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Constructing Functional Genotypes of Apartment Design: A Comparative Study of The Layouts of Apartments Buildings in Amman

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***Abstract*:- The emergence of apartment buildings as a residential buildings type in Amman, Jordan has motivated the researcher to describe and analyze their spatial form. Architects in Amman design these apartment buildings based on building codes and regulation for residential plots. The research assumes that despite the large variety in residential plots dimensions and areas, these building codes and regulations have standardized the ways of design, shaped the spatial layouts, and specified the functional structures. Therefore, the research aims to uncover the underlying relations of the functional spaces of apartment designs and establish them as graphs of genotypes. Altogether, 30 cases of apartments layouts were selected, and their underlying functional structures were analyzed. According to the analysis, the research determined that apartment designs fall under eight classifications of genotypes. A hierarchical order of the justified graphs was then established to develop an inequality genotype, manifesting the order of the integration of spaces from highest to lowest to determine the consistencies and inconsistencies in spatial patterning in the apartment layouts. The findings confirm each genotype, that captures the topological relationships, can assume different geometrical forms.**

INTRODUCTION

March and Steadman (1971), Hillier and Hanson (1984), and Mitchell (1990) argued on the topic of understanding spatial relations between the functions of spaces to describe an architectural form, regardless of its actual theory. According to their observations, there are abstract rules that underlie the form of a building. Notably, these rules present common spatial relations and can be formalized in the form of graphs that represent “abstract rules underlying spatial forms, rather than spatial forms themselves” (Hillier & Hanson, 1984, p. 12). Hillier and Hanson labeled these graphs as genotypes “because they refer not to the surface appearances of forms but to deep structures underlying spatial configurations (Hillier & Hanson, 1996, p. 27). They also noted that buildings of function type, such as residential buildings of different geometrical forms, have common configurational relations and a specific order of integration between spaces and that configuration can be presented as genotypes (Hillier & Hanson, 1998). Genotypes represent the underlying structures of a spatial form rather than the phenotype, or the physical appearance, of the genotype.

The rise of apartment buildings as one of the most popular residential buildings occurred together with urban growth in Amman. Apartments emerged as an acceptable solution for economic problems, rapid urbanization, and the growing population. Codes and regulations were therefore issued for residential land use to accommodate these conditions and suit various of dwelling needs.

Concerning land usage, apartment buildings are subject to codes and regulations to control the design, as architects should conform layouts and forms of these buildings to the codes and regulations. The research therefore assumes that despite the large variety in residential plot dimensions and areas and thus the various forms and compositions of apartments layouts, these forms have underlying commonalities of functional structures due to the constraints building codes and plot regulations. In other words, the research assumes that these codes and regulations are design constraints that limit the range of potential design solutions and particularly functional relations therefore it can be argued that there are specific sets of functional relations as well as forms that show common characteristics in topological structures. Moreover, this research advances the researcher’s previous work (Naimat, 2015). Apartment plans in Amman that use a particular functional program were selected as a case study that aims to not only determine the underlying relations between their functions of the apartments’ forms but also formulate them as graphs.

The following section presents a brief overview of apartment buildings as a residential building type and discusses the codes and plot regulations that affect the design of these apartments. An analysis (evaluation) of the apartment’s architectural plans, and the final section addresses the conclusions.

APARTMENT BUILDINGS IN AMMAN

The emergence of apartment buildings as residential buildings type is considered one of the distinctive architectural elements that took place in Amman due to the local population growth and the subsequent high demand for residential units, especially for low-income population (Betawi, 2013). Jordan’s government thus began to assemble the provisions needed to construct apartments in Amman. these apartment buildings’ design must adhere to the codes and regulations that authorities have issued. In addition, the apartments’ general design should include at least three major spaces with its facilities: a living, a kitchen, and one bedroom. Indeed, according to Schram “a well-designed house should provide space for three basic activities: living, working, and sleeping. Ideally, the spaces provided for each of these activities should be separated, and so that one activity does not interfere with another." (Schram, 2006, p. 225)

Under the current regulations, residential land use in Amman is divided into four zones, based on the following criteria: the minimum plot area, the maximum area percentage of the plot that can be built upon, and setbacks that are correspond to the distance between the building and the plot limit. The zones are distinguished using notations A, B, C, and D, from the largest to the smallest plots. This division is also based on population density, income level, and political issues. For instance, residential zone of A is usually for high- income areas; zones B and C are for middle-income areas, where most apartment buildings are constructed; and zone D is for low- income areas. Table 1 and Table 2 summarize the regulations for residential land use including, including those concerning setbacks, the percentage for construction, and thr minimum area required for a plot in each residential zone.

Table 1

Required building setbacks and plot area in GAM planning for residential zones

Greater Amman Municipality regulations for residential zone				
Residential Zone	Frontal Setback (m)	Side Setback (m)	Rear Setback (m)	Minimum Plot Area (m^2)
Zone A	5	5	7	1,000
Zone B	4	4	6	500
Zone C	4	3	4	300
Zone D	3	2.5	2.5	750

Note: These numbers as per article No.11 from The Regulation of Zoning and Building of the City of Amman No 76 of the year 1979 and Amendments thereto. (Greater Amman Municiplity, 1979)

Table 2

Required building regulations in GAM Planning for Residential Zones

Greater Amman Municipality Regulations for Residential Zones			
Residential Zone	Allowable Built Area (Percentage)	Height of the Building (m)	Minimum Frontage Dimension of the Plot (m)
Zone A	39%15		25
Zone B	42%15		18
Zone C	51%15		15
Zone D	55%15		13

Note: These numbers as per article No.11 from The Regulation of Zoning and Building of the City of Amman No 76 of the year 1979 and Amendments thereto. (Greater Amman Municiplity, 1979)

The maximum allowable floor area is determined by calculating the area percentage of the plot and the area within setbacks, the smaller area, is the maximum area allowed for the plot's design. However, it should be noted that the area of the duct, the interior space within the construction limits opened and exposed to the outside air to deliver lighting and ventilation to the rooms overlooking the duct, is excluded from the total area of the apartment plan if its area and length are equal to or less than regulation requirements. Table 3 depicts the regulation for ducts in apartment buildings.

Table 3

Requested areas of ducts for residential units.

Request area of the ducts		
Space	Area m^2	Minimum Length (m)
Rooms	10	2.5
Kitchen, Laundry and Bathrooms	7.5	2.5

Note: These numbers as per article No.11 from The Regulation of Zoning and Building of the City of Amman No 76 of the year 1979 and Amendments thereto. (Greater Amman Municiplity, 1979)

APARTMENT BUILDING CODES

Building codes, which comprise a list of rules, drawings, and standards that stipulate the most acceptable level of general welfare in construction and design are instituted for health and safety, accessibility, and fire and structural protection. The Ministry of Public Apartment and Works (MOHPW) is responsible for the building codes that govern the design of apartment buildings in Jordan. These codes are not merely guidelines for architects but establish the minimum standards, which is not allowed to be crossed. Architects in Jordan should refer to Ghaniem's "Code of Space Requirements in the Building" (Ghaniem, 1993) to address the space requirements for residential buildings. This research cannot mention all the numerous codes related to apartment buildings from the book; Rather, it mentions the most important codes that affect the design of residential buildings. For instance, Table 4 illustrates the required areas for residential rooms.

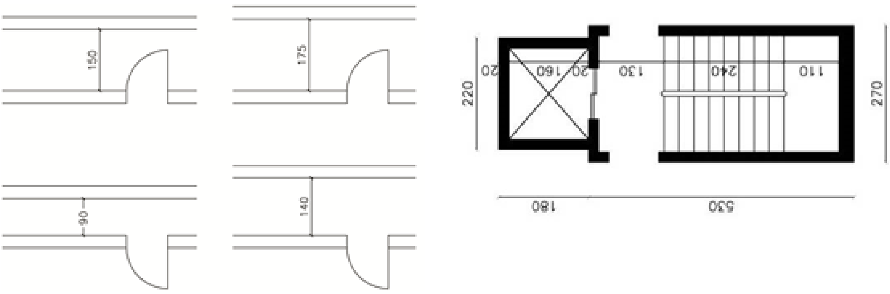
Table 4

Minimum areas required for residential units Function Area (m^2)

Function	Area (m^2)	Function	Area (m^2)	Function	Area (m^2)
Living Room	10.8	Dining	3.65	Bathroom	1.3
Bed Room	6.30-6.70	Kitchen	2.7	Guest Room	8.0
Master Bed Room	9.0				

Note: these areas refer to The Jordanian National Building Codes: Code Of Space Requirements In The Building. **(Ghaniem, 1993)**

Apartment buildings generally include a minimum of eight living units, with one staircase and one elevator for the vertical circulation to link between floors. As to horizontal circulation, which the code defines as space for moving from one space to another, its width should not exceed 40% of its length. Figure 1 presents the required dimensions for halls, staircases and elevators designing of apartment buildings in Amman derived from Ghaniem's book.



(a) (b)

Figure 1: (a) The required dimensions for halls and (b) the required dimensions for staircases and elevators.(Ghaniem, 1993)

based on the above, building codes also control the design of apartment layouts. The research speculates that there are limited variations in the spatial layout and forms of apartment buildings across various of plot areas due to the constraints these codes and regulations.

Identifying Genotypes of apartment building

Peponis, Hillier, and Hanson proposed a descriptive theory based on three levels: (1) is identifying spatial elements, (2) analyzing the spatial relations, and (3) modeling the genotypes (Peponis, Hillier, & Hanson, 1984). However, March and Steadman first noted this idea: "Objects which appear to be very dissimilar on first acquaintance may be seen, later, to share an underlying structural pattern" (March & Steadman, 1971, p. 27) . They have proposed that functional relations of the form can be presented as graphs that consist of nodes and lines, whereas nodes represent the functional room or spaces, and lines represent the adjacencies between the rooms. (March & Steadman, 1971).

In the study of the three plans of three houses that Frank Lloyd Wright designed, March and Steadman noted that: "Whilst they (plans) may look different, they are in fact topologically equivalent. If each functional space is mapped on to a point and if, when two spaces interconnect, a line drawn between their representative points we produce a mapping known as graph. Having done this for the three houses, we found that they are topologically equivalent in plan. Therefore,

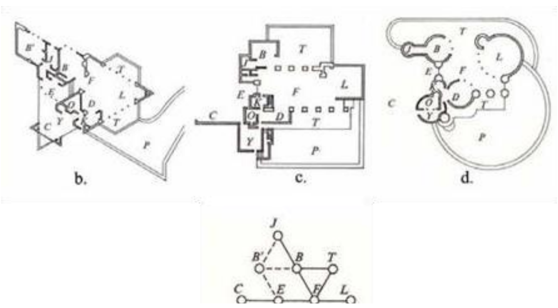


Figure 2: Tolpogical three equivalnices plans for F.L. (Mitchell, 1990)

one topological structure was open to three different expressions." (March & Steadman, 1971, p. 28). Figure 2 depicts the three houses of Frank Lloyd Wright and their topological structure.

Mitchell described these houses as equivalent under nonlinear continuous transformations, stating that "floor plans in building are equivalent under nonlinear continuous transformations when the shapes of the corresponding rooms differ but the adjacencies remain the same" (Mitchell, 1990, p. 116) He noted that a practical imperative on the plans that have same building type determines room adjacencies, architects have the freedom to vary the room shapes.

Nevertheless, a distinction between Hillier's ideas on topological structures and March and Steadman's idea exists. March and Steadman stated that nodes of spaces are not interchangeable and they should be labeled in the sense of the adjacencies, as seen in **Error! Reference source not found.** reveals (March & Steadman, 1971) , which conflicts Hillier, who submitted the idea of stable relationships, which does not involve in repetition of the same graphs for different geometrical layouts. They rather noted that "although the genotype specifies necessary relations, it does not specify which cells should satisfy those relations in a particular position. In this respect, all cells are interchangeable (Hillier & Hanson, 1984, p. 13). Moreover, they indicated the stability order of the different nodes of the graphs based on a measure of access. Hillier and Hanson called this measure "integration" as the number of nodes that must be passed from one node in the graph to the other nodes should be the least. In other words, the more central a node, is the closer is to all other nodes; the less the depth, the more integrated the space. Hiller, Hanson & Graham described the recurring relationship between functional elements (i.e., the ranking of the nodes) through the different degrees of spatial integration within a plan as an inequality genotype (Hillier, Hanson, & Graham, 1987).

The following section argues that in the design of apartment building with a particular functional program, topological structures specify spatial relations among the components and affect the number of possible spatial arrangements between the spaces' function. The research aims to uncover the functional relations and presents them as genotypes. The resulting genotypes should allow correlation between the different spatial relations of functions that underlie the design of apartment buildings and their spatial patterns. Followed by, the analysis part which graphs are used to represent the functional spatial relations that underlie apartment building designs to examine whether the functional relationships of the different spatial patterns of apartment buildings that will be established as genotypes are stable in graphs or instable in genotypes.

For this study, thirty different apartment plans with full of functional program were selected as Figure 3 illustrates. While the layouts vary in area and circulation pattern, they all have the same functional set in order to produce a proper analysis. The research focuses on the apartment buildings designs that include two symmetrical apartments on each floor, separated by a staircase and an elevator, and a one-storied plan redrawn by the author.

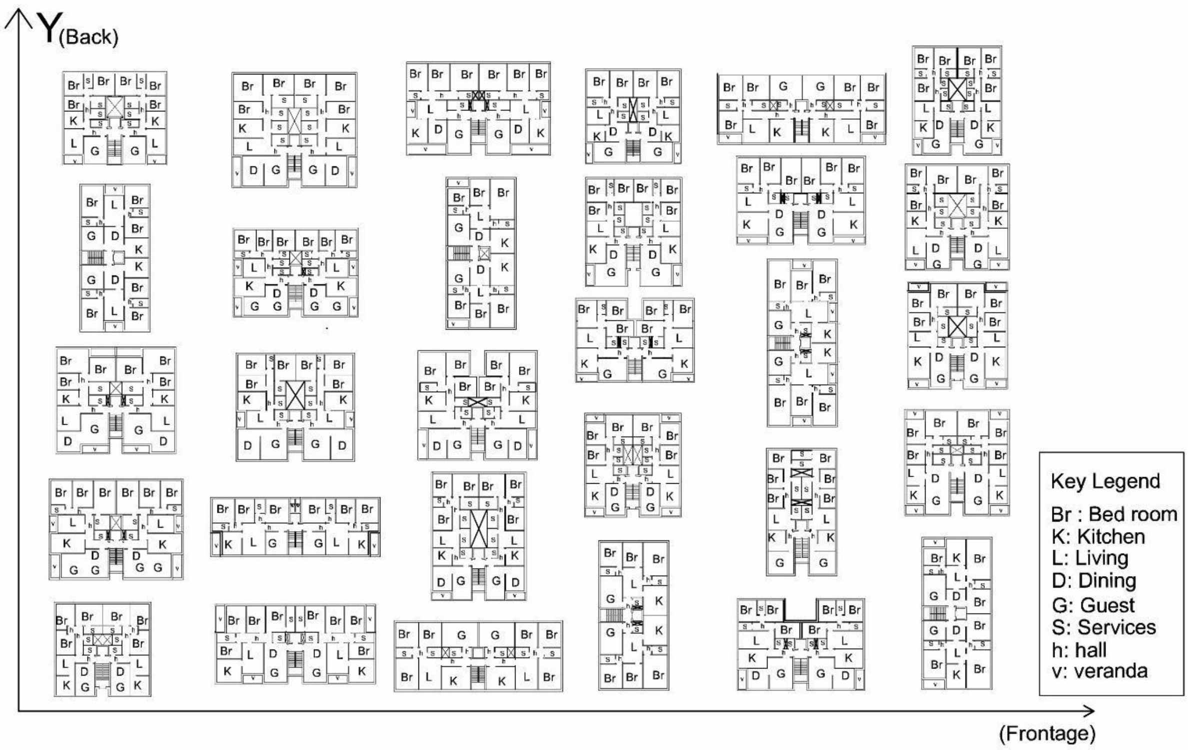


Figure 3: Various designs of two apartment buildings (author)

Functional units that represent the elements of an apartment layout were identified to construct the analysis. According to Mitchell, a functional description of a space establishes what it achieves in a certain context (Mitchell, 1990). The architectural plans of the 30 apartments, excluding unnecessary elements, are presented as geometrical compositions, that correspond to the spaces in the apartment building layout, colored according to the space's function to indicate the spatial arrangement of functional spaces as Figure 4 demonstrates.

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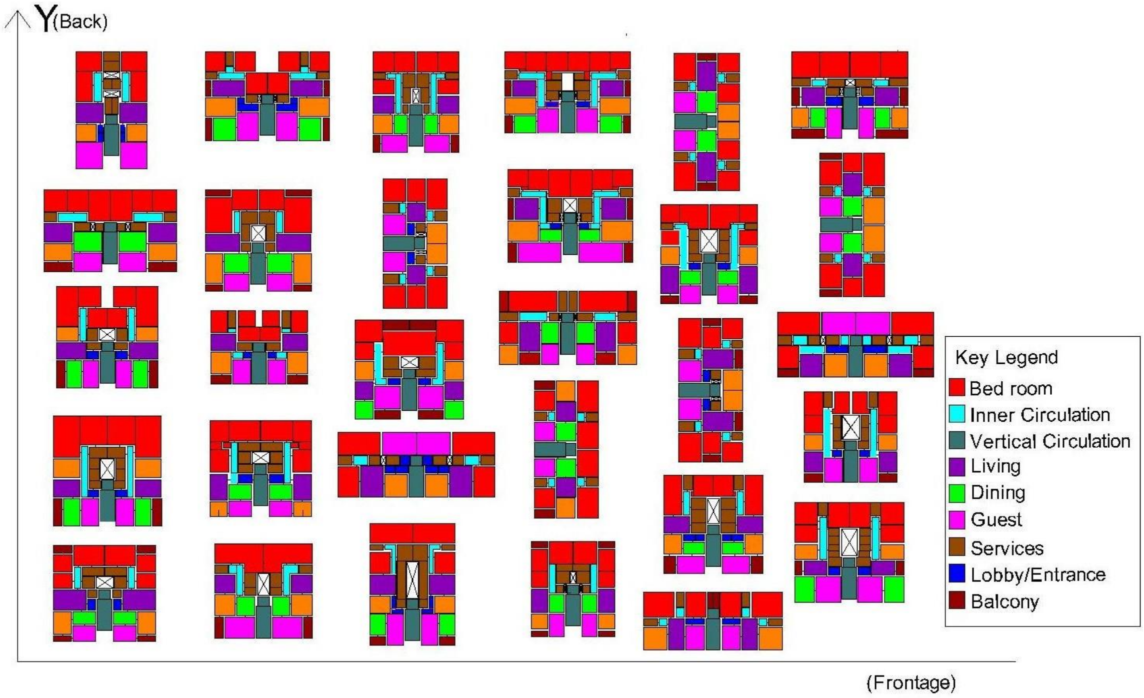

Figure 4 : The same 30 apartment designs, excluding unnecessary elements, abstracted into geometrical form. (author)

In the presented compositions, which assumed is the connectivity and the adjacency of shapes with respect to overall compositions. In other words, they are presented in which a configurational pattern of connections is realized. However, two adjacent spaces that the same function, but no connection, such as the bedrooms, are treated as one spatial unit in the geometrical forms. The functions of apartment layouts are categorized into three zones that maintain a particular relation: public (the Entrance/hall, guest room, dining room, and their services, such as bathrooms and balconies), semipublic (the living room), and private (the kitchen, bedrooms and their services such as bathrooms, balconies and stores).

As the figure indicates, the arrangement of functional spaces in the compositions is divided into two categories according to the position of the vertical circulation (i.e., the staircase and elevator); one category moves from public to semipublic to private horizontally (in the X-axis), while other moves from public to semipublic to private vertically in the (Y-axis). Functional zones are thus distributed based on the staircase and elevator's position in the apartment plan. When the staircase is located at the front of the plot, the public and semipublic zones are viewed from the street, and the private is concealed from the street. When the staircase is located on the left or right side of the plot, the private zone is viewed from the street. In most plans, the semipublic zones are mediators between the private and public zones. The figure suggests, the three zones are arranged according to their closeness to the staircase, where the entrance /hall is placed, or, in some cases, the dining room is placed adjacent to the staircase.

Despite the variation in the patterns of connections and spaces, the accessibility between spaces is limited, and the spatial relations regarding the accessibility between spaces are therefore limited. When these relations were transformed into J graphs, an outstanding result derived among these graphs, the spatial relations were proven to fall under only the eight genotype graphs presented in Figure 5. In other words, each genotype occurs in more than one geometrical form. Therefore, Figure 6 elaborates the categorization of the geometrical forms that conform to the eight genotypes graphs, where seven different geometrical forms are classified in Graph A, two in Graph B, three in Graph C, five in Graph D, two in Graph E, four in Graph F, six in Graph G, and one in Graph H.

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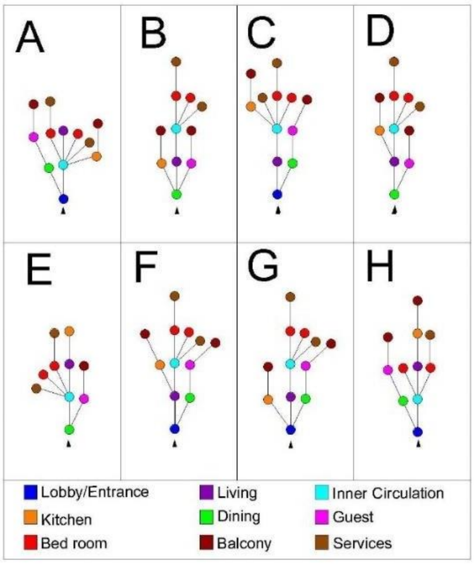
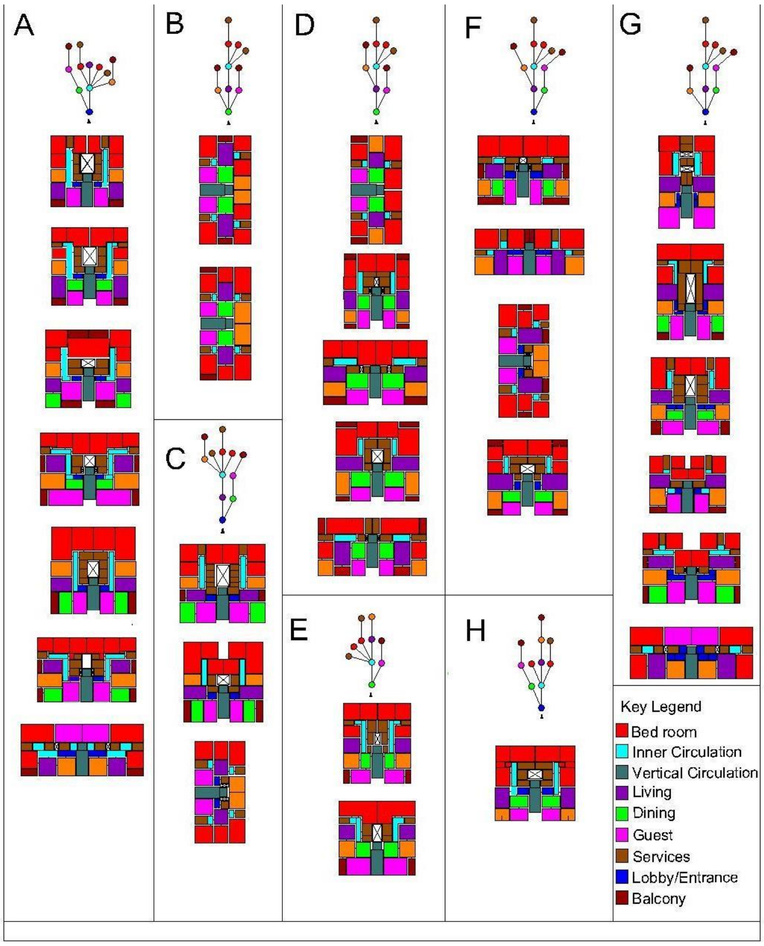


Figure 5: The Eight Genotypes (i.e., connectivity graphs) derived from the apartment building plans, beginning with the node beside the staircase which is the entrance or dining room. (author)



The analysis results confirm that despite the variation in the patterns of connections and

Figure 6 : The categorization of the geometrical composition according to the genotype. (author)

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between spaces and the spatial relations are limited. Although the graphs do not satisfy the functional relations in a particular position, however, each category of the plans are topologically equivalent and share the same underlying structure.

In order to facilitates a more profound comprehension of how functional spaces accessible through transitional spaces is locating the inner circulation and living room on the one side and the remaining spaces on the other side. Based on the compositions, halls offer most accessibility between transitional spaces. Followed by the living and dining rooms. The integration method; ranking order is thus used to examine the distribution of spaces and describe how it relates to each other in a configurational system.

This approach graphically demonstrates which activities occur in highly integrated areas. The living and inner hall spaces are assigned as an integration value. The analysis was also conducted across the thirty layouts by observing the integration value differences among the functions. Spaces are arranged according to their closeness to the living room and inner circulation. **Error! Reference source not found.Error! Reference source not found.**, are graphs justified from the inner circulation and living space assigned as an integration value. The order of integration differs from that of the previous graph, as in these figures illustrate. While Figure 9 dissects the changes of spatial structures considering the hierarchical order of the depth of functions which quantifies the relative depth from any space to all other spaces and summarizes the similarities and differences between the graphs.

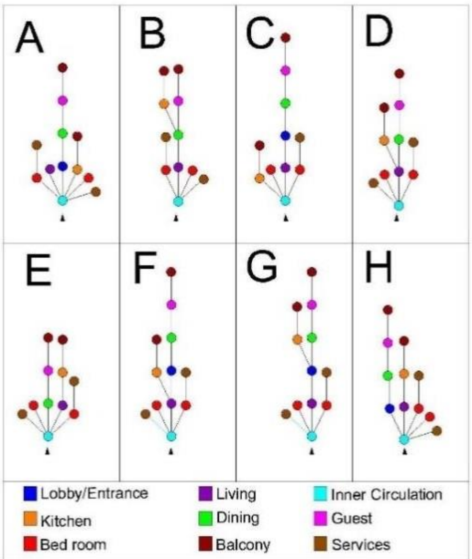

Figure 8: Genotypes justified from the inner circulation. (author)

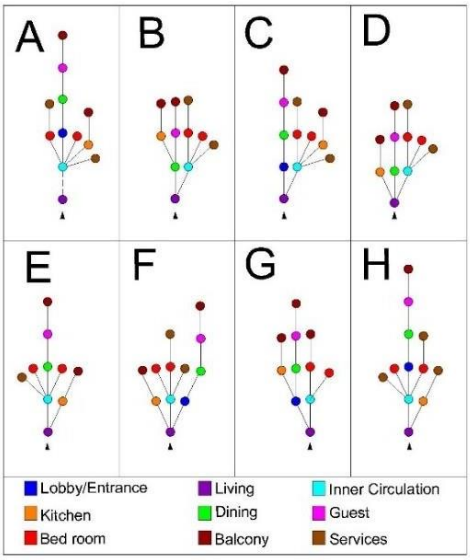

Figure 7: Genotypes justified from the living room. (author)

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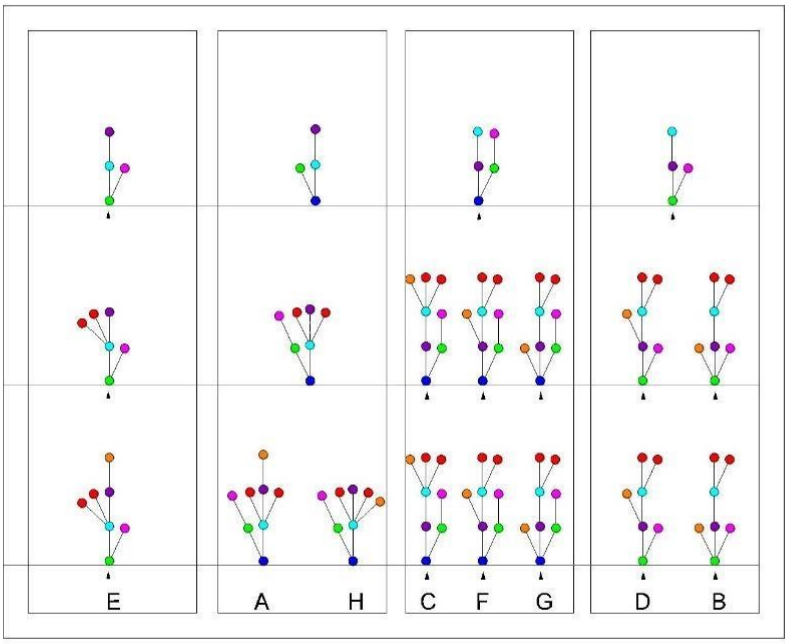

Figure 9-a Represent the hierarchical order from entrance / dining room. (author)

Figure 9 : 9-a, 9-b, 9-c: Graphs analyzed hierarchically from different nodes identify the changes of spatial structures. (author)

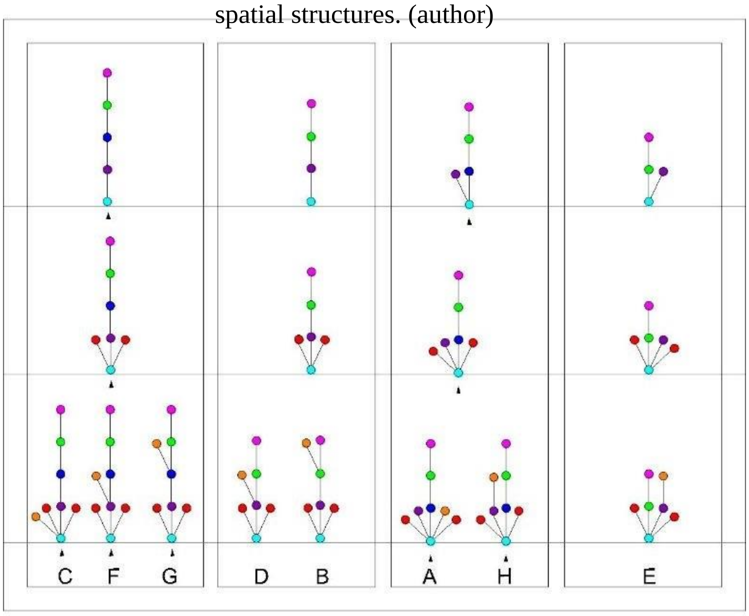

Figure 9-b Represent the hierarchical order from the inner circulation. (author)

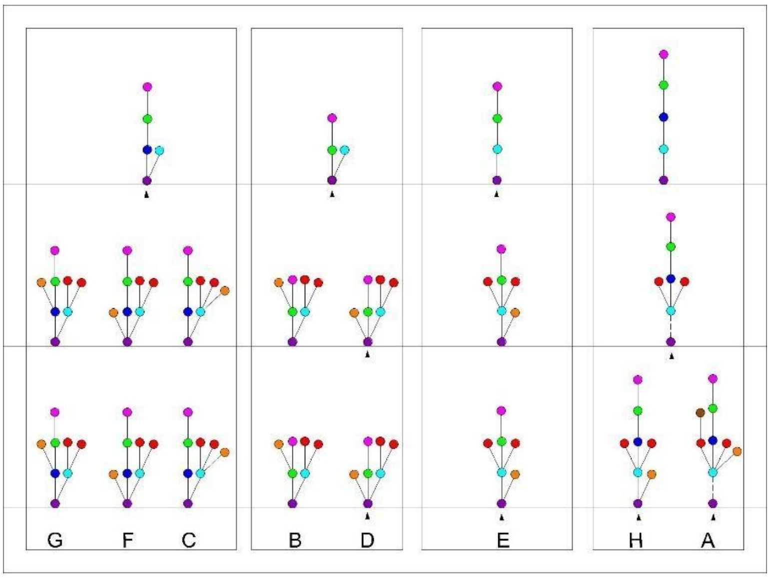

Figure 9-c Represent the hierarchical order from the living room. (author)

Figure 9 : 9-a, 9-b, 9-c: Graphs analyzed hierarchically from different nodes identify the changes of spatial structures. (author)

Based on the graphs in **Error! Reference source not found.** they represent the rank order of the integration pattern of key spaces, it is observed that Graphs A, and H have the same permeability graph, the only variation being the kitchen location. Moreover, Graphs C, F, and G are the same, the only variation being the kitchen. Finally, Graphs B and D have the same ranking order with a variation in the kitchen location. In **Error! Reference source not found.**-b graphs A, E, H, D, B, C, F and G respectively indicates the highest level of connectivity and the highest integration value, and are therefore defined as the most integrated spaces**.** In these graphs, hallways dominate the genotype as the most integrated spaces. According to Bafna **"**it is natural that the circulation areas and lobby will be more integrated and that the bedrooms and the services will occupy the other pole along the integration-segregation axis" (Bafna, 2001, p. 20.8). Nevertheless, strong inequality genotypes also seem to occur, particularly regarding to semi-public spaces, such as the living which is manifest in **Error! Reference source not found.**-c in graphs D and then B. Followed by, in **Error! Reference source not found.**-a graphs H and A, **Error! Reference source not found.**-c graphs E, F, G, C and in **Error! Reference source not found.**-a graph E are mediated in, while **Error! Reference source not found.**-c graphs D, B, F, C and G, and in **Error! Reference source not found.**-c graphs H and A indicates a single sequencing of spaces and a single option for the movement pattern within the plan and has the least integration value (i.e., reveal more depth) between the graphs.

When the above integration sequences for the identified graphs of the 30 apartment plans were compared, a striking resemblance appeared, which means that the spatial configurations of the plans are quite similar. While the graphs are diverse, the ranking of spaces according to their integration values is more consistent, suggesting that the functional structures are more stable as genotypes than graphs and that genotypes that capture topological relationships can assume different geometrical forms. So, it can be said that despite the geometrical differences of apartments, their spatial layouts tend to have a common pattern in which functions are spatialized in terms of their configurational relations within the apartment layout, which means there are inequality genotypes govern the underlying spatial structure of functions. It is therefore clear that the restrictions that building codes and plot regulations impose limit the sets of spatial relations

This method assessed the strength of the spatial genotypes and the similarities and differences between graphs that compare spatial structures, while figures identified the changes of spatial structures considering the hierarchical order of the depth of the functions.

CONCLUSIONS

This study did not intend to investigate the architectural history of apartment buildings in Amman. Indeed, the Purpose of this research is to demonstrate how codes and regulations, acting as constraints, significantly contributed to limiting and thus shaping the specified range of potential design solutions for apartment buildings, despite the various form and compositions apparent in Amman, resulting to have limited number of functional genotypes.

The researcher schematically associated the codes and regulations, with the actual design of apartment buildings to include them in the design process in which the allocation of functions follows the codes constraints of the codes and regulations.

The analysis established the 30 apartment plans as geometrical forms of shapes and classified them according their genotypes. Nevertheless, the purpose of these geometrical forms was not to reconstruct the apartment plans, but to describe and classify the arrangement of the functional spatial relations in terms of their genotypical structures. The graphs of genotypes that arose from

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the analysis confirm that no specific program is required for apartment building functions. While architects design apartment buildings based on their own notions and experiences, ensuring that the building codes and plot regulations are observed, they also generate apartment building designs using known designs adjust into design solutions to produce new designs while satisfying the same codes and regulations.

Furthermore, the analysis revealed the genotypical trends and the strength of the spatial genotypes regarding the pattern of the spatial structures in the apartment layouts across various integrations by measuring the hierarchical order of the depth of functions and summarizing the similarities and differences between graphs. The analysis elaborates that an inequality genotype governs the relations between the spaces and that these spatial relation topologies are more stable genotypically than the graphs. The analysis also indicates have commonalities in their topological structures that underlie the design of apartment buildings. In other words, genotypes that capture topological relationships can assume different geometrical forms.

The study results can be used in several ways to get a better understanding of social and cultural patterns that play a significant role in modifying the design of a building's program. These Findings can be further adapted to capture the design process using formal methods such as shape grammar to interpret the repetition of apartment buildings as a form of computation procedures to delineate apartment building layouts schematically and prove that these constraints can be transformed into an algorithmic system for generating the alternatives designs. Moreover, software could be developed to generate apartment designs, in which case the knowledge of shape grammar as a production language for apartments would be defined in the software.

Finally, the purpose of this research was intended to investigate the functional and spatial topologies that underlie the design of apartment buildings. The analysis reveals that apartment buildings with various compositions have a finite set of functional genotypes that underlie the apartments' design, as well as limited forms of geometrical compositions.

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