

Designing Alternatives for Residential Apartments in Cairo Using Shape Grammars

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ABSTRACT

Through observation, it is noticed that the design solutions of the inner spaces of residential units in Cairo have circulation problems. These problems are represented in direct and indirect separation between different zones in apartments, whether private or semi-private. This is due to; reduced areas, site location, building policies, etc. Such problems obstruct resident's way of everyday life, and their living quality. After introducing such problems, this paper proposes a set of shape-grammars rules that facilitate designers, through their process to produce a range of design alternatives for the same area. Shape grammars' rules are set according to three aspects: a) required relationship between zones for Carians culture, b) building policies as a constrain, c) the given building area in different situations (attached to neighbours or free standing, etc.) That rule works as a design tool for any designer in Cairo to select the suitable alternative and facilitate his creativity through the process.

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1. Introduction

Lodging plays a basic part in well-being openings for individual laborers and their families, influencing current and future specialists, managers, communities, and territorial communities. The benefits of fitting and reasonable lodging and results when such lodging is inaccessible are most concrete at the person and neighbourhood level. In any case, as required for lodging mass generation increments and the lodging ventures gets to be more costly to deliver, its execution qualities have particular impacts on homes on all levels. This overview of the significance of lodging highlights a few associations between lodging, person well-being opportunity, workforce, and quality of social and social improvement that

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analysts have investigated. In any case, the impacts of homes—for case, measure, quality, area, and cost—extend past the cases given here.

People and families that make a domestic selection, choose their sanctuary with related characteristics, assets, civilities, and opportunities. On occasion, they select to get to particular schools, nearness to merchants and other shopping, vicinity to family and other imperative social systems, and opportunities for amusement and work out. Families select the appropriate lodging they can be stratified in and perform superior "packages" at the most suitable costs. In spite of the fact that lodging needs are not among the beat components influencing where family units select to live and work (Wang, Lyu & Xu, 2021), they have vital impact on their social response and improvement.

A community that needs a mental and comfortable lodging regularly need lodging for the community's fundamental, low-income labourers. To supply high quality of life for all families, the territory and its locales must empower engineers and builders to create lodging that's fitting and fulfilling for families at each salary level. For those with the most reduced salaries, neighbourhood governments must combine their land-use devices and resources with state and legislative assets to supply easy access and suitable lodging and guarantee that low-income labourers can proceed within the community.

Planners have been since decades investigating conceivable outcomes for making expanded plans that fulfil the requirements and yearnings of clients. In lodging plans, a few techniques have been created to realize this objective of user-centeredness, such as counting tenants within the planning as in a participatory plan, and as creating plans that give several format choices for tenants to select from. The most point of the research described here is to investigate how shape language structures can fortify these existing procedures. It'll be examined how the use of shaping - as a linguistic tool- can consolidate inhabitants' wishes in a planning device for customizing their houses such that it complies with their wishes and styles, whereas at the same time encoding engineering information with respect to style and building directions. In this paper, we, in addition, concentrate on customizations by occupants of existing lodging designs.

2. Aim and methodology

The purpose of this study is to analyse the formal and syntactic information within the plan layouts of Cairo residential houses, to trace achieving the ideal zoning for residents. Separating residential private spaces from the semi-private ones can be defined as design language and presented through an interactive and visual expert system. In this study, shape grammar was chosen as a method, which can be used in analysing proposed design languages and producing new designs, that preserves Carians social needs for privacy.

The research seeks to solve issues concerning today's residential buildings that not mostly satisfy users with their living spaces and levels of privacy they need, that affect their emotional responses to the place, with respect to Carians customs, traditions and contemporary lifestyle. The goal of this paper is to propose a new model for a contemporary house based on the teachings of Cairo residential houses. Therefore, this study attempts to recognize the relationship between spaces in some houses in Cairo and propose a pattern for these houses using the shape grammar based that can be used in Shape grammar applications. Understanding the mostly ideal patterns of housing can be a pivotal step towards a better future. This is important in terms of both theoretical and practical aspects. From the theoretical point of view, it is possible to read and analyse the shape grammar theory in these residential houses, which can be pursued elsewhere in Egypt; the practical aspect is associated with design programs and activities in teaching architecture design.

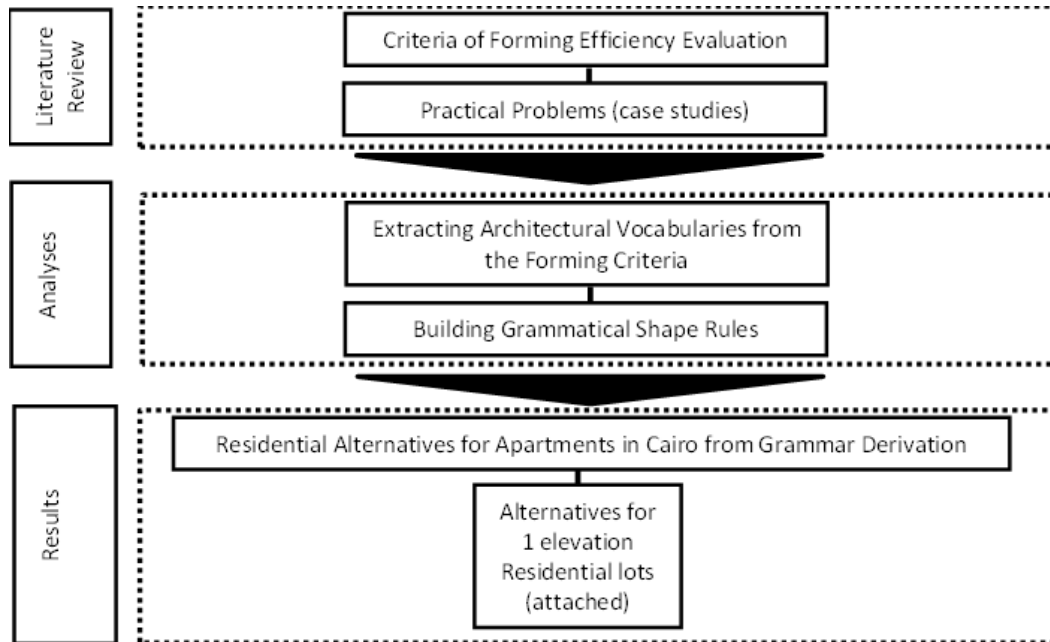


Figure 1. Structure of the Study

3. Criteria of forming efficiency evaluation

This study relies on three sources to ensure the design and construction efficiency of housing units in Egypt in general and Cairo in particular. The source for any architect in designing any qualitative building is the architectural standard books, which ensure that the standard dimensions are taken into account in the designs to achieve comfort for the user. Also, to design residential buildings in Egypt, the architect must fulfill the structural requirements mentioned in the Egyptian Building Law (Building Law, 2008). The third which the architect must take into consideration is the social and cultural aspects of the society, where the customs and traditions. In addition to the needs and requirements of the users of the housing unit and the design keep pace with their daily lifestyle.

These three sources guarantee the designer to develop alternatives to his design solution that achieve living efficiency, comfort and transcend the residents' sense of quality of life and thus positively affect their productive efficiency.

Regarding the first point (Standard books) like Time Saver and Neufert one can extract some important data regulating the design process of residential units such as the appropriate areas of different spaces of the apartment as well as the minimum and maximum dimensions of all spaces used in any apartment. These references also give useful data about the different spaces forming a residential unit and the functional relations between them. The data coming from these references is universal and can be applied on residential apartments built anywhere.

This automatically takes us to the second point (Egyptian Building Law) which provides us with all the specific regulations and restrictions applied on the residential buildings in Egypt. These rules provide designers with all the permissible and non-permissible during the design process. They for example give a clear constraint that all the living spaces including bedrooms, living rooms, and receptions should be either oriented outwards or towards residential courts with areas varying from around 20 squared meters and reaching more than 100 squared meters based upon the building height, to provide those spaces with proper natural lighting and appropriate ventilation (Building Law, 2008). Also those rules state that the service areas like kitchens, bathrooms, toilets, corridors and stairs should also gain natural lighting

and ventilation either form outwards or residential courts or preferably from service courts with areas varying from 7.5 to 15 square meters (Building Law, 2008). The rules as well regulate the areas and minimum dimensions of the open courts, the setbacks, and the residential pockets which are found mainly to provide natural lighting and ventilation to different living spaces (Building Law, 2008).

Then comes the third point which is related to the social and cultural aspects. In Egypt because of being an Eastern country with Islamic conservative culture; Privacy is highly valued especially in residential places. Therefore, the zoning that is considered appropriate for Carian residential units depends on dividing the residential unit into three main zones according to privacy aspects (Tomah, Bani Ismail & Abed, 2016):

- A. Private zone consisting of the bedrooms and bathrooms and sometimes internal living area.
- B. Semiprivate zone which is the reception area consisting of saloon(s), living, and dining area.
- C. Service zone consisting mainly of the kitchen and guest toilet.

Each of the three zones should be accessed directly from an entrance lobby which is directly accessed from the main entrance. Reaching one zone should never be done through another one.

The three mentioned points should be relied upon integrating the regulations coming from each in order to reach an appropriate architectural design of a residential apartment in Cairo.

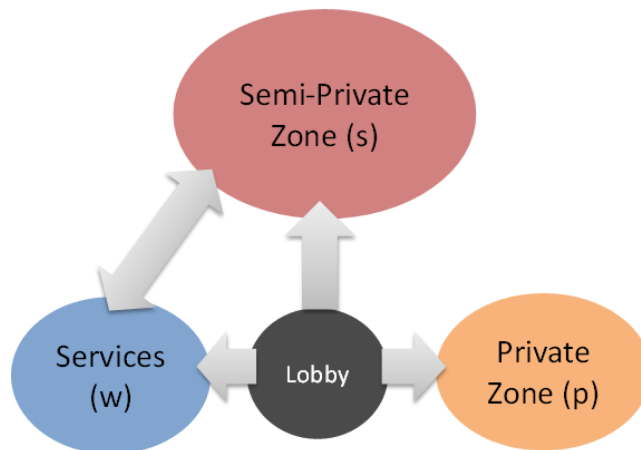


Figure 2. A proposal of appropriate zoning for Carian residential unit

4. Residential units currently offered in the real estate market in Egypt

Residential buildings being the type of buildings that every single resident or family in any country should own or at least rent one is a fact that lets residential buildings to compose the greatest share of the building industry in any country. In Egypt this fact is accompanied by another fact stating that a huge sector of Egyptian residents and citizens deal with residential units as a source of future investment in which they save the value of their money. This gives a great importance and priority for the Egyptian Government, investors and developers to produce great numbers of residential buildings and offer them for sale especially in the new settlements surrounding Cairo such as Sixth of October City, Al-Sheikh Zayed City and New Cairo. A small sample of the residential units being offered for sale nowadays in the Egyptian market is going to be presented and analysed in this section.



(a) An example of the residential units being offered for sale through the Ministry of Housing



(b) Samples of residential units being offered by different investors of the private sector

Figure 3. Residential units currently offered in the real estate market in Egypt (Source: Egyptian new papers, ads sections, for the last 5 years, labelled by arrows by the authors)

The above examples are just a significant sample of a great amount of the residential plans being designed in Egypt nowadays. They are designed following the most common improper zoning being used recently. The selected examples have a common feature which is all the living spaces of the apartment being oriented towards a single elevation.

It is evidently clear from analysing the above examples that major design problems contradicting with the appropriate design measures and standards explained above that should be followed in residential units are committed repeatedly. One can conclude these problems mainly in improper zoning.

All of the above examples do not follow the proper zoning regulations. Almost in every single plan of them the bedrooms zone is always accessed through the reception not directly from the entrance lobby causing several problems inside the apartment the most significant of which are related to circulation and privacy.

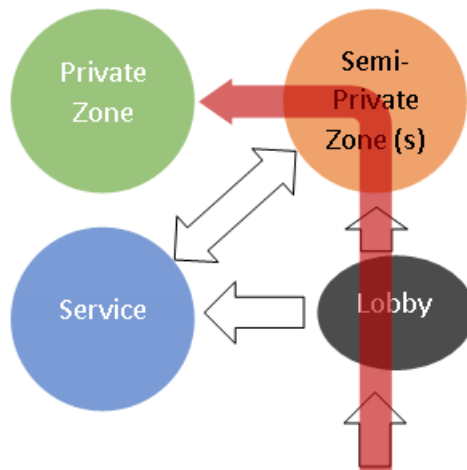


Figure 4. From analysing the current offered residential units in the real estate market, there is a common mistake concerning their design zoning, forcing user to cross a zone to access the other

The following plans are a just a trial to introduce design guidelines for residential units with different areas being oriented towards one elevation. The plans are generated from the proper zoning being explained above.



Figure 5. Proposed plans for residential units, having one elevation and various surface areas. All of them consider the appropriate zoning with different design (1 module equals 1 squared meter)

The above plans designed by the authors are just a trial to produce a design guide that can followed during the residential units' design process. The three models presented above are preliminary designs that can be easily modified to produce several other alternatives.

The important point is that these models were designed strictly following the regulation and standards coming from The Criteria of Forming Efficiency Evaluation. All the proper areas and dimensions for different spaces are used precisely, as well as following the regulations coming from the Egyptian Building Law, and finally being stuck to the appropriate zoning.

The entrance of each apartment leads to an entrance lobby with convenient area which leads to three main zones each of them to be reached directly from the lobby without crossing another one.

The living spaces in each apartment are all oriented outwards towards a single elevation providing them with natural lighting and ventilation. The services and wet areas are always oriented towards service courts with areas referring to the Egyptian Building Law.

The areas and dimensions of the different spaces are also extracted from the standard books and The Egyptian Building Law. Bedrooms and living rooms with areas varying between 13 to 20 square meters, with a minimum side dimension of 3.6 meters., while corridors width always vary from 1.2 to 1.5 meters.

As a result, the three models can be considered appropriate with respect to the regulations that should be followed in Egypt.

5. Shape rules to generate Carian residential houses plan layouts

Using grammatical rules for a certain building type helps the designer to generate new alternatives related to the same family and preserves its architectural features. Such rules can be used manually and also can be installed in some computer applications. However, computer applications designed for using "Shape Grammars" needs more detailed and precise information. Such applications help designers to generate more new alternatives. Also, they help designers to put their modifications on the rules themselves, considering new needs or to solve previous problems.

The derivation of a design in the grammar goes through three successive stages: defining the private areas (PA), defining the semiprivate areas (SPA), and defining the wet area (WA). As the outcomes of the private spaces continue, annotations are put on the semi-private. When the development of the semi-private zone wraps up, a state annotation changes, subsequently enacting generating of the wet zone. The enunciation between the development of the semiprivate zone and the wet area works in a comparable way. Each of these stages, in turn, incorporates a few steps. For occasion, the stages of the private zone are placing utilitarian zones, finding the staircase, separating functional zones (into rooms), and initiate detailings. Dividing them into steps is just explanatory, as there are no state annotations to go from one step to another, like those utilized to alter organize.

As it is mentioned in previous section, city governors and architects are committed with the local building regulations. However, architecture understood that the structure should contain cultural and social values, so they attempted to make integration between traditional costumes and contemporary life style.

5.1.Context

In the Carian residential shape grammars, the initial shape is a rectangle with a label 'Lot' representing the area of the residential unit which varies between 12*14 and 14*19 m², they can be clustered in plots. The plots are clustered together to make lodging aggregates. In most cases, these aggregates are in regular linear shapes, but they might take other shapes to fit the shape of curvilinear streets. As a result, in normal plots all but the front edge border other plots, but in a few plots edges other than the front edge might border a road, under certain restrictions. For occurrence, separated plots are not allowed. The sort of environment characterizes the urban setting of the parcel and affects the utilitarian organization of its house by limiting the number of facades with openings.

This paper works on residential units that can be designed on area with one elevation, which has one elevation and surrounded by three neighbours.

5.2.Composition

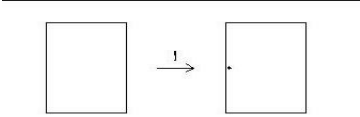
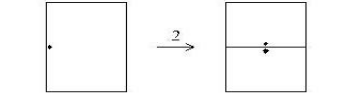
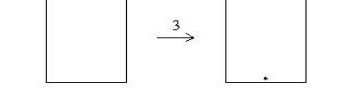
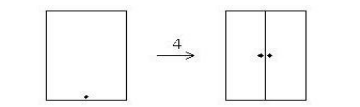
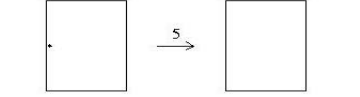
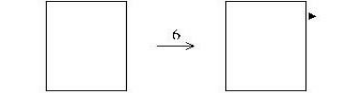
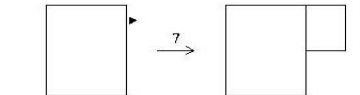
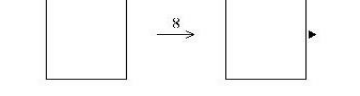
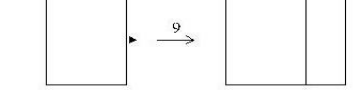
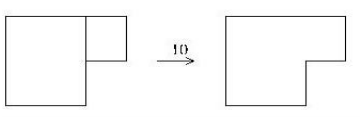
Generating grammatical shape rules for residential buildings in Cairo provides a tool of design for architects and educational tool for scholars. Before, many authors used shape grammar as a tool to

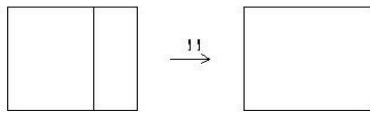
study and analyze residential units. One of the most famous is the basic composition rule schemata of the prairie houses that was designed by Frank Lloyd Wright (Koning & Eizenberg, 1981). By time many researched used that tool to put precise grammatical shape rules for certain cultures or locations, such as; Vasco Granadeiro (Granadeiro, Duarte, Correia & Leal, 2013) who worked on linking between the shape rules and the needed used energy, Wael Al-Azhari (Al-Azhari, 2020) who worked on extracting shape rules for Amman houses and others. Here, this research depended on the work of Jose" Pinto (Duarte, 2005) that dissert shape rules for the houses of Siza's houses at Malagueira. His rules schemata are considered as a good start to work on that for Egyptian houses.

Compositional standards behind the generation of a Carian house plan are based on the control of rectangles representing rooms by implying rules for slicing, combining, and expanding rectangles. To facilitate creating it for the peruser to get the compositional principles of the grammatical composition, a really streamlined set of shape rules is introduced in table 1. In this simple system, rules incorporate as it were the two-dimensional design component and lines are considered as borders.

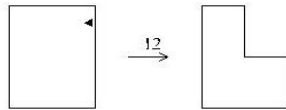
Such rules are deducted mainly from; a) standards of residential structures as a building type (Time-saver standards, 1954), b) Egyptian building code (Law No. 119, 2008), and c) considering social aspects concerning privacy and not to intersect between private and semi-private zones (Tomah, Ismail & Abed, 2016). Those considerations provide users satisfaction, well-being, and social satisfaction in addition of suitability with the contemporary life-style needs. Also, from the proposed plans of the residential units, and to be able to achieve the suitable dimensions, the total surface area of the unit must not be less than 100 m².

Table 1. Shape rule schemata for Egyptian residential units

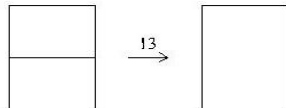
	<p>For any rectangular space, whether the whole area of any room, this rule marks the side form which this space will be divided.</p> <p>The dot mark is a label that identifies the last line placed and indicates on which side the next dissection may occur.</p> <p>Rule 1 marks the larger side of the rectangle.</p>
	<p>Opposite separation is the initial compositional rule. In rule 2, separations are opposite to the wider edge of the rectangle. Next step can occur on both sides or one side according to the marked line.</p>
	<p>Rule 3 marks the shorter side of the rectangle.</p>
	<p>Rule 4 divides the space into two linear spaces. The added line is parallel to the longer side of the rectangular. Similar to rule 2, next step can occur on both sides or one side according to the marked line</p>
	<p>Rule 5 deletes the label, preventing further dissections.</p>
	<p>Rule 6 marks, using ► any side in the rectangle, indicating an addition on a part of that side.</p>
	<p>Rule 7 is an addition rule that applies on the labelled side in rule 6.</p>
	<p>Rule 8 marks, using ► on a side in the rectangle, indicating an addition along that side.</p>
	<p>Rule 9 is an addition rule that applies on the labelled side in rule 8.</p>
	<p>Rule 10 is a merging rule. It widens the space from a part of one of its sides.</p>



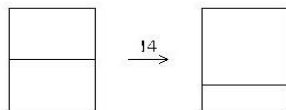
Rule 11 is a merging rule. It widens the space from a one of its sides.



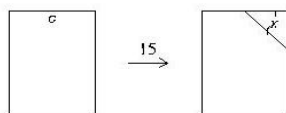
Rule 12 labels a side of one line in the space. The label ◀ looks inside the space. This is a subtracting rule, which cuts off apart from the space.



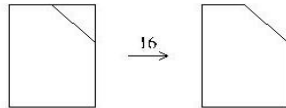
Rule 13 is a merging rule without expanding the area of the space.



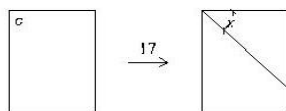
Rule 14 saves the whole area of two rooms, however, widening one and shrinks the other.



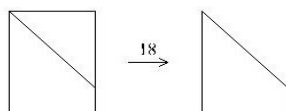
Rule 15 labels the center of one of in the space, by applying this rule at this part a chamfered line is drawn, where $15^\circ \leq x \leq 165$. The line divides the space into a polygon and a triangle.



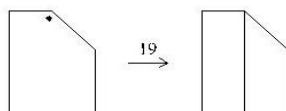
Rule 16 is a subtracting rule, that cuts off a triangle and keeps the polygon shape.



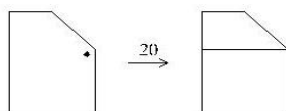
Rule 17 labels a corner in the space, by applying this rule at this part a chamfered line is drawn from that corner, where $15^\circ \leq x \leq 165$. The line divides the space into a trapezium and a triangle.



Rule 18 is a subtracting rule, that cuts off a triangle and keeps the trapezium shape.



Rule 19 is a dividing rule, that divides the polygon shape vertically.



Rule 20 is a dividing rule, that divides the polygon shape horizontally.

From the previous rule schemata in table 1, architects can derivate them as a systematic tool to produce different alternatives for the same unit. Figure 6 present how the derivation works.

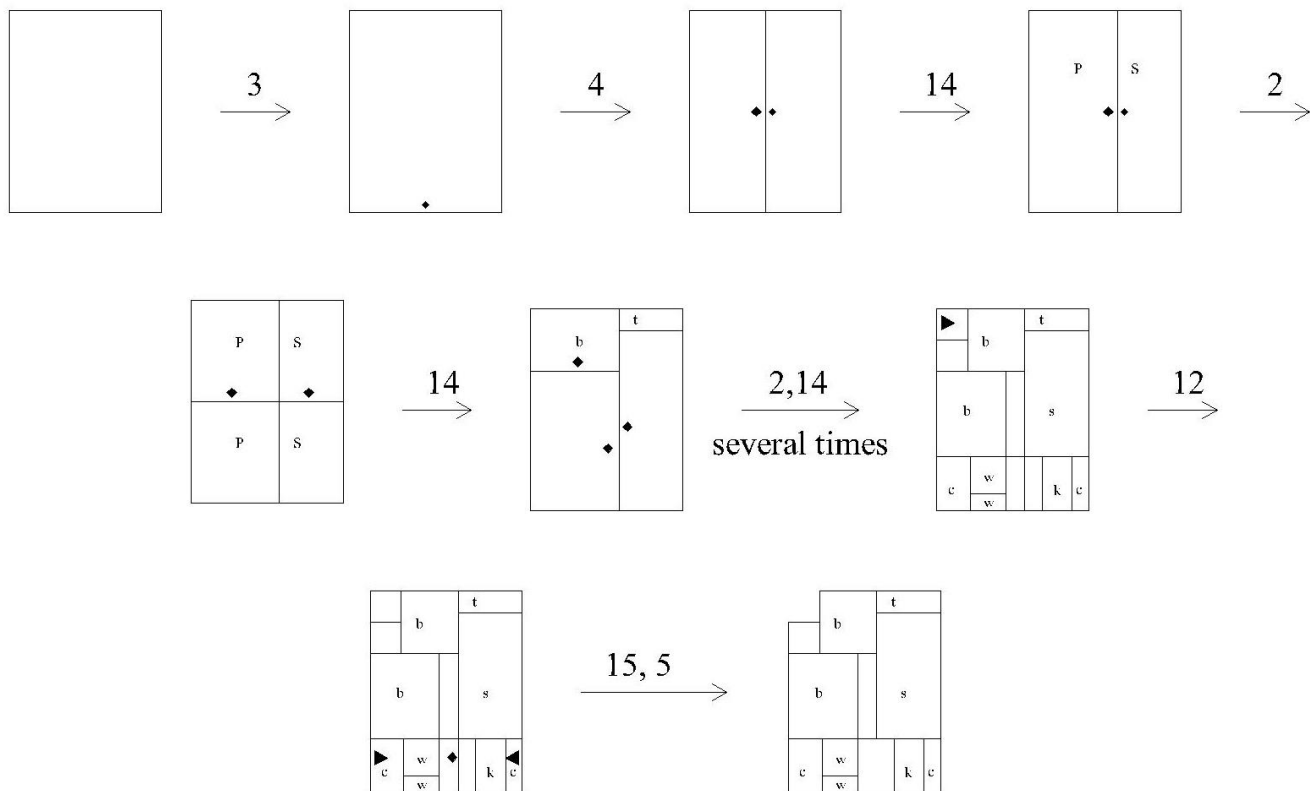


Figure 6. Derivation model proving that the deduced primary rule schemata work

The steps included within the definition of the utilitarian organization of the floor plans are appeared in figure 7 (see over). The sketch takes the frame of a tree in which nodes are considered as the state of the plan and arrows are considered as the application of rules. The tree outlines how the application of rules to allocate functional zones creates the essential said forms behind the houses in Cairo. It identifies also how the diverse sorts in reasonable units infer from these designs by a diverse application of the rule to place the spaces practically. At last, it appears that subtypes vary from one another in little varieties of the format caused by distinctive applications of the rules for separating zones.

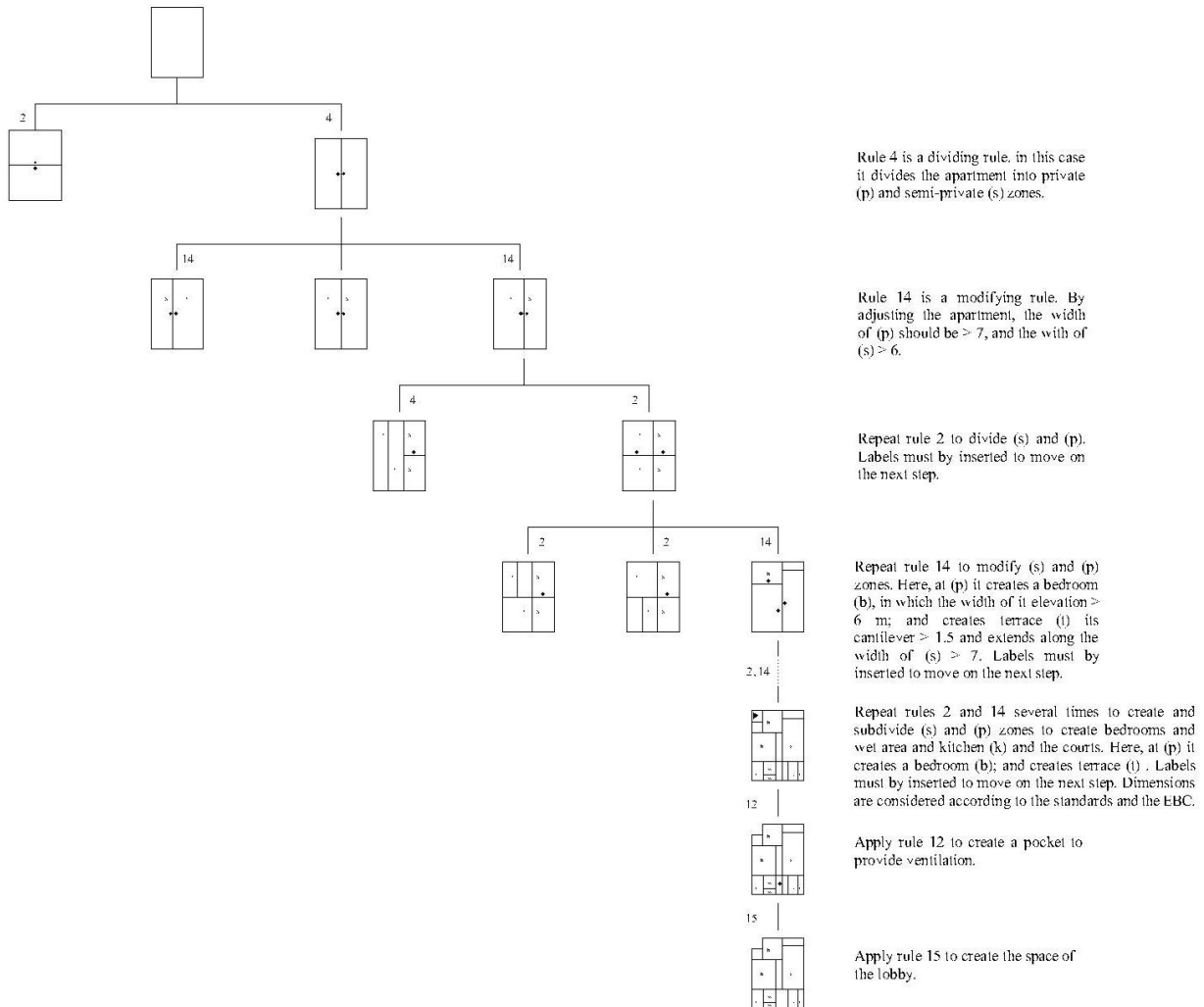


Figure 7. Part of the tree sketch represents the determination of essential designs, sorts, and subtypes. The designs are not dimensioned to stretch the commonalities among different sorts. The sketch incorporates suitable creative plans for Egyptian house buildings

6. Conclusion and recommendations

At the beginning of this paper argument about if shape language tool can give the design as a device to create Egyptian plan rules for private house units. This contention is settled with the introduction of a language structure taking into consideration the EBC, private building guidelines and considering social perspectives. The utilisation of straightforward compositional rules comprising the separation of rectangles to determine the type of style. The language structure accounts for the development and production of the ten houses considered within the corpus, as well as creative houses related to the same design family. These new designs were created both by the authors of the grammar rules, achieving the EBC and separates between the private and semiprivate zones in the apartments. Therefore, the grammar successfully works.

So, practically wise, architects can use the illustrated grammatical shape rules to find different design solutions that suit their ideas and satisfy users functionally and socially. On another hand, this can be a simple tool for the academics to teach students how to respect the EBC and find various design solutions for the same area or the same context.

Finally, the illustrated grammatical shape rules can be considered as primary pattern language for the Egyptian residential units. Such rules can take another layer of reviewing to generate more precise details such as inserting openings, defining the heights, applying the suitable surface areas for the inner spaces, ducts, and courts. etc. In addition, this paper introduces to generate more grammatical shape rules to consider different context conditions, where residential units having two or three elevations.

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Data availability statement

The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

Ethics statements

Studies involving animal subjects: No animal studies are presented in this manuscript.

Studies involving human subjects: No human studies are presented in this manuscript.

Inclusion of identifiable human data: No potentially identifiable human images or data is presented in this study.

Conflict of Interests

The author declares no conflict of interest.

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