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Evaluation of the Wind Catcher in the Traditional Cairene Courtyard Houses' Integrated Passive System for Natural Ventilation and Cooling

* Dr. **Ahmed S. Zaki**

Faculty of Engineering, Architectural Engineering Department, Egyptian Russian University, Badr City, Egypt

E-mail: ahmed-samir@eru.edu.eg

A B S T R A C T

Many Islamic architectural features have been used continuously in Cairene Courtyard houses as one of the primary environmental standards. Wind catcher represents the keystone of passive green features among other used features. The response of chosen case studies to the thermal environment had proven to vary concerning the type of green features involved and its role in the whole integrated system. The evaluation matrix act as a model in assessing the performance of eco-architecture features regarding the type of integrated system. Wind catcher ended up being effective in expanding the efficiency of passive integration system for ventilation and cooling; especially when the opportunity is taken to involve other green features in the early design phase. It is recommended to take into consideration, the involvement of passive integrated systems in architectural projects. Accordingly, we can conserve energy, mitigate climatic changes, and achieve thermal comfort; besides preserving the local identity of the built environment.

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1. Introduction

The incorporated design system allows the consciousness and acquired knowledge by explanatory examination of designing are formulated, developed, and embedded into conception application (Heiselberg, P. 2007). The incorporated conception approach involves the identification of architectural features and their role in buildings to assess the performance of the thermal environment of the building's natural ventilation concerning environmental criteria in its context. So far, the structure procedure of the designing stage of buildings has obtained constrained approval. However, it is possibly conditional on drawing attention to interconnectivity with sub-systems of buildings commonly specified as self-sustenance. There are few perceptions on how the conception of various sub-systems can be incorporated to fulfil a broad range of building operations. Addressing the building like an intricate system, in which the entities interact to develop a rising performance that can be valued concerning its

Corresponding Author:
Dr. Ahmed S. Zaki
Egyptian Russian University, Badr City, Egypt
E-mail: ahmed-samir@eru.edu.eg

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usability. Accordingly, it can support improving the performance of the building in terms of how a shift in one field impacts effectiveness in some other way (Baudains, et al. 2014). Consequently, this ultimately demanded the implementation of a process that highlighted the use of passive systems to satisfy the thermal comfort needs of occupants inside the buildings. Energy use in buildings can be decreased with limited cost of complicated techniques, but only through the effective incorporation of passive eco architectural features. The achievement of improved energy utilization through the integrated design approach of the building is associated with respect to the relation between the building, its environment, and the demands of occupancy. Furthermore, the integrated design system will secure an advancement in the optimum environmental fulfilment of the building. The uniqueness of Islamic historic houses that has given rise to independent spaces that have appropriate for various environmental modifications.

The originality of Islamic historic houses is a matter of conception that has generated independent spaces which adapted to different environmental changes (El Sorady, D. & Rizk, S. 2020).

The Egyptian traditional architecture had adapted to local climatic conditions through specific passive techniques; to fulfil a better thermal environment and occupant's comfort inside their houses by affording natural ventilation and cooling (Ficarell, I, 2009). Inheritance of old Islamic houses involves varied features concerning faith-based and socio-culture parameters along with the uniqueness of their local environment. In particular, Cairene houses were the predominant traditional domestic architecture in Cairo from the end of the Mamluk era (1259-1517) and across the Ottoman era (1517-1805). During these two periods, Egyptian architecture was dominated by Islamic principles, even though fulfilling its environmental context (Mohamed, G. 2014). These houses have several storeys that do not exceed three or four. Local building materials like stone and bricks were used to construct these houses. Particularly, the space arrangement of Cairene courtyard houses was affected instantly by Islamic regulations. Furthermore, some architectural features were generated as a response to the extraordinary environmental conditions of Cairo. They were exceptional so that it is patterning an emerging architectural trend that is diverse from the Islamic architecture in other countries (Abdelkader, R & Park, J. 2018).

Traditional spaces of Cairene courtyard houses (like Qa'a, Maqad, Takhtabush, etc.) were adapted to local climatic conditions. Many eco-features were used to induce natural ventilation through these houses. Such features include: a courtyard, Mashrabiya, wind catcher, Shokhshekha, and ventilated dome. Most previous studies on traditional Cairene courtyard houses had analyzed the role of previous features separately, not as an integrated system.

2. Literature review

Most of the previous studies did not address the concept of integrated systems as an entry point to improve the performance of the thermal environment of traditional Cairene courtyard houses. These studies were also limited to highlighting the environmental treatments used for these types of traditional houses. On the other hand, it did not address the role of wind catchers in integrated systems of buildings to provide natural ventilation and cooling. Maybe more, they were restricted to featuring the role of environmental treatment of wind catchers independently in raising the performance of the thermal environment of buildings.

A study by Dalia Al Shorady and others in 2020 investigates passive design elements used at Bayt Al Suhaymi concerning the organization of internal and external spaces. Shokhshekha at the hall of Bayt Al Suhaymi was used to promote warm air breaking out the inner spaces. Its roof surface supports heating the air utilizing direct orientation to the sun; to highlight an effective system for natural ventilation. In addition, Mashrabiya helps acquire the breeze to inner spaces of halls throughout the summer season.

The elements of passive design were presented in the halls of Bayt Al Suhaymi; especially with the incorporation of a courtyard, wind catcher, Takhtabush, and Mashrabiya to maximize the circulation of air (El Sorady, D. & Rizk, S. 2020). Another study in 2018 by Reem and others state that the environmental context of Cairo influences the space arrangement of traditional Carine courtyard houses in Cairo. Accordingly, the spatial principles of these houses were taken into consideration where the sun and wind direction were given priority in the environmental design process of these houses. Natural cooling is best accomplished by using high windows. In simple terms, the breeze passes to the inferior holes of Mashrabiya. However, warm air escaped outside the roof shaft, whether it was a Shokhshekha or a ventilated dome. In this case, Mashrabiya is used to enable continuous stream of wind by convection. It also identifies the interaction with Shokhshekha and the wind catcher in transit of wind circulation in Muhibb Al-Din house.

The study also highlights the role of the courtyard in reducing the warm climate by storing the breeze in the evening to prevent the warmth of daytime; besides, providing daylighting and cooling. Occasionally, plantations and fountains coexist to refine and cool the wind to fulfil the psychical convenience of residents (Abdelkader, R & Park, J. 2018). A study by Mady A. in 2018 proves the effectiveness of the courtyard with the Takhtabush in the hot arid region. It conducts the value of engaging the Takhtabush to improve the thermal efficiency of the courtyard (Mohamed, M. 2018). However, according to Nik Muhamad and others in 2017 discussed the elements used in the courtyard design of Bayt Al Suhaymi. The Takhtabush provides a cool sitting area in the morning, while the open courtyard functions as a temperature regulator and diffuses cool air into the rooms of the house (Nik Man, et al. 2017). Another review by Hanan Saleh and others in 2017, highlights the systems component of the architectural element of Bayt Al Suhaymi to obtain thermal convenience, as a premise of environmental architecture. This study attempts to draw attention to integrated systems used in many halls of the house including main, winter and summer hall. The analysis lacks the mechanism of work of these systems and the acting level of eco features, regardless of the absence of an assessment method to evaluate their performance concerning passive ventilation and cooling (Saleh, H. & Saied, S. 2017). El-Borombaly and others in 2015 stated the role of wind catchers in the middle east and old Islamic houses of Cairo. Respectively he considered a wind catcher as a sloped termination tower possessing an opening air edge that acts as an air shaft. Commonly it is upraised regarding the northern side of the building to grab the breeze and force it down inside inner spaces (El-Borombaly, H. & Fernando, L. 2015).

A study in 2014 by Nermine Abdel Gelil and others makes the best use of motion to achieve maximum possible cross-natural ventilation in Shokhshekha of Bayt Al Suhaymi; besides that, it declares the role of wind catcher as a separated eco feature for inducing natural ventilation inside inner space of the house (Mohamed, N. & Ali, W. 2014). In the study by Mohamed N.A.G in 2014, he states the role of Mashrabiya and its wooden lattice windows to fulfil daylighting control, thermal regulation, and sociable privateness (Mohamed, G. 2014). Another study in 2012 by Amanda Webb illustrates the eco features used in Bayt al Sinnari that embody thermal diversity (Webb, A. 2012). However, according to Mohamed Gamal in 2011, there was an investigation to the spatial order of Bayt al Suhaymi's principal Mandharah including a sitting area with natural lighting and ventilation circulation of the ventilated dome. Another study by Mohammed. M.A. in 2010 concluded the close relationship between the courtyard and the Takhtabush at the Sinnari house. The air heats up the backyard of the house over the courtyard causing warmed air in the backyard to draw the breeze from the courtyard through the Takhtabush, generating a constant refreshing air (Mohamed, M. 2010). However, the study by El-Shorbagy, in 2010 explained this relationship in another way. A steady breeze was acquired through convection by employing an inner courtyard and the Takhtabush. Wind warms up clearly in the uncovered courtyard regarding the backyard forming minimum air pressure. Warm wind shifts upright and pulls the breeze in contrast into the Takhtabush and in consequence creating a cold draft (El-Shorbagy, A. 2010).

However, an investigation by Reynold. J in 2002 concluded that the courtyard is considered the predominant compositional core in traditional Carine courtyard houses. Most of the rooms of these houses surround the open courtyard according to cultural and environmental factors (Reynolds, S. 2002). Before that, a study by Behrens in 1989 concluded that the courtyard is considered the dominant feature in providing ventilation, daylighting, and connection among varying facilities of old Islamic houses (Abouseif, B. (1989).

3. Methodology of research

The methodology of the research is composed of three main steps: description phase, analysis phase, and assessment phase. A coordinated framework of the applied methodology is presented in figure 1. Description phase starts up with types of passive integrated systems including natural cooling and natural ventilation employing passive techniques. It also discusses components of the integrated system and green architectural features applied in each case study. For the analysis phase, illustrated figures are used to examine the conceptual acting level and mechanism of working of applied green passive features. For the assessment phase, an evaluating matrix is proposed to assess the acting level of green passive features concerning a group of factors. Score ranking calculations are transformed into a classification matrix, that states the classified ranking of each case study, concerning the existence of green features and its criteria. The result of the assessment is used as a feedforward to identify weak points and opportunities for improving the acting level of the integration system in the future.

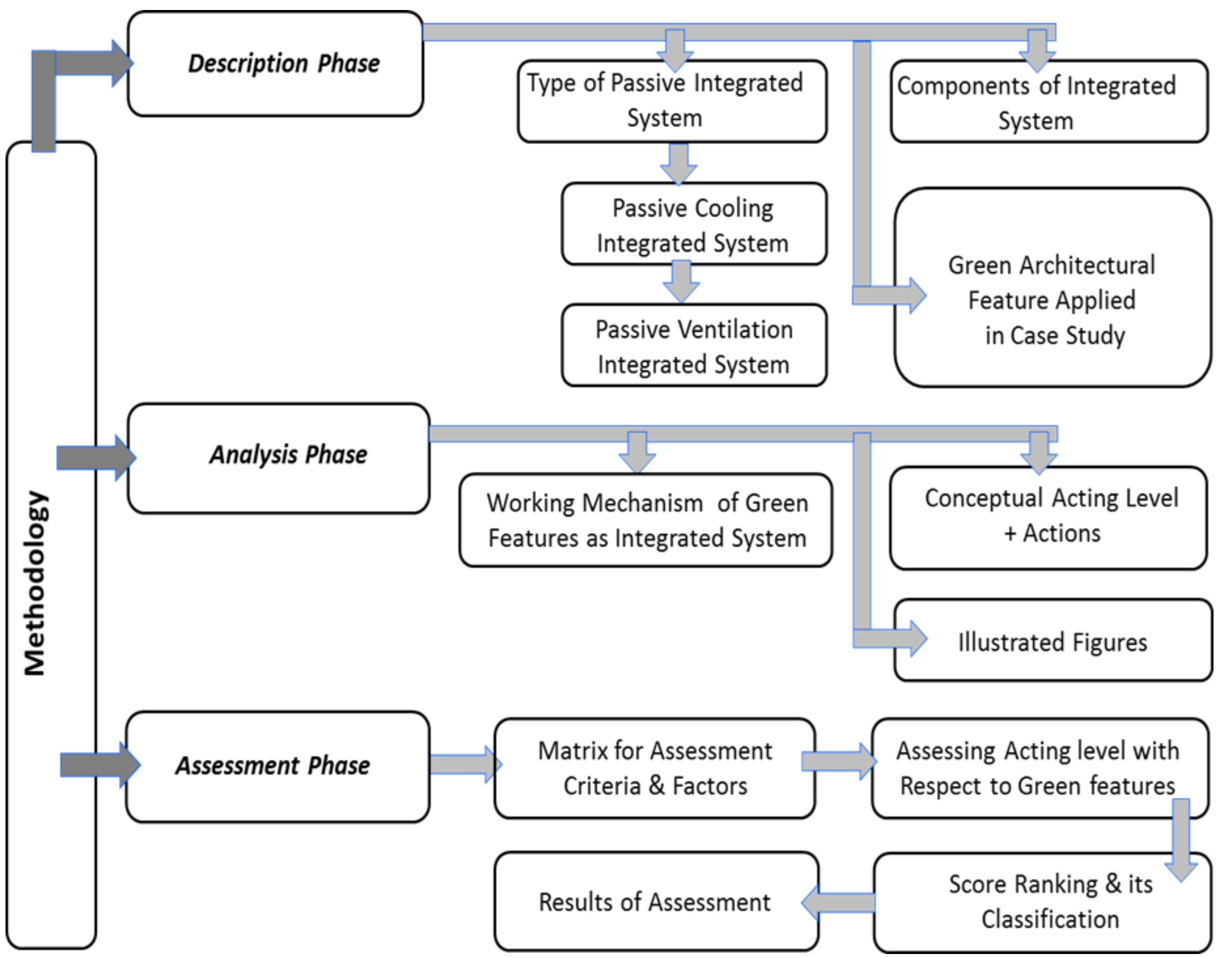


Figure 1. Conceptual diagram for methodology of the research

4. Case studies

Three houses related to Cairene Courtyard houses in old Islamic Cairo were chosen to be analysed and evaluated with respect to a passive integrated system used in ventilation and cooling:

Case 1: Qa'a of Muhib Al Din

Case 2: Hall 5 at Bayt al Suhaymi

Case 3: Main Qa'a at Bayt al Sinnari

The approach of choosing case studies is based on a group of variables and constants. Table 1 indicates the constants and variables of chosen case studies.

Table1. Categories and parameters for the constraints and variables of case studies under investigation

a- Constants		
	Category	***Parameter***
Building Envelope	Location	Old Cairo
	Context	Urban
	Orientation	The positioning of the house on its site that take full advantage of the climate.
	Building Layout	Main living area facing the breeze.
	Space	One space of the house is being investigated. Qa'a or hall
	Common used green feature	Wind catcher
	Thermal mass	High thermal mass
	Material used	Stones, wood and marble
	Window design	Mashrabiya with wooden lattice works.
Building services	Type of system	Integrated
	Operating regime	Passive
	Building use	Private resident
	Functionality	Natural cooling + natural ventilation
Socio-culture Dimensions	Social aspects	Life style and behavior*
		Social needs*
		Social pattern*
	Culture aspects	Family values*
		Culture needs*
		Architectural style and local identity*
		Similar spatial composition of houses*
		Space arrangement *
Environmental Considerations	Climatic conditions	Respect local climatic conditions
		Selected case studies have similar climatic zone
		Hot dry climates with low humidity levels
	Conservation of energy	Depends on passive design + techniques to create passive solar building.
		Depends on natural ventilation and cooling.
	Zero emission	Limitation of environmental pollutants
b- Variables		
	Category	***Parameter***
Building Envelop	Size	Varity in size of Qa'a or hall under investigation
	Green features	Variation in types, role and magnitude of effects of green feature used in each case study.

5. Analysis of case studies

5.1. The Integrated Passive System at Palace of Muhīb al-Dīn, known as Uthmān Katkhuda - AD 1350

The main Qa'a of the palace act as a living space with a rectangular shape with two Iwans facing each other on the main axis and a sadla on other edges. The central space between the Iwans, called Dorqaa is one step lower covered with marble and possesses a central fountain, and has a higher ceiling called Shokhshekha. The Dorqaa rooftop is on greater plane than the Iwan roofs. It lays on the drum, accentuated with windows subsequently permitting ventilation and daylighting into the hall. The north side Iwan had a "wind catcher" composed of a shaft between the two walls at the edge of the Iwan, roofed by an inclined roof and unsealed on its northern and western edges. Wind catcher was created to capture the breeze, which all the year-round blow-up along north-western. The wind passing by the inclined shift towards the bottom edge of the hall would supplant warmer air outside across the higher openings of the Dorqaa. Furthermore, the height of the ceiling supports the efficiency of natural ventilation. The mechanism of the Shokhshekha is illustrated in figure 2. Dorqaa acts to host the resident's owner's visitors and is arranged in the centre of the Qa`a. The Dorqaa is regarded as other form of courtyard that is not the hub of everyday routine. Hence it could be a minor sociable place that performs the function of a sitting room (Fathy, H. 1986). The integrated system of passive ventilation and cooling in Qa'a of Muhib Al-Din is composed of a- Iwan, Dorqaa, and Shokhshekha, b- Wind catcher, c- Mashrabiya.

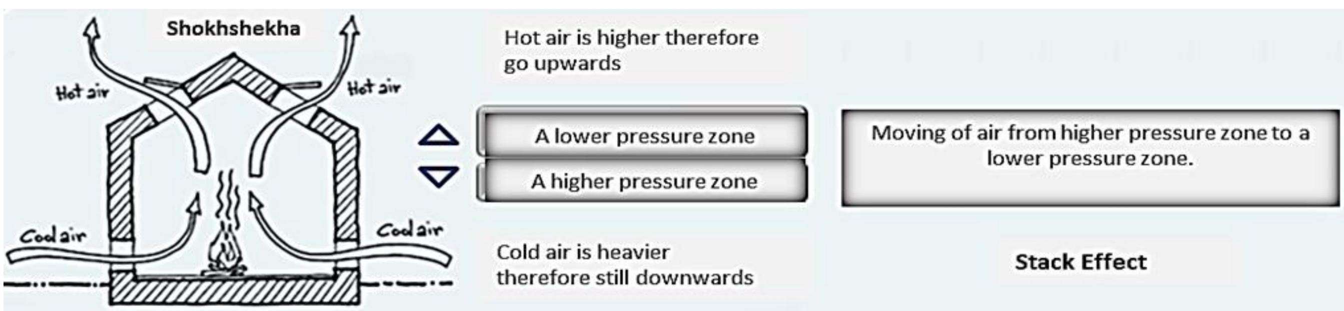


Figure 2. Conceptual diagram of Shokhshekha for mechanism of its working (Source: UN-Habitat, 2014, edited by author)

Mechanism of Working of the Integrated System in Qa'a of Muhib Al-Din

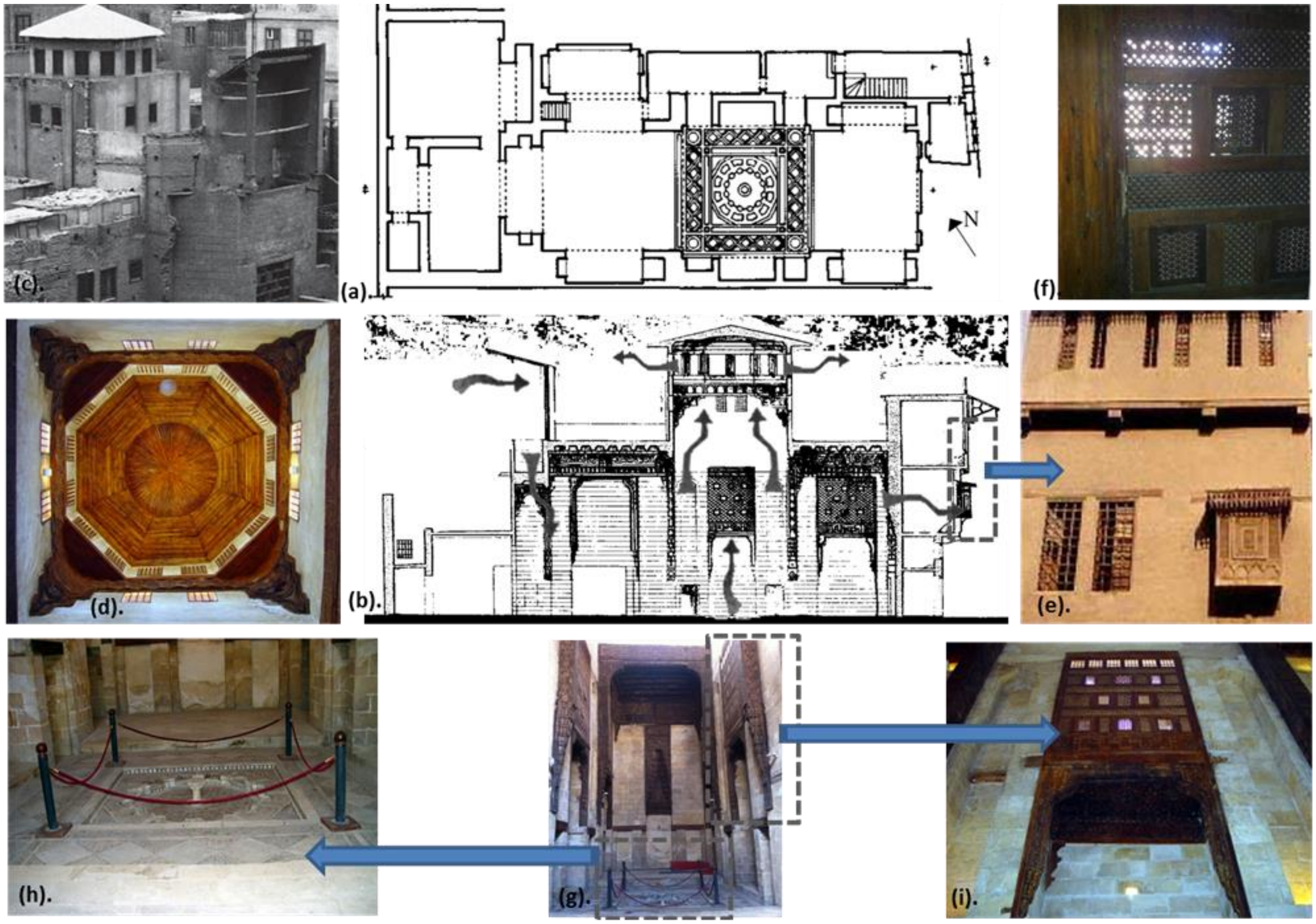
The conceptual acting level of the ventilation passive system in Qa'a of Muhib Al-Din is analysed as follows:

Action 1: Breezes enter from the inlet (a) through Wind catcher passing inside inner space.

Action 2: Dry air is cooled through the marble floor and fountain at Dorqaa, that distribute around the Iwan where residents actually sit. It intensifies the humidity in hot seasons.

Action 3: Cooled air remains downwards at the resident's user level, while hot air raised up to escape through high openings of the Shokhshekha by the stack effect.

Action 4: Upper openings of wooden Mashrabiya at Iwan help to get rid of hot air; thus, supporting the flow of air.



Key of figure

a. Plan Qa'a of Muhib Al Din
b. Section of Qa'a of Muhib Al Din passing through Malqaf, Iwan, Dorqaa and Shokhshekha
c. Exterior view of Malqaf with Shokhshekha
d. Looking up to roof towards Shokhshekha
e. Exterior view of Mashrabiya
f. Interior details of Mashrabiya
g. Interior view of Iwan with double height.
h. Detail view of marble fountain in Dorqaa
i. Inner view of opening at upper level of Qa'a

Figure 3. Integrated passive system for ventilation and cooling in Qa'a of Muhib Al Din (Source of a + b: Neet,et al., 2009, Edited by author); (c - i) visual survey

5.2. The integrated passive system in "Hall 5" at Bayt al Suhaymi

Bayt Al Suhaymi was originally constructed in 1648 CE with further modification in 1796 through the Ottoman period. At the present time, the house is intended to be an open museum for old Islamic architecture in Cairo (El Sorady D. & Rizk, S. 2020). The house serves as viable paradigm of sustainability that reflects the application of integrated passive systems for environmental thermal control and conservation of energy. The design had given rise to self-reliance spaces appropriated for various environmental variations. The inner courtyard operates as an optimizer for heat control of the house. Additionally, the Mashrabiya screen supports cooling the air in interior spaces over the warm season. Moreover, getting rid of hot air from upper openings screened by wide latticework thus creates a reasonable climate inside indoor spaces during flow of wind (Abdelkader, R. & Park, J. 2018).

With the intention of achieving thermal comfort of residents, the wind catcher is engaged in hall 5. It embodies an upper shaft than the surrounding buildings and closes upright with a wide opening to trap the breeze. It is erected on the northern edge of the hall to catch the cool air and force it below towards the inner space (El Sorady, D & Rizk, S. 2020). Wind catcher grabbed the breeze resembling the sails trapping the wind and drive it inside the space of hall 5 on the second level. Wind circulation is accelerating since the high position of the wind upon the floor increases its velocity. In this manner, it could freshen the air inside inner spaces that do not have openings outward from the hall. On the other hand, the wind catcher together with the Mashrabiya and courtyard ensures the steady flow of breeze (Abdelkader, R & Park, J. 2018). The integrated system of passive ventilation and cooling applied in "hall 5" in Bayt al Suhaymi is composed of the a- courtyard, b- Wind catcher, and c- Mashrabiya.

Mechanism of working of the integrated system in "Hall 5" at Bayt al Suhaymi

The conceptual acting level of ventilation passive system in "Hall 5"at Bayt al Suhaymi is analysed as follows:

Action 1: Dry air is cooled when passing through courtyard 1.

Action 2: Cooled air from courtyard is directed towards sloping vent of wind catcher towards the lower part of hall 5. Inlet of one-way wind catcher is composed of wooden lattice resemble Mashrabiya screen. Tight lattice work increases cooling of passing air by the effect of Venturi effect.

Action 3: Hot air raised up to escape through high openings of Mashrabiya with respect to the stack effect. Figure 4 illustrates this mechanism.

Figure 4. Integrated passive ventilation in hall 5 between wind catcher, courtyard1 and Mashrabiya in Bayt al Suhaymi: (Sources: (a) Abdelmonem, M. 2011, edited by author; (b – g) Developed by author)

5.3. The integrated passive system at Bayt al-Sinnari

Bayt al-Sinnari was constructed in 1794 and is situated in the area of the Al-Sayeda Zainab Mosque. This house comprises most of architectural elements of traditional Cairene house including the courtyard, Maq'ad, and the harem hall that extends along the outlook of the street forward to sight of the Maq'ad from behind (Williams, C. 2002). The main Qa'a is located on the second floor of Bayt al Sinnari. It is composed of two Iwans; a large one with a flat roof and full height wooden Mashrabiya and the other one is small with a Mashrabiya and large-scale wind catcher at its top. Dorqaa is centered in the middle containing a marble fountain and a wooden Shokhshekha at its top.The integrated system of passive ventilation and cooling applied in "main Qa'a" at Bayt al-Sinnari is composed of the a- courtyard, b- Wind catcher, c- Mashrabiya, d. Dorqaa and the Shokhshekha.

5.4. Mechanism of working of the integrated system in main Qa'a at Bayt al Sinnari

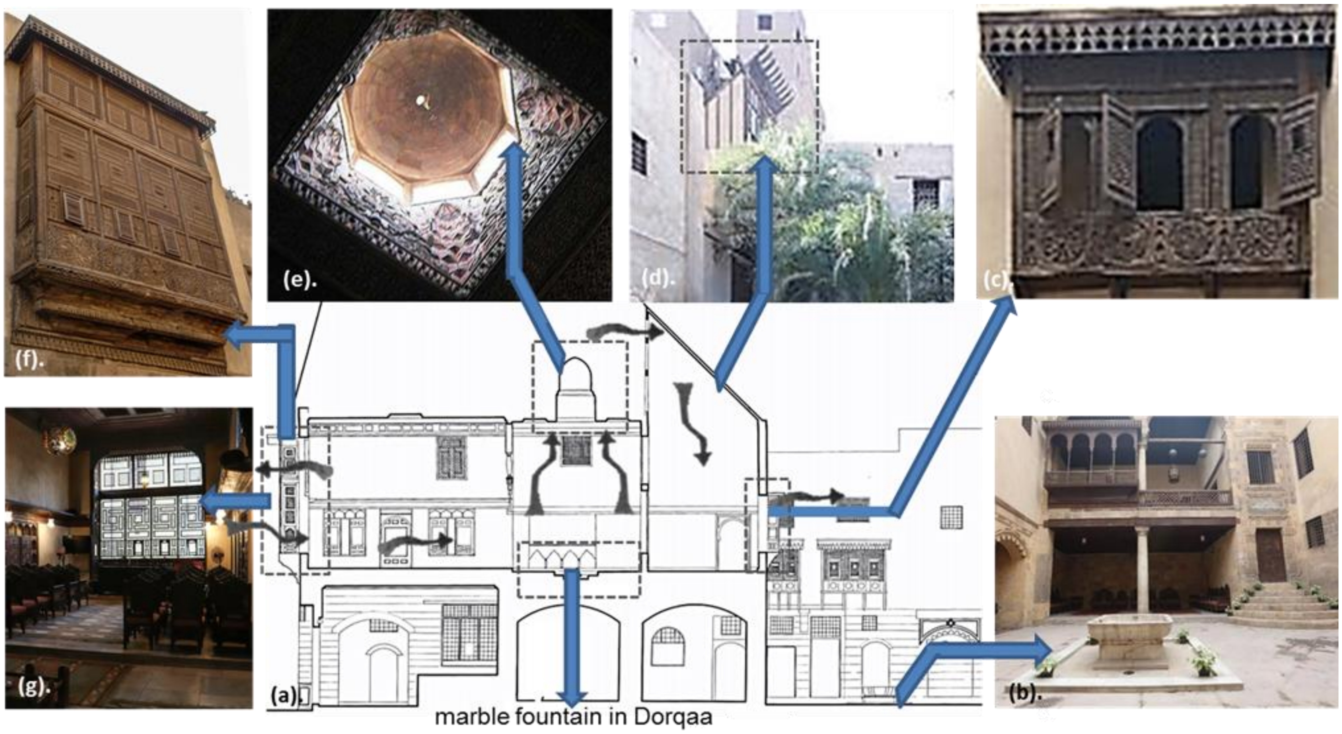
The conceptual acting level of the ventilation and cooling passive system in the main Qa'a at Bayt al Sinnari is analysed as follows:

Action 1: cool breeze is maintained by employing the phenomenon of the stack effect induced by the courtyard. An outdoor fountain is used to cool the air entering the court. It also increases humidity levels during the hot season.

Action 2: cross-ventilation occurred inside the Qa`a on the second floor between two Mashrabiya located on the edge sides of the Qa`a. Action 3: air entering the Mashrabiya is cooled by the effect of the Venturi effect. The lower section of Mashrabiya with tight lattice supports the cooling of air. On the other hand, the upper section of Mashrabiya with wide lattice supports the escape of hot air outside the Qa`a. The switching of wind among interiors and exteriors may happen through the same opening if it is a large opening. In this case, the lower part of the opening operates a supply process, and the higher part operates an extracted one.

Action 4: north part of Qa'a comprises a wind catcher with large inlets that allow the breeze to enter through the wooden latticework. Action 5: a cantered marble fountain located at Dorqaa to support cooling of the air at sitting level. In the upper part of Dorqaa; a wooden skylight act as Shokhshekha where hot air escape through its openings.

Air movement is indicated in figure 5 where the cooling effect and ventilation are enhanced through integration between green design features; wind catcher, courtyard, Mashrabiya, Dorqaa, and Shokhshekha.



Key of figure

a. Longitudinal section of Bayt al Sinnari
b. View of inner courtyard with central fountain/
c. Exterior view of wooden Mashrabiya.
d. View of Wind catcher.
e. Interior view of the Shokhshekha (wooden skylight).
f. Exterior view of Mashrabiya in north facade.
g. Interior view of Main Mashrabiya at main Iwan.

Figure 5. Integrated passive ventilation in Bayt al Sinnari (Source: Webb, A. 2012, edited by author)

6. Assessment of case studies

The assessment criteria of the integrated system of green features applied to case studies are based upon factors affecting criteria and value of scoring, as illustrated in table 2. On the other hand, table 3 represents the acting level of used green features, concerning their role in natural cooling and natural ventilation.

Table 2. Assessment criteria of the integrated passive system of green features of case studies under investigation

System	**Passive Cooling System**					
Green Fearture	***Factors Affecting Criteria***			***Value of Scoring***		
Courtyard	Out door water element			**1**		
	Out door plantation			**1**		
Mashrabiya	Tight lattice work			**1**		
Dorqaa	Marble floor			**1**		
	In door fountain			**1**		
Wind catcher	Tight lattice work			**1**		
	Cooling element inside wind catcher			**1**		
Total score of passive cooling system (optimum score)				**7 points**		
System	**Passive Ventilation System**					
Green Fearture	***Factors Affecting Criteria***			***Value of Scoring***		
Courtyard	Breeze is maintained by employing the phenomenon of the stack effect			**1**		
Mashrabiya	Size of lattice work			**1**		
	Position of openings			**1**		
Shokhshekha	Hot air escape from its openings			**1**		
Wind catcher	Induced breeze inside inner space			**1**		
Cross ventilation	Exchange of air between openings at same level			**1**		
Attic ventilation	Relative position of openings at different levels			**1**		
Total score of passive ventilation system (optimum score)				**7 points**		
Score ranking	**1-2**	**3**	**4**	**5**	**6**	**7**
Classification	**Very weak**	**weak**	**Medium**	**Good**	**Very Good**	**Excellent**

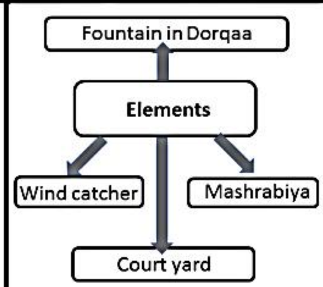
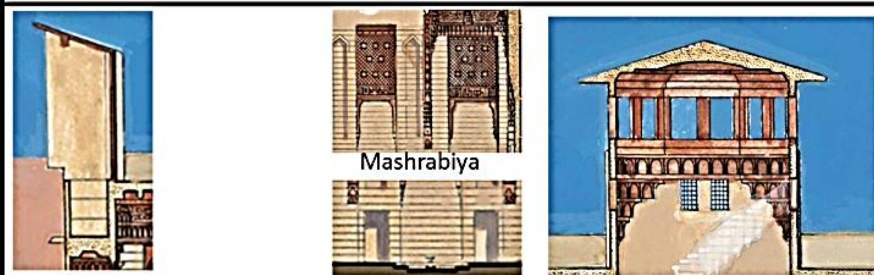
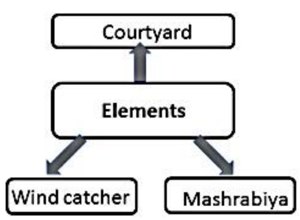
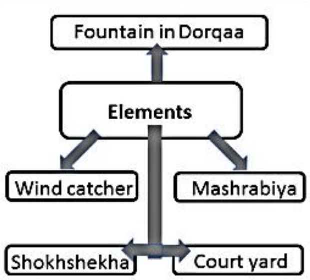
Table 3. Assessing acting level of case study under investigation with respect to green features

Case Study	**Passive Green Feature for Natural Cooling**							**Passive Green Feature for Natural Ventilation**						
	Courtyard		***Mashrabiya***	***Dorqaa***		***Wind catcher***		***Courtyard***	***Mashrabiya***		***Shokhshekha***	***Wind catcher***	***Cross ventilation***	***Attic ventilation***
Qa'a of Muhib Al Din	✓	X	✓	✓	✓	✓	X	✓	✓	✓	✓	✓	X	✓
Hall 5 at Bayt al Suhaymi	X	✓	✓	X	X	✓	X	✓	✓	✓	X	✓	X	✓
Main Qa'a at Bayt al Sinnari	✓	X	✓	✓	✓	✓	X	✓	✓	✓	✓	✓	✓	✓

Symbol used for evaluating acting level of passive green feature	**X**	**✓**
Meaning of Symbol	Absent	Existence

To show the comparison among case studies, the following table set the components of the integrated system used concerning figures of green features.

Table 4. Comprehensive scope of the integrated passive system in case studies under investigation with illustrations (Source: Neet, et al., 2009, Edited by author)

Case study	Component of green features involved in integrated system	Images of integrated green features
Qa'a of Muhib Al Din		 Wind catcher; Mashrabiya; Fountain in Dorqaa; Shokhshekha
Hall 5 at Bayt al Suhaymi		 Wind catcher; Mashrabiya; Courtyard 1
Main Qa'a at Bayt al Sinnari		 Shokhshekha; Wind catcher; Fountain in Dorqaa; Mashrabiya; Courtyard 1

7. Results of assessment

Main Qa'a at Bayt al Sinnari had reached the highest score ranking in the acting level of integrated passive systems used to achieve natural cooling and ventilation, in comparison with other case studies. Although 3 case studies had common Constants like environmental conditions, climates, architectural style, and general characteristics, their response to the thermal environment with the building envelope had proven to vary with respect to the type of green architectural features involved and their role in the whole integrated system. Green features of the design in Main Qa'a at Bayt al Sinnari had succeeded in achieving high performance towards climatic conditions, thermal environment, and comfort of occupants and their needs. Wind catcher, Dorqaa and Shokhshekha, besides; Mashrabiya did work together to enhance the air movement and cooling effect inside the space of Main Qa'a at Bayt al Sinnari. Such a system guarantees excellent natural ventilation and cooling through passive architecture elements and actions. Result of assessing acting level of case studies for integrated passive system used for ventilation & cooling is illustrated in table 5.

Table 5. Result of assessing acting level of case studies for integrated passive system used for ventilation & cooling

Case Study	Score ranking of passive green features for natural cooling	Classification	Score ranking of passive green features for natural ventilation	Classification
Qa'a of Muhib Al Din	5 points	Good	6 points	v. good
Hall 5 at Bayt al Suhaymi	3 points	Weak	5 points	Good
Main Qa'a at Bayt al Sinnari	5 points	Good	7 points	Excellent

8. Conclusion

The analytical approach of the research contributed to clarify the mechanism of suggested integrated systems with respect to role of each eco features as influencing factor in type of the ventilation strategy.

Evaluation matrix act as a model to assess the acting level of eco architectural features with respect to the type of the integrated system. Wind catcher proved that it is the keystone in a successful passive integration system for ventilation and cooling; especially when the opportunity is taken to involve other green features in the early design phase of the project.

As wind catcher affects positively the efficiency of attic ventilation in chosen case studies; however, Mashrabiya represents another keystone of passive green features concerning cross ventilation and cooling factor. It is recommended to take into consideration, the involvement of passive integrated systems in contemporary and future architectural projects. Accordingly, we can conserve energy, mitigate climatic changes, and achieve thermal comfort for building occupants; besides preserving the local identity of the built environment.

More research might be done to examine the integrated passive ventilation and cooling systems in other old Islamic homes across the world. In addition, the work of architect Hassan Fathy poses a significant opportunity to investigate applied ventilation systems. Wind catchers can be investigated thoroughly in these case studies to evaluate its role with mixed ventilation strategy.

Further, investigation can be carried out on similar case studies, with respect to environmental context and involving passive architectural features in early phase of the design procedure. Environmental efficiency should not be supplementary conception to architectural scheme process, however, act as essential component through life cycle of the building.

Other assumptions will be necessary integrated through determination of orientation, shaping, building materials, and other systems within the building including heat insulation, shading, and daylighting to fulfil functionality, thermal comfort, and energy efficiency.

The lessons learned from this study could be summarized as follows:

- Architectural passive elements of Traditional Courtyard Houses in Cairo; can be utilized in contemporary design practices.
- Need for a model to develop new Egyptian house designs concerning a comprehensive integrated passive system.

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Data availability statement
The original contributions presented in the study are included in the article/supplementary material, further inquiries can be directed to the corresponding author/s.

Ethics statements
Studies involving animal subjects: No animal studies are presented in this manuscript.
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Conflict of Interests
The author declares no conflict of interest.

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