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The Proportions Code and the Environmental Aspects as a Design Generator for the Minarets in Cairo of the Mamluks

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Abstract: One of the logic approaches to improve the contemporary design criteria of the Minarets understands the design methods of the built Minarets of Mamluks. To demonstrate how the geometrical proportions and environmental aspects played the role of design generator which remained the backbone of the process of "designing" a geometrical analyses of various designs of Mamluk Minarets were presented by concentrating on the derivation process of the design idea. By geometric morphological analysis of 20 Minarets a not fixed certain proportional relationships were found. The study depended on analyzing the proportions of the geometric shapes and the Minarets heights in relation to the whole composition to suggest the proportions code and the environmental principles, which may be considered as the inherent design method that govern the design of the Minarets in Cairo of the Mamluks. The research reached to suggest a design generative technique; this technique is a combination of architectural grammar which can be understood as a bundle design principles which formulate a design guideline. This technique illustrates how Mamluk architects proceeded to apply the proportions code and environmental principles to the practical problem of Minarets design, the research name it 'Unwritten Design Method', which is orderly and methodical arrangement of proportions to produces the Minarets design.

Keywords: **Proportions Code, Environmental, Minaret, Mamluk**

I. RESEARCH INTRODUCTION

If much is known about the Mamluk Minarets, however, much remains to be discovered. Minarets are a tall towers attached to the city's mosques, a distinguishing sights in any Islamic city, from which mu'zzins call five times a day the faithful to pray. Minarets have always delighted the people of Cairo. Indeed they sometimes call their city "Madeenet Alf Mi'dhana," or "The City of the Thousand Minarets". Minarets can be looked at as an architectural element designed to harmoniously fill a spatial gap within the urban fabric, and also a form environmentally performing, that visually pleases the pedestrians and psychologically effects his/her soulful.

Research Problem

The research determined two observes from studying the Minarets architecture, as follows:
- There were no scholars devoted their study to the field of design techniques of the Minarets in Mamluk architecture
- The necessity of combining the design criteria and design principles of the Minarets in Mamluk architecture with the contemporary architecture has not earning great attention among the scholars whose studied Islamic architecture.

From the previous observations two questions formulated the research problem and this research will try to answer: "What is the proportions code which controlled the design of the Minarets in Cairo of the Mamluks?" and "How did the proportions code and the environmental aspects play the role of the design generator for the Minarets in Cairo of the Mamluks?"

Research Contributions

Two points summarized the research contributions as follow:
- The research discovered the proportions code which controlled the design of the Minarets, and demonstrated the role of the environmental aspects as a design generator for the Mamluk Minarets.
- The research suggested a morphological analysis method for the Minarets this aids architects in contemporary societies to understand the role of the geometry and environmental aspects in the design of the Minarets

Research Method

In order to achieve the research objectives this study is divided into four main parts: The first part is the research introduction, which demonstrates the roots of the research problem and the research contributions. The second part is the theoretical study, which begins with shading light on the Minaret in Mamluk architecture, then it focuses on the role of proportions in formulating the design criteria of Minarets architecture, then it demonstrates the environmental aspects in the design of the Minarets, and it ends with a morphological analysis of the Minarets. The third part presents the methodology of design by the proportions code, in which the research formulate the proportions code of the Minaret design and suggest a design generative technique of the Minarets. The fourth part is the applied study which presents the applying of the design generative technique in the case-study Minarets. After these four parts the research formulates its results and conclusion.

II. THE MINARETS IN MAMLUK ARCHITECTURE

A. The Definition of the Minarets

Minaret is a tower-like structure usually associated with mosques or other religious buildings. During the Mamluk period all kinds of buildings could have Minarets including smaller mosques, tombs, khanqas and madrassas [1]. The

Mamluk Minarets usually consist of a square part, then an octagonal part, and then a round part. It is topped by a bow that ends with a helmet to which poles are attached to which "chandeliers" or lanterns are attached [2]. The minaret is the location of the call to prayer, inside it a staircase that leads to the "balconies" surrounding the Minaret on which the muezzin is called to reach his voice as far as possible.

Historical resources employed three words to denote Minarets: mi'dhana, sauma'a, and manãra. The first, properly pronounced mi'dhana, is derived from Adhan, the call of faithful to pray, and simply means the place where the Adhan is pronounced. Sauma'a appears to have been the name given by the Arabs to hermits' towers. The third term, manãra, originally can only have meant "an object that gives light" or "candle-stick" or "a place in which to place a light" [3]. By examining the terms used for the Minaret, we find that "manãra" and "mi'dhana" are the most commonly used. Manãra literally means place of fire (a lighthouse), while mi'dhana means the place where the ãdhãn (call to prayer) take place [4].

B. The Origin of the Minarets in Islamic Eras

The Minaret architecture is unified and the design idea is constantly despite the vast area of the Mamluk states and despite the long ears of Islamic architecture. The first minaret erected in Egypt was in the mosque of Amr Ibn al-As at Fustat (52 A.H./673 A.D.), which was built with mud bricks. The following table indicates the development of the Minaret in Islamic eras in Cairo from the proportions and composition point of view.

Table 1: The Development Of The Geometric Design Of The Minarets In Cairo [5](After)

Period	No. of Storeys	Composition description
Fati-mids period	Two	- Square at the base and octagon on top crowned by a dome.
	Three	- The first storey had a square plan, the second circular, and the third octagonal and it is crowned by dome or lantern
Ayyu-bid period	Two	- The lower one was square and the upper octagonal. - The ends with a pyramidal form, formulated with cloves and palm leaf stalks. - Wooden balconies placed between the storeys
Bahri-te Mam-luk	Three	- A third level, circular in plan, was added to the minaret. - Each level ends with a balcony, carried on stalactites, with wooden balustrades - A triangular squinches used on the transition from the lower square plan to the upper octagon. - The third level of the Minaret composed of marble posts, instead of stone piers, on a limestone sill. - The Minaret was crowned with a bulbous dome. - The Minaret pedestal was a blank mass within the body of the building
Circa-ssian Mam-luk	Three	- The circular plan prevailed in the second storey. - Stalactites rows at the end of each storey increased. - By the end of that period, minarets ending with twin domes were found.

C. The Components of the Minarets

The research determined eight components form the composition of the Minaret: The base, the storeys, geometric shapes, fenestration system, Muqarnas, decoration elements, columns and the head. The Mamluk architect determined specific design criteria for each one of them, as follows:

- The base must be in square shape
- The heights of the different storeys of the Minaret must be determined in interrelated relationships governed with specific proportion.
- The geometric shapes must be one of three: square, circle or octagonal shape
- The size of windows in the fenestration system must be small as much as possible
- The size and the shape of the Muqarnas must be suitable to its location in the Minaret composition
- The decoration elements must be designed according the visual harmony criteria.
- The columns which carry the head dome they must be in octagonal composition
- The dome on the head must be an onion dome shape.

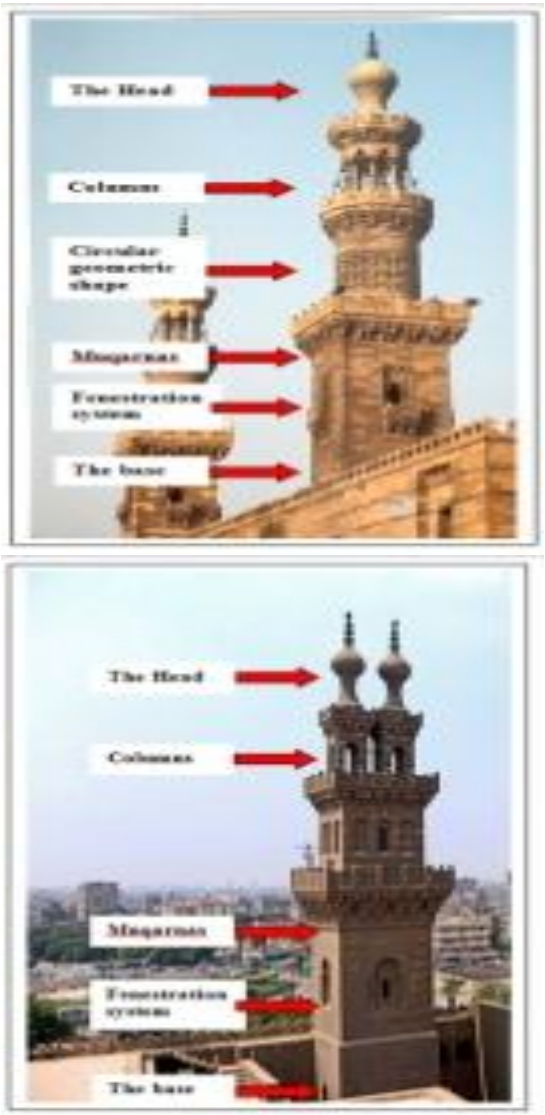


Figure 1: The components of the Minarets: left to right: The Khanqah of Farag Ibn Barquq, The Mosque of Emir Qanibay Qura al-Rammah [author]

D. The Design Methods of the Minarets in Mamluk Eras

Nasser Rabbat in his study "Architects and Artists in Mamluk Society" stated that "…No Mamluk architect seems to have left us any writing about his profession, his individual work, his general concepts of art and architecture, or craft schools he might have belonged to, in a manner comparable to the familiar way in which other cultural agents did, especially the Ulama and literati in their assorted array of professions [6]. The research presents many questions to understand the process of designing and constructing Minarets in Cairo of the Mamluks, as follows:

1- Was there a particular design method the Mamluk architect depended on it?
2- Was there a system of proportion governs the whole composition of the Minarets?
3- How were the design ideas and the design methods of the Minarets transferred between different generations of builders and masons through eras of Islamic architecture?
4- What is the source of unity and integration in Minaret architecture all over the Mamluk eras despite the vast distance that separates the Mamluk states?
5- How many persons were participating in the design process of the Minarets? And who was highly on ranking to be responsible about taking the main design decisions? And how the complementary between them was happen?
6- Were there craftsmen responsible about the construction of the Minarets?

Historical resources did not determine a fixed design method in Minarets architecture, but there is a fixed criteria, principles and content, this content controls the architecture design process. The Quran and the Sunnah are the main reference books for this content and from them the Mamluk designer derived design principles, design ideas, design values and general rules of the Minaret design.

The Quran text transferred these design rules, ideas and values between different generations and different places during the long eras of Mamluk architecture, and the fixation of Quran texts ensured the unification of Minarets architecture despite the long ages that separate the different Mamluk eras. The research determined four principles of the design theory of the Minarets, as follows:

double proportion	Equal proportion	Two-third proportion	Half proportion	One third proportion
A = 2A	A = A	A = 2/3 A	A = 1/2 A	A = 1/3 A

depending on dynamic geometric composition, design by centrality and axial articulation form, express the concept of unity in plurality and environmental adaptively.

III. THE PROPORTIONS IN THE MINARET ARCHITECTURE

This section demonstrates the role of proportions in formulating the design criteria of the Minarets architecture, to demonstrate that the following points will be explained:

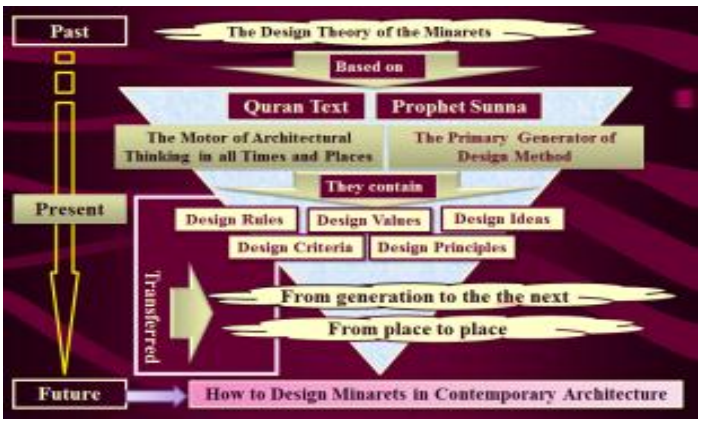


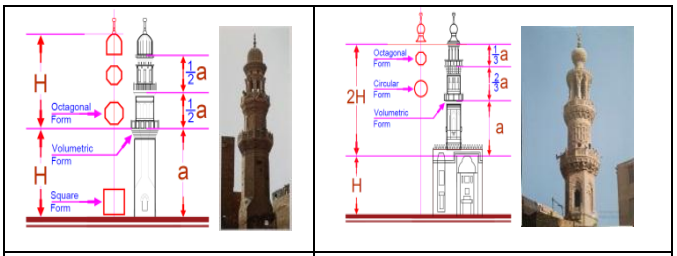
Figure 2: The design theory of the Minarets in Mamluk eras [author]

E. Complementary between the proportions of the form and its function

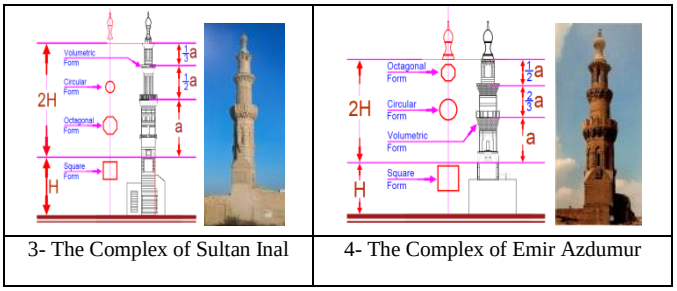
A large number of scholars have argued that (a) Islamic architecture is hidden, in the sense that its interior is not articulated on the basis of its exterior; (b) the form of Islamic buildings neither expresses nor embodies its function [7]. From studying and analyzing the proportions of the forms in the Minarets, the research presents three points as a pretext against these allegations as follows:

- The Minarets to introduce its functions in calling for praying, source of light, a Landmark of the city and as a symbol of religion, the Mamluk architect depended on five main types of geometric forms to serve these functions: square, circular, octagonal, linear and volumetric form.
- The research determined five types of proportions control the relationship between forms in the whole composition of the Minarets in Cairo of the Mamluks, as follows:
- There are dynamic interrelatedness relationships between form and function In Minaret design based on two criteria: firstly: form and function deal with change as one unit, when one of them is change the second one changed consequently, so that the form of the Minaret determines the functions can have and the function of the Minaret determines the form which the designer can imagine.

Secondly: the functional aspect is the only standpoint, from which the Minaret form could experience, as in functional architecture "form follows function" and specific function must envelop on specific form.



1- Mosque of Manjaq al-Yusufi | 2- The Madrasa of Emir Asanbugha



3- The Complex of Sultan Inal | 4- The Complex of Emir Azdumur

Figure 3: Geometric forms in the Minaret design [author]

F. Design by Centrality and Axial Articulation Form

In the design of the Minarets the research found that there was a "Reference point", it was responsible about generating and ordering force onto the whole design process, like all waves extracts and refers to the falling point of stone in a pond. The research emphasizes that the Mamluk architect depended on one center point as the source of centrality in the whole composition of the Minarets, from which one main axis extended upward articulating all the forms in the Minaret.

The Mamluk architect connected Minaret' plan with its façade by a hidden factor, the research name it "the axial articulation form", this axis all compositions and forms in Minaret were articulated around it, so that it was the main responsible about the visual harmony of the Minaret shape.

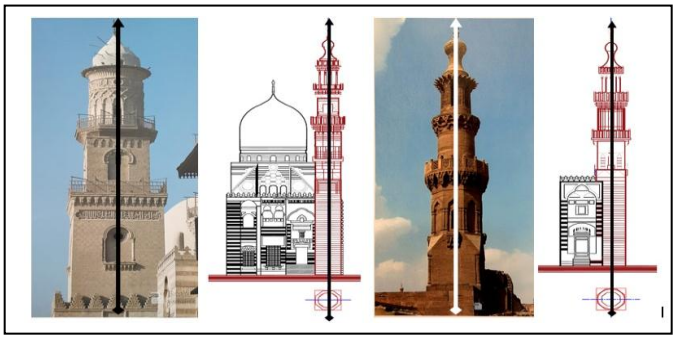


Figure 4 : The axis of articulation in form composition: left to right: Sultan Qalawun Complex, Mosque of Sultan Qaytbay, Complex of Emir Azdumur, Mosque of Qadi Abu Bakr Ibn Muzhir [author].

G. Depending on Dynamic Geometric Composition

Mamluk architect considered environment control an intrinsic part of the design process. He takes advantage of geometric shapes, such as octagon and circle, and manipulates them to the advantage of the space. His choice of dynamic geometric composition is mainly to reach the comfort of the architectural spaces.

The dynamic composition is that composition that has the ability to generate harmony between many internal forms to appear as integral elements in one body [8]. Mamluk architect manipulated with four components of the Minaret to achieve the dynamic composition in its design, they are: the geometric shapes, the storey heights, the fenestration system and the Muqarnas shape.

Geometry controlled two aspects in the Minarets design:

- The formal aspects: he depended on extended upward from taller to shorter to control the whole formal aspects.
- The visual aspects: he designed the geometric composition to have the ability of taking the eyes of the pedestrians from the ground to the sky.

Achieving the visual continuity in the visual design of the streets in Cairo of the Mamluks was one of the main goals which the Mamluk architect tried to achieve behind using the dynamic geometric composition in the design of the Minarets. one of distinctive visual continuity is the mutual visual relationship between the Minaret of Sultan Qalawun and the Minaret of Muhammad Ibn Qalawun and the Minaret of Barquq, they compose a changeable visual image in the pedestrians mind even their movement changed across the street, as follows

Figure 5: The role of the Minarets in the visual design and visual continuity between the Madrasa of Sultan Qalawun and the Madrasa of Sultan Barquq. [from left to right: (1,2) [Author], (3) [9], (4) [10]]

IV. THE ENVIRONMENTAL ASPECTS ON THE DESIGN OF THE MINARETS

Three main points demonstrate how the environmental aspects were an effective design generator tool for the design of the Minarets in Cairo of the Mamluks, they are as follows:

A. Environmental Adaptively

The environmental adaptively in the design of the Minarets can be seen in four aspects:

First: Using natural material on their natural texture, especially for the external façade for the Minarets: lime-stone, red bricks, marble, stone, and wood.

Second: Using special architectural elements to cover encircling balcony or platform between the levels of the minaret this to avoid wild delight and offer shadow on the Minarets form, for example embellishing the Minaret surfaces with intricate arabesque, Muqarnas and geometric designs: vines, leaves and star patterns

Third: Depending on self-shadow to avoid the direct falling of sun rays on the Minaret body, so the architect depended on the multi faces geometric forms as octagonal form.

Fourth: From the analysis of the proportions between the solid and the void in the outer faces of the Minarets, the research founded that the Mamluk architect minimized the size of the windows as much as possible and in some Minarets one or more storeys of it have no widows, this was for two reasons, the first is avoiding the direct sun ray and the

second is to make the temperature in the inside space more comfortable.

B. Dramatic Visual Play of Light-Colour and Orientation

The Islamic architects pegged their creativity on evoking their inner beliefs through the use of abstract forms that produced magnificent works of art. For these architects, the main aim of the architectural works was to transmit Islamic messages and not to offer aesthetic gratification to the eye [11]. He manipulated with two visual syntax elements to create unique environmental design for the Minarets, they are: light-colour and orientation.

1- Light-colour in the design of the Minarets

The Quran states that "God is the Light of the Heavens and the Earth" (The Holy Quran, El Nour, 35). The idea of a direct contact between a person and light (god) had a dominant position in the Mamluk Minaret style. In case of an early court Madrasa the centre of the composition was a wide internal courtyard flooded with bright light.

There are two sources of light in the Minaret design:

- Direct natural light: it penetrates the Minarets spaces through the roof (dome above columns) or through the fenestration system.
- Hanging glass lamps placed in patterned metal containers (on the top of the Minarets or inside it): it was decorated with coloured calligraphy and geometrical patterns.

Mamluk architect depended on two colours in the Minarets:

- White colour is the main colour in Islamic architecture, being the symbol of holiness and dignity, bliss and true word. White colour point out completeness, sacredness purity, sunlight and enlightenment,.
- Natural colour of the construction material as stone or marble (green, red or blue).

2- Orientation in the design of the Minarets

Monuments in Mamluk Cairo had to meet two often orientation differing needs: to face the street and to face Qibla direction. Taking into consideration that the streets were already laid out and could not be altered [12], and the position of the Minaret in the building composition must be placed facing the street, so that the Mamluk architect make the position of the Minaret fixed in the building space syntax and make the position of all other architectural functions flexible and changeable in the design of the building.

In Mamluk architecture buildings were formed around a functional, spatial, visual, and formal hierarchy system, this system is based on the importance of the Qiblah axis as a spiritual orientation [13]. The role of orientation as design criteria controls the proportions of the Minaret composition is explained as follows:

- The Minaret vertical axis become the main axis in its composition, around it all forms were articulated,
- The Minarets have to be oriented according to the street and the Qibla direction, but any other architectural space has its own orientation, for example the entrances must be orientated according to the street but the Iwans and prayer hall must be oriented according to the Qibla direction
- The fixed orientation of the Minaret is not only the main point of departure in organizing its exterior shape but also control its overall shape of the final design.
- The orientation of the Minarets having an environmental function besides the religious function. It makes Minaret composition more comfortable through the perfect orientation to the ventilation and the sun.

The *Qibla* unifies and calls all the Minaret components in an orderly manner around its axis. The following figures show the effect of orienting buildings toward Qibla direction and the fixed position of the Minaret.

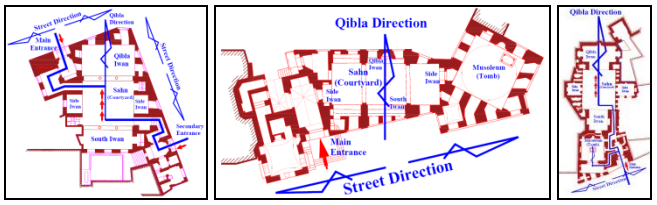


Figure 6 : The Qibla orientation and Minaret position on building' design: left to right: Madrasa of Qadi Abu Bakr Muzhir, Amir Khayrbak Complex, Khanqah of Baybars al-Jashankir [author].

C. Dynamic Relationship with Urban Context

Mamluk architect considered environment control an intrinsic part of the design process. He takes advantage of the dynamic relationship with urban context to the advantage of the Minaret design. His choice of materials and the manipulation of orientation are mainly to reach the comfort of the architectural spaces.

An initial reading of Mamluk architecture reveals form governed by urban factors, and, as a result, Mamluk monuments cannot simply be read as containers of spaces or objects in space, but rather as complex mediators between interior architectural spaces and exterior urban spaces. Individually, Mamluk monuments were more responsive to their context than initiators or dictators of new ones. It was from their collective power that a new concept of space emerged. It becomes clear that the concept of space expressed in it is not manifested in isolated buildings but in urban infills [14]. The research determined five roles of the Minarets in the urban design of the city:

1- They are visual connections between the pedestrians in the paths and the directions of the city.

2- They are landmarks in the image of the city

3- They connect the building with its urban context in harmonious relationship.

4- They controlling the orientation of the pedestrian's movement in the street and make the aberration of the building from the surrounding streets and from the Qibla direction more smooth urban relationship.

5- They integrated the building with its urban context, for example in the mosque of Muayyad Shaikh, the designer constructed the mosque's Minarets above the stone bases of Bab Zuweila, also in El Ghuri complex as a clear example of design by urban context, the architect divided the building into two parts and placed them facing each other across the

street, and he put the dome in one of them and facing to it he placed the Minaret on the other part.

Figure 7 : The role of the Minarets in the urban context: left to right: (1),(2) Connection element between inside and outside, (3) Orienting the movement of the pedestrians in the street [author]

Related to the position of the Minaret in the building design the research determined five types of connections relationship depended mainly on the proportions between the Minaret and the urban context as follows: the connection relationship Minaret-Street, Minaret-Minaret, Minaret-Entrance, Minaret-Dome and the connection relationship Minaret-Courtyard, as follows:

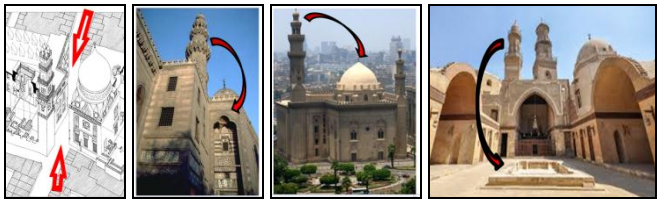


Figure 8: Types of connections relationship between the Minaret and the urban context, left to right: Complex of Sultan al- Ghuri (Minaret-Street), Amir Qijmas al-Ishaqi Mosque (Minaret-Entrance), Sultan Hassan Mosque (Minaret-Dome), The courtyard of sultan al Nasir Mohamded and Minaret of Sultn Qalawun. [(1) [10] after, (2,3,4,5) [Author]].

V.THE MORPHOLOGICAL ANALYSIS

The Mamluk architects relied on the science of geometry on the process of choosing the geometric shapes which ensure a highest efficiency of the environmental design of the Minarets. This part of the research will focus on the geometric morphological analysis of the Minarets to understand the mutual relationship between the geometric shape and the environmental performance of the minarets

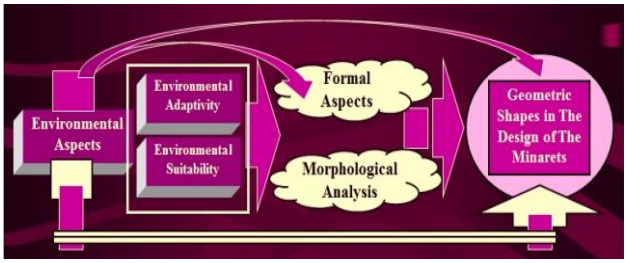


Figure 9: The environmental aspects and geometric shapes in the design of the Minarets [author]

A. Geometric Morphological Analysis of the Minarets

Geometry played the role of the organizer factor between all the Minaret components; it can be seen in three phases in the design of the Minarets, as follows:

- Geometric shapes: square, circle, rectangle and hexagon.
- Geometric forms: cube, cylinder, dome and Muqarnas.
- Geometric relationships: linear and perpendicular

In this section a geometric morphological analysis of the Minarets will be done, the aim of this analysis is to study the geometric shapes in the composition of the Minaret in order to search for proportions that dominate their dimensions. First, the geometric shapes in the Minaret will be determined then proportions between them will be examined. Two questions are forwarded: the first is: how can the size of the geometric shape be determined? And the second is: is there a proportional relation between the dimensions of the geometric shape and its place in the whole composition of the Minaret? To answer both questions, several examples are geometrically analyzed, starting with determining the geometric shape of each story of the Minaret. After going through many attempts to find out a meaningful geometrical relation between the sequences of arranging the geometrical shapes upward in the whole composition of the Minaret. The following figures indicate the sequence of geometric shapes upward in the Minarets design.

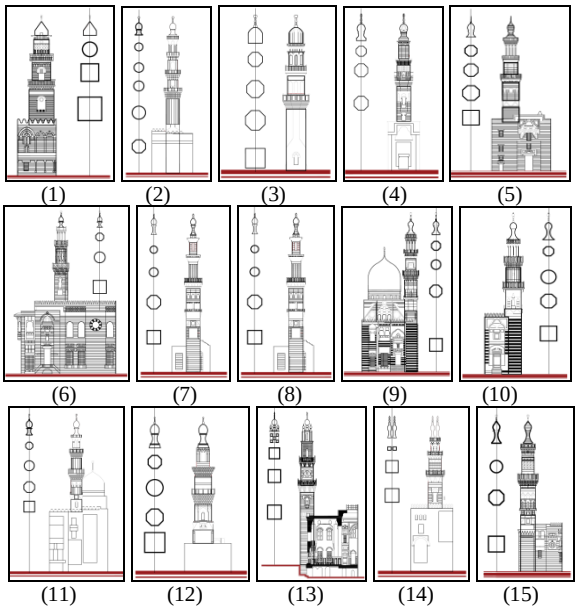


Figure 10: The geometric analysis of the Minarets in Cairo of the Mamluks. [author]

The research reached five remarks from the geometric morphological analysis of the Minaret:

1- The Mamluk architect depended only on three geometric shapes in the design of the different storeys of the Minaret they are square, octagon and circle.

2- In case of the designer using one geometric shape in all the storeys of the Minaret, it must be square or octagon.

3- The first story of the Minaret was always square shape.

4- All the Minarets ended with onion-shaped dome rested above 8 pillars column (form octagonal shape) and in some cases this dome is directly rested above the final upper storey of the Minaret.

5- There are three types of geometric morphology in the design of the Minarets, they as follows: centralized morphology, linear morphology and radial morphology.

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B. The Morphological Analysis Method

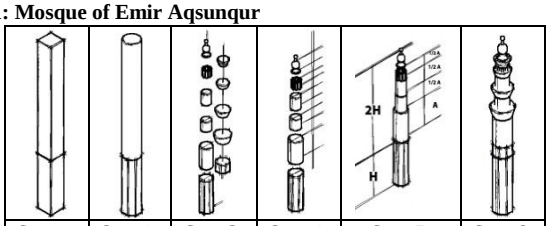
The research suggested morphological analysis method for the Minarets, it comes on eight steps and depended mainly on the analysis of the geometric shapes as follows:

- Step 1: Division/ Decomposition
  Decompose the whole composition of the Minaret into its two main parts
- Step 2: Transformation
  Transform the main shape by addition and deletion into a shape close as possible as to its proportion
- Step 3: Articulation
  Articulate its separate parts around the vertical articulation axis and place the balconies as a connecting element between the different parts
- Step 4: Comparing
  Apply the dimensioning code to compare the dimensions of each parts, taking into consideration achieving the visual harmony between them
- Step 5: Extension
  Extend the dimensions of any storey in the Minaret on one direction without being accompanied by a change in other directions in the formation to reach the required proportions
- Step 6: Transition and Connection
  Connect between the spatial dimensions to create unity relationship to these spatial dimensions and connecting all separated parts to reach the final composition.

D. Applying the Morphological Analysis Method on the Minarets

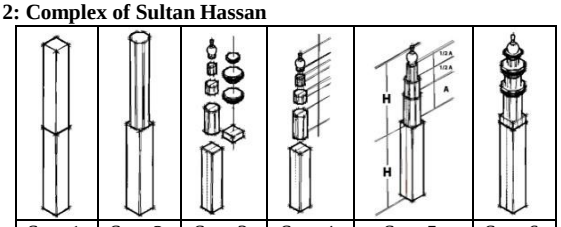
In this section the research will apply the suggested morphological analysis method on four of the Minaret, the choice of them had done without any exception to emphasize the high validy of the suggested morphological analysis method.

Case 1: Mosque of Emir Aqsunqur



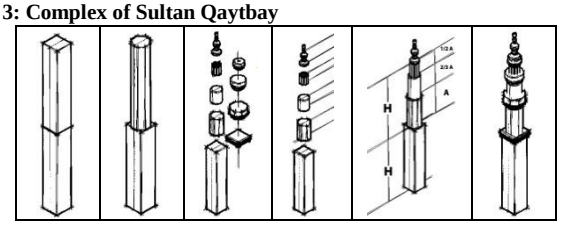
Step 1	Step 2	Step 3	Step 4	Step 5	Step 6

Case 2: Complex of Sultan Hassan



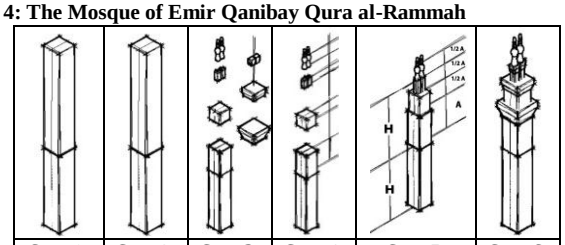
Step 1	Step 2	Step 3	Step 4	Step 5	Step 6

Case 3: Complex of Sultan Qaytbay



Step 1	Step 2	Step 3	Step 4	Step 5	Step 6

Case 4: The Mosque of Emir Qanibay Qura al-Rammah



Step 1	Step 2	Step 3	Step 4	Step 5	Step 6

C. The Results of the Morphological Analysis

From the morphological analysis of the Minarets the research reached four main objectives:

1- Providing an insight into how morphological analysis can be used as a design support tool within the design method.

2- Providing greater understanding of the generating processes of the Minarets form taking into account the basic design elements and geometric structure that synthesizes

3- Understanding how Mamluk architect manipulated with the geometric shapes and the dimensions to generate this visual harmony in the final configuration of the Minarets.

4- Developing a general morphological analysis of the Minarets design, as a method for investigating the totality of relationships contained in multi-dimensional, non-quantifiable and multi-geometrical relationships problems.

VI. THE METHODOLOGY OF DESIGN BY PROPORTIONS CODE IN THE MINARETS

The methodology of design by proportions code in the design of the Minarets has two main components: the proportions code and the design generative technique.

A. The Proportions Code in the Design of the Minaret

The Mamluk architect depended on a proportions code to generate the design of the Minarets, it based on one principle and two rules, as follows

1- The Proportions Code Principle

The Mamluk architect manipulated with four types of proportions between the dimensions of the main parts of the Minaret: the equal proportion (1/1), the half proportion (1/2), the third proportion (1/3). Two third proportions (2/3),

2- The Proportions Code Benefits

The proportions code helped the Mamluk architect in determining three main elements:

- Determining the total height of the Minaret
- Determining the numbers of the storeys of the Minaret
- Determining the height of each storey of the Minaret

According to that he determined the geometric shape of each storey.

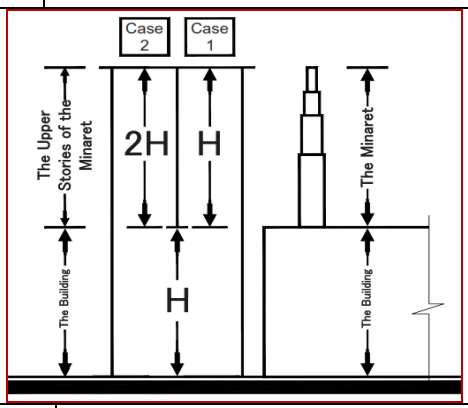
3- The Proportions Code Rules

Applying the proportions code in the design of the Minarets comes through two rules:

Rule 1: Determining the total height of the Minaret

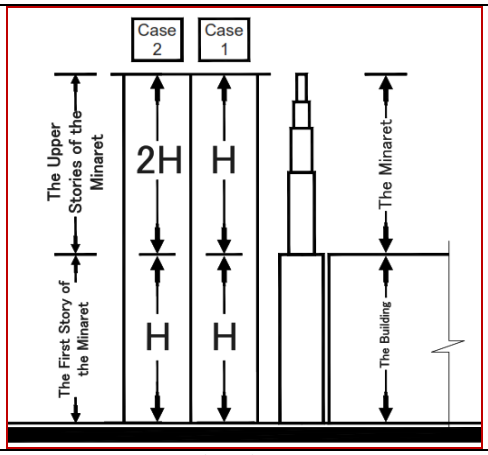
The total height of the Minaret depended on the total height of the building and on the position of the Minaret in the building, so determining the total height of the Minaret comes in two sequence steps, begins with determining the height of the first story of the Minaret and then determining the total height of the rest part of the Minaret.

First Case	**The first storey of the Minaret is embodied in the body of the building and the upper storeys starts from above the roof of the building**

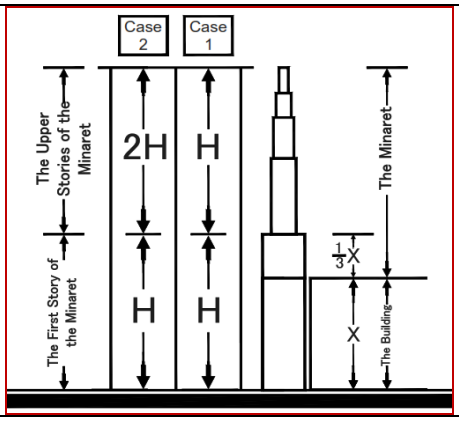


Second Case	**The body of the Minaret is separated from the building and the first storey of the Minaret starts from the street level**

Second Case (A) the height of the first storey of the Minaret is equal to the height of the building

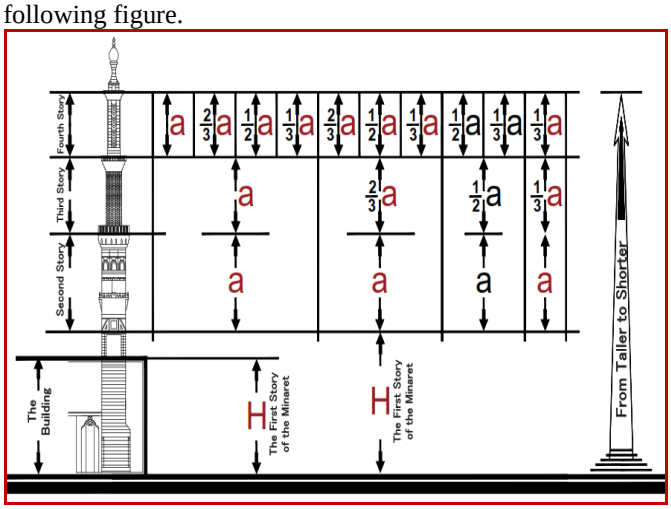


Second Case (B) The height of the first storey is higher than the height of the building



Rule 2: Determining the heights of each upper story

The height of each upper storey is determined according to the internal proportions between them as presented in the following figure.



B. The Generative Technique of the Design of the Minaret

1- *The Generative Technique Description*

Drawings were not seen as essential to the processes of design in medieval Islam [15], from this notion the suggested technique is a fixed consequence steps to generate the design of the Minarets

2- *The Generative Technique Idea*

The idea of the generative technique of the Minaret design by the aide of proportions code is based on four main principles:

First: There is an overlap and integration between the process of designing the Minaret and the process of constructing it in the building site, and some design decisions may change and other decisions may arise as a result of the conditions and nature of the site.

Second: The construction of the upper storeys of the Minaret begins after the completion of the construction of the whole building

Third: The total height of the building is determined in three steps as follows:

- Determine the dimensions of the Qibla Iwan (length and width in plan).
- The Qibla wall is a square shape as a symbol of unification and equality and according to that he determined the total height of the Qibla wall.
- The total height of the building is equal to the total height of the Qibla wall

Fourth: The total height of the Minaret is determined according to a proportions code.

3- *The Generative Technique Steps*

The generation of the design of the Minaret according to this generative technique comes in seven main steps as indicated in the following table:

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Table 2: The Generative Technique Steps

Factor	Steps
Environmental Aspects	**Step 1: Pre-design Step (Design by Urban Context)**
	a- Determine the site boundary
	b- Determine the Qibla direction
	c- Determine the position of the Minaret according to the position of the entrances in the building design (its position was one of three positions: right to the entrance, left to the entrance, or above the entrance)
Proportions Code	**Step 2: Design the Base**
	Determine the geometric proportions of the dimensions of Minaret' base
	a- Determine the final design of the plan
	b- Determine the geometric shape and the dimensions of Minaret' base
	Step 3: Applying the Proportions Code of the Minarets
	First: Determine the total height of the Minaret
	a- Determine the height of the Qibla wall.
	b- Determine the height of the Qibla Iwan.
	c- Determine the total height of the building
	d- Determine the total height of the Minaret
	Second: Design the body of the Minaret
	e- Determine the numbers of the storeys of the Minaret
	f- Determine the height of each storey of the Minaret
	Third: The Design of the Storeys
	g- Determine the geometric shapes of each storey in the Minaret
	h- Determine the plan dimension of each storey in the Minaret
Environmental Aspects	**Step 4: Design the Fenestration System of the Minaret.**
	a- Determine the place and the shape of the openings in each storey.
	b- Designing the head of the Minaret
	Step 5: Design the Transition Zone
	a- Design the ringed balkons around the transitional zone
	b- Constructing the Muqarnas
Proportions Code	**Step 6: Constructing the Geometric Decorations**
	Designing the decorations panels on the faces of the Minaret body
	Step 7: The Final Form Composition of the Minaret.

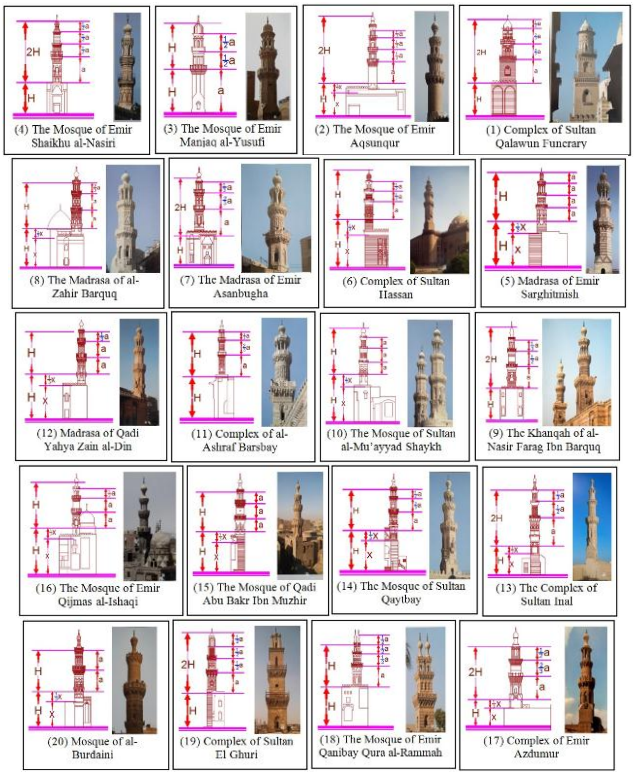
VII. APPLIED STUDY

Understanding the Mamluk methodology in designing the Minarets and how the Mamluk architect relied on proportions and environmental aspects as a design tools is the most apprehension and interest for this research.

The research formulated a systematic technique for the illation of the Miarets design in Mamluk eras, The generative technique was putted up and erected using twenty Minarets that were built during the Mamluk periods in Cairo. The research applied the proportions code of the Minaret design in twenty case study buildings and applied the design technique of the Minarets in eight buildings as a case study, all of them were constructed in Mamluk period except one which is The Mosque of al-Burdaini (1616-1629/1025-1038 AH) which constructed during Ottoman period and this to emphasize the validity of the suggested proportions code to continue over centuries of time.

E. Applying the Proportions Code of the Minarets Design on the Case-study

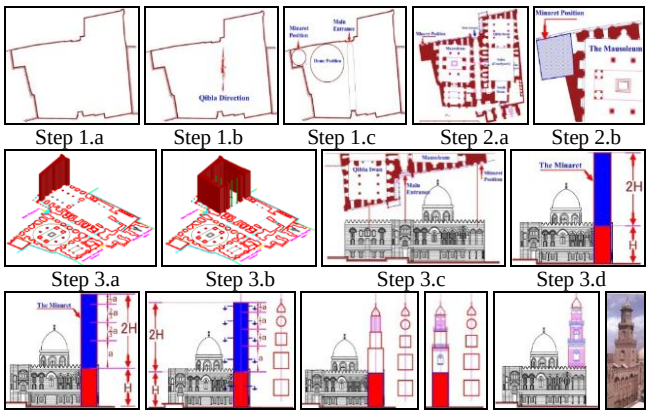
The following figures present the result of applying the proportions code on twenty of case-study Minarets.



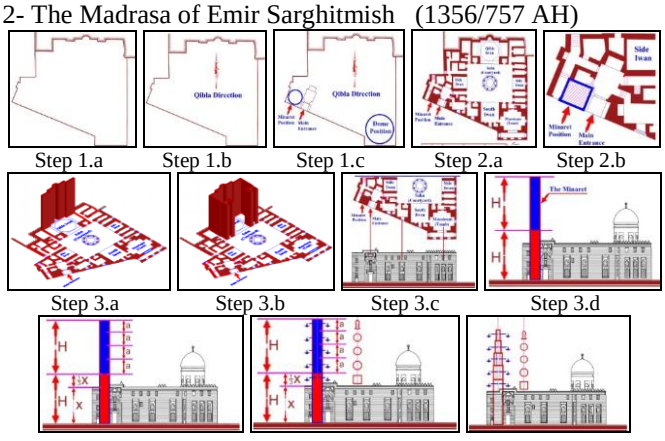
F. Applying the Generative Technique of the Minarets Design

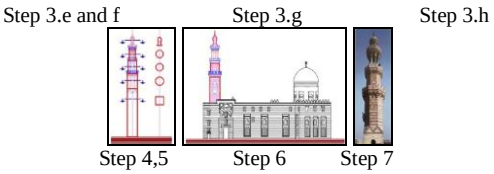
The applying of generative technique on eight case studies will be shown as follows:

1- Complex of Sultan Qalawun (1284-1285/683-684 AH)

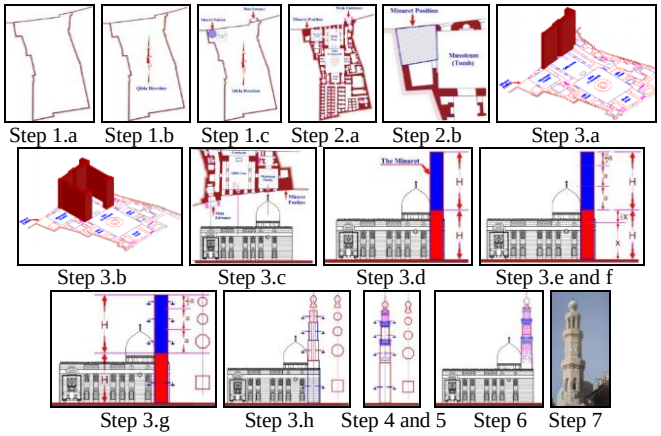


2- The Madrasa of Emir Sarghitmish (1356/757 AH)

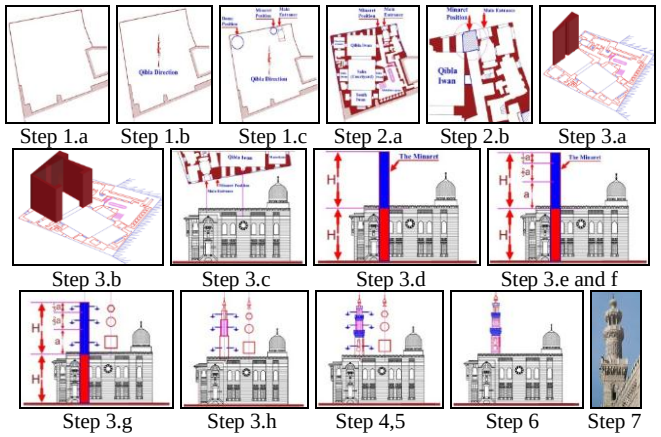




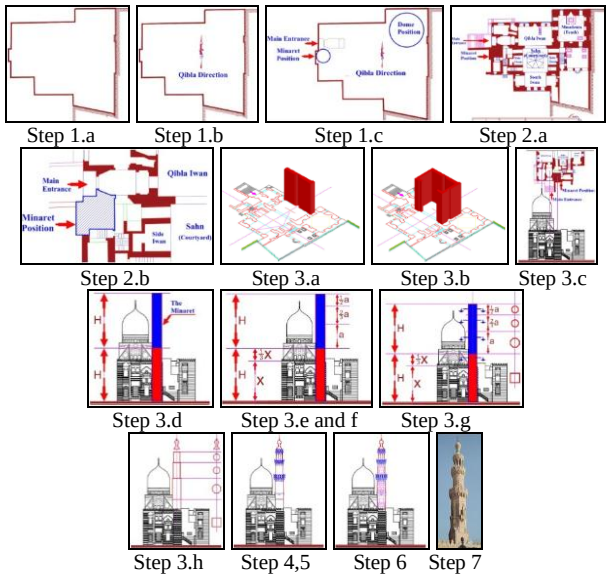
3- The Madrasa of al-Zahir Barquq (1386/786-788 AH)



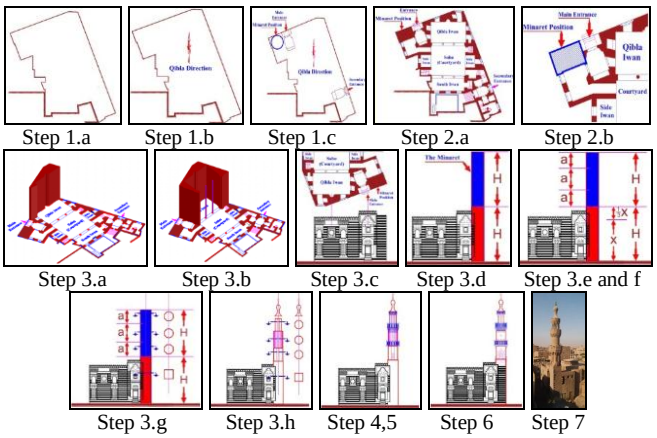
4- Complex of Sultan al-Ashraf Barsbay (1425/829 AH)



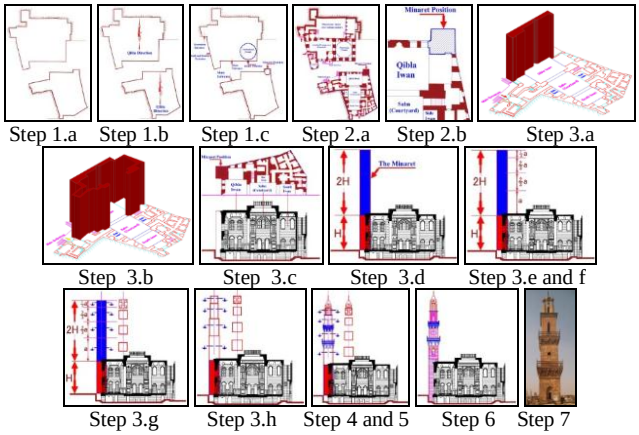
5- The Mosque of Sultan Qaytbay (1472-1474/876-879 AH)



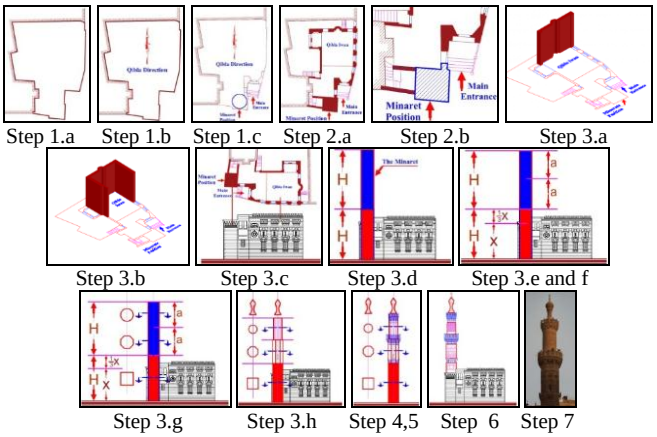
6- The Mosque of Qadi Abu Bakr Muzhir (1479/884 AH)



7- The Complex of Sultan El Ghuri (1504-1505/909-910 AH)



8- The Mosque of al-Burdaini (1616-1629/1025-1038 AH)



VIII. RESULTS AND CONCLUSION

The research reached the following main results:

1- There is an inherent proportions code controlling the design process of the Minarets and it play the role of a guideline for the designer and the Mamluk architect used it as a formative idea determining the built form,

2- The environmental aspects helped the Mamluk designer to combine many design elements with each other to form a 'mixed type of composition' in the design of the Minarets.

3- The Mamluk architect depended on two aspects on the design of the Minarets: the proportions code to control the

geometric aspects and the environmental principles to control the formal and functional aspects

4- The Mamluk architect based on the geometric proportions in dividing the composition of the Minarets into storeys, and as we go upwards the upper storey always shorter than the lower and all of them articulated around a vertical axis to make the Minaret lead vision upwards, so that the eye follows its components from end to end, pointing upwards or downwards and moves by inertia from the longer section to the shorter. He used a harmonic system of proportioning to shortened these sections, and to have specific a harmonious movement upwards he used two vertical lines instead of one, upon placing these two lines at an angle, this make the eye follows them in the direction of their meeting point, and to increase the vertical acceleration he dividing such a figure pointing upwards by horizontal lines into sections that are shortened as we go upwards.

5- During the Mamluk period almost Minarets composed of three distinct zones: a square section at the bottom, an octagonal middle section – in some cases followed by circular section - and a dome on the top which take the form of a stone bulb. The zone of transition between each section is covered with a band of Muqarnas decoration.

6- In all Mamluk Minarets there was a backbone around which all the composition was articulated and interconnected through geometric relationships.

7- Mamluk designer used Islamic content as his leader and proportions code beside environmental aspects as his tools to formulate a design generative technique for the Minarets in Mamluk eras. This technique controls the developing of the Minarets architecture during Mamluk eras.

8- The design process of the Minaret has one direction: ending with the form but starting with the function and connects between them with a proportional code to bring a sensual beauty to the forms.

The conclusion of the research can be formulated in two points as follows:

- Unlike other cultures, there is not a fixed proportions governing the design of the Minarets in Cairo of the Mamluks partially and as a whole, but it is flexible as different cases may require different proportions, or a range of proportions. That helped the resulted architecture to respond to different perception that people usually have and to different standards of beauty that vary among peoples within the same society.
- Through my studying and analyzing of Islamic architecture I founded that contemporary architecture is separated from its historical roots in our Arab and Islamic societies, beside that there is no intellectual link between the architecture design process in contemporary architecture and Islamic architecture, and there is a weakness in the designers' attempts to achieve the design criteria by proportions and by environmental aspects in Minaret architecture, all these aspects forced me to hold this research which just an interpretation of the design process of the Minarets in Cairo of the Mamluks. Finally, the Minaret' proportion code introduced in this research aims to bridge the gap between the the Minaret' functions and the needs of contemporary Islamic or non-Islamic societies.

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