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The Visual Perception of Residential Buildings: Le Corbusier's Modernism and Zaha Hadid's Parametric Architecture

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Abstract: ***This research paper studies visual perception by focusing on the material functionality of residential buildings in the different architectural style periods, which are the modernism and parametric styles periods. Two pioneer architects of these architectural style periods were selected to study and focus study on their works, Le Corbusier, a pioneer architect of the modernism architectural style period, and Zaha Hadid, a pioneer architect of the Parametric architectural style period. This research uses a mixed-methods approach including quantitative and qualitative approaches, represented by a survey directed at architects to study and analyze the visual perception of the selected architects' building designs. Besides, this research studies the material functionality of each selected case study. The results showed that the residential buildings designed during the modernist architectural style period by Le Corbusier were characterized by simplicity, comfortability, and regularity. However, the residential buildings of the parametric design style period designed by Zaha Hadid were characterized by complexity, un-comfortability, and irregularity but meaningful.***

Keywords: Le Corbusier, Modernism, Residential building, Parametric design, Visual perception, Zaha Hadid.

I. INTRODUCTION

This research studies how the residential architectural buildings' designs have changed during the parametric design style period compared with the previous modernist architectural style. Related to Patrick Schumacher, who is Zaha Hadid's partner, sees that Parametricism is a great style after modernism [45]. But what are the differences between the two architectural styles in terms of visual perception and materialism? How do users evaluate their experiences with these architectural style period buildings? Answering these questions can be achieved through studying the works of the pioneers of both styles, including Le Corbusier, who is one of the main pioneers of modern architecture, and Zaha Hadid founded the coined the parametric design style [11].

The previous research studies focused on the visual perceptions for each architectural style period separately, without studying comparing different styles together or focusing only on specific architectural building types such as residential buildings to determine the similarities and differences between them. For that, doing this type of research can help to understand how the architectural style periods have changed from the perspective of visual perception with the help of the material functionality used in the design and construction process concentrating on the residential architectural types of building designs. Parametric design has changed the architectural space in different ways, such as aesthete and functionality enhancement, complexity space management, main design tools, the third industrial revolution, and others, which are different or didn't exist in the previous architectural style periods [3]. In this research paper, the study will be focused only on the visual perception analysis combined with the functionality including the material used for both periods' styles architects to understand how the residential architectural buildings' designs have changed and improved through these specific architectural periods. This shows the importance of studying the visual perception of the residential architectural building design in different architectural style periods taking into consideration the material functionality for each architectural style period. Besides, this research studies how architecture has changed over time focusing on the similarities, and differences of each architectural style period by studying one of the pioneers of the selected architectural style periods. The main research problem of this research is the architects' visual perception evaluation of the modernism and parametric styles for the residential buildings. Besides, what is the role of materiality in this evaluation? The subproblems of this research problem of this paper are: Firstly, the definition, and history of architectural buildings, and how it has improved through time, especially during the modernism period represented in Le Corbusier's work, and the Parametricism period which is represented in Zaha Hadid's works. Besides, this subproblem includes what are the characteristics of the residential architectural buildings' designs for each specific architectural period, and how each architect defined and expressed the meaning of architectural building design.

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Secondly, the study of visual perception, and material functionality of the modern architectural style in Le Corbusier's building design. Thirdly, the visual perception, and material functionality used in the Parametricism period which is found in the architectural buildings of Zaha Hadid. This subproblem includes the characteristics, and details used to achieve the visual aesthetic of the architectural designs and the material choosing and using processes for the whole design process. fourth, and the last subproblem includes the differences between the two architectural style periods specializing in the visual perception, and material of the residential architectural building design. This subproblem also focuses on how the residential architectural building design has improved through time, and what are the main characteristics for improving the residential architectural building design.

The structure of this research paper consists of the introduction, literature review, methodology, data analysis, results, conclusion, delimitation, and discussion.

II. LITERATURE REVIEW

A. Visual Perception

Visual perception is a phenomenon where the geometric shape of space is observed and interpreted [9]. It's a coordination of imagination and memory and transferring cognition to self-consciousness through the senses [29,31].

Human visual perception is an incredible, very complex process with a highly creative experience, and it does not match any artificial system but is still limited in ways that computers are not [36], because it involves gathering information through our senses, processing it to formulate particular responses based on previous experiences, since it depends on the physical objects [8, 41]. Visual perception is the first step to interacting with a space and it's influenced by the cognitive structure of the individual [41].

Visual perception consists of mental and physical images since experiencing space is a subtle act of the human body and mind [32,42]. The mental representation is based on the information received through the senses, and visual images [42]. Besides, the visual perception responses can be measured by analyzing the reactions from the acquisition of visual information to the brain and the perception of visual stimuli [35]. While, the physical image can be built from the cognitive perception, which is analyzed, recognized, and deconstructed into components of the space which is the core of the architectural design [39], and it's largely based on the user's relationship with scale [20,32].

Visual expression and content are the main components of the contemporary architecture form, and that's from the understanding of the continuity and properties of space, time parameters, and the knowledge of architectural history [49]. The Form has the quality of shape inside it since it isn't the aim of our work, but only the result [49]. This shape continues to define the space in different ways such as interior/exterior continuity, or lighting/ shading continuity with finite and infinite boundaries, which are the base of user preferences and their satisfaction [1, 15]. The architectural building gains its meaning from its architectural users [1]. Visual space perception is not about how people judge the size or distance but how they cognitive the distance and how people think about space and spatial behavior [28,30, 33]. The components of its solidity, geometrical and non-geometrical detail, complexity, and constraints are the perceptual representation [18, 38]. However, thinking of space in terms of its material instead of its vacuum, helps the user to feel the sense of space [13]. There are very different conceptions of how vision controls the action, firstly, the visual space, where the internal assumption is built on the stimulation providing a visual space and then providing an action. Secondly, the ecological approach, originating with Gibson, its optical invariants lead to the actions such as the global radial flow leading to aiming, and optical expansion leading to braking. Thirdly, the "two visual systems" of the internal assumptions of the visual space, and visuomotor control from stimulation to provide action [25,26,38].

Lehar saw that studying visual space perception needed to focus on characterizing the spatial correspondence between physical and visual space to figure out the computational theory of visual perception [37]. On the other hand, Hildebrand combined the idea of form and space related to pure vision, and image received through kinetic vision [13].

Dana Pop analyzed the common ground between the field of visual perception and architectural design. The results of her studies showed that the design shouldn't solve the functional issues only but provide environmental meanings to correspond to the needs of the users which the space reflects [42]. Tavsan and Akbarzadeh studied the linguistic patterns that influence the formation of architectural forms considering the mental images for the selected case studies of Zaha Hadid designs [46]. Another paper has studied the quality of the architectural space through the study of the virtual physical qualities and properties [18]. Jack Loamis in his paper studied the visual properties from different aspects including philosophy, perception observation, the phenomenology of the visual space, and the main conceptions of the visual control actions [38]. Another study has focused on environmental aesthetics to identify the differences and similarities between the design buildings of Zaha Hadid to understand how the individual style fosters aesthetic awareness of cultural differences. The results of this paper showed that the rhythm and organic lines of a building are the most significant elements for building facades and masses in aesthetic elevations.

B. Le Corbusier – Modern Architectural Style

Modernism is one of the most important architectural styles of the 20th century [7]. This architectural style was associated with the functionality of the building, rational use of the material, and structural innovation [7].

Le Corbusier is among the most influential figures in modern architecture and twenty-first-century architects such as Zaha Hadid [50]. He is the forefather of the Modernist architectural style [7]. Le Corbusier agreed that the material affects the building design, emphasizing geometry [2].

Le Corbusier focused on design thinking by achieving visual and spatial concepts through applied sketches and drawings [14]. He expressed these concepts in the plan through visual and spatial experiences [16]. He recognized the integration between the building, and its surroundings and perceived it through visual perception [40].

Le Corbusier expressed visual perception through the term space by conceptualizing the breadth, spatial proposition, and direction terms and used the plan as a generator [40]. Besides, he represented the space through movement. For example, in villa Savoye, when spaces terminated physically, a further movement continued visually with an open-view terrace [40].

C. Zaha Hadid – Parametric Architectural Style

The parametric architectural style is based on computer technology and algorithms [52]. This architectural design approach has resulted in many curving, smooth-flowing lines like fabric, and non-rectilinear buildings, which gives the design a unique shape that attracts attention [34]. The term 'Parametricism' was coined by Patrick Schumacher, partner at Zaha Hadid Architects, who promoted it as the natural successor to post-modernism [34]. Zaha Hadid is an Iraqi architect, well known for her architectural building design since she is the pioneer of the architectural style [34].

Hadid pushed architecture to a new era, forming her style by injecting the dynamic into architecture to form fluent architectural language and applicable characteristics using rhythmic organic and inorganic natural systems [1].

Zaha Hadid's work has a form of complexity, that originates from her trans-geographic and trans-temporal attitude toward language [46].

While Zaha Hadid invented the plan as a three-dimensional section to flow fragments [27]. Zaha Hadid worked on visual perception to increase eye speed communication through the designed concepts [27]. These concepts were translated into experiences and then physically formed [27]. This form has a fragmented vocabulary to provide a radically re-order syntactic relationship in a new space with a new identity of dynamic, fluidity [27]. She didn't see the space as a void but as a transmitting force, which affects the space-forms inextricably linked relation, where they together generate the building itself [27].

III. METHODOLOGY

This research paper has used a mixed-methods approach including the quantitative approach, which represented the online survey questionnaire for 100 architects for the number of selected case studies for Le Corbusier, and Zaha Hadid. The second approach is the qualitative method approach, which represented the observation analysis for the survey and materialism analysis of the designs.

The selected case studies have specific characteristics such as famous residential buildings, and turning point buildings in the design process of the architects. The selected case studies of Le Corbusier's designs are Villa Savoye, which is one of the important houses of the 20th century, and it's a UNESCO world heritage site [24,48], and Villa La Roche, which exhibits cubist art and purism and it's a UNESCO world heritage site [23,47], and Citrohan house, which displays the five characteristics that le Corbusier defined as the conception of modern architecture [10]. The selected case studies designed by Zaha Hadid are Capital Hill Residence, which is an early visionary innovation [22,51], the Kusnacht Villa, which is a unique futuristic house [5,17], and Nassim Villa, which has special visual characteristics about the extending the topography into the sky to reduce sun exposure [21].

The data collection process was through the online survey questionnaire to get architects' opinions about the selected case studies for the selected architects. Besides, reading materials from books, research papers, and online architectural websites.

IV. ANALYSIS

The main target of this research paper is to figure out the similarities and differences between the Modernism architectural style, and the parametric architectural style by studying Le Corbusier, and Zaha Hadid's design works. The analysis is divided into parts: firstly, doing and analyzing the online survey questionnaire that focuses on the visual perception of the residential architectural buildings of some of the selected case studies for each selected architect. Secondly, analyzing the materials of these case studies. Lastly, as result, comparing the visual perception survey questionnaire and connecting it with the material analysis to find out the similarities, and differences between each architect of the selected architectural styles.

A. The Survey Questionnaire

This part studies the visual perception of the architectural space of Le Corbusier and Zaha Hadid buildings. The online survey was directed to 100 architects who were asked to fill out this questionnaire about the selected case study buildings. The survey was divided into two main parts: the studies of the sensory effects, and the studies of the physical effects. The study of each effect was divided into three parts. The studies of the sensory effects included the studying of meaningfulness and comfortability. The studies of the physical effects included the regularity, and simplicity of the selected case studies of each selected architect. After the survey, all the collected data was analyzed and figured out the effects of the residential architectural buildings of the two pioneers' architects of the different architectural styles on the users.

Starting with the study of the sensory effects, the study of meaningfulness includes the terms creativity, originality, and emotion [4]. From the results, the creativity responses are connected to originality but not to emotion. The Villa Savoye and Citrohan houses have high percentages of responses about creativity and originality compared with the responses about the Villa La Roche (figure 1-2). The results showed that Citrohan house has the highest percentages of emotional effects on users than Villa Savoye and Villa La Roche which has the lowest effects of Le Corbusier designs (figure 3).

The analysis of the survey showed that the creativity and originality of Zaha Hadid's designs were very high but the emotional effects of the buildings varied. The Capital Hill Residence has the highest emotional effect than the Nassim Villa and Kusnacht villa (figure 1-3).

Comparing the two architects, the analysis of the survey showed that Zaha Hadid's designs are more meaningful than Le Corbusier's designs (figure 4).

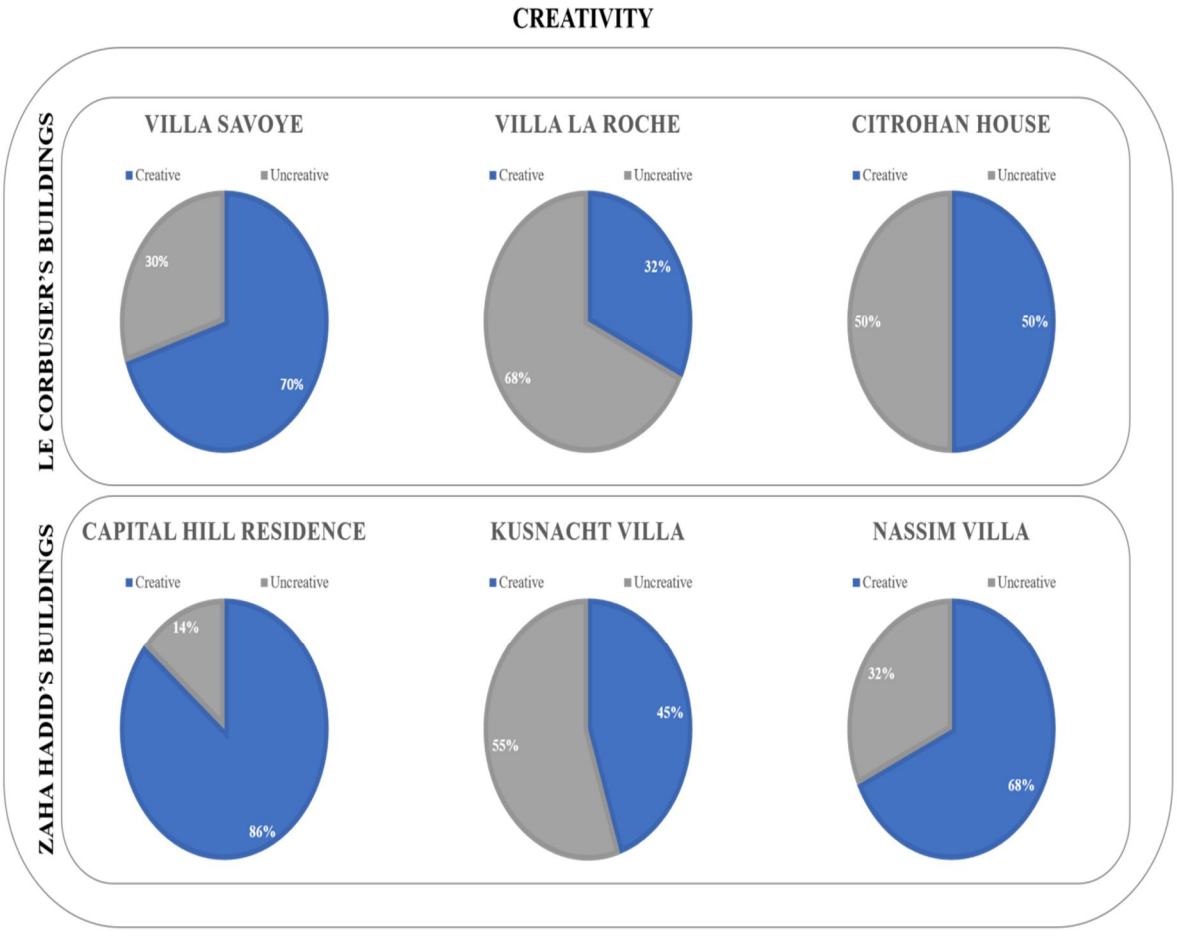


Fig. 1: The survey's answers to the creative part of the case studies.

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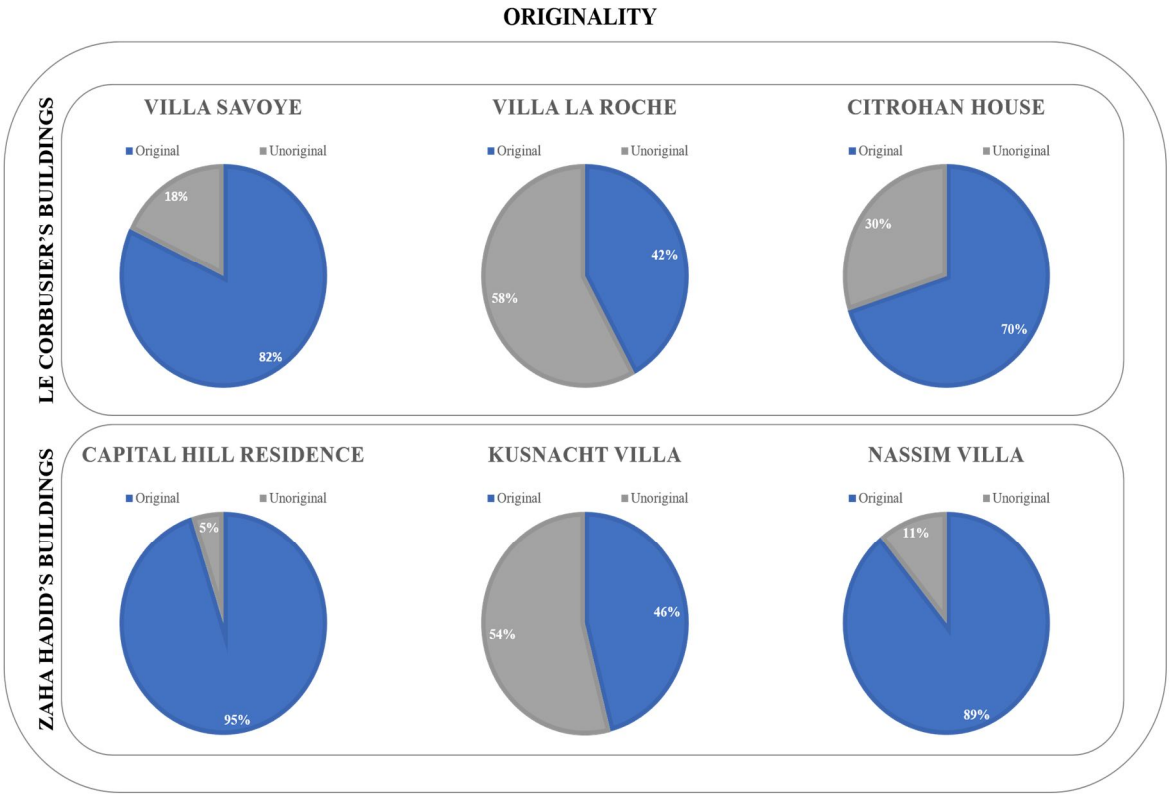


Fig. 2: The survey's answers to the originality part of the case studies.

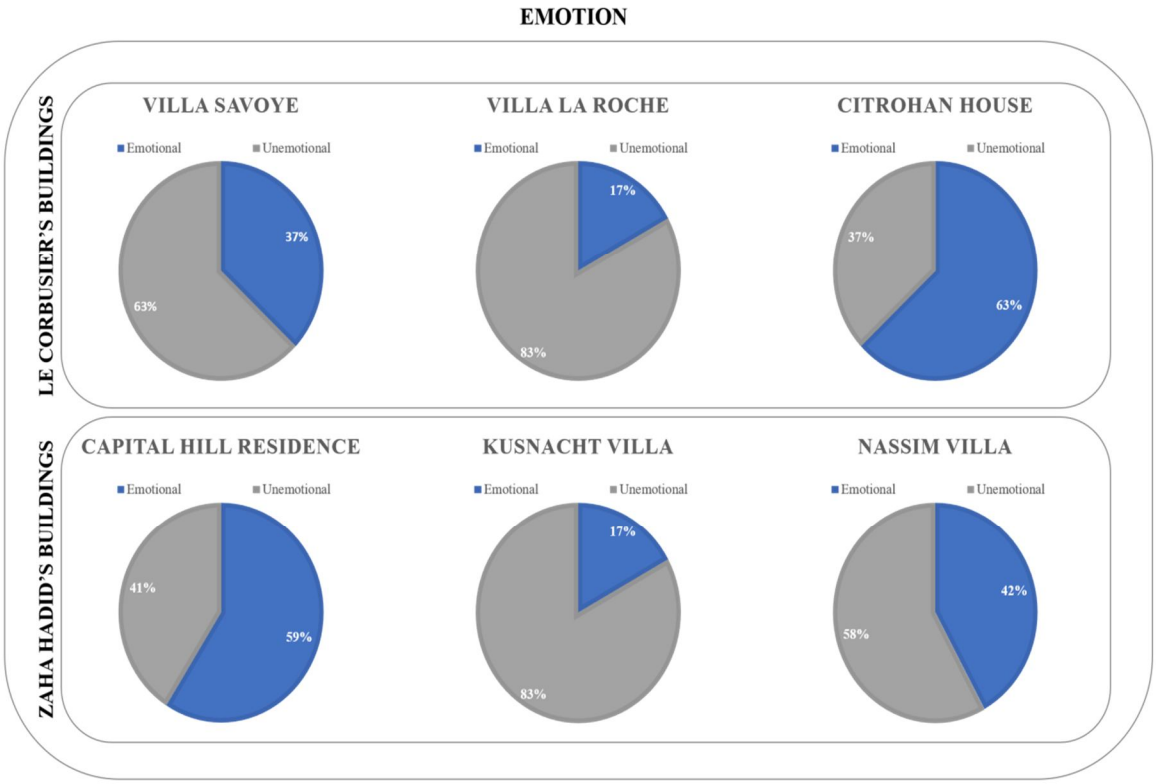


Fig. 3: The survey's answers to the emotional part of the case studies.

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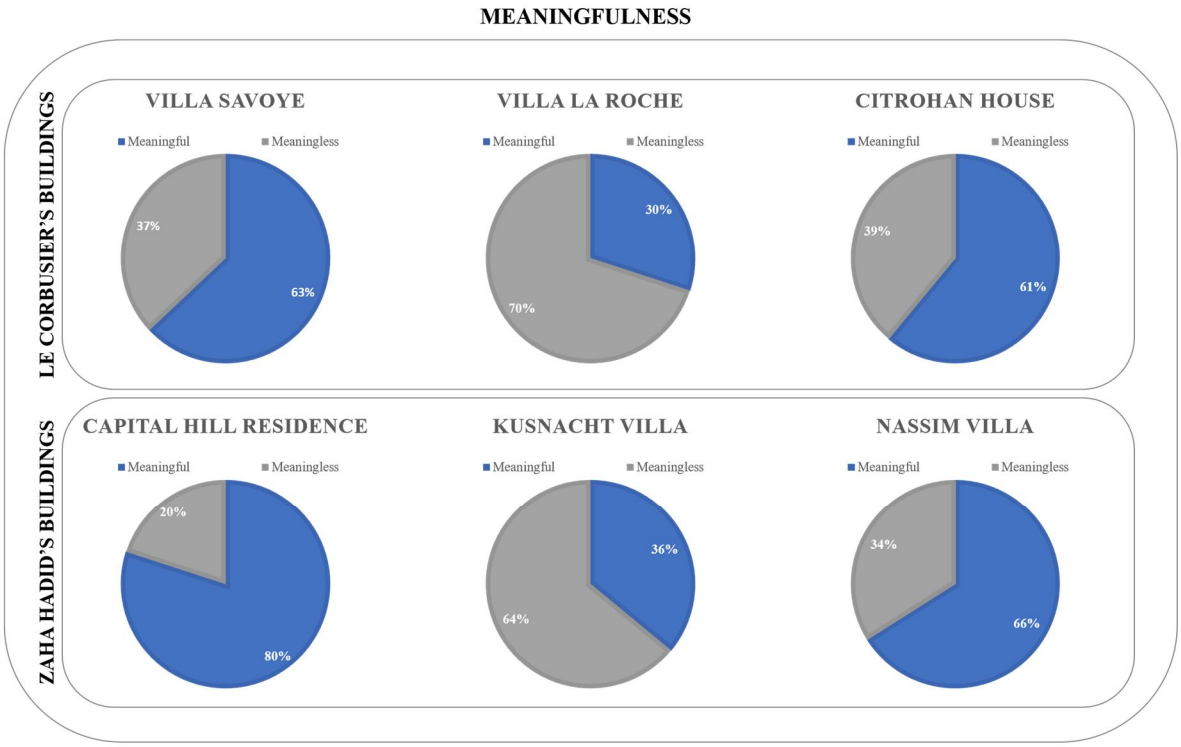


Fig. 4: The survey's answers to the meaningfulness part of the case studies.

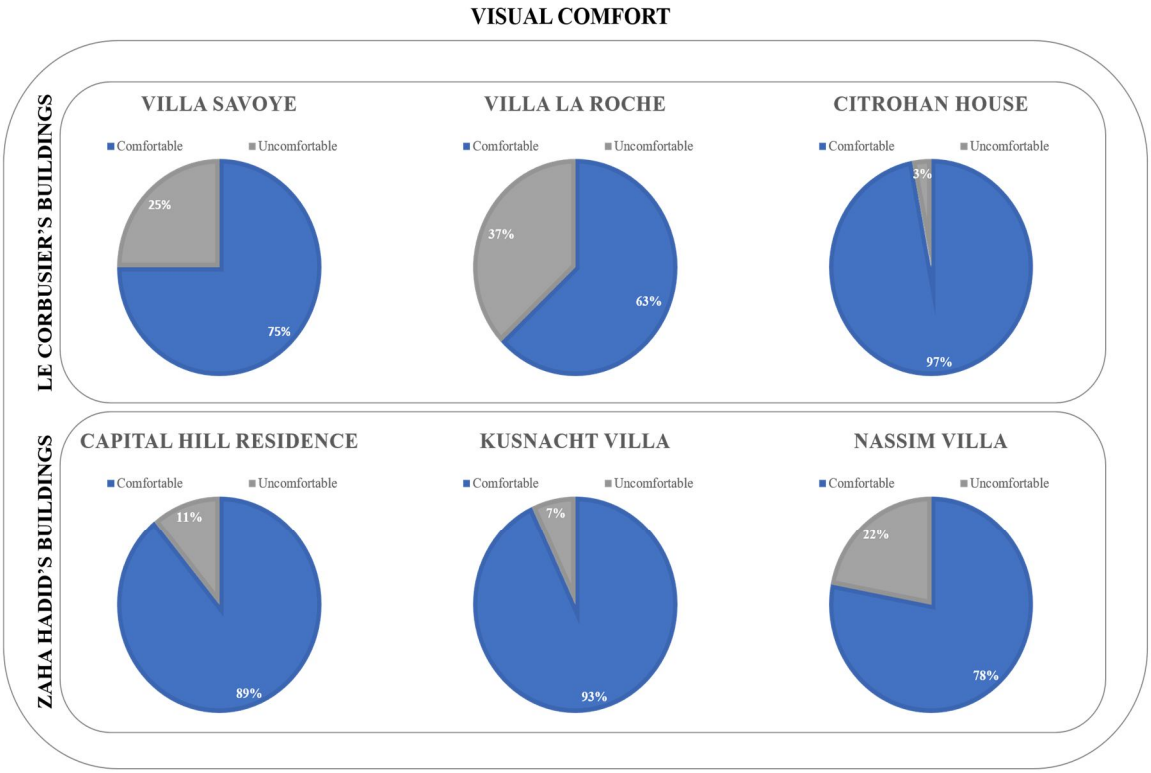


Fig. 5: The survey's answers to the visual comfort part of the case studies.

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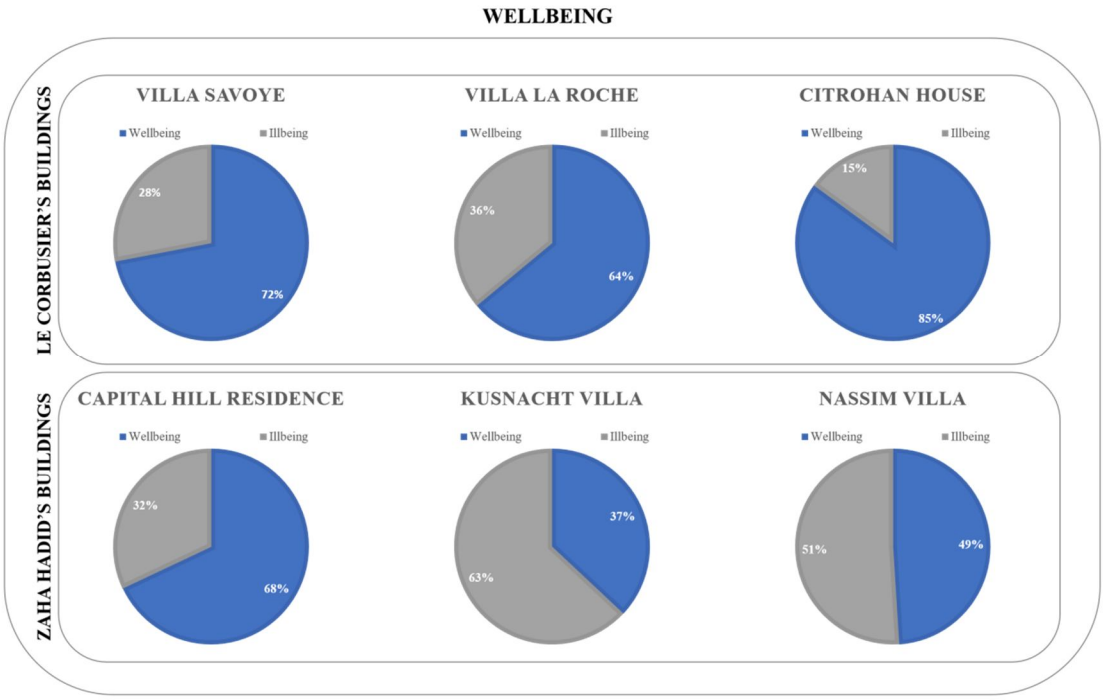


Fig. 6: The survey's answers to the well-being part of the case studies.

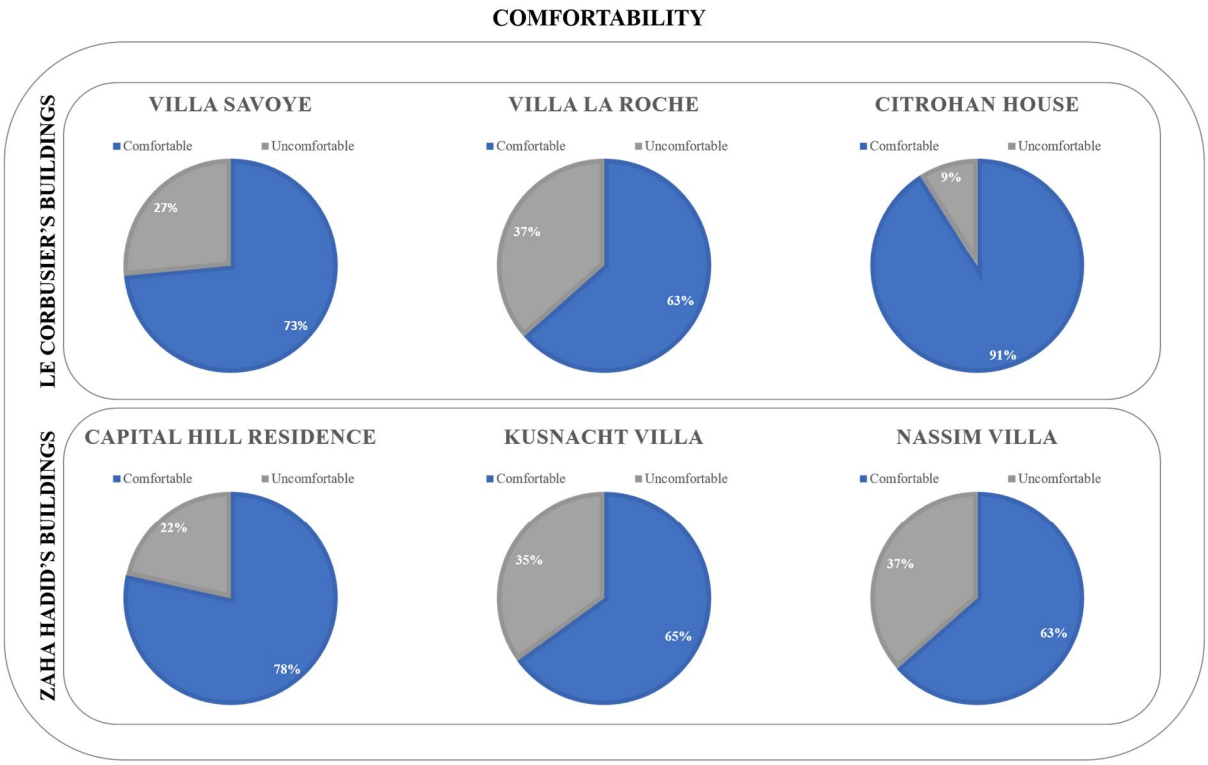


Fig. 7: The survey's answers to the comfortability part of the case studies.

The study of the comfortability part includes visual comfortability, which includes a sufficient amount of natural light, access view to the outdoors [44], and well-being, which has organized support and emotional balance [12].

The results of the survey showed that both architects' designs of the selected residential buildings have visual comfortability of the buildings with high percentages (figure 5). However, the percentages of the well-being results are different. For example, the results showed that the well-being effects of Le Corbusier's designs are high (figure 6). On the other hand, Capital Hill Residence has the highest percentage of well-being responses than the Nassim Villa but the Kusnacht villa has the lowest percentage of well-being points (figure 6).

Comparing the two architects' designs in the survey result analysis, a high percentage of respondents agreed that both architects' buildings' designs have visual comfortability but differed in the well-being survey's results (figure 5-6). However, the survey showed that the comfort of Le Corbusier's buildings was higher than Zaha Hadid's designs (figure 7).

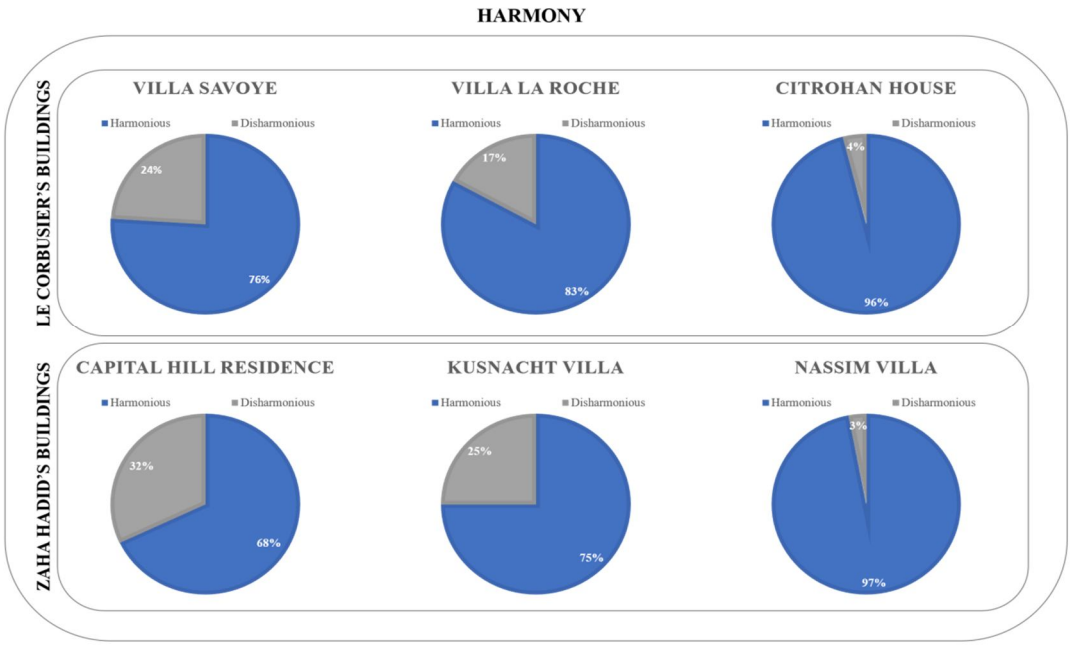


Fig. 8: The survey's answers to the harmonious part of the case studies.

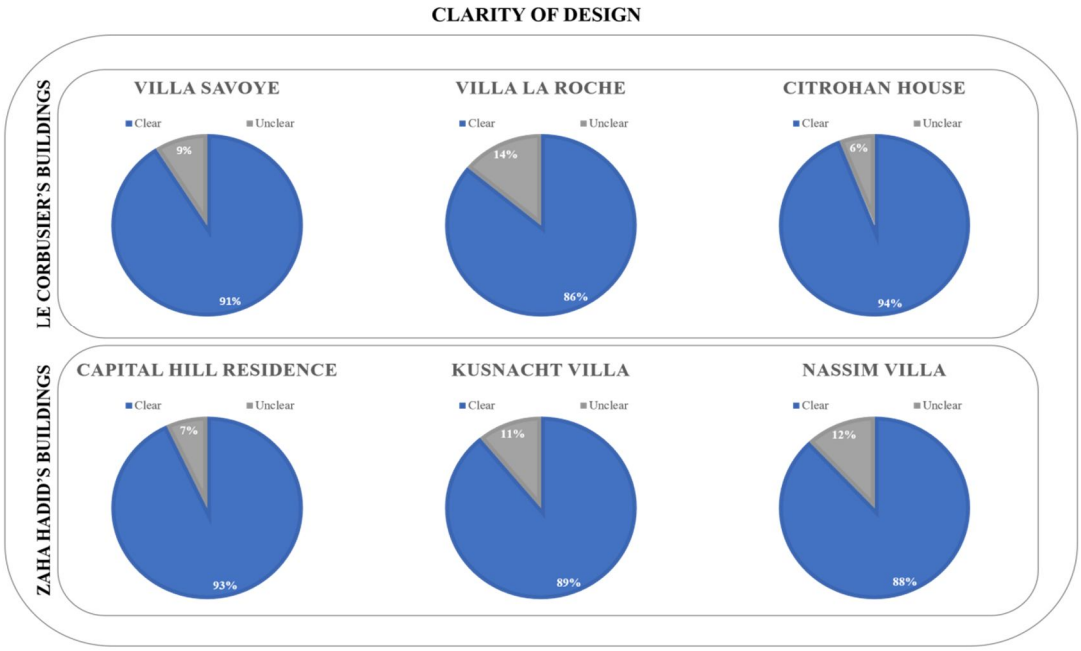


Fig. 9: The survey's answers to the clarity part of the case studies.

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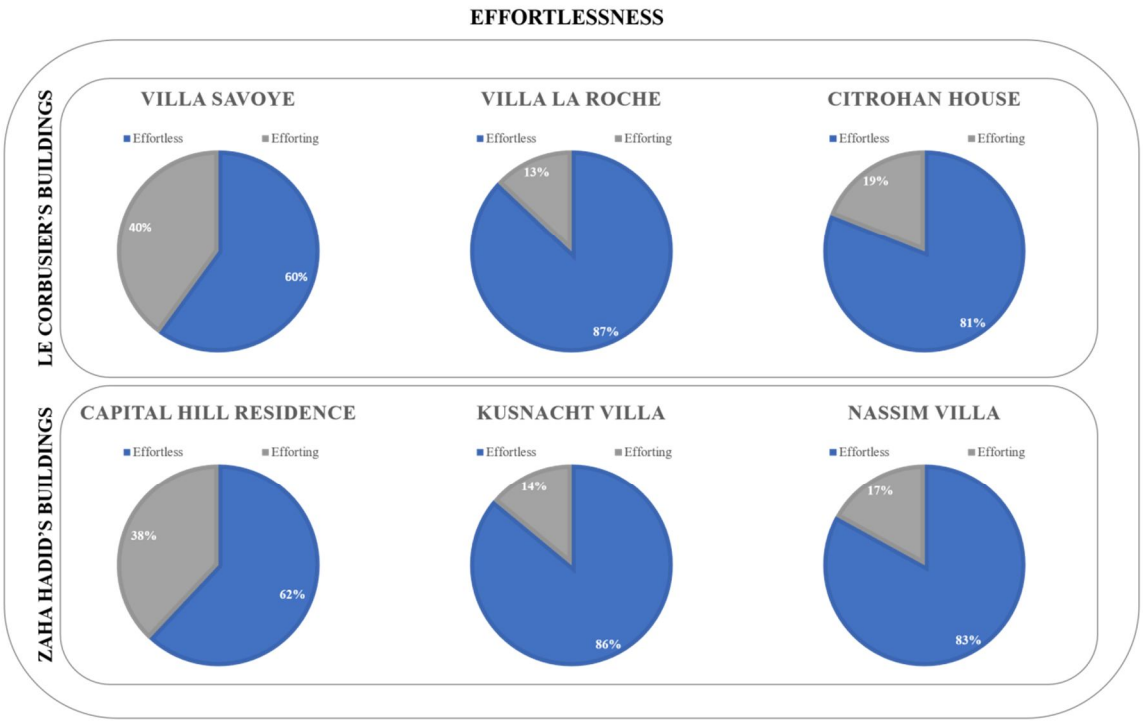


Fig. 10: The survey's answers to the effortlessness part of the case studies.

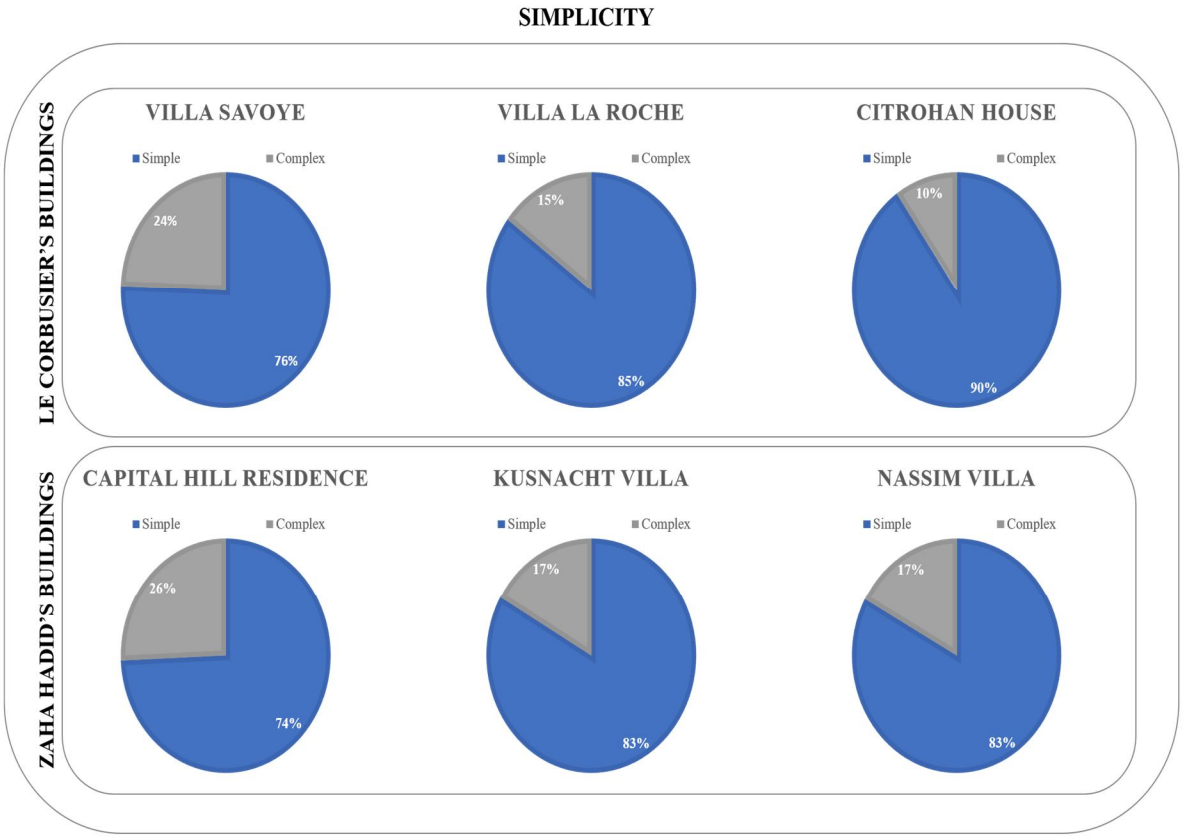


Fig. 11: The survey's answers to the simplicity part of the case studies.

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The study of the physical effects includes the study of the harmony, clarity, and effortlessness of the designs [19, 43]. Related to the survey results, the respondents saw that the selected case studies designed by Le Corbusier have more harmony compared with the selected case studies designed by Zaha Hadid (figure 8). The survey's results analysis showed that the clarity of the designs of both selected architects is very approximate (figure 9). Besides, the study of effortlessness which indicates the aesthetic, usability, and efficiency showed approximated similarities between the selected case studies of the two architects (figure 10).
The study of the simplicity of the designs of both of the architects for the selected case studies showed that the selected case studies designed by Le Corbusier are simpler than the selected case studies designed by Zaha Hadid (figure 11).

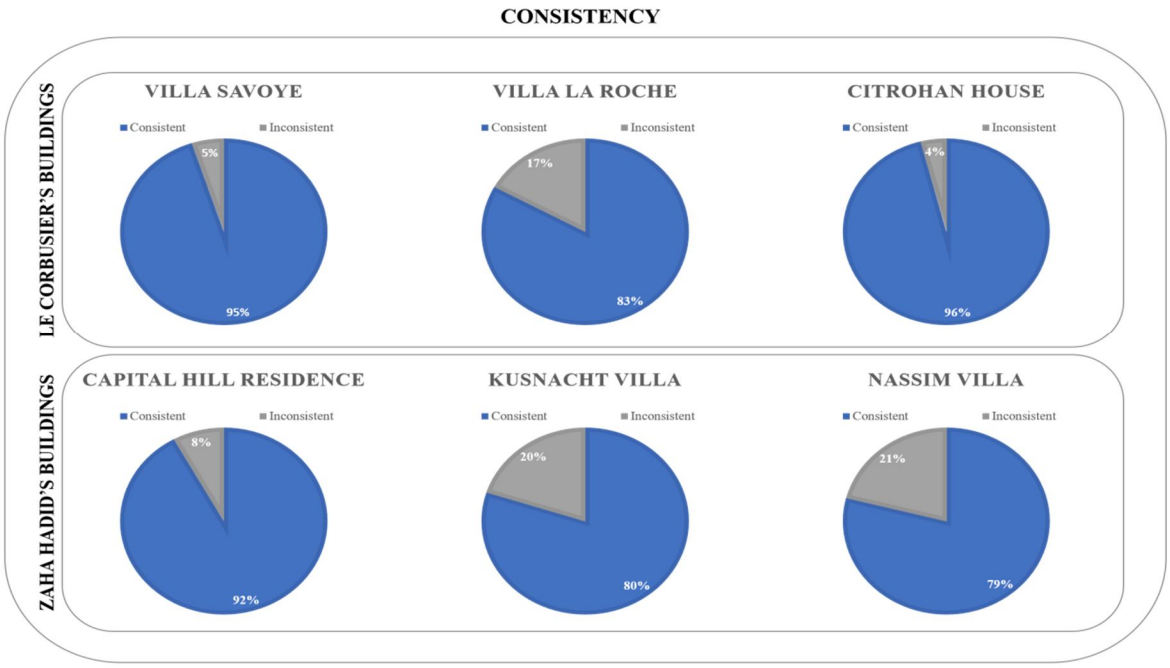


Fig. 12: The survey's answers to the consistency part of the case studies.



Fig. 13: The survey's answers to the order part of the case studies.

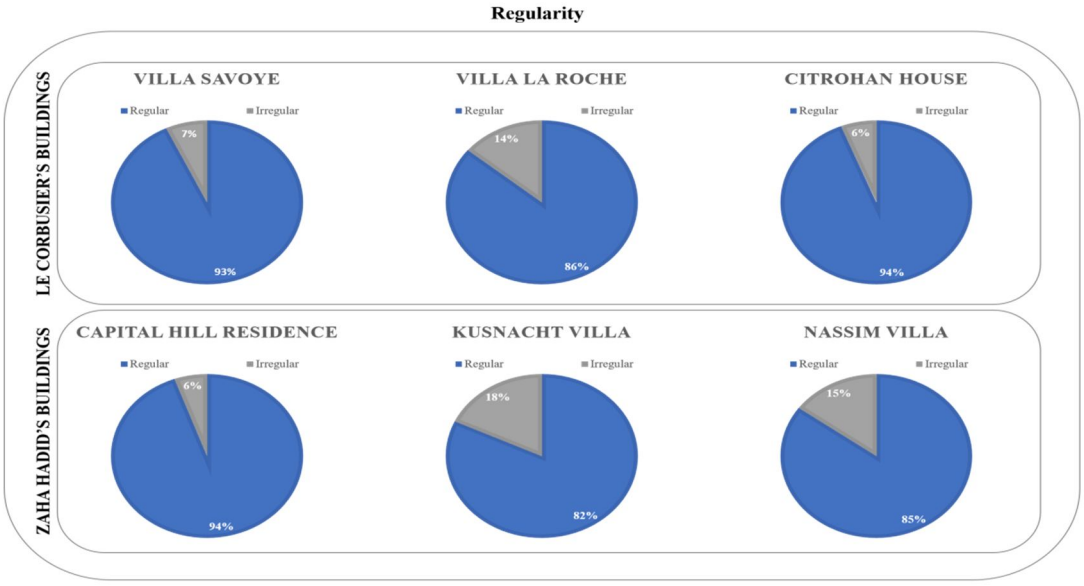


Fig. 14: The survey's answers to the regularity part of the case studies.

The study of regularity includes studying the consistency and order of the design [6]. Related to the survey's results analysis, the consistency of the selected case studies designed by Le Corbusier is higher than the designs of Zaha Hadid (figure 12). However, the results of the respondents showed that the ordering percentages are the same as the designs for both architects (figure 13).
The analysis of the survey results showed that the regularity of the selected case studies designed by Le Corbusier is higher than the selected case studies designed by Zaha Hadid (figure 14).
From the analysis of the online survey questionnaire, the results showed that the selected case studies by Le Corbusier are simpler, more comfortable, and regular than the selected case studies by Zaha Hadid. However, the selected case studies by Zaha Hadid are more meaningful than the selected case studies by Le Corbusier.

B. Materiality

This part studies the materials used in the construction of each case study designed by Le Corbusier, and Zaha Hadid. Le Corbusier used mostly glass, steel, and reinforced concrete as the main materials for the construction of all the selected case studies. On the other hand, Zaha Hadid used more developed concrete such as pre-cast, and in-situ cast concrete, with steel and glass for constructing the selected case studies. In the Nassim Villa which is located in Singapore, she used cast aluminum for the exterior façade, and fiber-reinforced concrete as an interior material for the building design, which is different from the first and second case studies of her designs which are the Capital Hill Residence in Russia, and the Kusnacht Villa in Switzerland (table 1).

Table 1. The material of each case study project.

Architect	Projects	Location	Year	Material
Le Corbusier	**Villa Savoye**	Poissy, Paris, France	1929	steel, glass and reinforced concrete
	Villa La Roche	Paris, France	1925	steel, glass and reinforced concrete
	Citrohan House	Stuttgart, France	1927	steel, glass and reinforced concrete
Zaha Hadid	**Capital Hill Residence**	Moscow, Russia	2006 - 2018	pre-cast and in-situ cast concrete, steel and glass
	Kusnacht Villa	Zurich, Switzerland	2006	pre-cast and in-situ cast concrete
	Nassim Villas	Singapore	2007	Cast Aluminum and Fiber-Reinforced concrete

C. Similarities and Differences

This part combines the first and second parts of the analysis section to figure out the similarities and differences between the two architects. The combination of the white reinforced concrete, with glass, and steel buildings of Le Corbusier reflects the simplicity, regularity, and comfortability. This reflects his design's philosophy of function as form with the help of using the technology available in that architectural style period [50]. However, using the pre-cast and in-situ cast concrete in Zaha Hadid's building design helped to achieve a more complicated, and irregular. However, a high percentage of respondents in this survey saw that these buildings were uncomfortable but meaningful. The two architectural pioneers used the same essential material which is concrete. However, Zaha Hadid used more improved concrete technology such as fiber-cast and in-situ cast concrete to achieve irregular form designs. In addition, she used cast aluminum in constructing the design of the building. This can show how she used the sensory effects purely as the foundation for the design concept, and construction. On the other hand, Le Corbusier's main focus was on functionality and physical effects, and use them as the main foundations of making his designs.

V. CONCLUSION

This paper studies the similarities and differences between Le Corbusier, a pioneer in the modern architectural style, and Zaha Hadid, a pioneer of the parametric architectural style, using the online survey questionnaire, and observation method analysis to combine the survey's results with the material functionality analysis. The results showed that even though the two selected architected used the same material, their philosophies were different. For example, Le Corbusier used the function of form philosophy and as result, the respondents of the survey agreed that his designs were comfortable, regular, and simple [50]. However, Zaha Hadid used the philosophy of visual perception to attract the users' emotions, with the help of parametric design methods. In the results, the respondents of the survey agreed that her buildings are meaningful even if they are complicated, irregular, and uncomfortable.

VI. DELIMITATION

The delimitations of this study can be summarized as this research focused only on studying the residential architectural buildings' designs by focusing on the visual perception, and the material functionality, and it didn't cover other parts. Besides, this research only focused on two pioneers of two architectural style periods, which are Le Corbusier, who represents the pioneer of the modernist architectural style period, and Zaha Hadid, who represents the pioneer of the parametric architectural style period.

A. Discussion

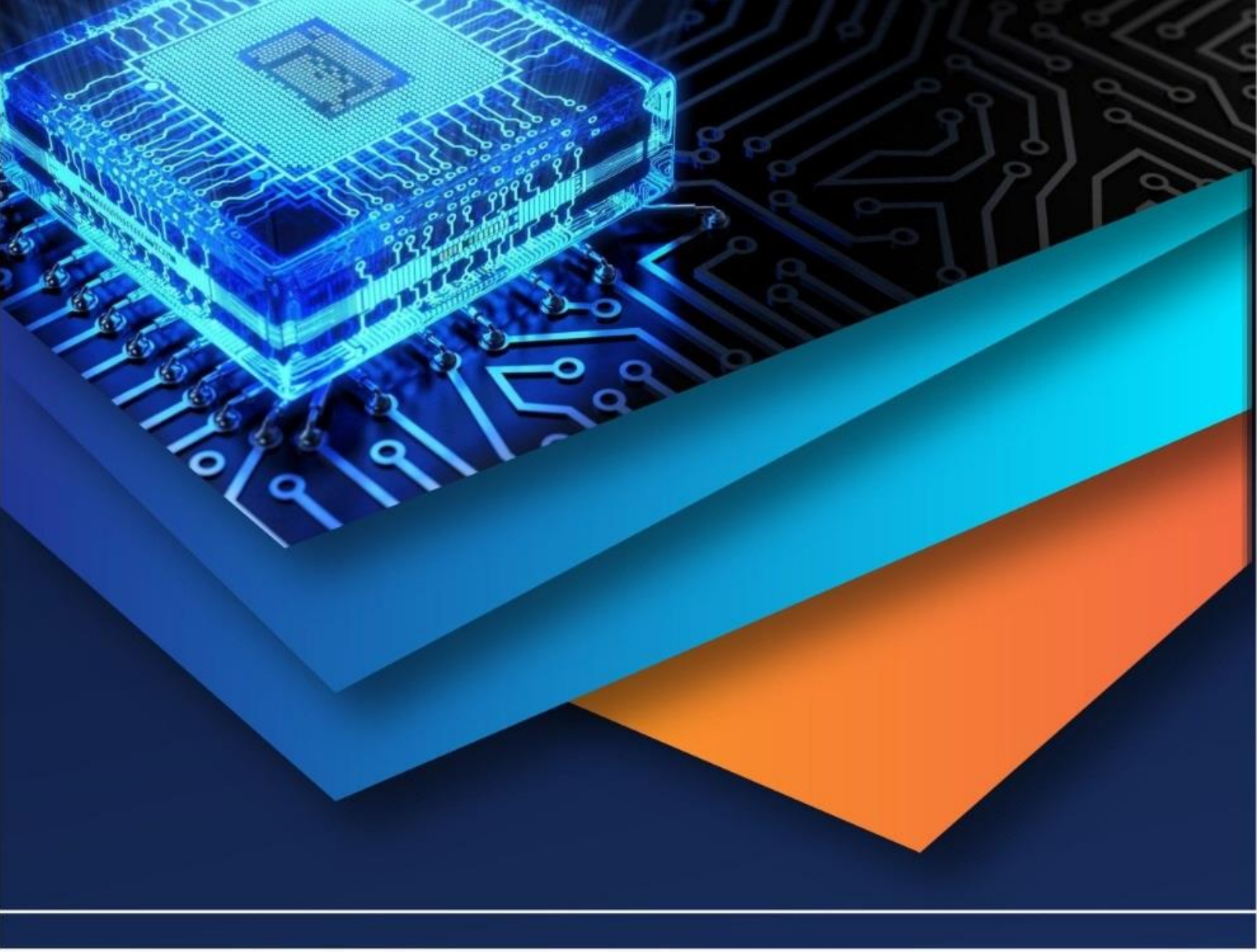
This research paper shows that the visual perception of the building design is connected with the philosophy of the design of the architect. Besides, even though the designed buildings can be irregular, complicated, and uncomfortable but still can be meaningful and achieve the meaning they were designed for. However, the results can't show the relationship between the visual perception of the sensory and physical effects of the study. This can be the foundation and starting mark of the following studies. Future studies can work on studying the other parameters of the visual perception of the architectural buildings and they can study the works and philosophy of other architects, and their visual perception targets of the design.

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