Muthanna Journal of Engineering and Technology, Vol. (12), Issue (2), Year (2024)

Muthanna Journal of Engineering and Technology

Website: https://muthjet.mu.edu.iq/

Submitted 4 October 2024, Accepted 9 November 2024, Published online 20 November 2024

Methods to enhance compatibility in designing of campus facades

Zeina Abdulhaq Hammoodi Al-jarah[a] and Asmaa Hassan Al-Dabbagh[a]

[a]Department of Architecture, College of Engineering, University of Mosul, Mosul, Iraq
**Corresponding author E-mail: ziena.22enp52@student.uomosul*

DOI:10.52113/3/eng/mjet/2024-12-02/100-120

Abstract

Universities are experiencing a state of visual chaos that affects the campus environment, due to the diversity of design practices and the varying morphological and visual characteristics of their facades. This arises from the continuous need for universities to change in order to accommodate future developments. Achieving compatibility among the facades creates an integrated and cohesive environment. The study aims to identify the variables that designers focus on to achieve compatibility in the facades at the level of the aggregation (a part of the university's master plan that includes at least three buildings and the space they contain) and to rank these characteristics according to their priority. The study proposes a theoretical framework that includes variables such as: finishing characteristics, relational characteristics, geometric characteristics, along with their secondary properties. To achieve this goal, four aggregations from the University of Mosul with cumulative construction were selected. The study employed quantitative measurement methods to assess the research variables, where the dimensions and areas of the facades were measured within the geometric characteristics variable using AutoCAD software, and the proportion and diversity were evaluated. Fractal3 software was also used to measure fractal symmetry within the relational characteristics variable. The research concluded that the facade characteristics encompass two levels of variables: some of which holistic and detailed. It was found that in aggregations where designers focus on specific facade detailed variables, the holistic variables are and less concentrated by the designers, and vice versa. Additionally, there are cases where designers are able to achieve of balance between focusing on both levels (detailed and. holistic), which is influenced by the area of the aggregation and the functional requirements of its buildings.

Keywords: *Compatibility, Termination characteristics, Relationship characteristics, Geometric properties, Campus*

1. Introduction

Is a key component in the design of buildings, whether commercial, residential, educational, or otherwise. The façade plays a vital role in the design of various types of buildings, including commercial, residential, and educational structures, as it contributes significantly to shaping the urban environment's visual identity. On university campuses, the importance of the façade is even greater, as it helps define the campus's character and overall image. Universities, especially those with buildings constructed over different periods due to growing student numbers and evolving functional needs, often face ongoing and sometimes unplanned development. This can result in a lack of coherence among building façades. This research focuses on the concept of compatibility as a key solution to this issue. Linguistically, "compatibility," as described in Lisan al-Arab, refers to the idea of suitability and agreement, where things align in compatibility [1]. Technically, compatibility means the ability of urban forms to integrate seamlessly with surrounding structures and open spaces [2]. Scheel described compatibility as maintaining harmony, balance, and unity in the shapes and styles of buildings [3]. From these definitions, related terms such as harmony, integration, coordination, consistency, and unity can be identified. Thus, an operational definition of compatibility is established as the harmonious relationship among the façades of adjacent buildings, ensuring the highest degree of coherence and unity.

2. Research problem

The research problem was the lack of clarity regarding the characteristics that designers focus on to achieve compatibility within the assemblages of university sites in relation to the research term "façade." The aim of the study was to discover the characteristics (variables) that designers emphasize in achieving compatibility at the assemblage level and to prioritize those characteristics according to their importance. Ultimately, the study sought to explore how designers achieve compatibility in façades.

3. Research methodology

- Identify the façade characteristics from the theoretical framework derived from previous studies.
- Determine the variables included in the measurement within the façade and their type (quantitative or qualitative).
- Analyze case studies by selecting four assemblages in the University of Mosul campus.
- Collect data by analyzing façade diagrams, documented with photographs and field documentation of the façades of the four assemblages.
- Analyze the data using statistical methods.
- Present the results and conclusions.

4. Limits of the study

The research considers that the façades in the assemblages are façades within the modern movement style, with buildings constructed using a structural system (columns and beams). Moreover, the buildings were designed by local designers to mitigate the characteristics affected by these factors. Therefore, the same methodology can be applied to other university sites, taking into account the same considerations.

5. Previous studies

5.1. Previous studies were classified into general studies on facades

This includes two groups.

5.1.1. First group

The first group focused on (the style and visual characteristics of the elements Askai and et al., [4] addressed The façade is considered the face of the building, which reflects its value. The study aimed to understand how people assess the importance of visual elements affecting the image of historical building façades in Malaysia. The research relied on a set of visual elements in a public survey, which included (architectural style of the building façade, façade shape, ornamentation, materials, color, and texture). The study concluded that architectural style, shape, ornamentation, and materials, respectively, are the most important visual elements in presenting the image of building façades, while color and texture are of lesser importance. Nevertheless, their impact should not be underestimated in preserving and developing the environment in the future. Abbasiasbagha et al., [5] discussed the importance of building features and street elements (space) in achieving continuity and coherence in urban environments. These elements play a crucial role, through their integration, consistency, and continuity, in creating an attractive urban environment. The research, in one of its aspects, focused on the characteristics of building façades, such as style and rhythm, to understand the role of repeating façade elements, like openings and architectural details, in achieving integration. Additionally, it explored the role of element characteristics (such as color, material, texture, and other details). The study concluded that rhythm and architectural style are the two main factors contributing to the cohesion of buildings in the studied streets. Taher [6] studied the formal characteristics of urban scene elements and their role in achieving the phenomenon of harmony in city centers. The study divided the elements that make up the urban scene into two categories: building façade elements and external space elements. Among the most important façade elements whose characteristics were analyzed are (walls, openings [doors and windows], prominent elements [awnings, columns, balconies, shanasheel]). The study identified key formal characteristics related to harmony and the mechanism for achieving it. These characteristics include (form, finishing material, size, texture, details, color, ornamentation). The mechanism for achieving harmony at the element level involves unification, harmony, and balance among different elements (such as walls), while at the characteristic level, it involves similarity and continuity of the façades' formal characteristics. Moawd et al., [7] studied the architectural integration between traditional and modern forms in the treatment of building façades and its impact on modern architecture. The research presented methods for achieving architectural integration, including: harmony between new and existing forms, which can take several shapes (harmony through unity or symmetry, relative similarity, harmony through overlap, and harmony through camouflage); and contrast with existing forms, which can be either complete contrast or partial contrast. The study concluded that harmony can be achieved in several forms, while contrast takes two forms. Architectural integration can be achieved by studying the formal characteristics of traditional architecture and attempting to simulate them in the proposed design treatments.

5.1.2. Second group

The second group focused on (the relational properties such as proportion, repetition, etc.). Khudr [8] addressed the visual appearance of the city of Baladruz, focusing on the importance of analyzing and evaluating the urban and visual appearance of cities, highlighting the factors that enhance the visual appearance. The research emphasized the concept of visual unity, which achieves visual integration in aspects such as (mass, space, and façade). The indicators for the façade aspect were: (uniformity of style [material homogeneity, texture, color], homogeneity and harmony of vertical and horizontal lines, harmony and cohesion between the widths of building façades, façade proportion, and the organization and proportioning of openings in various buildings). The study concluded that the best arrangement of visual design elements is the one that adheres to the principles of formational and compositional design Baper [9] aimed to test the relationships between modern façade design factors and the continuity of architectural identity in terms of architectural appearance, as well as to identify the significant correlation between the factors affecting visual continuity. The study examined modern façade design factors such as (mass, openings, architectural details, and principles of façade arrangement). The research concluded that all factors are positively correlated with the continuity of architectural identity, except for the principles of façade arrangement, which showed a weak correlation. The results thus proved that façade design factors have a decisive impact on the continuity of architectural identity from a visual perspective. Zulestari and et al., [10] addressed Identify the physical characteristics of street space and building façades in three important commercial streets in Malaysia, with the goal of improving the visual quality of the street space. This was achieved by evaluating and analyzing visual elements and then directing the design to enhance the design unity of the street space. The study identified visual quality indicators based on characteristics such as (rhythm, sequence, proportion, unity, and symmetry). The street elements analyzed included storefront façade elements (ground level), signage elements of various types, and upper-level elements (windows, cornices, building materials). The study then compared the current situation with the previously mentioned visual quality standards. The research concluded that differences in building materials, along with the disregard for proportions, sequence of surrounding buildings, signage dimensions, and placement, all negatively affect the street's visual quality. Al-Ghabsha and Al-Omari [11] explored the mechanisms for achieving formal unity in Islamic architecture. The research aimed to uncover the existence of mechanisms that resulted in formal unity in the interior façades of Islamic architectural buildings. The study identified several mechanisms that contribute to the unity of architectural form, the most important of which include: spatial organization of elements, which encompasses (inclusion, symmetry, hierarchy, repetition, complementary elements), proportion, the use of the same treatment (ornamentation, texture, material), integration, and symmetry. The research concluded that the formal treatment of interior façades is distinguished by the organization of its elements, reflecting unity and coherence in their composition. Transitions from one shape to another, one size to another, and one level to another occur according to a precise system. Shatwan [12] studied the impact of building façade design on visual pollution in the city of Jeddah, as well as how undefined building regulations contribute to this pollution. The research analyzed adjacent façades based on four elements: color, material, shape, and rhythm, as they are considered the main factors influencing visual pollution. The study focused on the principle of alignment in these four design elements to achieve integration and harmony in the urban scene, emphasizing that guidelines should be established for designing adjacent façades on the same street.

5.2. Additional studies

There are specific studies on campus facades. Gandawijaya [13] studied the Bandung Institute of Technology, which features a division pattern consisting of heritage areas, transitional areas, and modern areas. The research focused on the center of the campus, which is a modern building made up of two sections located between the heritage and transitional areas. To analyze the relationship of the center with its context, two neighboring buildings were selected: one from the heritage area and the other from the transitional area. The building was analyzed based on the contextual theory in its material and non-material aspects. The research emphasized physical aspects such as (form, mass, style, rhythm, and ornamentation), and the contextual aspect was analyzed according to these dimensions as well as design principles (such as proportion, harmony, unity, variety, and rhythm). The results highlighted similarities and differences among the three buildings. Similarities included external and internal design and the presence of columns on the façades as a unifying element, while differences were observed in building materials, colors, and construction techniques. Dwidayati et al., [14] aimed to showcase the identity and character of the university campus building through its façade. To achieve this goal, the researchers considered the contextual value of the façade by analyzing several exemplary heritage buildings in the city and its surrounding areas. The study concluded that the analyzed buildings were influenced by (traditional) architecture. The analysis involved examining the components of the façade from functional, decorative, and distinctive perspectives. (Functional elements: doors, windows, roof; decorative elements: color, material, vertical and horizontal lines; distinctive elements: proportion of openings, building height, repetition and balance in composition). In the second section of the research, three buildings were taken, and their façades were designed according to the previous analysis results (based on the forms of functional, decorative, and distinctive elements). The study concluded that since the campus building is old and lacks identity, designing buildings with façades inspired by the context of heritage buildings with a modern touch enhances the identity of the university campus.

It can be said that the researchers addressed a range of variables or characteristics influencing the achievement of integration/harmony in adjacent façades to varying degrees, as illustrated in the theoretical framework (Table 1). Their objectives varied from analyzing and evaluating the urban appearance of cities, improving the visual quality of space, and showcasing environmental identity through façades, among others. Furthermore, their measurement methods varied, including public or expert surveys, descriptive or quantitative analysis, etc. The objectives were closely linked to the results obtained, where architectural style was highlighted as a significant aspect in achieving harmony, which is related to the elements used and their interrelationships, as well as their geometric properties.

6. Theoretical Framework

The term of the research 'façade' has been classified as shown in Table (1).

Table 1: Classification of Compatibility Variables

Vocabulary	Main Variable	Secondary Variable	
Façade	Finishing Characteristics	Style Unity (Building Reference)	
		Visual Characteristics	Color, Vertical and Horizontal Lines, Texture, Details, Finishing Materials, Ornamentation
	Relationship Characteristics	Façade Component Relationships	Repetition, Rhythm, Balance, Diversity, Proportion, Fractional Homogeneity, Symmetry, Dominance, Hierarchical Gradation, Inclusion
	Geometric Characteristics	Area	Length, Width

7. The Practical Study

The practical study aims to discover how compatibility is achieved in the university campus façades by designers. (that the aim of the study was not to survey the opinions of users or the goals of the designers, as many of the designers are unknown due to the time gaps between the construction of the buildings. Rather, the aim of the study is the practices of designers in architectural output Four). Assemblages were selected at the University of Mosul, which have cumulative construction over different time periods. The assemblages are: (the Engineering Complex, the College of Arts, the College of Science, and Nineveh Medical College). The study samples (the façades of each assemblage) were documented and drawn using AutoCAD, followed by taking the required measurements.

7.1. The research has established some definitions

- Assemblage: A part of the overall university plan that includes at least three buildings surrounding a space, constructed gradually over time (in a cumulative manner).
- The Facades: is the exterior part that faces the street or public space, and it serves as the 'face' of the building.
- Contained Space: The main space of the assemblage, which is enclosed by the main buildings. It is the largest and most dominant space.

7.2. To define the façades of the four assemblages, the following steps were followed

- Determining the Limits of the Assemblage: The boundaries of the space and the buildings overlooking it were established by creating a site plan in two phases using AutoCAD.
- Phase One: The assemblage plan was drawn along with its surrounding areas and connected boundaries (such as movement axes, buildings, and fences). This phase highlighted the contained space and the spaces between the buildings, with the center identified using AutoCAD.
- Phase Two: A preliminary drawing of the contained space was created, and its center was identified (the back lines of the buildings facing the space were used as a defining parameter). The center of the previously mentioned contained space was projected onto the overall site plan in AutoCAD, and the file was saved in (dxf) format.
- Analysis Using Depth Map: The map was imported into the Depth Map software, where Isovist analysis was conducted, using the center of the contained space as a point to determine the visual field space (Isovist area). Consequently, the Isovist area at the center point was adopted as the final boundary for the contained space, with the façades of the buildings facing it serving as the defining parameters for the façades, as shown in Figure (1).

7.3. Considerations for Selecting the Façade and Its Components

- Measured Façade: The measured façade is the long façade facing the space for the four assemblages.
- Windows: Measurements were taken for three types of main windows in the single façade. If other types are present, they are disregarded in measuring the area and proportion indicators. However, for assessing diversity in the façade based on window openings, all types of windows were included regardless of their significance, in order to determine the level of diversity.
- Secondary Mass: This refers to the prominent or recessive mass that is clearly visible in the façade.

7.3.1. Variables included in the measurement

"The variables to be measured were selected based on their clearer representation of the research term (as they were frequently mentioned in studies), along with the selection of variables for which appropriate measurement methods are available."

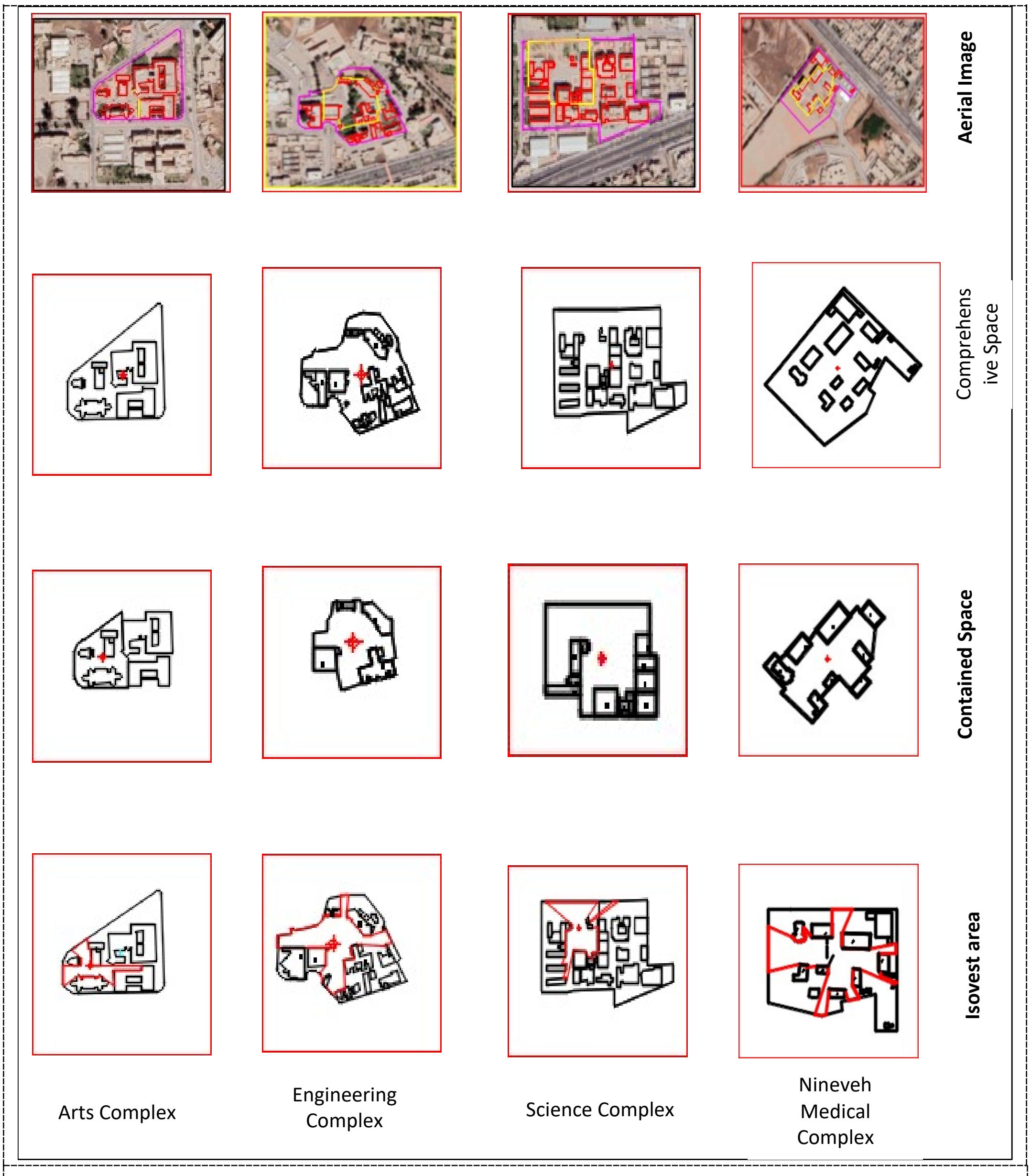

Fig. 1: Steps for Selecting the Façades of the Four Assemblages

Table 2: Variables Included in the Measurement

Primary Variable	Secondary Variable	Measurement Method
Characteristics of Relationships	Diversity	Number of Elements / Number of Element Shapes * 100
	Fractal Homogeneity	Measuring Fractal Dimension Using Fractal3 Software
	Proportion	Proportion of the Overall Building Façade
		Proportion of the secondary component
		Proportion of the Windows
		Proportion of the Doors or Glass Façade of the Entrance Door
		Open Ratio.
Geometric Properties	Total Area	Total Façade Height
		Total Façade Width
	Secondary Component Area	Height of the Secondary Component
		Width of the Secondary Component
	Window Area	Height of the Windows
		Width of the Windows
	Door Area	Height of the Door or Glass Façade of the Entrance Door
		Width of the Door or Glass Façade of the Entrance Door

7.3.2. Preparing diagrams to begin measuring variables

After documenting and drawing the façades using AutoCAD, the area (length, width) of the façade and its secondary elements was measured. The second variable, the ratio of the façade, was measured using a mathematical formula (height/width), and the diversity variable was measured using the formula (number of elements/number of element shapes * 100). The variable of fractal uniformity was measured using the Fractal 3 program, which is a fractal analysis software. It will determine the fractal dimension of the selected building façades using the box-counting method to measure the degree of uniformity at the level of the overall façade, the main level (the façade without the secondary component), and the secondary level (the secondary component only) within the same assembly. The box-counting method is an approximate mathematical approach for calculating the fractal dimension and is suitable for the height of buildings and façades that are not entirely fractal, as it measures the fractal dimension of the image based on roughness, texture, and detail quantity. Two-dimensional elements such as diagrams and images have fractal dimensions ranging from (1-2), while three-dimensional elements range from (3-4). Thus, two-dimensional images with a dimension ranging from (1.1-1.5) contain fewer details than those with a dimension ranging from (1.6-1.9). Therefore, the closer the value is to (2), the more detailed the façade becomes, and the less correlation there is among its elements. Conversely, the closer the value is to (1), the more monotonous and regular the elements become [15].

7.4. Method for calculating the fractal dimension of façades using the FRACTAL3 program

After selecting the research sample, draw the facades using AutoCAD and remove any finishing materials, colors, lines, or details that do not fall within the measurement parameters, then save them as a pmb format image. After opening the software, from the "File" menu and then "File Name," import the facade image in pmb format. From the "Fractal Dimension" menu, select "Black," which refers to the black line. The software will calculate the fractal dimension and generate a graph representing it. The same steps are repeated for the remaining facades, as shown in Figure (2).

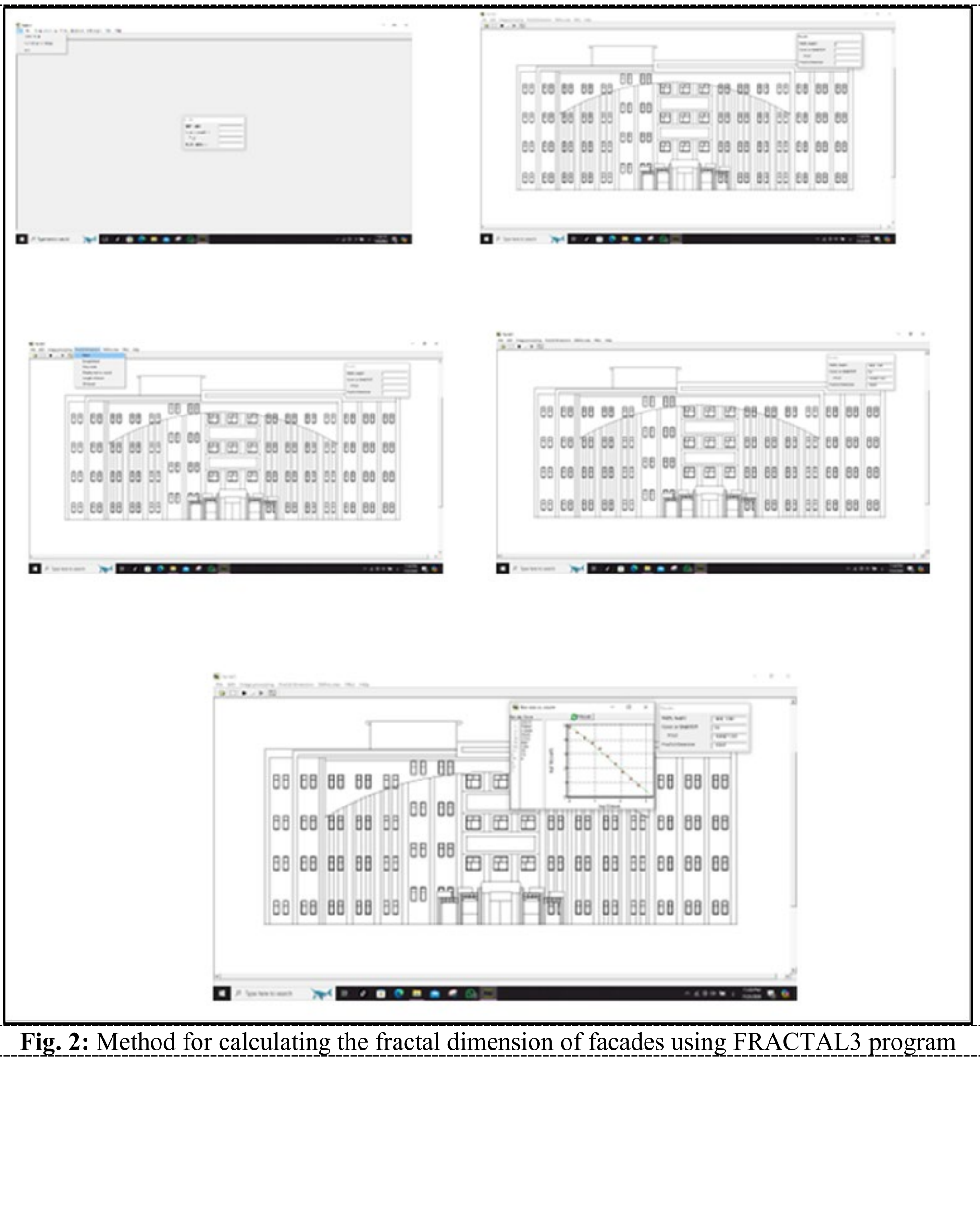

Fig. 2: Method for calculating the fractal dimension of facades using FRACTAL3 program

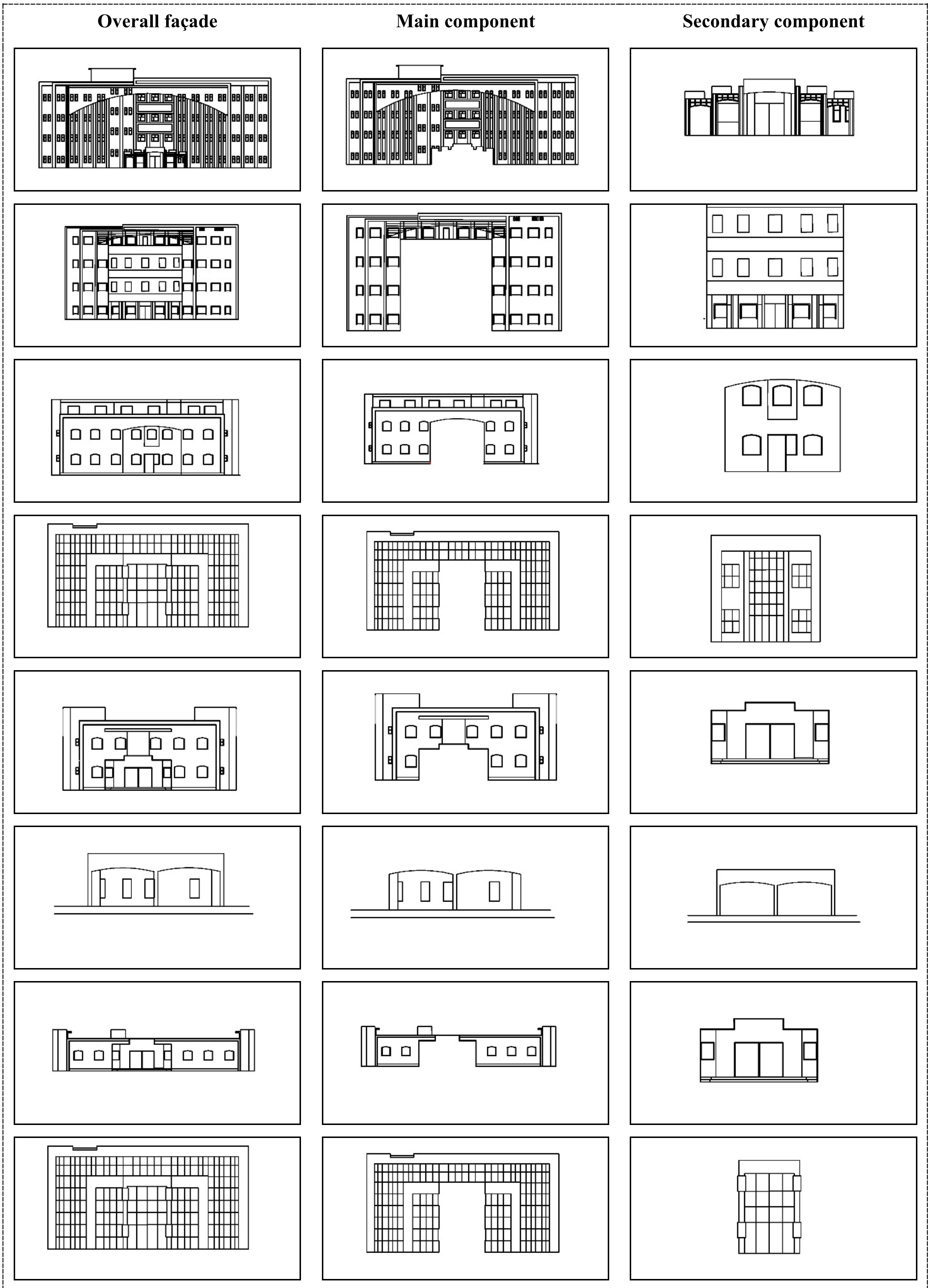

Fig. 3: Analysis of the façades of the medical college complex

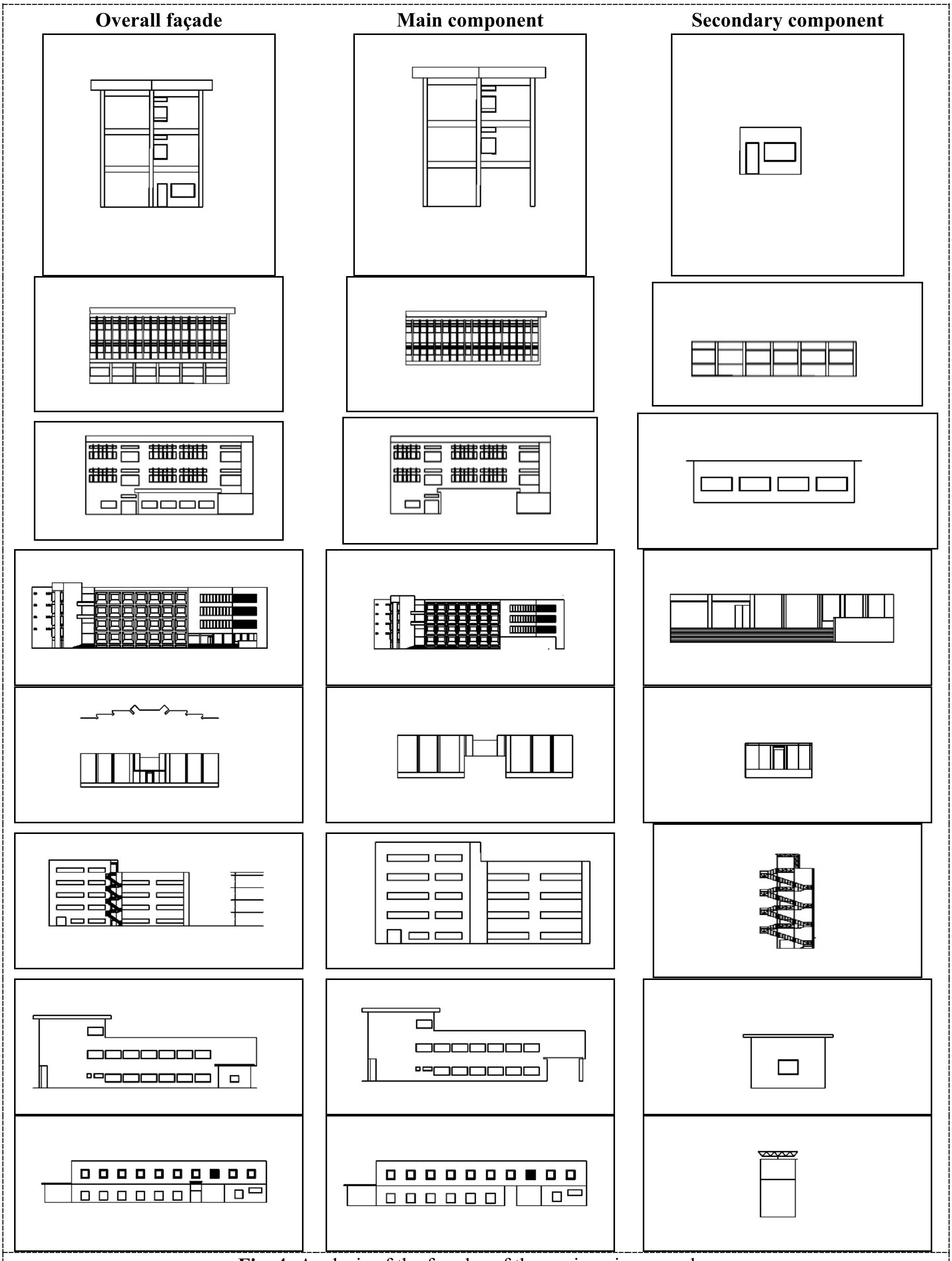

Fig. 4: Analysis of the façades of the engineering complex

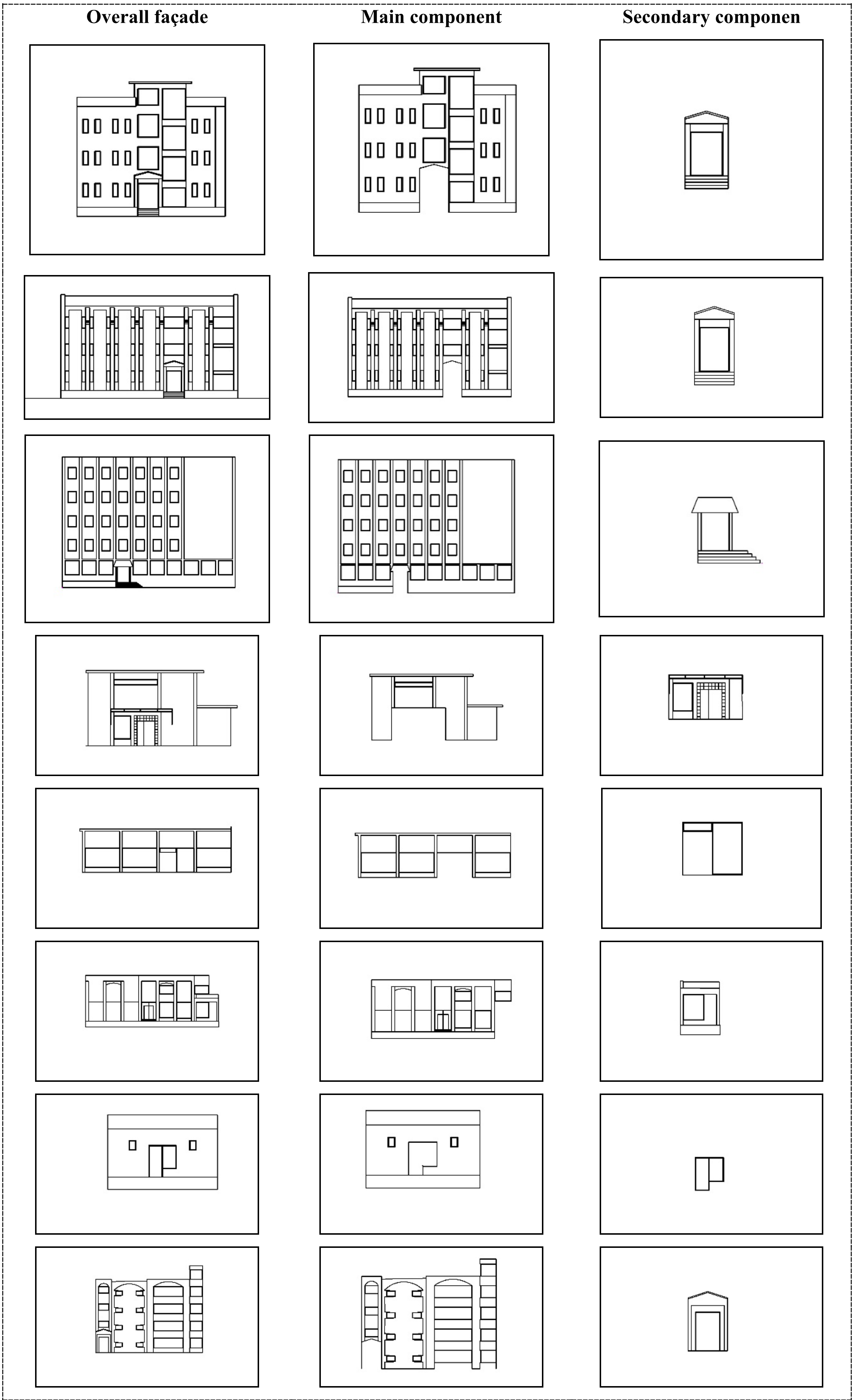

Fig. 5: Analysis of the façades of the science complex

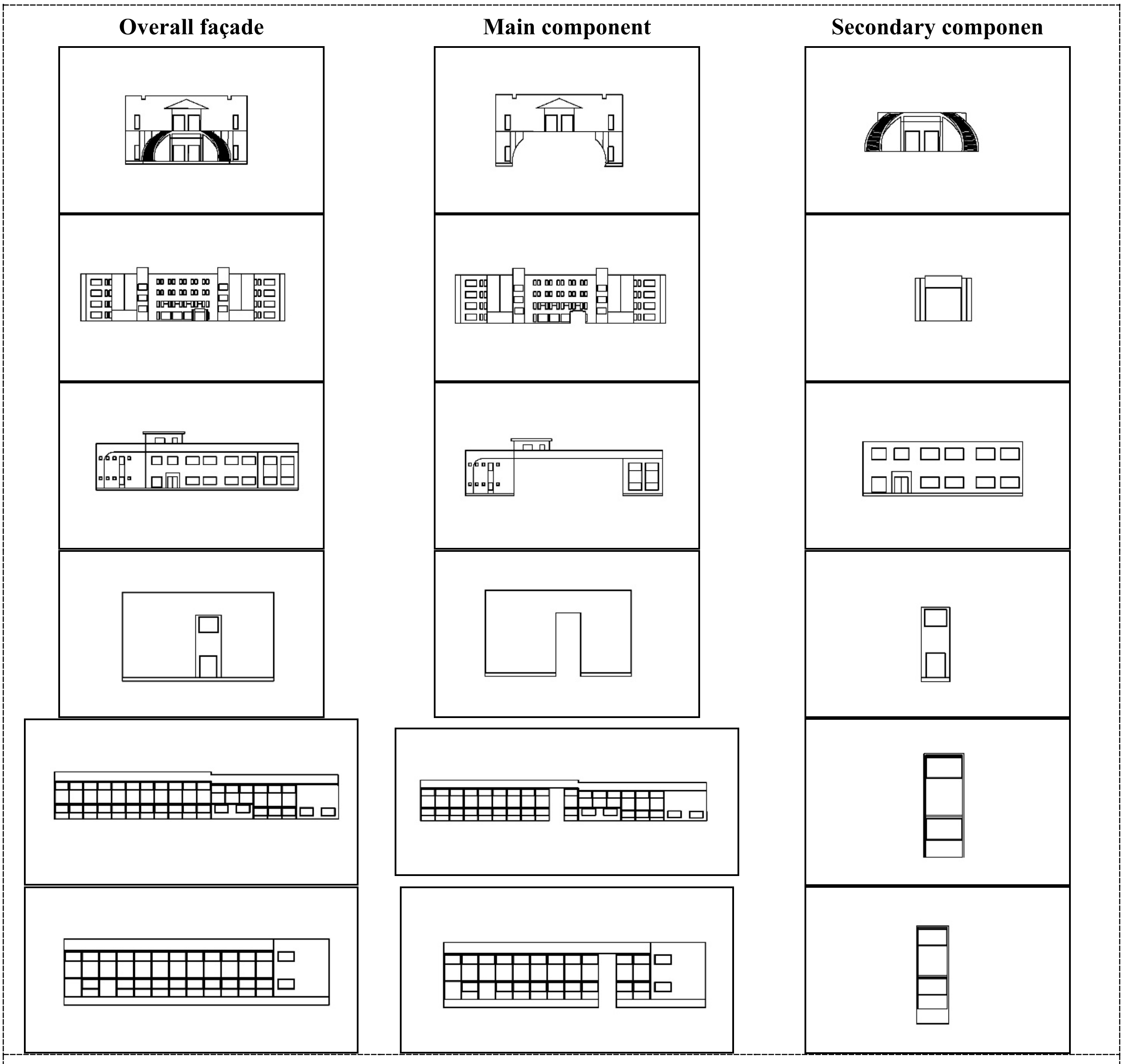

Fig. 6: Analysis of the façades of the arts complex

8. Research methodology

8.1. Area and proportion variable

A Levene's test for equality of variances was conducted. This statistical procedure is a method for assessing the homogeneity of variances. The values of F and p are the main elements in the Levene's Test, which are calculated using Analysis of Variance (ANOVA) based on the absolute deviations of the data.

If the standard deviations are: (S1, S2, S3, ...), then to evaluate these deviations, we rely on two hypotheses:

- Null Hypothesis (H0): There is homogeneity between the deviations (H0: S1 = S2 = S3 ...)
- Alternative Hypothesis (H1): There is no homogeneity between the deviations (H1: At least one of them is not equal, S1 ≠ S2 ≠ S3 ...)
- If the P-Value (Sig.) is less than 0.05, we reject the null hypothesis and accept the alternative hypothesis.
- If the P-Value (Sig.) is greater than or equal to 0.05, we accept the null hypothesis.

8.2. Diversity variable

The diversity in window openings was used as an indicator of façade diversity. A Fisher's Exact Test (P-value) was conducted, based on the differences between the highest and lowest proportions within a single building, and also based on the differences between the highest and lowest proportions within an entire complex.

8.3. Fractional homogeneity variable

A Test of Homogeneity of Variances (Levene's Statistic, P-Value) was conducted based on the presence of differences in the fractional dimension among the three components.

9. Results and discussion

The research relied on measuring the most influential variables in achieving integration, according to previous studies and those derived from the theoretical framework of the study. These variables include the area variable (length, width) within geometric properties, and the variables of proportion, diversity, and fractional homogeneity within relational properties. The strength of homogeneity between the building variables within the same complex was tested, in addition to ranking the variables in each complex from the highest to the lowest homogeneity. Then, the four complexes were compared to determine the extent to which these complexes achieved integration. The more the variables exhibited high homogeneity, the more the complex achieved integration, and vice versa. One of the complexes will be presented in detail, with less detail for the remaining complexes that applied the same procedures.
Testing the degree of homogeneity within each variable, such as (area) and (façade proportion), and ranking the strength of homogeneity for each complex.

9.1. Arts complex

9.1.1. Area variable

The statistical results showed that the highest degree of homogeneity was for the window height variable, while the lowest degree of homogeneity was for the total height variable. The values at the detail level, such as window height, secondary component height, component width, and the height of the glass façade of the entrance door, were generally close, as shown in Table (3). This proximity may be due to the presence of six façades for the complex overlooking the space, four of which belong to two buildings (two façades for each building). Therefore, this closeness at the detail level appeared, or it may be attributed to the designer's ability to control the details when designing.
His attempt to bring the building closer to or resemble its surroundings is evident. As for the height, it is determined by functional requirements. Given that the available area for the building is defined by the space and location, the variation in height is necessary to meet the functional needs of the building.

Table 3: Test of the degree of homogeneity within each variable of the area and ranking the strength of homogeneity for the Arts Complex

Ranking according to the degree of homogeneity at the individual level for each variable	Levene's Test for Equality of Variances				Subsample	Variable
	Sig.	F	Std.	S		
8	0.017	15.334	2.771 0.058	A B	Total height	Area
2	0.660	0.225	10.604 12.212	A B	Total width	
3	0.599	0.325	2.150 1.597	A B	Height of the secondary component	
4	0.195	2.420	14.090 7.572	A B	width of the secondary component	
1	0.662	0.222	0.197 0.300	A B	Window height	
6	0.142	3.341	0.436 0.929	A B	Window width	
5	0.152	3.119	0.611 0.202	A B	Height of the glass façade of the entrance door	
7	0.045	8.345	0.814 0.173	A B	Width of the glass façade of the entrance door	

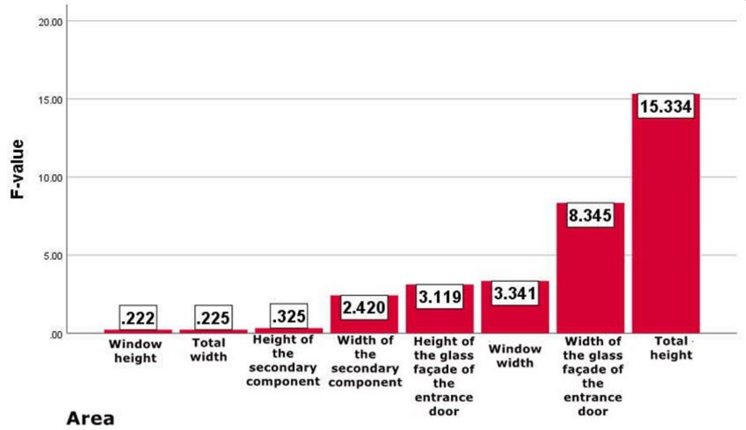

Fig. 7: Ranking of the strength of homogeneity among the area variables at the Arts Complex

9.1.2. Proportion variable

The statistical results showed that the highest homogeneity value was for the variable of the proportion of the glass façade of the entrance door, while the lowest homogeneity value was for the variable of the total building façade proportion, as shown in Table (4). This is due to the closeness of the proportions of the variables at the detail level, while the total façade proportion is controlled by the space area, which is defined and somewhat small.

Table 4: Test of the degree of homogeneity within each proportion variable and ranking the strength of homogeneity for the Arts Complex

Ranking according to the degree of homogeneity at the individual level for each variable	Levene's Test for Equality of Variances Sig.	F	Std.	S	Subsample	Variable
5	0.027	11.762	0.188 0.023	A B	Total building façade proportion	Façade proportion
2	0.813	0.064	0.867 0.893	A B	Proportion of the secondary component	
4	0.098	4.603	1.262 0.512	A B	Window proportion	
1	0.926	0.010	0.153 0.151	A B	Proportion of the glass façade of the entrance door	
3	0.194	2.426	0.087 0.026	A B	Openings ratio	

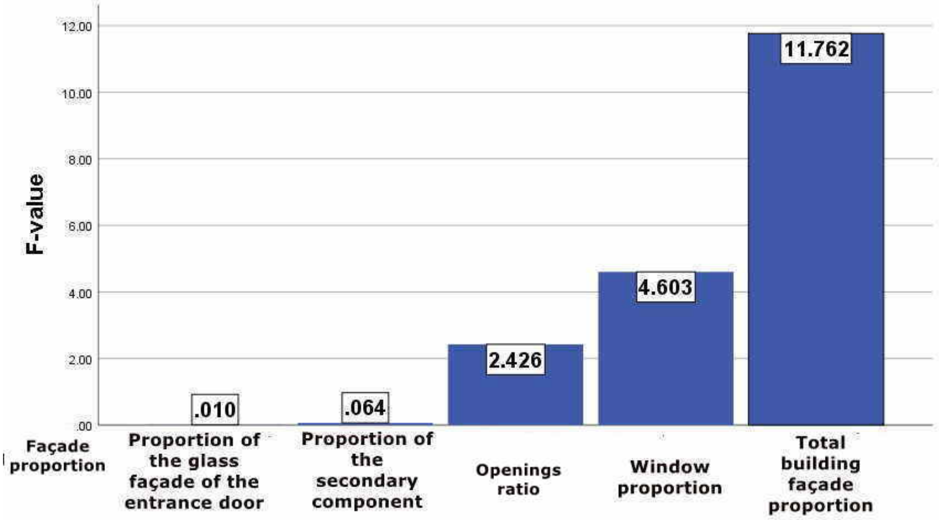

Fig. 8: Ranking of the strength of homogeneity among the proportion variables at the Arts Complex

9.2. Science complex

9.2.1. Area variable

The statistical results showed that the highest homogeneity was for the total height variable, which, as mentioned earlier, is determined by functional requirements. Given that the space area is large, there were opportunities to increase homogeneity by bringing the heights closer together. The lowest homogeneity was for the window height variable, with notable variation at the detail level (window height, secondary component height, etc.). This may be due to the fact that the complex was expanded gradually according to need, leading to a lack of homogeneity at the detail level, as buildings were added at different times. Additionally, there are service buildings in the complex designed solely for functional reasons without consideration for neighboring structures, which explains the mismatch/variation in the mentioned proportions, as shown in Figure (9).

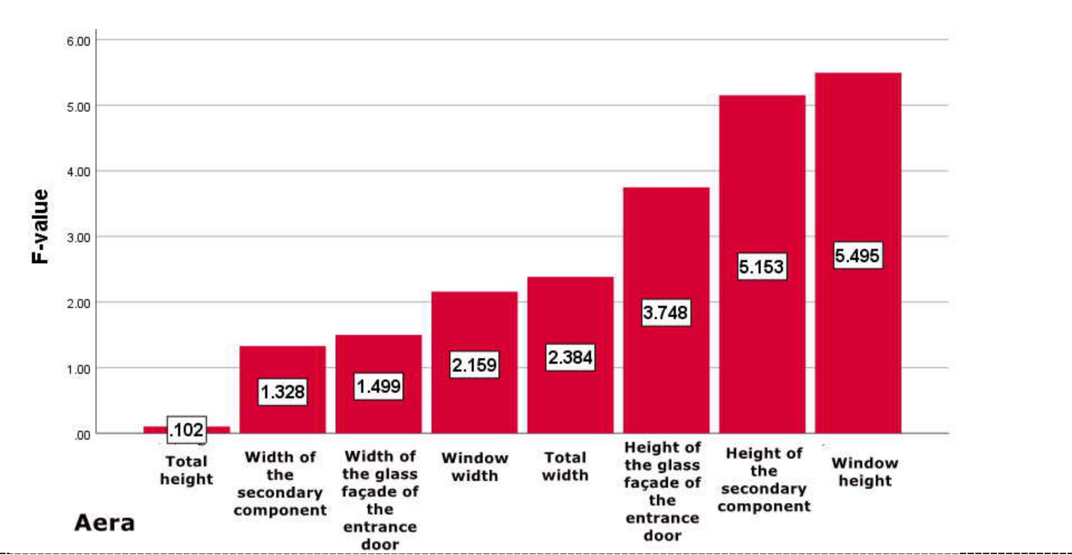

Fig. 9: Ranking of the strength of homogeneity among the area variables at the Science Complex

9.2.2. Proportion Variable

The statistical results showed that the highest homogeneity was for the window proportion variable, while the lowest homogeneity was for the opening ratio variable, as shown in Figure (10). There was some degree of similarity in the indicator proportions. The opening ratios depend on functional requirements, which may vary somewhat in this complex.

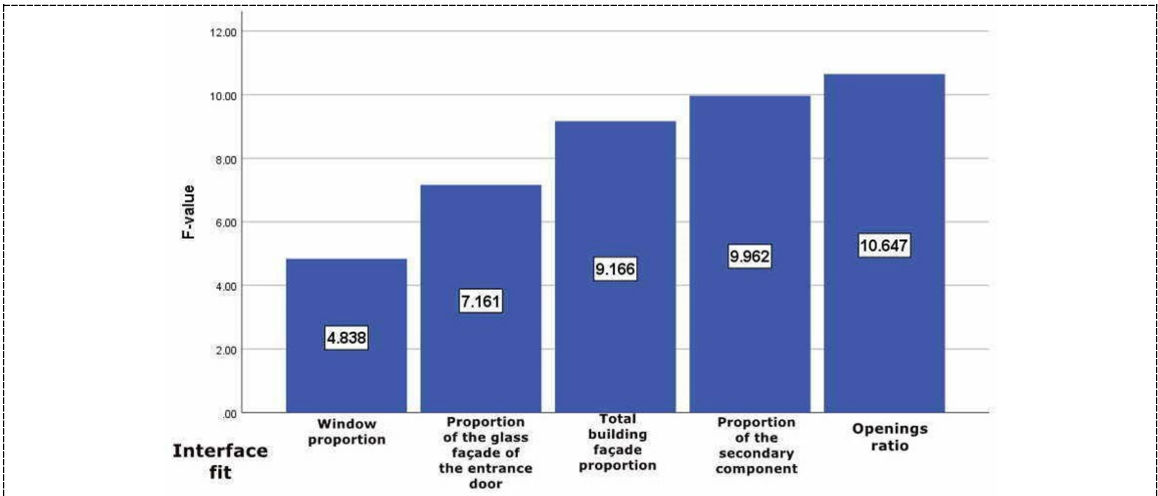

Fig. 10: Ranking of the strength of homogeneity among the proportion variables at the Science Complex

9.3. Engineering complex

9.3.1. Area variable

The statistical results showed that the highest homogeneity value was for the width of the glass façade of the entrance door variable, while the lowest homogeneity value was for the height of the secondary component variable, as shown in Figure (11). This may be due to the lack of clarity and variation in the secondary components of the buildings, as some are prominent, others recessed, or they may contain columns or different roofing structures.

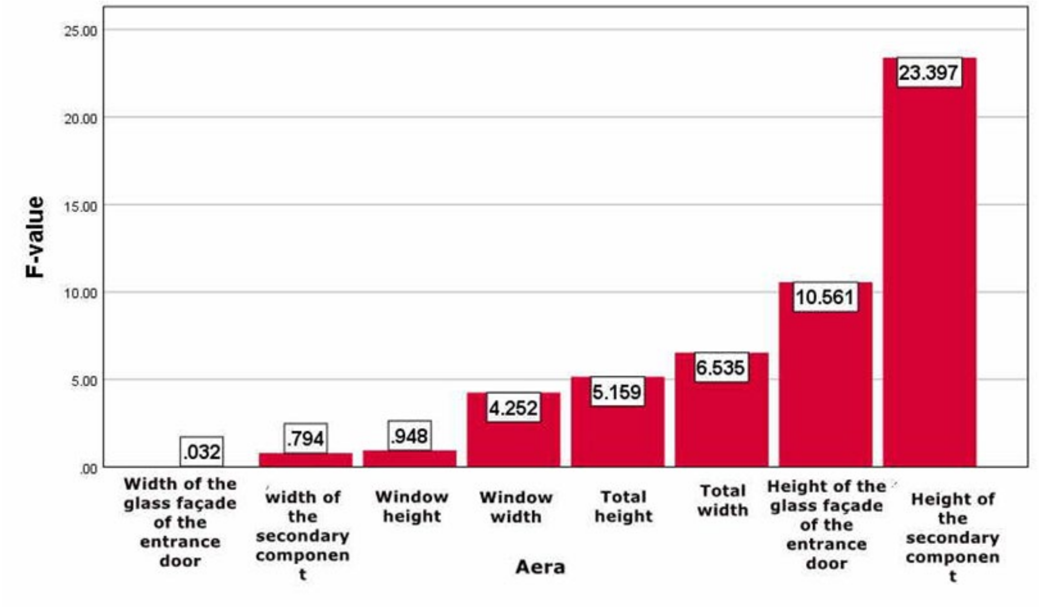

Fig. 11: Ranking of the strength of homogeneity among the area variables at the Engineering Complex

9.3.2. Proportion variable

The statistical results showed that the highest homogeneity value was for the proportion of the glass façade of the entrance door variable, while the lowest homogeneity value was for the total building façade proportion variable. This may be due to the different building sizes based on functional requirements, as shown in Figure (12). This result is consistent with the findings for the area variable.

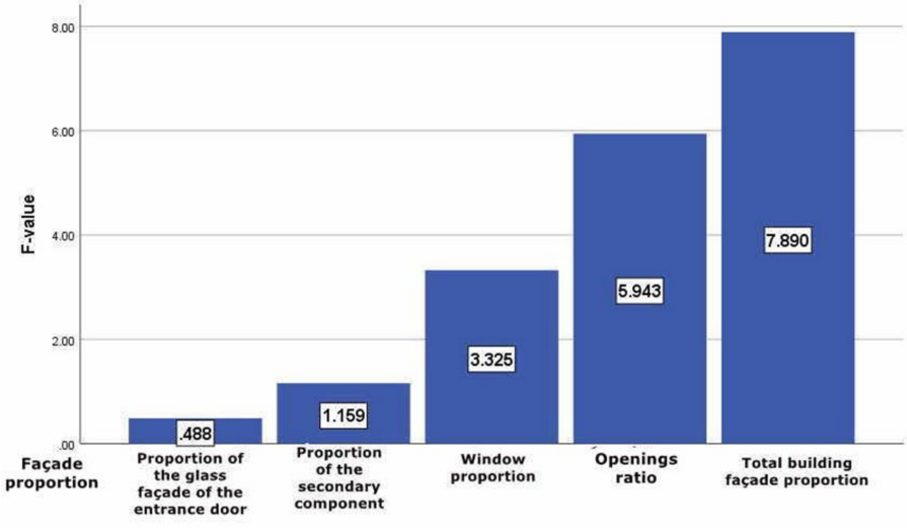

Fig. 12: Ranking of the strength of homogeneity among the proportion variables at the Engineering Complex

9.4. Medical complex

9.4.1. Area variable

The statistical results showed that the highest homogeneity value was for the window height variable, while the lowest homogeneity value was for the width of the glass façade of the entrance door, as shown in Figure (13). This may be due to the use of the same types of windows in buildings constructed within close timeframes, as well as the designer's attempt to create similarity and coherence between the buildings and their surroundings. The total width and total height came in second and third place, likely as a result of designers' efforts to balance details with overall characteristics, or due to the large space available, which allowed for better control over these aspects.

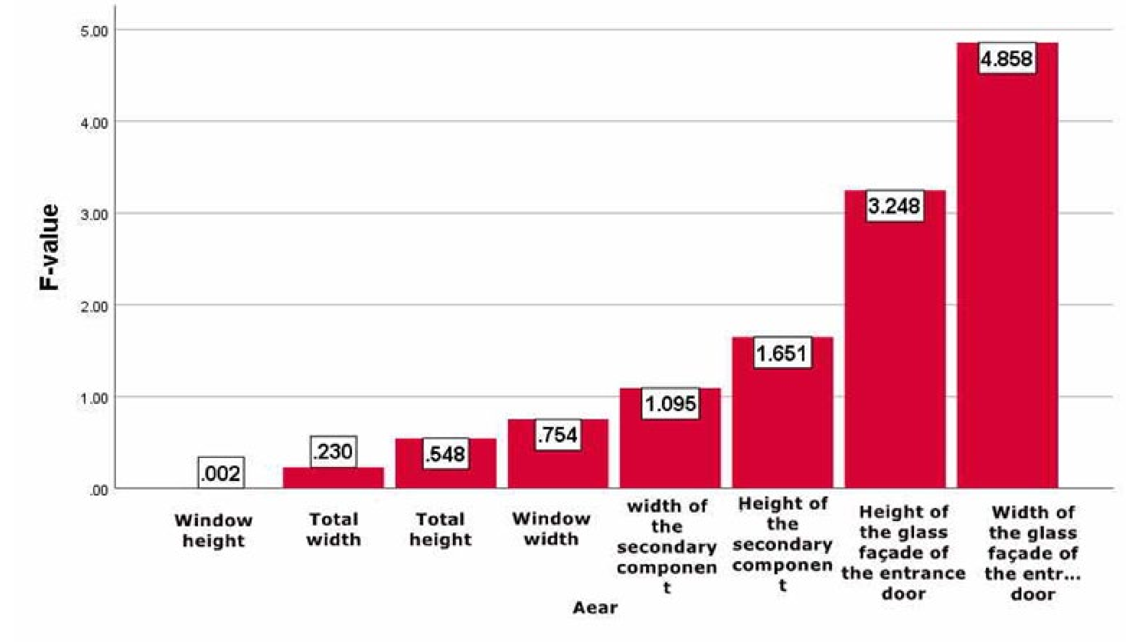

Fig. 13: Ranking of the strength of homogeneity among the area variables at the Medical Complex

9.4.2. Proportion variable

The statistical results showed that the highest homogeneity value was for the window proportion variable, while the lowest homogeneity value was for the opening ratio, as shown in Figure (14). These results are consistent with the findings for the area variable. The variation in the opening ratio may be attributed to functional needs, as the complex accommodates different functions. For example, the auditorium and the Faculty of Agriculture have higher opening ratios, while the classrooms and administrative buildings have lower opening ratios.

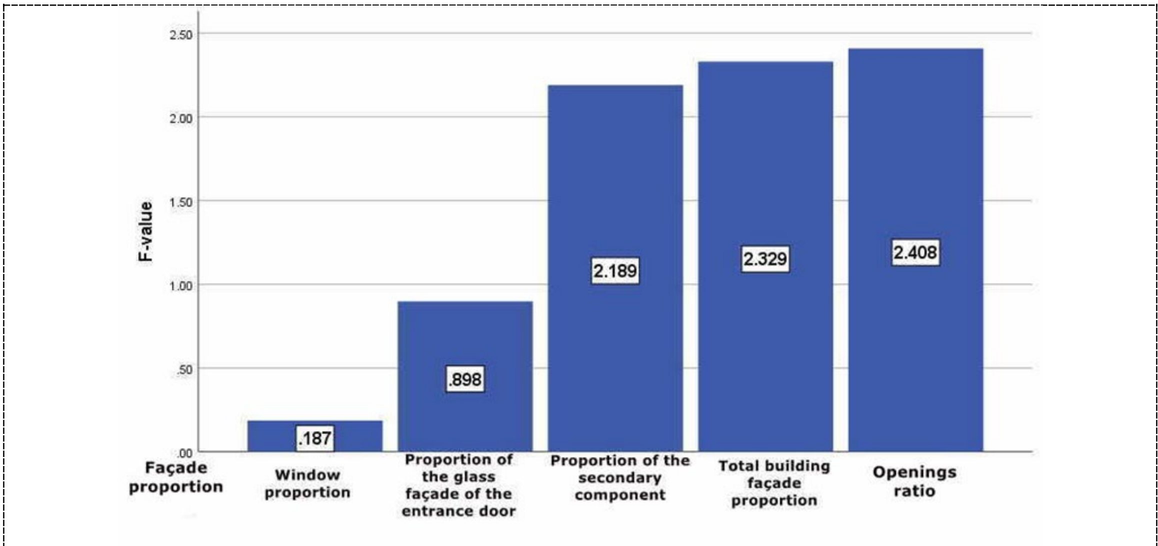

Fig. 14: Ranking of the strength of homogeneity among the proportion variables at the Medical Complex

9.5. Comparison between the four complexes

9.5.1. Area variable

The results indicated that the highest homogeneity value among the four complexes was for the total width variable, which depends on the size of the open space and the area allocated for the building. The lowest homogeneity value was for the height of the secondary component, with the window details and entrance door dimensions ranking second, third, and fourth, respectively. The designer can control these variables based on proximity to neighboring buildings or based on functional requirements, as shown in Table (5).

Table 5: Test of the degree of homogeneity for each area variable across the four complexes and ranking the strength of homogeneity among the four complexes

The ranking based on the degree of uniformity at the overall level	The ranking based on the degree of uniformity at the individual level for each variable	Levene's Test for Equality of Variances			Compound	Subsample	Variable
		Sig.	Statistic	Std.			
5	1	0.157	1.876	2.03	College of Arts Complex	Total height	Area
	2			5.37	College of Science Complex		
	3			5.40	College of Engineering Complex		
	4			5.60	College of Medicine Complex		
1	3	0.359	1.119	18.47	College of Arts Complex	Total width	
	1			7.89	College of Science Complex		
	4			18.62	College of Engineering Complex		
	2			12.38	College of Medicine Complex		
8	2	0.000	9.412	1.69	College of Arts Complex	Height of the secondary component	
	1			1.16	College of Science Complex		
	4			12.34	College of Engineering Complex		
	3			3.86	College of Medicine Complex		
7	3	0.002	5.726	10.29	College of Arts Complex	Width of the secondary component	
	1			2.82	College of Science Complex		
	4			11.33	College of Engineering Complex		
	2			4.12	College of Medicine Complex		
3	1	0.175	1.784	0.23	College of Arts Complex	Window height	
	4			1.18	College of Science Complex		
	3			0.40	College of Engineering Complex		
	2			0.27	College of Medicine Complex		
4	2	0.165	1.833	0.69	College of Arts Complex	Window width	
	3			1.34	College of Science Complex		
	4			2.26	College of Engineering Complex		
	1			0.37	College of Medicine Complex		
2	2	0.174	1.782	0.48	College of Arts Complex	Height of the glass facade of the entrance door	
	3			0.86	College of Science Complex		
	4			1.16	College of Engineering Complex		
	1			0.42	College of Medicine Complex		
6	1	0.068	2.663	0.70	College of Arts Complex	Width of the glass facade of the entrance door	
	2			1.07	College of Science Complex		
	4			1.87	College of Engineering Complex		
	3			1.38	College of Medicine Complex		
	4			1.59	College of Arts Complex		
	3			0.52	College of Science Complex		
	2			0.17	College of Engineering Complex		

To compare the four complexes, we present Table (6) at the level of the area variable. The Arts Complex focused on details such as window height at the expense of overall characteristics like total height, while the Science Complex showed the opposite trend. In contrast, the Engineering and Medical complexes maintained a balance between both aspects.

Table 6: Comparison among the four complexes at the level of the area variable

Sequence	College of Arts Complex	College of Arts Complex	College of Arts Complex	College of Arts Complex
1	Window height	Window height	Width of the glass facade of the entrance door	Window height
2	Total width	Total width	Width of the secondary component	Total width
3	Height of the secondary component	Height of the secondary component	Window height	Total height
4	Width of the secondary component	Width of the secondary component	Window width	Window width
5	Height of the glass facade of the entrance door	Height of the glass facade of the entrance door	Total height	Width of the secondary component
6	Window width	Window width	Total width	Height of the secondary component
7	Width of the glass facade of the entrance door	Width of the glass facade of the entrance door	Height of the glass facade of the entrance door	Height of the glass facade of the entrance door
8	Total height	Total height	Height of the secondary component	Width of the glass facade of the entrance door

9.5.2. Proportion variable

The highest homogeneity value among the four complexes (1, 2, 3) was found at the detail level, while the lowest homogeneity value was for the total building façade and opening ratio, as shown in Table (7).

Table 7: Test of the degree of homogeneity for each proportion variable across the four complexes and ranking the strength of homogeneity among the four complexes.

The ranking based on the degree of uniformity at the overall level	The ranking based on the degree of uniformity at the individual level for each variable	Levene's Test for Equality of Variances			The complex	Subsample	Variable
		Sig.	Statistic	Std.			
5	2	0.067	2.676	0.18	College of Arts Complex	Total building facade ratio	Facade proportion
	4			1.47	College of Science Complex		
	3			0.34	College of Engineering Complex		
	1			0.11	College of Medicine Complex		
2	2	0.234	1.513	0.79	College of Arts Complex	Proportion of the secondary component	
	4			1.47	College of Science Complex		
	3			1.00	College of Engineering Complex		
	1			0.21	College of Medicine Complex		
1	2	0.357	1.123	0.90	College of Arts Complex	Proportion of windows	
	3			1.42	College of Science Complex		
	4			1.51	College of Engineering Complex		
	1			0.36	College of Medicine Complex		
3	1	0.096	2.334	0.17	College of Arts Complex	Proportion of the glass facade of the entrance door	
	4			1.30	College of Science Complex		
	3			0.67	College of Engineering Complex		
	2			0.49	College of Medicine Complex		
4	1	0.068	2.661	0.08	College of Arts Complex	Openings ratio	
	4			1.59	College of Science Complex		
	3			0.52	College of Engineering Complex		
	2			0.17	College of Medicine Complex		

To compare the four complexes, we present Table (8) at the level of the proportion variable.

Table 8: Comparison among the four complexes at the level of the proportion variable.

Sequence	College of Arts Complex	College of Arts Complex	College of Arts Complex	College of Arts Complex
1	Proportion of the glass facade of the entrance door	Proportion of windows	Proportion of the glass facade of the entrance door	Proportion of windows
2	Proportion of the secondary component	Proportion of the glass facade of the entrance door	Proportion of the secondary component	Proportion of the glass facade of the entrance door
3	Openings ratio	Total building facade ratio	Proportion of windows	Proportion of the secondary component
4	Proportion of windows	Proportion of the secondary component	Openings ratio	Total building facade ratio
5	Total building facade ratio	Openings ratio	Total building facade ratio	Openings ratio

9.6. Measuring the diversity variable at the single façade level in the arts complex

The diversity measurement for the façade was based on the window openings. A detailed example of the Arts Complex will be presented, which was applied to the other complexes as well. The results showed that two out of six façades exhibited diversity in the window openings, as shown in Table (9).

Table 9: Degree of diversity at the single façade level and across the total complex for the Arts Complex.

College of Arts Complex								
N.O.	Facade name	Element shapes	Number of shapes for each element	Total number of shapes	Percentage	Standard deviation	Fisher's exact test (P-value)	Fisher's exact test (P-value) Are there differences between the highest percentage and the lowest percentage among the six buildings?
1	Software 1	1.7*2.2	1	1	100	0	---	0.043
2	Software 2	1.7*2.2	3	23	13.043	4.5	0.002	
		1.7*2.8	12		52.173			
		0.5*0.5	8		34.782			
3	Education 1	1.4*2.4	34	34	100	0	---	
4	Education 2	1.4*2.4	22	22	100	0	---	
5	Cybersecurity	2.00*0.7	4	4	100	0	---	
6	Computer Science and Mathematics	1.5*0.85	20	69	28.985	9.3	0.000	
		1.9*3.4	8		11.594			
		1.9*0.85	26		37.681			
		1.9*2.8	6		8.695			
		0.85*1.4	4		5.797			
		2.4*3.1	3		4.347			
		2.4*0.5	2		2.898			

The results for the Science Complex showed that three out of eight façades exhibited diversity. The Engineering Complex showed that six out of eight façades contained diversity. The results for the Medical Complex indicated that three out of eight façades demonstrated diversity.

In comparing the four complexes, the Engineering Complex exhibited the highest percentage of diversity among the individual façades, while the other three complexes were relatively close in their diversity levels. This may be attributed to the presence of large buildings, such as the Geological, Physics, and currently under-construction Electrical departments.

The differences between the highest and lowest percentages at the overall complex level were as follows: Arts (0.043), Science (0.000), Engineering (0.023), and Medicine (0.097). The highest differences in sequence at the overall complex level were (Science Complex, Engineering Complex, Arts Complex, and Medicine Complex). This aligns with the results for the window height variable, where the window height in the Science Complex had the lowest homogeneity, followed by the Engineering Complex, which ranked third in terms of homogeneity. In contrast, the Arts and Medical complexes had the window height ranking first in terms of homogeneity. Thus, the lower the window height's homogeneity within the complex, the greater the diversity.

9.7. Measuring the fractal homogeneity variable at the single complex level

9.7.1. Arts complex

The results showed that the homogeneity among the façades of the complex ranked from highest to lowest as follows: (secondary component, total façade, main component), based on standard deviations. The p-value was (0.152), indicating fractal homogeneity at the level of the (total façade, main component, secondary component) for the single complex. This is consistent with the results for the area variable, which was more homogeneous at the detail level.

Table 10: Measurement of the fractal homogeneity variable at the Arts Complex level.

on	Buildings	fractal dimension total facade	main component	secondary component
1	Software 1	1.1978	1.1301	1.1727
2	Software 2	1.3279	1.2247	1.2486
3	Education 1	1.3578	1.4519	1.2623
4	Education 2	1.3661	1.3482	1.2623
5	Cybersecurity	1.3552	1.2215	1.3455
6	Computer Science and Mathematics	1.3215	1.3469	1.1264
	Standard deviation	0.0768	0.1160	0.0629
Test of Homogeneity of Variances Levene Statistic(p-vale)			0.152	

9.7.2. Science Complex

The results showed that the homogeneity among the façades of the complex ranked from highest to lowest as follows: (total façade, main component, secondary component). The p-value was (0.087), which is consistent with the results for the area variable that exhibited higher homogeneity in the total height variable.

9.7.3. Engineering Complex

The results showed that the homogeneity among the façades of the complex ranked from highest to lowest as follows: (secondary component, main component, total façade). The p-value was (0.9270), which is consistent with the results for the area variable that exhibited higher homogeneity at the detail level

9.7.4. Medical Complex

The results showed that the homogeneity among the façades of the complex ranked from highest to lowest as follows: (total façade, secondary component, main component). The p-value was (0.772), which aligns with the area variable results, showing a balance between details (window height) as the highest homogeneity, followed by overall dimensions (total height, total width) as the second and third highest. This indicates a correlation between the fractional homogeneity variable and the area variable, as their values rise and fall together.

The measurement of the fractional homogeneity variable across the four complexes showed a homogeneity ranking from highest to lowest for the following elements: the main component, the secondary component, and the overall façade. This ranking was based on the (P-Value), as shown in Table (11).

Table 11: Measurement of the Fractional Homogeneity Variable Across the Four Complexes.

N.O.	Compound		fractal dimension total facade	main component	secondary component
1	Arts	fractal dimension	.07688	.11603	.06290
2	Medicine		.06569	.11695	.10885
3	Science		.04118	.08476	.08977
4	Engineering		.13290	.12754	.11421
Test of Homogeneity of Variances Levene Statistic(p-vale)			0.108	0.595	0.415

10. Conclusion

- The compatibility between old and new building facades is achieved through various characteristics such as spatial harmony (length by width) or through the alignment of relationships like proportion, variety, and fractional harmony. These characteristics are divided into two levels: holistic (e.g., the total facade area, overall facade proportion) and detailed (e.g., the area and proportion of windows, the area and proportion of the glass facade of the entrance door, and the area and proportion of secondary components).
- In variable space, it appears that in complexes with defined and relatively small spaces, designers tend to focus on the similarity and proximity of the building to its surroundings, particularly on detailed variables (such as window height, the height of the entrance glass facade, secondary component height, etc.), as opposed to holistic/general variables (such as the total facade height, overall width). This is because the building is allocated a specific space within the site, and to meet the functional requirements of the building, the designer might resort to adding floors, thereby increasing the height. On the other hand, in complexes with relatively larger spaces, the designer's focus on achieving harmony with the surroundings shifts to holistic/general variables, as the allocated space for the building is less restrictive. This allows the designer to achieve consistency in general/holistic indicators and balance between both holistic and detailed levels.
- In the proportionality variable across the four complexes, the overall building facade ratio showed the least uniformity. This may be due to the designer being constrained by the site and the space allocated for the building. As for the variables (such as window proportions, secondary components, and the entrance glass facade), which ranked among

the top three in terms of highest uniformity, this could be attributed to the designer being influenced by the building's function and its need for windows and entrances, as educational buildings are functional structures that designers tend to emphasize. Alternatively, it could be easier for designers to achieve harmony through detailed variables, or they might focus on these details because they have a greater impact on the observer compared to holistic variables.

- The level of openness appeared to be less uniform in the complexes, which could be due to the fact that it depends on the functional requirements of the building, which may vary between administrative offices, lecture halls, multi-purpose halls, laboratories, and others.
- The results for the variables of area and proportionality matched previous studies, particularly studies [13] and [14]
- Studies have shown that complexes with less uniform window dimensions (height and width) achieved greater diversity, while those with uniform windows exhibited less diversity, aligning with the findings related to space variables. Diversity is closely linked to the size and area of the buildings; larger buildings demonstrate greater diversity due to the variety of activities and functions within them, which leads to different window shapes. Additionally, the diversity of buildings may be related to their multiple functions, as these functions influence the design of windows and other elements.
- The comparison between the results of measuring building area uniformity and fractional uniformity showed that buildings focusing on details achieved greater uniformity in secondary components, while those emphasizing overall aspects achieved higher uniformity in façades. This indicates a consistency in the results between the two measurement methods.

11. Recommendations

- It is essential to balance between holistic characteristics and detailed to ensure design consistency.
- New buildings or elements can be added so they do not conflict with the surrounding environment or disrupt its balance. This requires studying the visual elements of existing façades before designing new ones and simulating them with innovative approaches that enhance harmony. Variable measurements can be used in this study to determine the values of existing facades, based on which new buildings will be added
- Considering existing visual elements does not limit the designer but aims to balance modern designs with existing buildings using the methods outlined in the research.
- Additions should align with the context and original architectural composition while maintaining a contemporary character that reflects the time of the addition.
- It is important to consider functional similarity between new and existing buildings to ensure visual harmony.
- A comprehensive design vision for all campus buildings should be established, and committees of experts formed to monitor designs and avoid randomness

Acknowledgement

The authors would like to express their gratitude for the scientific support provided by the University of Mosul, particularly the Department of Architecture in the College of Engineering.

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