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Achieving urban sustainability by revitalizing the performance of Islamic geometric pattern on residential façades

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ABSTRACT

Cultural awareness is becoming increasingly important in an effort to reinvigorate local urban heritage into modern production. Considering that, one of the most significant aspects of sustainability is preserving socio-cultural and environmental specificities and restoring local heritage. The aim is influencing the local identity by promoting sustainability through the revival of Islamic geometric patterns (IGP) and their performance as effective components in local urban facades. A set of indicators related to the purposes for reusing IGP in facades within three main performances (decorative, structural, and functional). Their sustainability was studied and extrapolated, and a checklist has developed and tested by Likert scale on fifty residential facades in Baghdad's districts. The findings demonstrated the feasibility of measuring urban sustainability by evaluating the effectiveness of Islamic geometric patterns on residential facades. Furthermore, it has clearly achieved in the decorative performance of the IGP. It has also attained functional performance on the Socio-Cultural side, with a weakness in its environmental performance. In contrast, the checklist revealed a flaw in its structural performance.

Keywords: Islamic geometric patterns (IGP), Revival, Performance, Local identity, Urban sustainability

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1. Introduction

The use of geometric patterns is one of the main characteristics that give the Islamic city its distinctive identity [1], [2], [3], [4]. In the last two decades, cities all over the world have witnessed urban transformations by the influences of technology, environment and globalization, disregarding the priceless cultural heritage, particularly in Islamic countries [5], [6], [7]. As a result, several Islamic nations have tried to investigate the link between sustainability and cultural expression, pushing toward sustainable urban architecture and better cityscape [2], [8]. Therefore, as the world became more urbanized, new urban expressions emerged to address global environmental concerns [6], [9]. In Arab cities, IGP was used at the level of building facades in the urban scene. It is resulted of the combination of environmental, social and cultural requirements over centuries [9]. Emphasis was placed on evaluating the application and performance of the geometric patterns used in building facades, like shading screens, external covers, and patterns embedded in the details of the facades as a symbol of the Arab-Islamic cultural integration with technology and modern urbanism. Studies focused on reviving the local identity in the face of rapid globalization towards a sustainable urban scene [2], [8], [10], [11]. Some studies dealt with the methods and performance of geometric patterns as a design force, an environmental control system and a cultural component [9], [12]. Others emphasized the importance of reviving the local identity decoratively [2], [8], [11]. Intensive studies dealt with the structural aspect and its relationship to facades and contemporary technology [13], [14], [15],

[16].

In terms of decorative performance, many studies have proven the effectiveness of traditional Islamic geometric patterns in every time and place [8], [10], [12]. Some of them have tried combining traditional uses with contemporary context, like (Al-kodmany, 2016) and (Emami, Khodadadi, Buelow, 2014) which emphasized that the geometric patterns embedded in the wooden window partitions (traditional) are a vivid example of developing building screens within an authentic urban context and reconsidering them using new materials as a covering [8], [12]. Through this modernization, the facades evoke a new aesthetic rooted in the local culture based on sustainability and the expression of the cultural identity of the city [2], [8], [11]. The traditional developed from covering the windows to decorating the entire facades of the building in the contemporary urban context [2], [8], [12]. It is evolved to be a cultural heritage and environmental problem solving especially in a hot arid climate.

As for the structural performance, the technological role has been assigned with reusing IGP in contemporary ways in line with the current local contemporary methods. Previous studies confirmed the development of the selection of materials and technology used in the application of Islamic decoration in contemporary residential facades from its predecessor. After the traditional patterns were executed manually and with high craftsmanship; The development of implementation techniques contributed to the sustainability of decorative patterns as inherited cultural elements [17], [18], [19], and thus the sustainability of urban facades [2], [6]. The traditional decorative art that followed the prevailing craftsmanship methods implemented on wood, punching, mold pressing and welding [20] developed methods of manufacturing and digital machines appeared for urban implementation. These machines use computer technology, (CAD Computer Aided Design and CAM Computer Aided Manufacturing) programs to produce various engineering patterns [14]. As well as, the development of the use of decorative surfaces with the entry of CNC machines technology played an important and vital role in the manufacturing sector during the last fifty decades [13], [18]. It shortened the implementation time and cost and increased the accuracy compared to the traditional techniques. Some have shown that the original and changing pattern transformed from design to construction to performance to practice [11]. Others also compare traditional methods and digital technology in the engineering of Islamic geometric patterns in terms of composition, generation and performance [3].

In terms of functionality, technical advancements in its urban, architectural, and industrial aspects have resulted in the development of the usage of Islamic geometric patterns in a way that is respectful of cultural continuity while also being more sensitive to climatic conditions. Thus, using contemporary technology, the urban aspects of the current Arab Islamic city are being transformed towards artistic identity and civilizational communication [2], [24], [26], [30]. It is noticeable that the prevalence of the geometrical patterns incorporated in traditional Mashrabiya has decreased over time, owing to the high expenses of manufacture and maintenance, as well as their rusk to burn for utilizing wood material. Furthermore, strong social privacy needs are no longer a modern requirement, as the present tendency toward openness in modern façade ignores environmental considerations [12]. However, Alhadi analyzes current patterns, despite the style of its work, it fulfilled the same traditional purposes in giving shade, privacy and adapting to the hot conditions [15]. Contemporary geometric patterns are used as a daylight control system, as well as a design element in the transparent facades. During the past decade, the traditional patterns of shading screens have been transformed and developed into live cellular screens through the basic rules of mathematics [2], [5], [8], [22]. And performance simulations and analyses enabled them to embody the aesthetics of patterns and increase their efficiency in converting them from nature and biology to engineering [21]. Researches, including (Mutaz, T., Khalid, Z., H. & Kamoona, 2021) have indicated the importance of computing tools, algorithmic design programs and parametric design theories in presenting infinitely diverse generative IGP modes [6], [5], [12], [14], [22]. The advancement of technology and the creation of digital machines have led to the reduction of implementation time and cost while boosting pattern performance accuracy [13], [15]. However, in the local context, it is not defined clearly. As a result, the role of technical performance as an indicator in this study was restricted to extrapolating the processes of IGP implementation in the evaluation process to achieve urban sustainability.

As a consequence, the idea of this research has come to identify the importance of the IGP in enhancing and sustaining the local urban scene. It's an attempt to measure urban sustainability, through exploring the IGP decorative, structural and functional performance and extracting the most relative indicators.
Identifying each of these indicators helps in providing a checklist to recognize the strengths and weaknesses of the Baghdadis façade and diagnose the disqualifications and disorders in them. This will revitalize the local city façade toward the better sustainable urban scene.

2. Methodology

This study is a descriptive extrapolation of the local city's urban scene, in an attempt to demonstrate the effectiveness of reviving Islamic geometric patterns to residential building facades in terms of achieving urban sustainability and preserve cultural identity. The research is divided into two parts, the theoretical framework of the study aims to extract performance indicators (decorative, structural, and functional) as well as a checklist through which performance effectiveness can be tested in its various forms. The practical framework, on the other hand, is concerned with a checklist test using the Likert statistical scale on fifty local facades selected from Baghdad city.

3. Theoretical framework

This research has come to identify the importance of the IGP in the local urban scene and measure its sustainability, as a decorative, structural and functional (social, environmental, or both) performance indicators, with several subsequent components in each indicator. Identifying each of these indicators provides a checklist for evaluating the Baghdadi façade's strengths and shortcomings, as well as diagnosing its flaws and disorders. This checklist is created to revive the local cityscape in order to create a more sustainable urban environment, connected to the cultural identity.

3.1. IGP As a decorative performance

The term decorating or ornamentation is frequently implemented to refer to the beautification of the environment, objects, the human body, the cave, the village, architecture and the city [1], [17], [20]. The use of decorating is as old as humanity [3], [4]. According to historian David Brett, the embellishment is an expression of a profound human need for visual pleasure [17], [20]. In the urban and architectural practices, it is the decorative artwork devoted to the style, which is specific to each era and which develops over time and moves and affects others so that they are uninterrupted in a specific time and place [1]. The Decorative aims in Islamic styles were to create a visual pleasure, a means of defining urban and architectural spaces and which enhances aesthetic awareness and emphasizes the elements utilized [4], [5]. Decorating depends on the orientation of urban designers and architects concerned with designing and creating any façade's style [23], [24]. They divided into two groups. One of them is interested in the aesthetic of man-made decoration, and the other interested in the styles that fall behind the formation and performance patterns [1], [17]. Esthetically, the trend of motifs should be more abstract, formal and perceptible than the use of the direct, intellectually readable composition [2], [4], [6], [12], [25]. Modern technology has contributed to change the facades toward aesthetical decoration, as it currently provides positive elements that facilitate the design style, including facades that adopt simulations, precision, and aesthetic enhancement [18]. Recently, the decorations tended to be too "media-related", i.e. the ability to reflect the capabilities of materials and the ability of modern architectural techniques in design and composition [3], [22], [26]. The high-cross retail and cinema complex in Leicester is an example of the double-layered glass façade case for its functional and aesthetic effects that can be seen more imparts from the inside of the first floor than looking at the building from the street [4]. It's an expression of a media style as a smooth, continuous interface that gives the feeling of focusing on the unit that comes from repeating decorative patterns [20]. Additionally, there is a strong relationship between spaces with decorative patterns, where most of the structural elements are disguised behind many elements of Islamic decorative patterns [4]. The barriers between structural elements (bearing) and ornamental (non-bearing) dissolve and hide behind patterns, tall, ornate, simple urban facade creatively designed for the urban space it

occupies, and this is the case with the traditional style [13], [23]. Various sorts of digital technology and media have aided interest in decoration as it has progressed through the design scales, from CAD programming to digital printing in both 2D and 3D [6], [22], [21], [27]. In architecture, industrial and urban design, engineering patterns use a high standard idea to fit into the sustainable design in terms of providing more cultural aesthetic, openness, and durability dimensions [20], [24]. And reconsidered as a pattern for the urban facades that the buildings overlook and define the identity of the city urban spaces [1], [2], [3], [4].The design of the various facades in any city is a vivid representation of how traditional screens of buildings are developed within the contemporary context and reconsidered as a cover or a face that forms the identity of urban spaces [8], [11]. According to IGP Performance, decoration indicators contains aesthetics and style, and those include several components represented in Table1.

Table 1. IGP decorative Performance[1], [2], [3], [4], [5], [6], [8], [11], [13], [22], [12], [20], [17], [18], [21], [23], [24], [25], [26], [27]

IGP Performance		
Indicator		Component
Decorative Performance	Aesthetics	Abstracted
		Readable (nonabstract)
		Formal
		Informal
		Perceptible
		Imperceptible
	Style	Media style
		Traditional style
		2D decorative pattern
		3D decorative pattern

3.2. IGP As a structural performance

Just as with decorative surfaces, the structure of the façade is affected. The expressive potential of the building's envelope [26], reflects the ability of modern technologies to enable architects to develop techniques for elaborate Islamic geometric patterns. There are demands to reorient patterns to be higher-tech and, dynamic, conceptual, intangible, virtual, immaterial and invisible in their functions, effects, and type [8]. The ability to seamlessly manufacture Islamic patterns allows patterns to be directly controlled through 3D subject models, making it easier for them to employ patterns with effective, structural parts in unique architectural works [6], [28]. By the end of the last century, new possibilities of forming buildings façades were discovered from the use of innovative technologies and materials, which has made it common to implement complex patterns in several types of façades [26], [28]. However, it's until now a challenge to produce complex patterns and generate a modular paneling by some types of materials and manufacturing [2], [26]. Resulting, IGP As a structural performance includes the IGP process and the IGP materials. Previously, in IGP processing, traditional pattern styles including (woodwork engraving, template compression, and welding) having been applied manually with high craftsmanship [20]. Today, and with the development of implementation methods, techniques have contributed to sustaining the decorative patterns as inherited cultural elements. Afterward, the emergence of digital manufacturing methods and the implementation using computer-aided manufacturing programs [6], [13], [18] have dominated the market to produce various geometric patterns. In addition, decorative surfaces are developed with the use of the CNC process [13]. All these processes contributed to shortening the implementation time and cost and increasing accuracy comparing with traditional methods [13]. Resulting, the IGP process component includes, carving, screening, welding, CNC, 3d printer, as well as

template compression as seen in Table 2. On the other hand, IGP Materials play an important role in shaping and decorating the surfaces and adding artistic touches with high accuracy and balance. Adding traditional screens to the new buildings (such as wood, stone, and gypsum or clay screens) give a vivid representation of how the geometric patterns combined the contemporary context with the traditional facade [12]. These patterns are applied in glass, ceramics, tiles, and pottery, and are engraved on wood and metals like copper, gold, and silver [18], [20]. Nowadays, the use of panels, such as mud or aluminum panels, as thermal insulation materials, is widely applied to meet the standard of designing sustainable companies [11], [16], [18]. In the cities of the Middle East that have emerged to be a hub for trade, business and culture, such as Dubai, Abu Dhabi, Doha, Kuwait and Mecca, engineering patterns were used in a simple and an architecturally complex way to create effects for the façades of iconic buildings in the urban landscape [2], [25], [29]. The free-form engineering patterns are formed by the combination of geometric patterns to lace-like surfaces. The issue is influenced by materials and manufacturing restrictions. Patterns arise naturally by supporting flat and curved structures when working with glass and using metal, or making patterns from reinforced concrete with curved glass fibers [13], [16]. As a result, a structural performance of IGP contains two components represented in table 2.

Table 2. IGP structural performance [2], [6], [8], [12], [13], [20], [25], [18], [26], [28], [16], [29]

IGP Performance Indicator		Component
Structural Performance	Process	Template compression
		Welding
		Carving
		Screening
		CNC
		3d laser printing
	Materials	Brick
		Stone
		Wood
		Glazed tiles
		Steel
		Glass
		Plastic
		Aluminum, Gypsum, clay, metal, ceramics
		Others

3.3. IGP As a functional performance

The primary purpose of the functional performance is to introduce the principles of sustainability (environmentally, socio-culturally). Working with all these elements, bringing the sustainable urban façade to become more applicable. For IGP the Environmental performance, the current urban trends aim to design innovative and sustainable facades [1], [2], [24], [26], [30]. Cities with a hot-arid climate designed by taking advantage of sophisticated technologies [6], [11], [15]. While respecting the traditional way of living that reflects the cultural roots of the region and enhances the urban landscape of the city [1], [7], [12] [19], [31]. These innovative interfaces reduce the environmental impacts by integrating day lighting, and natural ventilation control systems with an enormous range of strategies that lead to energy-efficient designs [1], [27], [30]. On this basis, the trend was to reuse the Islamic engineering patterns in the facades of the traditional buildings (Mashrabiya, screens, and windows) that were performed environmental and social functions with high efficiency [12], [14], [19], [31]. These patterns constitute five essential functions that include; containing

the passage of light, controlling airflow, decreasing the current air temperature, increasing the current humidity [15], [30]. In addition to ensuring the privacy that will be mentioned later in the social and cultural performance [7], [8], [15], [19]. So, the use of IGP in the Islamic urban façade ensures a comfortable internal environment in terms of cooling efficiency, shading, heating, lighting, and sound insulation [2], [13]. Several studies proposed possible solutions for dealing with the architectural, hot-arid climate using advanced construction techniques with IGP in the traditional architectural elements, by providing thermal comfort by reducing HVAC consumption, heating, ventilating and air-conditioning providing shading, and gaining privacy[8], [11], [30]. Contemporary geometric patterns have been used as a daylight control systems [8], [27], [29]. As well as, a design element in a transparent façade like the Tessellate Panels at Simons Center for Geometry & Physics State, the University of New York at Stony Brook, Long Island, NY, 2010 [32]. IGP As an environmental performance indicator includes controlling the light passage, controlling the airflow, reducing the air temperature, increasing humidity, shading, and providing thermal insulation.

For IGP As a Socio-Cultural Performance, more than thirteen centuries, patterns worked as unifying factors that linked architectural products from all parts of the Islamic world, extending across Europe, Africa, and Asia despite the diversity of materials, shapes, and methods used [7], [33], [34].The use of geometric patterns is one of the main characteristics that give Islamic artistic heritage, its distinctive identity [2], [19]. The Sociocultural Islamic geometric patterns are a cultural, and intergenerational movable language that reflects the identity of a society [7]. These patterns have enabled the transformation of Islamic urban facades into a contemporary, trying to preserve the Islamic identity and culture with powerful environment re-sponsorship and energy-efficient designs [8], [10], [27]. For traditional architecture, the concepts of ‘character’ and ‘expression’ were spread to indicate the decorating relationship [14], [17]. For example, geometric patterns integrated with the traditional facades usually appear in Islamic cities for many reasons [11], [12]. These include; privacy and visibility [14], [15]. It has been reconfigured to present contemporary form and modern techniques, and start to cover not only the windows but the entire building's façade [11], [12], [15], transforming the ways of thinking. Additionally, the relationship between identity and the environment is the essence of sustainability [7], [35], [36]. Alejandro Zaera-polo claimed that patterns have cultural and political potentialities that transcend decorating and enabling it to address some of the local urban context problems posed by globalization [16]. To visualize a sustainable environment, people must define their environment through the past, present, and future [19], [36]. One of the goals of the sustainable urbanism design is how to connect the past to the present to protect the ecosystem and the historical and cultural production [10]. Simulations and analysis techniques have enabled the esthetics of patterns to be more efficient in transforming them from nature to engineering [21], [27]. The Doha Tower, Qatar 2012, inherent the beauty of Islamic Arab culture through the modernization of geometric patterns, paying attention to the local climate and culture. The façade of the building was designed from elements inspired by Islamic geometric patterns which represent a modern design by referring to regional architecture and local culture [2], [3], [31], [24]. Other examples attend The Arab World Institute (Institut du monde Arabe), Paris, France, 1987, and Al Bahar Towers, Abu Dhabi, UAE [2]. As a result, the functional performance indicator works as an environmental or Socio -cultural performance. It might be gathering some or all of their components as selections of this indicator as seen in Table 3.

Table 3. IGP Functional Performance [1], [2], [3], [6], [7], [8], [10], [11], [12], [15], [16], [19], [24], [26] [21], [27], [30], [31], [33], [35], [36]

IGP performance		
Indicator		Component
Functional Performance	Environmental	Controlling the light passage
		Controlling the airflow
		Reducing the air temperature

	Increasing the humidity
	Shading
	Thermal insulation.
Socio - Cultural	Privacy
	Openness (exposure)
	Visibility
	Invisibility
	Security
	Insecurity
	Enhance local Identity
	Represent Modernity
	Emphasize Islamic principles
	Deemphasize Islamic principles

4. Material and method

4.1. Selection of samples

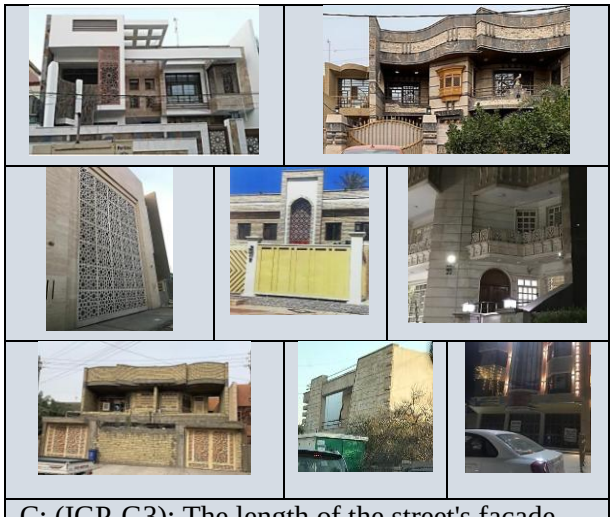
Field visits to various residential areas in Baghdad were conducted as part of the survey. The collections varied between day and night trips at random times, and were accompanied by the adoption of site observations and sample documentation via digital photography. The selection criteria were distinguished by spatiotemporal examples, as the residential samples were two story buildings built recently (after 2010), to cope with the contemporary urban-technological openness around the world. The samples were divided into four groups and reached fifty samples depending on the Baghdad Municipality's classification of residential plots, as shown in Figure 1.

- Group one (IGP-G1): Facades range from 1 to 5 meters in length.
- Group two (IGP-G2): Facades range from 5 to 10 meters in length.
- Group three (IGP-G3): Facades range from 10 to 15 meters in length.
- Group four (IGP-G4): Facades range from 15-20 meters and more in length.

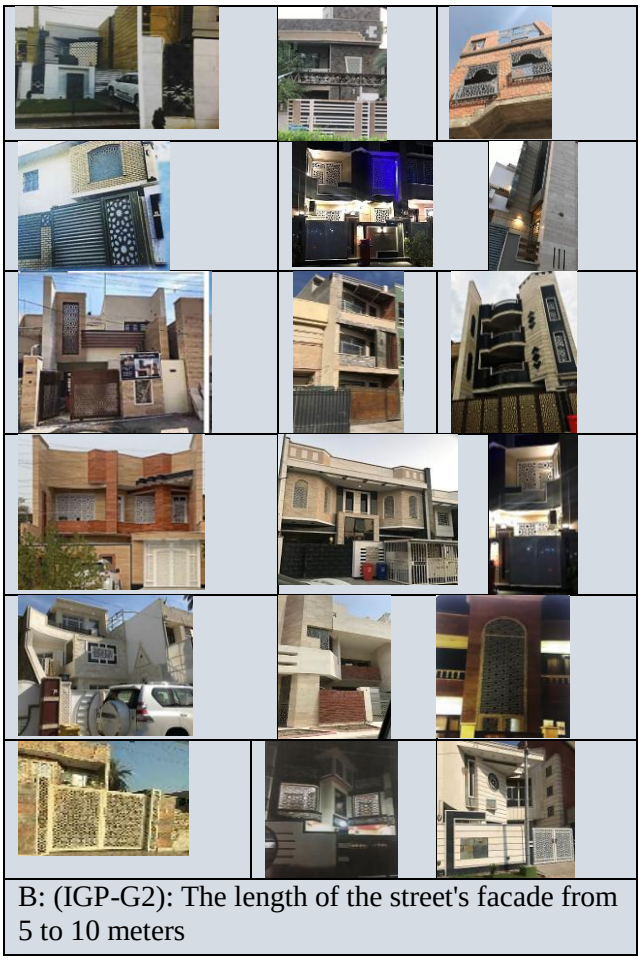
4.2. Samples analysis

According to the foregoing, the elected samples in its four groups (IGP-G1-4) was analyzed within the extracted indicators of the decorative, structural, and functional performance. The measurement process depended on the Likert scale, for its accuracy. The Likert scale, established by psychologist Renes Likert and utilized in the field of statistics, is a tool for evaluating preferences and validation used in many examinations [37]. The scale is based on responses that reflect a subject's degree of verification or non-verification, and it comes in a variety of formats, but the directions of the answer are determined by using an arithmetic average with the weights of (1-2-3-4-5) [38], [39]. The process begins by subtracting the number 1 from five and dividing the remaining space by the whole number (5-1 = 4, 4/5 = 0.8), thus representing the first trend (1-1.79) which is Not clear [37]. The same goes for the others, the second trend (1.8-2.59) which takes Little clear, the third trend (2.6-3.39) which represent Medium clear, the fourth trend (3.4 -4.19) as a Clear indicator, and the fifth trend (4.2 -5) as a Very clear indicator [37], [39], as shown in Table 4.

A: (IGP-G1): The length of the street's facade from 1 to 5 meters



C: (IGP-G3): The length of the street's facade from 10 to 15 meters



B: (IGP-G2): The length of the street's facade from 5 to 10 meters

D: (IGP-G4): The length of the street's facade from 15 to 25 meters

Figure 1. Selection of samples according to the Baghdad Municipality's classification of residential plots

5.1. IGP As a decorative performance

The Likert scale results in Table 4 showed that the majority of the IGP used in the facades was readable (not abstracted) and perceptible for the four housing groups in very close percentage. Additionally, there was a noticeable increase in the reliability of the 2D decorative pattern for all groups. This means, in all groups, the geometric patterns were clear, simple and perceptive in 2D decorative pattern. However, the use of IGP

tended to the traditional style, achieving the highest percentage in the two groups (IGP-G3, G4). As a result, (IGP-G4) is the best group in terms of decorative performance of IGP in total (0.89). Media style did not achieve a real response, so it should be neutralized as an indicator, mostly due to the short length of the elected urban facades, since this style is adopted for public buildings, mixed and recreational use; not for purely residential buildings [22]. This refers to a failure to take advantage of the possibilities offered by modulation methods as a consequence of the implementation of computer programs or three-dimensional simulations [22], [21], [27]. Which are currently utilized to increase aesthetic values [5], [17], [22], [21]. In other words, the standards of aesthetic values were easily achieved within the reliance on modern Islamic patterns, being the result of a tripartite relationship between engineering sciences, aesthetic phenomena and algorithms, and thus further enhancing urban sustainability. All of the decorative performance is depicted in chart1-A.

5.2. IGP As a structural performance

In the process component, of the structural performance, (IGP-G2) samples obtained the highest percentage of verification for CNC, followed by (IGP-G1), then (IGP-G3) and ranked last (IGP-G4). While (IGP-G4) achieved the second highest value after (IGP-G2) in the welding process, its use with IGP came as screens (iron structures meshed with geometric decorative patterns) and security barriers on doors and windows [20], [23]. It was widely applied in (IGP-G4), followed by (IGP-G3). CNC also dominated the (IGP-G2) port with steel on a huge scale and then (IGP-G1) with the lowest value. Recently, this approach has becoming increasingly commonly utilized in the development of interfaces [13]. Chart 1-B is showing the results of IGP as a structural performance. The largest value in IGP implementation with carving was for (IGP-G4) followed by (IGP-G3). Moreover, they achieved similar values for screening process, while (IGP-G1) did not achieve any significant value in Carving and Screening. In the implementation of template compression and 3D laser printing, the four groups did not achieve significant values, so they had to be neutralized [40]. It has been observed that larger width of facade gives better richness. New materials are being adopted (Marble, Aluminum sheets, and Carbon steel sheets), as well as different processes are being used. For the materials, (IGP-G4) achieved the highest value in the use of stone to represent the Islamic geometric patterns on the urban facades of the residential houses that have a relatively large area that allows the application of decorative elements in stone without any distortion [4], [40]. The value of the use of stone decreased by decreasing the width of the facade, successively. Wood as a sustainable material was not used extensively, and the small value representing the IGP of facades was limited to (IGP-G4) and in a manner similar to traditional with some contemporary [2], [15], followed by (IGP-G3) with a small value and then (IGP -G2), and it did not appear in (IGP-G1). See Chart1-B. For the usage of glass and plastic materials, none of the four groups achieved significant results, therefore they should all be neutralized. Aluminum, gypsum, clay, metal, and ceramic tiles were utilized rarely in (IGP-G4).

Table 4. Checklist evaluation of the residential examples by Likert scale

Indicator		Components	(IGP-G1)	(IGP-G2)	(IGP-G3)	(IGP-G4)	Summation	
Decorative Performance	Aesthetics	Abstracted	0.56	0.46	0.46	0.48	1.97	
		Readable (nonabstract)	1.29	1.42	1.34	1.40	5.44	
		Formal	0.94	1.23	1.11	1.08	4.37	
		Informal	0.56	0.54	0.62	0.71	2.43	
		Perceptible	1.31	1.37	1.40	1.32	5.40	
		Imperceptible	0.59	0.54	0.46	0.56	2.14	
	Style	Media style	0.46	0.46	0.46	0.46	1.85	
		Traditional style	0.65	0.58	0.87	0.92	3.02	
		2D decorative pattern	1.46	1.43	1.46	1.42	5.77	
		3D decorative pattern	0.46	0.48	0.46	0.54	1.94	3.36

			0.83	0.85	0.87	0.89	3.44	
	Process	Template compression	0.46	0.46	0.46	0.46	1.85	
		Welding	1.06	1.30	0.99	1.17	4.52	
		Carving	0.46	0.46	0.59	0.75	2.26	
		Screening	0.46	0.52	0.68	0.71	2.37	
		CNC	1.26	1.43	0.96	0.69	4.34	
		3d laser printing	0.46	0.46	0.46	0.46	1.85	2.87
Structural Performance	Materials	Brick	0.49	0.46	0.46	0.54	1.96	
		Stone	0.71	0.52	0.77	1.04	3.04	
		Wood	0.46	0.49	0.59	0.77	2.31	
		Glazed tiles	0.46	0.60	0.59	0.46	2.12	
		Steel	1.18	1.21	1.02	1.15	4.57	
		Glass	0.46	0.46	0.46	0.46	1.85	
		Plastic	0.46	0.46	0.46	0.46	1.85	
		Aluminum, clay, metal, ceramics	0.46	0.46	0.46	0.43	1.82	
		Others	0.46	0.55	0.65	0.88	2.54	2.45
			0.62	0.66	0.64	0.70	2.62	
	Environmental	Controlling the light passage	0.46	0.46	0.59	0.60	2.11	
		Controlling the airflow	0.46	0.46	0.59	0.62	2.13	
		Reducing the air temperature	0.46	0.46	0.46	0.46	1.85	
		Increasing the humidity	0.46	0.46	0.46	0.46	1.85	
		Shading	0.77	0.93	0.90	0.76	3.36	
		Thermal insulation.	0.51	0.56	0.93	0.92	2.93	2.37
			0.52	0.56	0.66	0.64		
Functional Performance	Socio - Cultural	Privacy	0.97	1.14	1.21	1.08	4.39	
		Openness (exposure)	0.79	0.88	0.78	0.85	3.29	
		Visibility	0.91	0.74	0.72	0.68	3.05	
		Invisibility	0.94	1.10	1.18	1.25	4.47	
		Security	1.06	1.17	1.24	1.06	4.52	
		Insecurity	0.84	0.72	0.63	0.66	2.85	
		Enhance local Identity	0.99	1.18	1.09	1.08	4.33	
		Represent Modernity	1.13	1.11	1.03	1.14	4.41	
		Emphasize Islamic principles	0.82	1.09	1.06	0.99	3.95	
		Deemphasize Islamic principles	0.46	0.46	0.46	0.46	1.85	3.71
		`	0.74	0.79	0.82	0.81	3.71	

5.3. IGP As a functional performance

On the functional performance indicator, chart 1-C shows its environmental performance fluctuations and unclarity of (2.37). In terms of shading, the most satisfactory performance of the IGP in (IGP-G2) within average values of (0.93) for its integrated structural and day lighting performance of a shading screen based on Islamic geometric patterns [8] . This is due to the effectiveness of the IGP applied by the CNC method in abundance in this group, which provides wide shading sustainable areas [13]. Followed by (IGP-G3) then (IGP-G1) with low convergent values. For the same reason (IGP-G2) considered Readable (nonabstract) decorative pattern as noted in Table 4. Thermal insulation achieved average values within minimum performance limits for (G4IGP-G3), within close values due to the properties of the material used to cover the facades of these models, such as stone and marble, which is a good thermal insulator [1], [41]. However, the performance of IGP facades for (controlling the light passage, Increasing the humidity, reducing the air

temperature, and Controlling the airflow) is weak and unclear and within close low values. The preference was for the two large groups (IGP-G3,G4), where they were used contemporary wooden with its traditional performance that contains wooden moving pieces open and close manually to allow the possibility of controlling the amount of incoming solar radiation and air movement [1], [12].

For the socio–cultural components, (IGP-G3, G4) achieved the highest performance value within the (0.81-0.82).This is due to the use of wooden screens in Arab homes, which, in addition to allowing the movement of the cool breezes, has the ability to preserve cultural peculiarities while using them in contemporary style and materials [8], [13], [31], [34]. IGP's use of all four groups represented contemporary and non-traditional forms that enhance the originality of the urban facade of the cityscape. They percentage of Enhance local identity facades and Represent Modernity components are relatively high. Therefore, it preserves cultural specificities within a modern and contemporary style that reflects the Islamic civilizational heritage [40].Deemphasize Islamic principles component of the four groups did not achieve significant values, so they should be neutralized. (IGP-G3) achieved the highest performance value, followed by (IGP-G2) in terms of privacy. Openness has the highest performance within average values of (IGP-G2), followed by (IGP-G4) with close performance, and then (IGP-G1, G3) with lower performance and close values. Invisibility was the highest performance value for (IGP-G4) as a result of using wooden that contain IGP, followed by (IGP-G3) for the same reasons. As for Visibility component, it was achieved by (IGP-G1) as a result of the small length of the facades which needed for the environmental openness within average performance values, followed by the rest of the groups. Security component is the use of geometric patterns in the form of protection screens placed on windows and external doors. (IGP-G3) achieved the highest performance value, followed by (IGP-G2) and then (IGP-G1, G4). In contrast, Insecurity came to achieve (IGP-G1) the highest performance within medium values, followed by (IGP-G2) and then (IGP-G3, 4) for relatively few and close performance; The smallness of the interfaces in (IGP-G1, G2) need to achieve more openness to the outside so that they do not give a feeling of closure, in addition to environmentally stimulating to provide the possibility of increasing the views [1], [23].

5.4. General discussion

Predominantly, the IGP is mostly used as a decorative element in the local environment, as it received the highest response rate of (3.44) for all groups of residential facades. As a result, it is classified as a Clear indicator on the Likert scale. The functional performance, which received a Medium clear with a percentage of (3.21), was followed by the pattern of G4 -large facades. Following that was the functional performance, which received a Medium clear scale with a percentage of (3.21), particularly in the pattern of the G4 large facades. The findings revealed that IGP is used as a security treatment, with a percentage of (4.52), invisibility (4.47), and privacy (4.39), indicating the reflection of the traditional habits on the IGP function in the Arabic world. As for the environmental component, it is relatively little clear indicator and has a low percentage of significance (2.3). As a result of the lack of suitable spaces between the panels and the windows, on which Islamic engineering patterns have been applied, there is an environmental defect that prevents air movement, which aids in climate mitigation. In fact, it was not managed for this purpose by residents or craftsmen except in the two large facade groups (G4-3), where the facades of some residential houses belonging to these models were covered with stone, which serves as a good thermal insulator and provides a higher percentage of shading than other materials.

According to the Likert scale in evaluating the applying and reviving the IGP in the facades of the dwellings, the decorative performance achieved a significant rate in the research samples related to the residents' choices, as shown in Table 4. In a similar way to the decorative aspect, the socio-cultural revival of Islamic styles achieved long-term functional performance. Because it adhered to Islamic principles and traditions of security, invisibility and privacy. As a result, the urban facades are both aesthetically and socio-cultural functionally sustainable, as they have achieved communication and interdependence with the urban heritage of Islamic civilization. On the other hand, a weakness in the IGP's environmental functional performance has been

identified as a result of the lack of proper pattern use and application in urban facades. This is understandable given the lack of passive design techniques and details and the absence of adequate intelligence technologies such as environmental responsive designs and sensitive screens.

Although structural performance received the lowest percentage (2.62) of all the types of performance, it is still within the acceptable Likert scale, Medium clear. The declining value is due to a lack of understanding of the IGP's technological significance and architectural potential. Also, because there are few specialists in this field, the craftsmen rely on traditional methods of building facades, or on experience, discovery, craftsmanship, and practice rather than specialized training. By relying on traditional practices, the entire concept of the façade design could take into account cultural identity. Furthermore, for the large facades G-34, the predominant manufacturing method is the welding process, while for the smaller facades G1-2, the CNC process is used. Steel has become the most popular choice among homeowners because it is the least expensive While IGP's technology is confined to machines, the use of CNC technology is beneficial since it allowed the designs to be revived and re-used in the local facades, especially in the steel material. Nevertheless, it negatively affected the decrease in the number of skilled craftsmen, in which the craft of making wood screens, Mashrabiya, and marble disappeared and the cost of their manufacture increased. Therefore, there is a need to replace iron and steel with more sustainable materials such as wood and stone, and preserving the CNC technology. This is recommended in hot, arid climates to allow for the control of air flow and the reduction of heat gained from solar radiation. However, despite the simplicity of implementation and its focus on craftsmanship rather than technology, Islamic engineering patterns have partially achieved urban sustainability in some performance aspects. This might record a new style of urban facade design has emerged in Baghdad, one that can be further developed to attain a better sustainable local urban scene.

5. Conclusions

The use of Islamic geometric patterns (IGP) in urban facades interprets a major role in focusing on Islamic principles that have been behind the formation of a distinctive identity and unified sustainable architecture through time. Therefore, the research started from the possibility of activating the role of the IGP as a design force in a decorative, structural and functional control system. In which, patterns and their performance are subject to a societal dialogue for a more significant sustainable urban scene. The idea seeks to extrapolate the best use of Islamic geometric patterns, by revealing the strengths and defects in the current performance of the patterns in the urban facade of the city of Baghdad and trying to develop them. It was based on extracting the indicators of each of the three aspects of performance within an integrative theoretical framework that explains the importance and capabilities of each indicator. The extracted (42) components of indicators were applied on four housing groups in the city of Baghdad, categorized on the basis of the widths of the facades in each of them.

The formal results of the urban facades of the decorative performance index were achieved by designing facades that simulate simplicity and clarity in the two-dimensionality within Islamic motifs measured by practice and experiment without study. It was also discovered that the modulation techniques arising from the utilization of digital programs or three-dimensional forms were deactivated. In addition, the structural aspect is not clear. Steel is the most common used material, which is welded or CNC-cut, whereas natural materials such as stone and wood are on the decline. As for the functional aspect, it was confined to the traditional social aspect in terms of safety, privacy and invisibility in the first place, and rarely was thought about the climatic aspect. As a result, it is necessary to raise the level of environmental performance of Islamic geometrical patterns on the facades of Iraqi city buildings by adopting a passive design approach based on the use of sustainable materials such as wood and stone, rather than steel or iron, which are unsuitable for the Iraqi climate. Industrial intelligence technologies must also be used to create responsive facades that react to the surrounding environment, increasing comfort levels and reducing energy consumption. In addition, shading systems that combine responsive Islamic geometric patterns to many software tasks should be studied and developed.

It is worth noting that the research is limited to the revival of the IGP as a decorative, structural and functional performance, which has shown that sustainability is partially achieved within these levels, without addressing the rest of the performance indicators such as contemporary technological, economic, design and other performance indicators in its sustainable aspect. Therefore, the research recommends addressing other levels of performance in future research related to this, to diagnose the imbalance in those levels and to attain the comprehensiveness of urban sustainability and its integrity.

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