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Performance of Traditional Iraqi Courtyard Houses: Exploring Morphology Patterns of Courtyard Spaces

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Abstract

The multiplicity of the courtyard form types of the traditional Iraqi house hindered a model formulation that can explain its morphology characteristics. Exploring these characteristics could improve architectural design knowledge. This paper investigated the geometry and positioning of the built-up massing surrounding the courtyard to understand their effect on the formation of the covered and open outdoor spaces. Accordingly, it established a new understanding of the courtyard spatial characteristics and designed a model that simulated the possible courtyard forms. The model simulates 149 courtyard patterns and depicts diagrammatic ground and first floor plans for houses containing these courtyards. Borrowing the extracted courtyard forms could improve the building's functional performance in contemporary architectural design. In subsequent studies, the evaluation of the environmental efficiency of the Iraqi traditional courtyard houses should not be limited to the model with a courtyard surrounded from all sides by walls of equal height. The evaluation may be conducted to the extracted types in the paper simulation model, as they are more representative of reality.

Disciplinary: Architecture Science & Engineering.

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1 Introduction

The objective of this paper is to explore courtyard (Cy) form spatial characteristics and patterns of Traditional Iraqi House (TIH), despite the lack of documentation that describes the built environment of Iraqi cities, which led to an ambiguous and foggy perception of its characteristics (Alsultani 2014). This paper supports Warren's and Fethi (1982) conclusion, about 30 years before,

that TIH had not been analyzed or documented scientifically. Much of the TIH essential orders and features have not been explored yet; the Cy morphology is one of these features. This paper studied the available documented architectural drawings and photos of local traditional houses. A better understanding of the Cy form may improve architectural design decisions concerning the interaction between indoor and outdoor spaces. Sthapak (2014) showed that, historically, the Cy style has been most popular in residential architecture in all climatic regions. Özkan (2006) clarified that Cy planning remains a considerable design tool for architects and designers to link the present with history in consecutive continuity. Auda (1988, p125), Wazeri (2013), and El Harrouni (2015) believed that Cy form plays a positive role in the house thermal performance. This paper is complementary to previous researches, which studied two building orders of the TIH concerned with the building materials in the external envelope (Ishik University 2018) and building orientation (Ishik University 2019).

2 Literature Review

Frequently, the current literature supports the notion that Cy aspect ratio alone can describe Cy form of the TIH. This perception implies that the Cy is an unroofed room in the house, which is nothing but a particular case that is less frequent in reality. Vedhajanani and Lilly (2016) adopted that understanding when they clearly defined a Cy as an opening inside the building. Jaim (n.d.) also described Cy as a room without a roof, and Abbas et al. (2016) considered it similar all over the world but with varied attributes. Through the Cy evaluating of the environmental and functional performance, Evans (1980), Al-Zarkani (2017), Al-Jameel and Hassan (2012), and Kareem (2012) had not clarified their perception of its form, which may imply the definition of an unroofed room. On the contrary, the Cy form of the TIH is of varying geometries that influence its spatial, environmental, and visual characteristics significantly. Fouda (2014) asserted that controlling the physical character of the built-up masses and the distances between them in the urban space would positively direct the urban form to a livable and sustainable entity.

Murad (2015) and Auda (1988, p16-19) defined Cy more precisely as an outdoor space surrounded from all or some sides by arcades that encircled by the house spaces or walls. Still, this perception of Cy form is not clear enough. This paper investigated the characteristics of the Cy form of the TIH that ensure its functional, environmental, aesthetics, and visual goals.

3 Method

Through the study of the TIH's designs, this paper found that they often contain, in addition to the Cy space, covered or open outdoor areas adjacent and connected to the Cy on the ground and first floor. These outdoor areas are not independent but rather constitute an extension to the Cy space. They participate in performing the spatial, environmental, visual, and aesthetic functions. Therefore this paper studied the spatial characteristics of the Cy form and those outdoor spaces as integrated into one.

The methodology constitutes the following three aspects: A description of the existing Cy structure, the Cy morphology analysis, and the Cy simulation model.

3.1 A Description of Courtyard Structure

This paper diagnosed three features that interact with each other to determine the Cy structure characteristics. They are shape and dimensions at ground level, the distribution pattern of the built-up masses surrounding the Cy, and the geometrical properties of these built-up masses.

3.1.1 Courtyard Shape and Dimensions at Ground Level

On the ground level, Cy is nearly a square to ensure a livable outdoor space and the climatic needs of the residents (Warren and Fethi 1982. P48). Courtyards may sometimes take other forms when the number of their sides is more than four. Cys of equal areas usually has different shapes due to the differences in their sides dimensions and or angles between them. These differences in shape and proportions most often follow the irregularity of the land plot. The Cy floor area of the TIH differs dramatically. It may range from less than 10 m^2 to more than 200 m^2 (see photos 5 and 10 in Figure 5). In a survey in Al-Kadimiya (Auda 1988, p18), Cys of 10-20 m^2 reached 40% of the total number, while those of 21-40 m^2 amounted to 32 %. 28% of Cys was of smaller or larger floor areas. Walls surrounding the Cys of almost 8 meters in height resulted in a vertical aspect ratio ranging from 0.2 up to 3.4 or sometimes even more. Hence, the paper concludes that there is no specific prevailing aspect ratio of Cys.

3.1.2 Distribution Pattern of Built-Up Masses Surrounding Courtyard

"Built-up masses" include the habitable indoor spaces (rooms) of the house, sheds (arcades), and walls surrounding the Cy. Built-up masses may occupy one or more sides of the Cy. The diagrammatic arrangement of built-up massing around Cy in Figure 1 shows that each side of the Cy may contain one or more of these built-up masses of a similar or different type. When a quadrilateral Cy includes a single built-up mass on every side, their number will be eight on each floor, as in case 1 of Figure 1. When each side of the Cy contains two or three of these built-up masses, their number will be 12 and 16, respectively, as in cases 2 and 3 of Figure 1. The Built-up masses' numbers may differ on the Cy sides, as in case 4 of Figure 1.

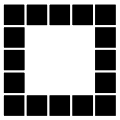
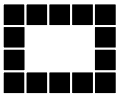
Case number	1	2	3	4
Number of built-up masses on each side of the courtyard	1	2	3	2 and 3
Configuration				

Figure 1: Configuration of different number of built-up masses surrounding the courtyard

Below is a description of the occupation pattern of these three built-up masses.

3.1.2.1 Occupation Pattern of Inhabitable Indoor Spaces

This paragraph studies the number of Cy sides that contain inhabitable indoor spaces. Pole Service (1977) reported that the Cys used in most urban areas of Iraq have the style in which the inhabitable indoor spaces occupy two or more sides. To specify that more precisely, the paper depended on two surveys conducted in Baghdad and Erbil as follows:

In a part of the Al-Kadhimiya area (in Baghdad) of one hundred and thirty traditional houses, Cys surrounded by habitable indoor spaces from two or three sides count 86%, while those surrounded from four sides constitute only 14% (Auda 1988, p19). In another survey of one hundred traditional houses in Erbil citadel (Ishik University 2019), Cys surrounded by habitable indoor spaces from two or three sides count 79%, while those surrounded from four sides constitute only 4%. A staircase, toilet, and or store usually occupy one of Cy's sides. Figure 2 illustrates the distribution details of the two surveys.

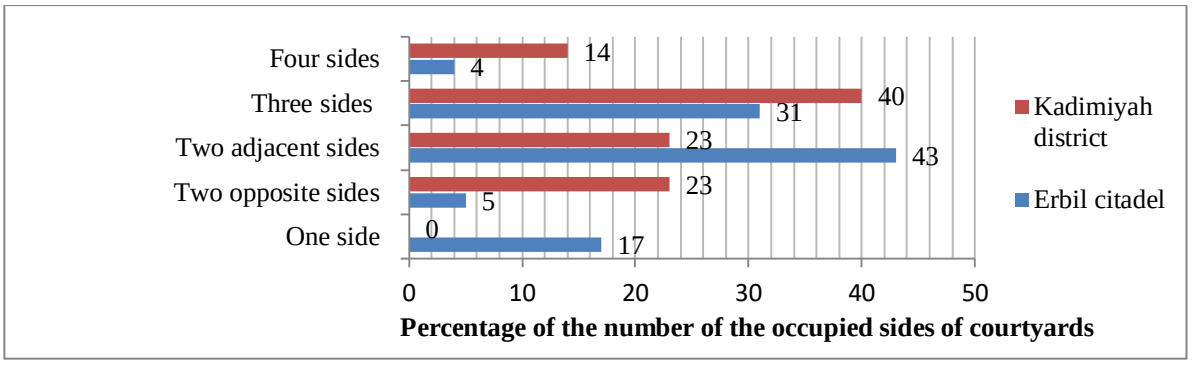
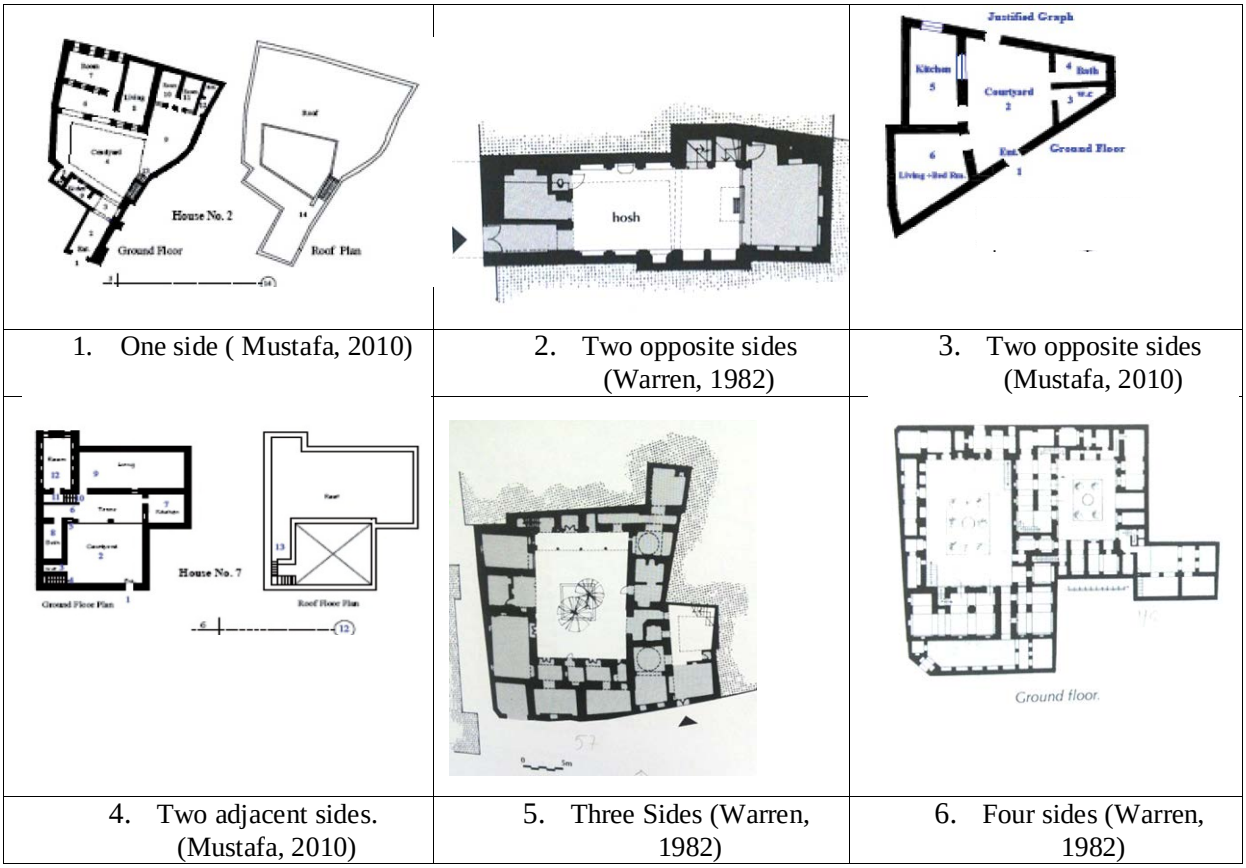


Figure 1: Configuration of different number of built-up masses surrounding the courtyard

The two surveys coincide with Yousuf (1975), Al-Dioachi (1975), and Al-Jameel (2012) opinions that the prevailing types of Cys are those surrounded by habitable indoor spaces from 1 to 3 sides, while those surrounded from four sides are of a limited percentage relatively. This reality refutes a current thought that the habitable indoor spaces surround the Cys from all its sides. In square land plots equal to or less than 100 m^2, the inhabitable indoor spaces may surround the Cy from one or two adjacent sides (Yousuf 1975; Al-Dioachi 1975) as in drawings 1 and 4 of Figure 3. If the land plot shape is suitably elongated, the habitable indoor spaces may occupy two opposite sides in the Cy (Warren and Fethi 1982) as in drawings 2 and 3 of Figure 3. In medium-size land plots of approximately 100 m^2 up to 150 m^2, indoor spaces may surround Cys from one, two, or three sides. In square land plots of more than 200 m^2, they may occupy four sides of the Cy's or fewer, as in drawings 5 and 6 of Figure 3. That is consistent with what Yousuf (1975) clarified that small or medium-sized Cys are often surrounded by indoor spaces from one, two, or sometimes three sides depending on their area and shape. Each Cy's side, equal to or less than 5 m in length, often contains one habitable indoor space, whereas longer sides usually have two or more.



1. One side (Mustafa, 2010)
2. Two opposite sides (Warren, 1982)
3. Two opposite sides (Mustafa, 2010)
4. Two adjacent sides. (Mustafa, 2010)
5. Three Sides (Warren, 1982)
6. Four sides (Warren, 1982)

Figure 3: Samples of the traditional Iraqi houses of different number of side occupation

3.1.2.2 Patterns of Covered and Open Outdoor Spaces

Covered outdoor spaces, such as arcades of single or double volume, are transitional spaces surrounding Cy from one or more sides on the ground and first floors. They perform as terraces on the first floor (Warren and Fethi 1982) and influence the indoor and outdoor environments (Choul & Jun 2016). These covered outdoor spaces are adjacent to the rooms or land plot boundary with the supporting columns or walls on the Cy sides. Narrow Cys may be naked of these spaces on its long sides. In addition to their living function, the outdoor open spaces on the first floor allow the sun to penetrate to lower levels. The covered outdoor spaces connect rooms on the first floor. Besides, they provide spatial and environmental diversity, expand the visual field of the Cy, and enrich the house aesthetics.

3.1.2.3 Walls Surrounding Courtyard on Land-Plot Boundaries

When any side of the Cy does not contain an indoor space or a shed, walls of two stories in height will occupy these sides. Stair and services as a toilet, bathroom, and kitchen usually occupy adjacent areas to these walls.

3.1.3 Geometrical Properties of the Built-up Masses

This paragraph analyzes the geometry and positioning of the built-up massing surrounding the Cy. The paper identified seven types of built-up massing labeled from (**A**) to (**G**), as explicated below. The diagrammatic drawings in Figure 4 depict these geometries. Photos in Figure 5 show similar existing cases.

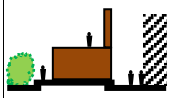
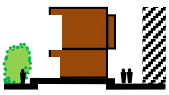
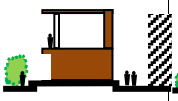
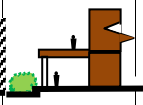
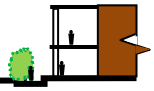
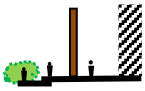
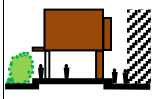
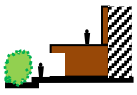
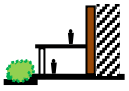
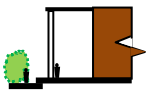
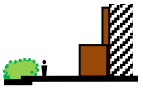
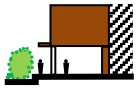
Built-up mass	A room on the ground floor	Rooms on two floors	A room and a shed above	A shed on the ground floor	Two sheds on two floors, or a two-storey shed (Ewan)	A two-storey wall with or without service rooms in front	A room on the 1st floor with an outdoor space under
Overlooking the alley and courtyard							
Overlooking the courtyard							
Name	**A**	**B**	**C**	**D**	**E**	**F**	**G**

Figure 4: Basic built-up masses surrounding the courtyard.

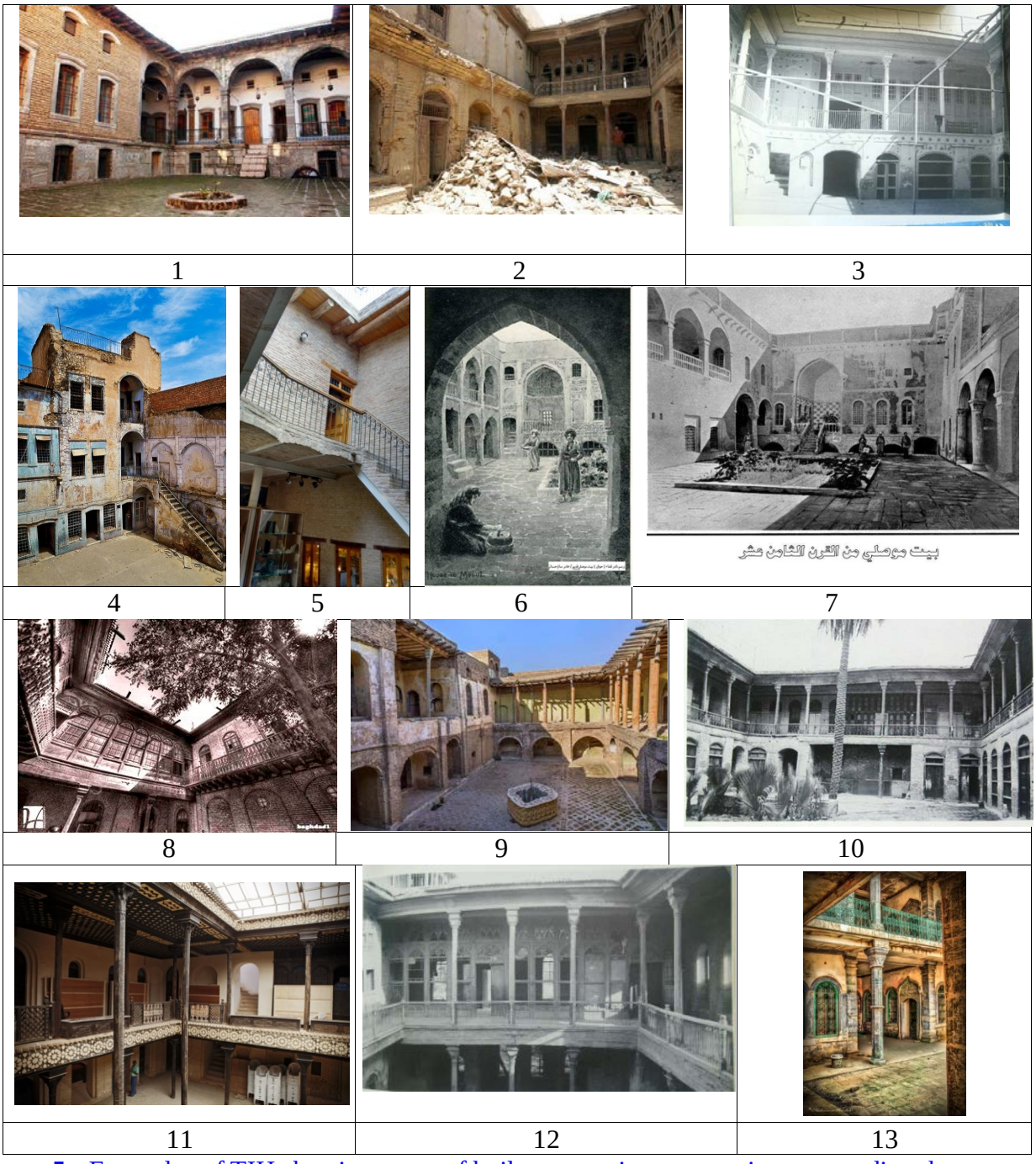


Figure 5: Examples of TIH showing types of built-up massing geometries surrounding the courtyard

A- An indoor habitable space (room) on the ground floor with an accessible roof as in photo 1.

B- Indoor habitable spaces on two-floor with an accessible roof, as in photos 2, 7, 8, and 9.

C- An indoor habitable space on the ground floor shaded by an accessible roof on the first floor as in photos 3, 7, and 10.

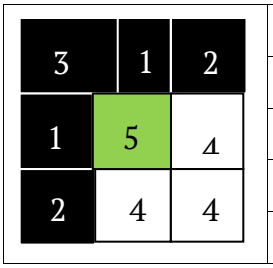
D- An outdoor space on the ground floor shaded by an accessible roof supported by columns or walls with openings on the side of the Cy, as in photo 1.

E- An outdoor space similar to (**D**) but shaded with a roof, as in photos 2, 6, 9, and 10. Sometimes, the shed is of double volume height, as in photos 6 and 7.

F- A two-story wall surrounds the Cy and lays on the land plot boundary as in photos 4 and 5. stairs or services often occupy an area adjacent to the wall.

G- An indoor habitable space on the first floor above an outdoor area on the ground floor, as in photos 5, 7, and 8.

All the habitable rooms in the studied samples overlook the Cy directly or indirectly. Photos 2, 3, and 4 of Figure 5 show the direct connection. Photos 1, 7, and 9 show the indirect connection through the covered outdoor spaces. These two types were diagrammatically represented in Figure 6 and labeled with the numbers 1 and 2, respectively. Some TIH contains a single habitable space on the land plot corner, adjacent to similar rooms from two sides. One side of this corner space extends to overlook the Cy directly, as shown in room number 3 in Figure 6.



1	Built-up mass directly overlooking Cy
2	Corner built-up mass indirectly overlooking Cy through covered outdoor space
3	Corner built-up mass partially overlooking Cy through the extension on an adjacent built-up mass
4	Covered or open outdoor space
5	Courtyard

Figure 6: The scheme of built-up massing interacting with the Cy

The used cases of the habitable rooms that occupy only one corner of the land plot in the TIH were shown in cells 1, 3, 4, and 7, in the first row of Figure 7. The second row shows the unimplemented cases where the number of habitable corner rooms exceeds a single one.

This paper adopted these attributes, which prevail over the studied drawings.

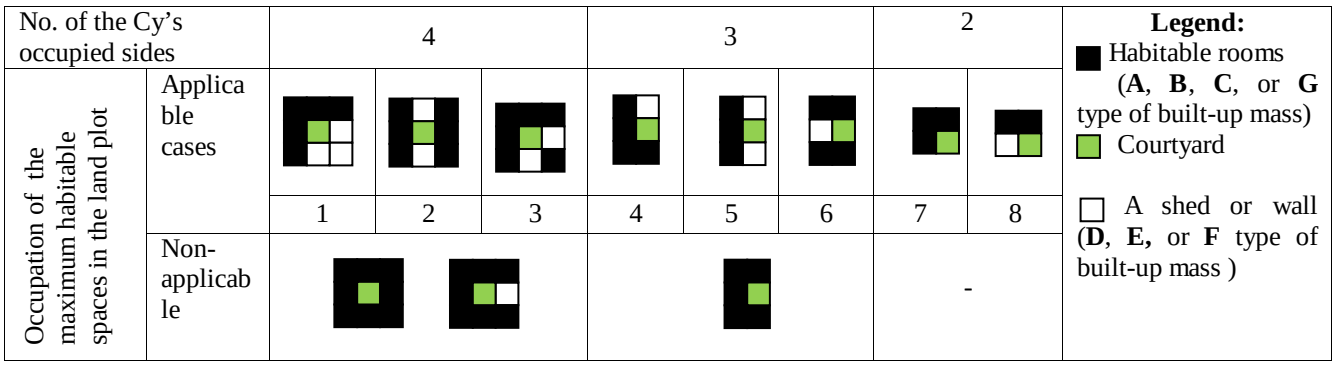


Figure 7: The employed occupation of habitable rooms in respect to the courtyard sides

3.2 Courtyard Morphology Analysis

This paragraph analyzes the Cy form and structure characteristics through the geometry and positioning of the built-up massing surrounding the Cy.

3.2.1 Cy Form

The Cy form expresses the following spatial characteristics:

1. the quantity and pattern of openness towards the sky,
2. the vision extension through the adjacent outdoor spaces,
3. the Cy facades diversity.

Besides, Cy form shares the passive systems by controlling the environmental performance of the house. The exposure extent of Cy to the sky is associated with the opened areas in the roof slabs on the first and second floor and the relative locations of these openings. These two openings, in most cases, do not coincide with the shape and dimensions of the CY determined by the walls on the ground floor, as shown in photo 11 of Figure 5.

The vision extension occurs when the Cy surrounding sheds and arcades allow the view to continue towards the adjacent spaces on both floors, as in photos 2, 5, 6, 9, and 13 of Figure 5. These outdoor spaces provide spaciousness, especially in narrow Cys, and they together form an integrated unity.

The variety in the facades overlooking the Cy is due to the multiple types and locations of built-up massing, as in photo 9 of Figure 5.

3.2.2 Scheme of the Built-Up Massing Occupation

As a result of the study in chapter 3.1, this paper identified the scheme of the occupation of the seven types of built-up massing surrounding the Cys of a single built-up mass on each side. The sides occupation varied according to the built-up massing type, as follows:

1. Any one of the built-up masses (A) and (B) may exist in one or more sides of the Cy. Thus, any group of the masses (C, D, E, F) may occupy three sides as a maximum.
2. Any one of the built-up masses (**C**, **D**, **E**, and **F**) could occupy one, two, or three sides of the Cy as a maximum, or none of the sides. The masses (**D** and **E**) may occupy an area next to the indoor spaces or boundaries of the land plot.
3. The built-up mass (**G**) might occupy one or two sides of the Cy as a maximum or no side at all. The reason for the occupation limitations is to override the inconsistency with the performance function of housing. Examples of these inconsistencies are: the hanging room (**G**) occupies three or four sides of the Cy, the wall (**F**), and the shades (**D**, **E**) surround the Cy from all its sides. Table 1 summarizes the occupation scheme.

Table 1: Occupation scheme of the built-up masses surrounding the courtyard.

Built-up massing designation		A	B	C	D	E	F	G
No. of built-up massing occupying the four sides of courtyard sides	Min	1	1	0	0	0	0	0
	Max	4	4	3	3	3	3	2

3.3 Simulation Model of a Courtyard

This paper designed a model simulating the Cy form patterns of the TIH to develop a clear perception. The model assumed that the shape and dimensions of the Cy are constant, and thus the simulation will be limited to the types and locations of the built-up massing surrounding the Cy. The model also assumed that the Cy in the plan is a square shape. Each side contains one of the seven built-up masses defined in chapter 3.2. Therefore, the maximum number of built-up massing in the land plot is eight, as shown in Figure 1, case 1. The reason for this assumption is to simplify Cy forms extraction by choosing the simplest case of formation probabilities. Small land plots constitute the most prevailing ones in the traditional fabric, as explicated in section (3.1.1). The model complied with the restrictions in Table 1 regarding the occupation of the built-up masses types surrounding the Cy. The exception is the repetition of the two built-up masses (**F** and **G**) that changed to 2 and 1 instead of 3 and 2. The reason for that change is that in Cys that contain a single built-up mass on every side, the researcher detected no case in which the number of built-up massing (**F** and **G**) exceeds two or one, respectively. As a result, the adopted occupation scheme in the model is according to Table 2.

Table 2 Constraints of the built-up masses occupation on the courtyard's sides

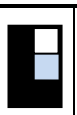
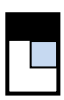
Built-up massing designation		**A**	**B**	**C**	**D**	**E**	**F**	**G**
No. of Built-up massing occupying the four sides of the courtyard	Min.	1	0	0	0	0	0	0
	Max.	4	3	3	3	3	2	1

All the habitable rooms in the simulation model, similar to the studied samples, overlook the Cy directly or indirectly.

The model, in Figure 8, shows the diagrammatic ground floor-plan probabilities when the number of Cy sides occupied by built-up massing is two, three, or four. It is worth noting that the model excluded the cases in which built-up massing occupy only one side of the Cy. Those cases exist when the Cy side contains more than a single built-up mass. Next to the ground-floor diagrammatic plans, in the model, are the possible patterns of the first-floor plans. Some of the first floor plans are similar to those of the ground floor. Each first-floor plan conforms with all the ground-floor ones and creates together particular cases. Therefore, multiplying the number of ground floor plan patterns by the first-floor ones resulted in the total of Cy patterns number.

The model excluded some inconsistent cases, which will be specified hereafter.

Occupation type	Ground floor patterns				First floor patterns							Excluded patterns due to	
												Repetition	Hanging rooms > one
1.Two adjacent sides			-	-	1	2	3	4	5	6	7	1.7-1.9 =3	-

							-			
	1	2			8	9	-			
	Net number of patterns =2*9–3=15.									-
2. Two opposite sides			-	-								1.7-1.9, 2.4-2.6, 2.9 =7	-
					1	2	3	4	5	6	7		
							-						
	1	2			8	9	-						
	Net number of patterns=2*9–7=11												-
3. Three sides												1.16-1.22 =7	3.1-3.4, 3.6-3.7, 3.9, 3.16-3.21, 4.5 =14
					1	2	3	4	5	6	7		
													
					8	9	10	11	12	13	14		
													
					15	16	17	18	19	20	21		
													
	1	2	3	4	22	-							
	Net number of patterns= 4*22–7–14= 67.												-
4. Four sides												1.3, 1.7, 1.11-1.12, 1.15-1.16, 1.19-1.20, 1.23-1.24, 1.27-1.28, 1.31-1.32, 1.35-1.36, 1.39-1.40, 1.43-1.44, 1.48-1.49, 1.54-1.55, 1.58-1.59 = 27. : 2.27, 2.34, 2.44, 2.48-2.49, 2.54-2.55, 258-259 = 15.	1.5-1.6, 1.8, 1.45, 1.47-1.48, 1.51 = 7. 2.1-2.8, 2.10-2.13, 2.15-2.19, 2.22-2.25, 2.28-2.30, 2.35-2.36, 2.38-2.39,
					1	2	3	4	5	6	7		
					8	9	10	11	12	13	14		
					15	16	17	18	19	20	21		
					22	23	24	25	26	27	28		
					29	30	31	32	33	34	35		
					36	37	38	39	40	41	42		

												3.49,3.53, 3.55, 3.59 = 4. : .	2.41,243 = 30. 3.1-3.25, 3.27-3.30, 3.34-3.36, 3.38-3.41, 3.43-3.44 = 38.
					43	44	45	46	47	48	49		
					50	51	52	53	54	55	56		
								-					
	1	2	3	-	57	58	59	-				46	75
	Net number of patterns= 3*59 – 46 – 75= 56											-	
Total patterns number=15+11+67+56= 149												-	

Figure 8: The courtyard simulation model of the traditional Iraqi house

The paper followed a three-cell numbering to name floor plans. The first cell indicates the occupation type of Cy sides. That cell contains one of the symbols (**L, Ⅱ, C, and** □) that expresses the occupation of two adjacent or opposite sides, three sides, or four, respectively. The second and third cells contain the numerals of ground and first-floor plans according to the numbering in Figure 8. For example, (**C**3.7) indicates that the Cy is of type surrounded by built-up massing on three sides on the ground floor and that the ground and first floor-plans numbers are 3 and 7.

The model excluded floor-plan patterns with more than one hanging room that does not comply with the model restrictions. The last column of Figure 8 shows the number of these patterns highlighted in green. Their numbers are 14 and 75 in the Cys occupied by three and four sides, respectively. The model demonstrates and excludes, also, identical floor plans of different directions, as they are considered recurring. The column before the last of Figure 8 shows the number of these floor plan patterns highlighted in green. They count 3, 7, 7, and 46 in the Cys occupied on two adjacents, two opposite, three, and four sides, respectively. The model subtracted the sum of the excluded cases from the total number of floor-plan patterns for the four types. Therefore, the sum of the Cy form patterns is 149, which is more than twice the number of the studied samples.

4 Result and Discussion

This paper extracted 149 different configurations for the Cy form, expressed by two diagrammatic ground floor and first plans, as in Figure 8. Figure 9 shows sixteen diagrammatic cross-section views depicting samples of the extracted Cy forms.

The outdoor spaces in the cross-sectional views are light blue in colour. These 16 cross-sections are in a sequence according to the number of outdoor spaces connected to the Cy. The cross-sections 1-4 contain one outdoor space connected to the Cy, cross-sections 4-12: two outdoor spaces, cross-sections 13-15: three outdoor spaces. Cross-section 16 is of a Cy form that does not connect with outdoor spaces. That type of Cy is erroneously sometimes referred to in the current literature as expressing the Cy form of the TIH.

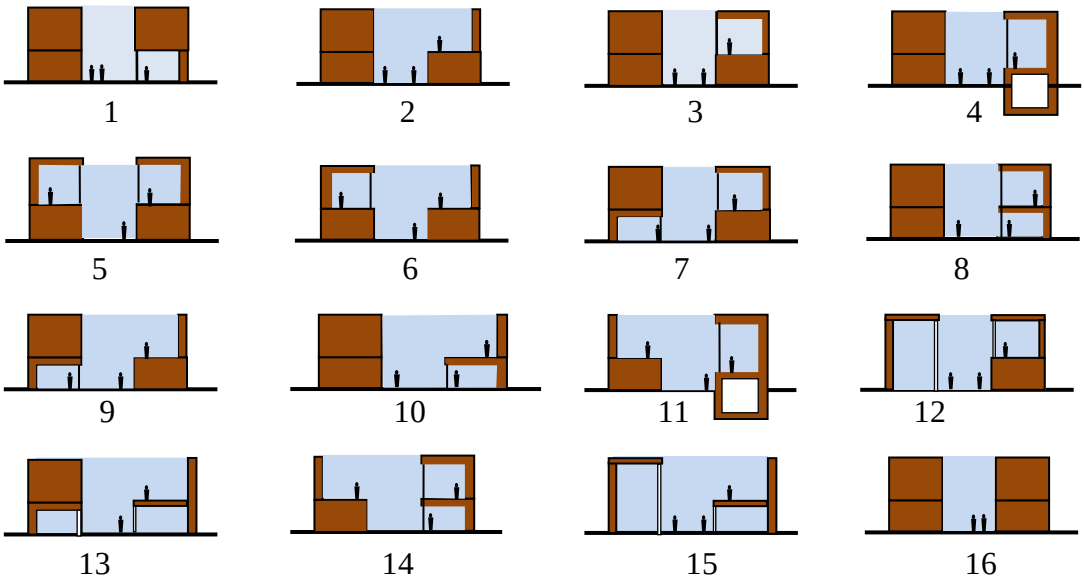


Figure 9: Sectional views of some extracted Cy forms of the simulation model

Figure 10 indicates some floor plans that contain Cys coinciding with some of those sectional views in Figure 9. Cross-sections numbers on the floor plans in Figure 10 refer to the number of the sectional view in Figure 9. These floor plans drawings represent some of the examples studied in this paper. This paper identified the Cy form characteristics of the TIH that achieve the design objectives. The Cy often connects to one or more adjacent covered or open outdoor spaces located on one or two floors. These outdoor spaces interact with the Cy constituting multiple harmonious forms that vary visually, environmentally, functionally, and aesthetically. Visually, the Cy integrated form expands the view to tackle cases of limited or narrow Cy volume. Environmentally, the form tectonic of Cy allows the sun to reach a lower level in winter. These outdoor spaces of different micro-climates on the ground floor, first, and roof, perform various functions throughout the year. Besides, the variety of forms creates a comfortable, livable environment.

The significance of the paper's findings is that it described the Cy forms of the TIHs by diagrammatic floor plans and their possible configurations. Thus, the description of the Cy as a room without a roof is only representing a special case that is less frequent in reality.

Therefore, the environmental and spatial analysis of that form cannot be adopted to express the TIH. The building's environmental performance programs should use the forms extracted by this paper to reach reality.

This paper could not obtain enough floor plans documenting TIH that correspond with all the Cy's extracted forms in the model due to their scarcity. Nevertheless, this paper expects that most of the explored patterns of Cy form exist in reality. The types of Cy form considerably exceed what was extracted in the model when the number of built-up massing on one side of the Cy increases to two or three. They also increase when the shape and dimensions of the Cy vary, such that the two Cy forms are hardly similar. Many other Cy patterns can be extracted when not restricted to the function of housing that the paper model followed. For example, the constraint

concerning the number of suspended rooms could be disregarded in buildings other than residential ones.

Figure 10: Floor plans of existing houses with Cy forms resembling the explored ones

The documented Cys form of the traditional houses in some neighbouring countries such as Syria, Egypt, and Iran, are usually more spacious and with fewer supplementing covered or open

outdoor spaces than these in Iraq. The reason may be due to the exposure to minor environmental impact compared to the local Iraqi one. Photos 1 and 2 in figure 11 illustrated some of those known Cys in Syria.

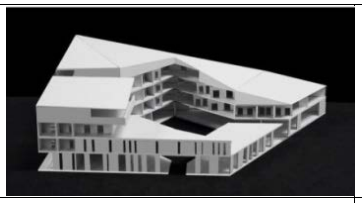
			
1 https://muslimheritage.com/the-courtyard-houses-of-syria/	2 https://muslimheritage.com/the-courtyard-houses-of-syria/	3 http://www.nexttoparchitects.	4 http://www.274b1833a209532a09f48

Figure 11: photos 1 and 2: courtyard form in Syria. Photo 3 and 4: courtyard concept employed in contemporary design.

5 Conclusion

The TIH can provide urban forms of various characteristics and microclimates. The extracted Cy forms achieve the spatial, environmental, visual, and aesthetical functions. The multiplicity of the outdoor forms and their integration with the habitable indoor spaces play an essential role in acquiring the local identity and distinguishes it from the neighboring countries. These integrated Cy forms have the inherent capacity to suit various land plot sizes by configuring multiple patterns ensuring the design requirements.

This new understanding of the Cy form may help contemporary designers to borrow its principles. The Cy form variety provides the freedom to achieve better performance. Many of the Cy forms extracted in this paper can be inspired to suit residential, educational, commercial, and community buildings, to name a few. Photos 3 and 4 in Figure 11 are examples of design proposals that employed integrated Cy forms.

This paper also investigates the environmental performance of the extracted Cy form's patterns. Besides, studying the Cy forms whose sides contain more than a single built-up mass. These Cy forms are usually more spacious than the types extracted in this paper.

6 Availability of Data and Material

Data can be made available by contacting the corresponding author.

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