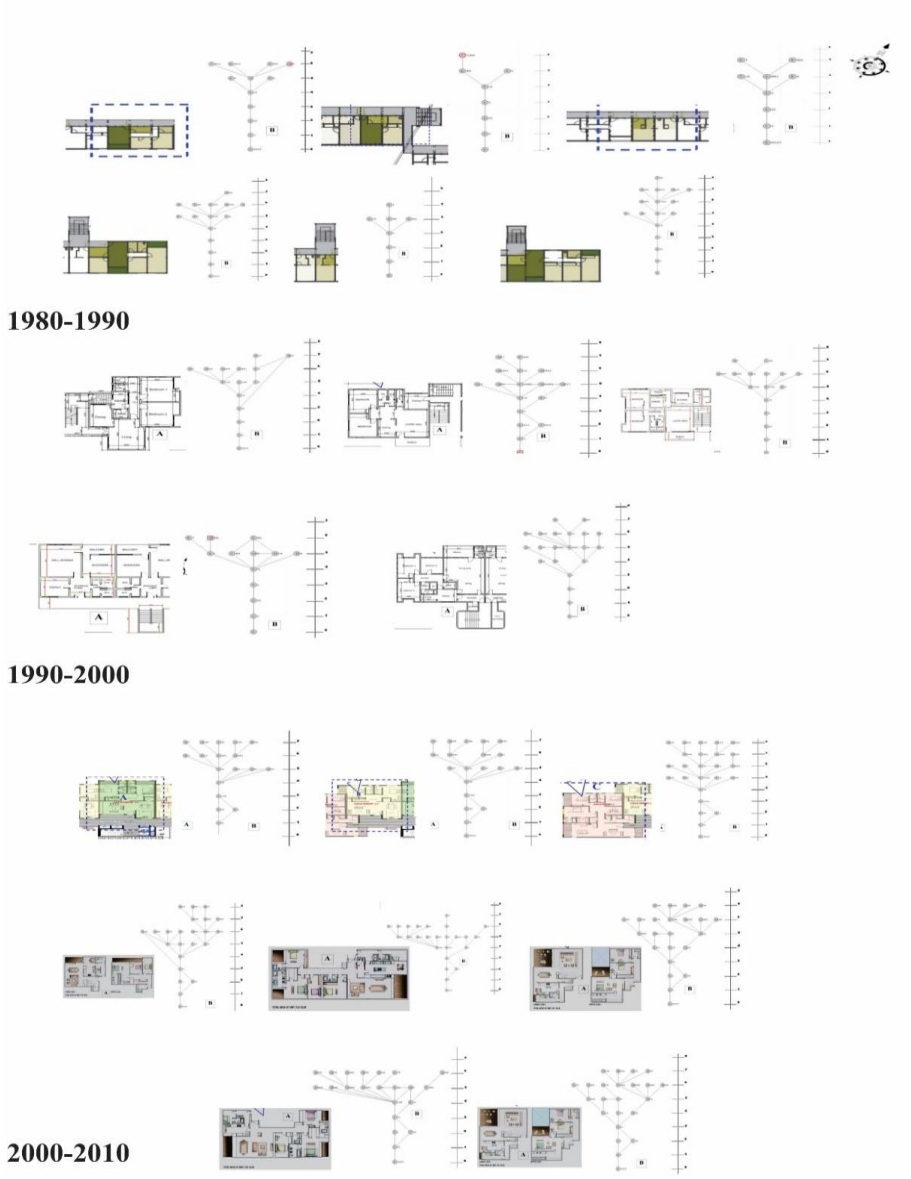

Figure 1: Justified Permeability Graphs (Gamma Maps) of some of the selected spatial Configuration Layouts

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4.0 RESULTS AND DISCUSSION

Mean Depth (MD) values of kitchen configurations can be summarized as follows: for the first period (1980-1990) is 2.617, the second period (1990 -2000) is 2.721, and the third period (2000-2010) is 2.793. The results shows an upward projection of the indicator from the old (1980-1990) to the new (2000-2010). Similar results was documented by Mzoori (2014). The author's finding was MD values of 2.713 for the first period (1900-1930), 2.718 for the second period (1930 -1960), 2.888 for the third period (1960-1990) and 3.546 for the fourth period (1990-2010). There is a clear ascendant prognosis of which the author commented that the spatial structure of the kitchen has gained prominence and become more important. Nonetheless, the first period (1980-1990), recorded the lowest depth, signifying the properties of symmetry and most efficient for lower depth values, comparatively to all three periods, followed by the second period (2.721), and consequently (2.793), the third period. This is in contrast to the findings of Brkanić, Stober, & Mihić, (2018), in Croatia, where the kitchen recorded the most depth signifying asymmetric configurations and inefficiency of the kitchen spatial configuration in the spatial structure, and this was due to a stagnation in apartment construction design solutions. Table 1 illustrates the MD for all the layouts within the study period

Table 1: Mean Depth values of all house layouts for all periods

Time Periods	**1st period (1980-1990)**	**2nd period (1990-2000)**	**3rd period (2000-2010)**
Kitchen			
Mean Depth (MD)	2.617	2.721	2.793
Bedroom			
Mean Depth (MD)	3.124	3.362	3.754
Living room			
Mean Depth (MD)	2.894	2.513	2.964
Bathroom and Toilet			
Mean Depth (MD)	2.924	3.322	3.941

Mean Depth values of bedroom configurations also followed similar ascending progression where the first period (1980-1990) recorded a value of 3.124, the second period (1990-2000) was 3.362, and the third period (2000-2010) was 3.754. Mzoori (2014) also reported a comparable trend and commented that the bedroom values indicates a difference in the values progressively in the overall time periods from the oldest to newest. The results also show that the 3rd period (much recent) bedroom layouts are much more asymmetry and has deeper depth (Hillier, 2007) : Meaning the layouts have been developed with privacy in mind than the 1st and 2nd periods according to Manum (1999) as cited by Mustafa et al. (2010). Mean depth values of toilet and bathrooms also take an upward curve, moving forward from the oldest period to the newest. This indicates the importance and efficiency of the bathroom, especially in the apartment layouts of the first period (1980-1990), and the second period (1990-2000). Nahyang & Jaepil (2016) in study, discovered a link between the bedroom the toilet and bathroom of recent periods all becoming more asymmetric within deep levels of the spatial systems due to privacy. The mean depth indicates that the bedroom and

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bathroom &toilet are deeper when compared to living room and kitchen for all the periods. This observation is in tandem with Nopadon (2001) who found that toilet, sleeping space and verandah were deeper when compared to external, under floor space and eating space.

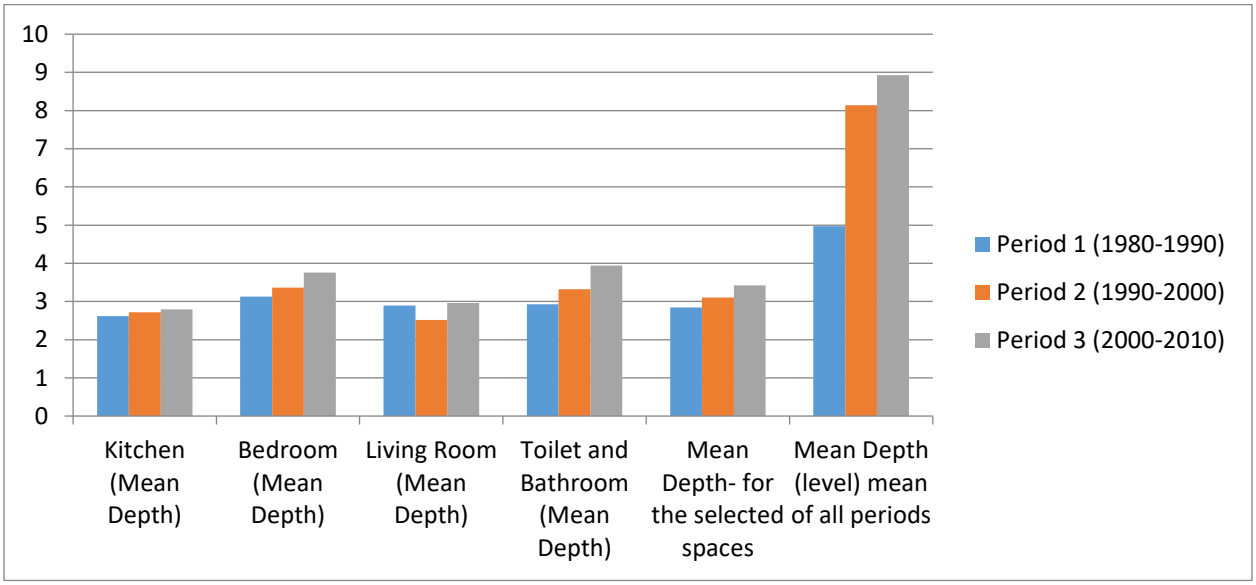

Figure 2: Comparative Mean Depth values and level of overall apartment layouts for all periods.

Figure 2 indicates that apartment layouts of the first and second periods reflects symmetry and permeability of the spatial system. This represent the best in terms of functional efficiency for the major domestic spaces (kitchen, bedroom, living room, and bathroom) measured.

The indicator of integration is based on giving high importance (efficiency) to a spatial system in terms of function, the importance of space will increase with a decrease in the integration values. Table 2 shows the results for integration.

Table 2: Mean values of Real Relative Asymmetry of the key functional spaces in all house layouts for all periods

Time Periods	**1st period (1980-1990)**	**2nd period (1990-2000)**	**3rd period (2000-2010)**
Kitchen			
RRA	1.275	1.022	0.725
Bedroom			
RRA	1.431	1.042	1.213
Living room			
RRA	1.431	0.654	0.931
Bathroom and Toilet			
RRA	1.304	1.086	1.437

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The integration results show the kitchen in the 3rd period being the most integrated and efficient with less segregation in comparison to the other periods. This finding is similar to findings in Mustafa et al. (2011), where the kitchens integration values depict efficiency and less segregation, but in contrasts with findings of Nopadon (2001), where higher integration values signified less efficiency and segregation of the kitchen space. The bedroom integration shows high level of segregation and less integration since all the values are above 1 but the second period being the least can be close to being integrated. The finding is consistent with outcomes from Nahyang and Jaepil (2016), where modern layouts were less integrated but were able to maintain a cohesive link and sustain domestic traditional Korean livelihoods. Results for living room shows the first period being segregated and therefore less efficient. The 2nd and 3rd periods however indicate integration and less segregation. For the function and concept of the living space/room, the afore-stated results couldn't have been any better. Brkanić, Stober, & Mihić, (2018) , Agyefi-Mensah (2013), and Nopadon (2001) all recorded low values of integration for living rooms describing their functional efficiency and cohesion of space, in relation to other spaces in the spatial system. The bathroom and the toilet show similar trend to that of the bedroom: an indication of the privacy of the function of the space.

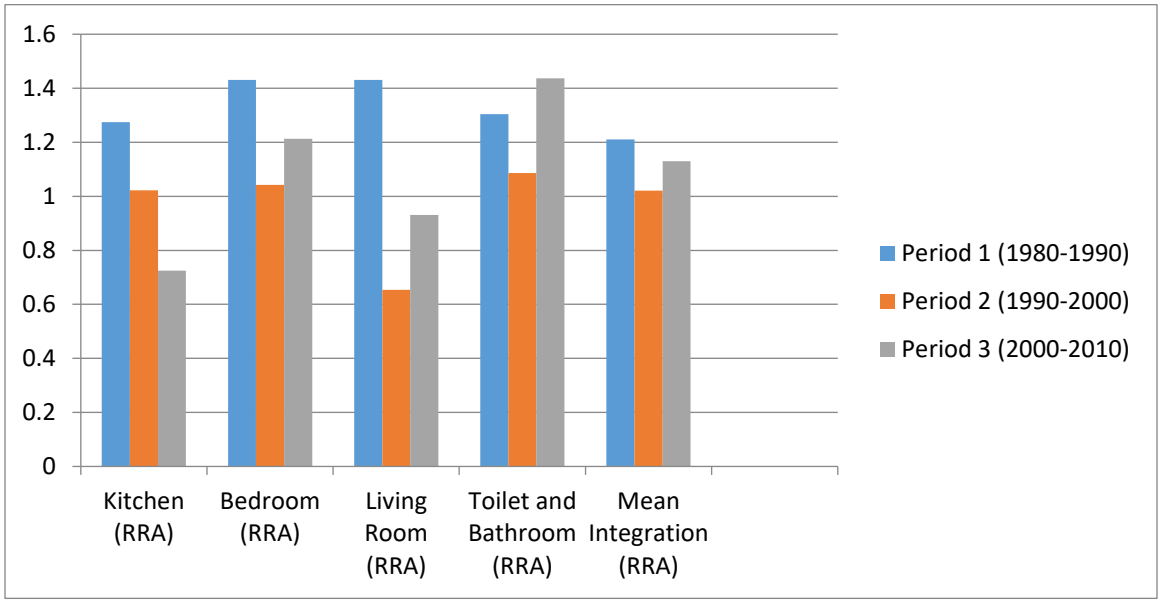

Figure 3: Mean Integration (RRA) values of overall apartment layouts for all periods.

From the study, it is seen that the apartment spatial layouts of the second period by comparison, reflects the best values from the mean integration. Similar findings were reported by from Brkanić, Stober, & Mihić, (2018) and Mustafa et al. (2011) showing less segregated spaces, incorporating functional efficiency into the spatial system.

In reference to the integration values obtained, the difference factor (H*) for overall layout of the study period is shown. The lowest difference factor is the second period (1990-2000) with 0.896. The 1st and 3rd periods have convergent values (0.938 and 0.936) respectively. This indicates that

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the apartment layouts of the second period (1990-2000) have the lowest difference factor comparing to the other periods. Table 3 demonstrate this finding.

Table 3: Difference Factor values of the overall house layouts for all periods

Periods	Mean Integration	Max. Integration	Min. Integration	Difference Factor (H*)
1st (1980-1990)	1.211	1.470	0.925	0.894
2nd (1990-2000)	1.021	1.234	0.864	0.823
3rd (2000-2010)	1.130	1.432	0.944	0.924

Base on the justified permeability graphs, results related to the indicator space-link-ratio indicate that 60% of the sampled layouts in the 1st period are tree-like, thus having values equal to 1 while the remaining percentage of the sample appear as "ringy" structures. This indicate how inefficient these layout are. The average (space link ratio) value of all house layouts in this period is 1.027. Apartment layouts in the 2nd and 3rd period depicts spatial layouts that are "ringy" structures with their mean (space link ratio) values 1.103, and 1.115 respectively. Apartment layouts of the 2nd and 3rd periods reflect high distributedness, thus giving an impression about their efficiency at the spatial-functional level comparatively. Similar results was achieved by Mustafa et al. (2011). The authors recorded mean space-link ratios values of more than 1 for spatial systems across all periods. However in Nopadon (2001), only two periods (1930-1960 and 1960-1990) out of 4 periods had spatial configurations that were distributed and efficient.
In relation to the indicator of space type "degree of space-ness", the following results in Figure 4 was achieved.

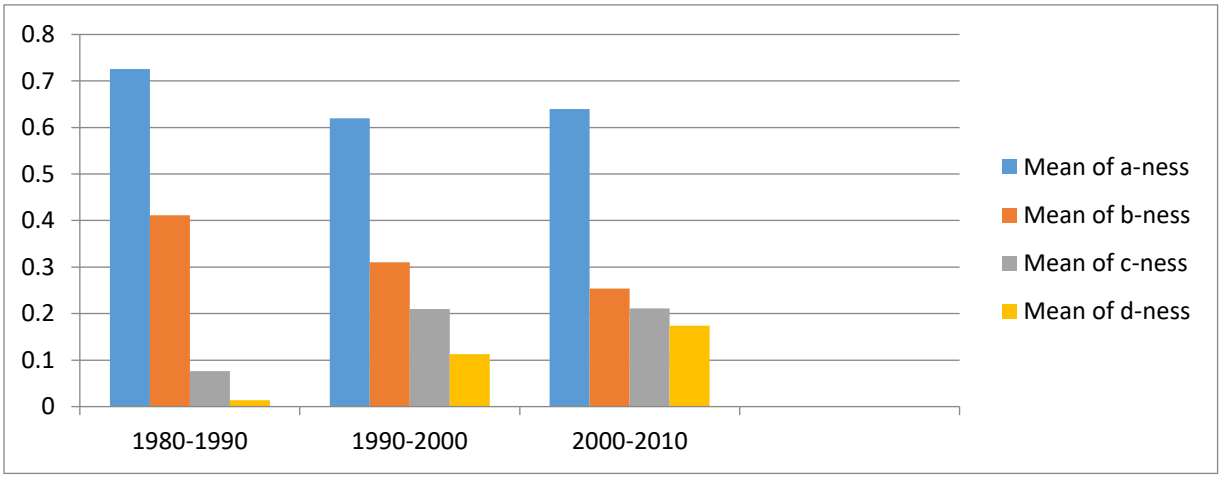

Figure 4: Mean space-type values (degree of space-ness) of overall apartment layouts for all periods.

It is observed that apartment layouts of the 2nd and 3rd periods (1990-2010) are the most efficient since the values of spaces of both types (c, and d), are highest (almost at par) and the spaces (a, and b) the least value in comparison with the entire period of study. This signifies more efficient and flexible structural systems.

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5.0 CONCLUSION AND RECOMMENDATIONS

Analysis of the connection between the spatial configuration and the functional efficiency of apartment layouts over different (30 years divided into 3 phases) time periods has been undertaken. Using the space syntax methodology, 5 key measurement indicators, thus spatial Depth, Mean Integration, Difference factor, Space-link ratio and Space-Type were assess on 30 apartment layouts (10 for each phase) within the study period. Key configuration spaces assessed included kitchen, bedroom, living room and washroom (bathroom and toilet).

In terms of mean depth, spaces in the 3rd period (2000-2010) all recorded high values: an indication of how segregated the spaces were. This shows that privacy has become very important in the spatial distribution of apartment floors in recent times. Layouts within the 2nd period showed less integration values. From all the indicators, bedrooms and washrooms were seen to show high privacy levels across all the periods. These results show a clear move towards privacy and nuclei family/spaces as the country develops. The negative effects (depression, marginalization, loneliness, etc.) of the drive for privacy and shunning away from communal living, even within nuclei family structures and spaces ought to be considered. Current housing developments in developed countries are looking for ways to better integrate communality into housing structures. In Ghana, further studies would be necessary since the concept and subject appear highly unexploited. For instance, the relationship between spatial configuration and homeowners' attitude could be looked at. Architectural students in Ghana could benefit immensely from this subject if it is integrated into the curriculum. Building designers are key players in design decision making towards the development of social structures and spaces. This study serves as a reminder on their role in carving a healthy path for the country for a healthy society.

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