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AN APPLICABLE APPROACH TO GREEN ARCHITECTURE IN EGYPT
PROPOSED MEASUREMENT MATRIX MODEL TO ASSESS THE USE OF HISTORIC ISLAMIC ARCHITECTURAL ELEMENTS AND REPERTOIRE IN THE APPLICATION OF GREEN ARCHITECTURE PRINCIPLES AND CONCEPTS

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ABSTRACT: *This research paper sheds light on how to stimulate the role of historic architectural elements and repertoire in Egypt in order to apply green architecture principles. The paper* ***assumes*** *that architectural solutions used in historic buildings constitute important elements favoring the application of green architecture principles in residential construction. A model measurement matrix intended for use in the realization of this assumption is proposed.The paper begins with an overview of the Egyptian Green Pyramid rating system, a tool used to measure buildings' adherence to environmental standards, and their fundamental conditions and criteria. The measurement matrix proposed by the researchers (along with its major evaluation criteria) is then presented. Following a discussion of green architecture in Egypt and a review of the green architecture aspects in the repertoire of historic Islamic architecture, an explanation of the measurement method employed is provided. The paper goes on to investigate historic residential buildings (the Al-Suheimi House and the Zeinab Khatoun House), pointing out the environmental elements and concepts featured in their architectural design. Analytical studies of green residential buildings (projects that were awarded first prize in the Toshka Green Architecture Competition) and of eco-friendly residential buildings reveal the environmental merits of Islamic architecture (Aga Khan and Hassan Fathy award-winning projects). The above buildings are examined and assessed using both the measurement matrix and the Green Pyramid rating system as comparative references in order to corroborate the environmental suitability of Islamic architectural elements and to demonstrate how they may be assessed and applied. The paper concludes that the degree of application of the measurement matrix is directly proportional to the degree of application of Green Pyramid rating system criteria. The proposed measurement matrix model can thus realistically be considered a major approach to the application of green architecture principles.*

KEYWORDS: Green Architecture – Islamic Architecture – Residential Buildings – Egypt – Environmentally Friendly Eco-Friendly – Green Pyramid

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INTRODUCTION

It has been found that many green architecture design principles were applied, in various manners and shapes, in historic buildings. Islamic architecture is one of the historic architectural designs that incorporates green architecture principles and elements the most (forms, orientation, ceilings, walls, openings, construction materials …). Consequently, the repertoire and elements pertaining to this architecture are studied in detail with a view to using them as an approach toward the application of green architecture principles in residential buildings in Egypt, thereby promoting sustainable future urbanization.

The use of Islamic architectural elements and repertoire in applying green architecture principles necessitates building upon Islamic architectural solutions already used in residential buildings (and the architectural elements resulting from these solutions). Comparing these to green architecture theories allows us to identify Islamic architectural elements and Islamic architecture that are suited to the application of the green architecture principles. Next, these elements are introduced into the measurement tool (measurement matrix) proposed by the researchers, prior to their incorporation into ecological residential buildings.

Research Hypothesis: The paper assumes that the use of Islamic architectural elements can contribute directly to the construction of sustainable buildings and the application of green architecture principles in these buildings - and that this can be put into effect immediately.

Research Objective: The aim of this research paper is to prove that the proposed measurement matrix is a useful tool that can help to assess and apply green architecture principles in residential buildings in Egypt by using historic architecture repertoire and elements.

Research Methodology: A comparative analysis methodology is used. The measurement matrix is used for analytical purposes, and the Green Pyramid system is used as a comparative model to assess the degree of application of green architecture principles.

Green Architecture and Buildings in Egypt

Numerous studies and papers providing detailed research and analysis of green architecture, its principles and standards have been published. They serve to identify the most important principles of green architectural design, which we will use here to analyze historic architecture. The most important green architectural design principles are outlined below:

Building's Architectural Design:

a) Form:

1. The structural design of the building bloc should minimize external surface and roof areas exposed to the sun's rays. The ideal form is a primary one (square, circle). Loosening the bloc structure by adding a courtyard augments the flexibility of an environmentally appropriate design.

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2. Natural light should penetrate 4.5 m into the building's interior; the deeper the light penetrates, the weaker the lighting becomes. Natural light that penetrates up to 9 m inside the building provides good lighting; beyond this distance, building interiors require artificial lighting.
3. The greater the height of a building, the more effective is ventilation and the wind's effect in reducing thermal radiation levels.
4. Sound insulation through judicious use of quiet spaces (they should be close together and separated from noisy spaces)

b) Orientation:
1. Orientation affects a space's thermal comfort level, ventilation and natural lighting. A northward orientation is the most suitable; it is not exposed to direct sunshine and allows for a steady level of natural light. Ensuring that the widest side of the building faces north will attract sought-after wind, and the largest openings should therefore be located on this side. The East and West-facing sides of buildings are not conducive to good natural lighting. Southward-facing sections are desirable in the winter season, and regulating incoming sunshine is an easy matter throughout the rest of the year.

BUILDING ENVELOPE DESIGN

a) Roofs:
1. Sloping roofs, heat insulation materials (lightweight brick) and heat deflective light colored materials should be used.
2. Creating insulating air vacuums by constructing double roofs (two tile layers)
3. Elevated ceilings allow for increased ventilation. Ceilings should be of different heights and upper openings (in ceilings) should be installed.

b) Walls:
1. Construction materials such as burnt brick should be used to reduce heat conduction from outdoors to indoors
2. Constructing double walls, using light colored, heat deflective materials
3. Shading walls and building ledges on the walls of upper floors
4. At both the vertical and horizontal levels, walls should be tilted to allow for the angle of the sun's rays.
5. Using coarse surfaces to deflect the sun's rays
6. Using openwork wall structures, upper openings and skylights

c) Openings
1. Narrow openings in hot zones; they should be shaded and equipped with sunscreens
2. In Egypt, openings facing north are the most suitable for lighting and ventilation.
3. The greater the width and height of the openings, the more natural light penetrates into and spreads in building interiors.
4. Openings should be installed on several walls and upper openings should be used as well.
5. At least one air inlet, larger than the air outlet, should be provided.

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Use of Construction Materials in Design

1. Natural and renewable construction materials that are suitable to the building site and the surrounding environment should be used.
2. Light color, low thermal conductivity materials with coarse surfaces to deflect radiation and heat should be used.
3. Durable, energy-efficient construction materials should be used.

ISLAMIC ARCHITECTURE FROM A GREEN ARCHITECTURE VIEWPOINT

Green Architecture Principles in the Islamic Home:

Many studies and references have noted that the Islamic home is harmoniously integrated into its natural environment, and that it provides protection against the effects of natural elements, environmental and climatic conditions. Because they use renewable natural energy sources, such as solar and wind energy, Islamic homes are well adapted to their natural environment. Islamic residential architecture incorporates many of the principles of green architecture, including:

Energy Conservation: The Islamic home is a perfect example of ecological architecture design. Design principles, construction materials and environmental solutions make use of natural resources and energy sources (sun, wind, and construction materials) to provide an interior environment that is both comfortable and in harmony with social values and culture.

Adaptation to Climatic Conditions: In spite of the small size and number of windows on external facades (opening unto the street), Islamic home design is perfectly adapted to climatic conditions because it uses innovative ventilation methods. Interior courtyards serve to regulate the temperature, while the use of locally available natural resources and construction materials and various architectural solutions, such as *salsabeels*, domed roofs, *mashrabeyas* (wood latticework panels) and *shokhshekhas* (small skylights) resolve all climate-related problems.

Efficient Use of Construction Materials: The thermal performance of building envelopes in Islamic homes is based on applying heat transmission resistance and heat gain reduction principles to interact with and adapt to the environment. This is achieved by using locally available material, such as stone, gypsum and brick. The substantial thickness and high thermal capacity of these materials slow down heat transmission and provide permanent resistance to external elements.

Site Respect and Protection: Islamic architecture considered building sites part of the urban fabric of a city. A city consisted of organized blocs of buildings (both public structures and housing units), connected by pathways that varied in length and width depending on their importance and exclusiveness. Islamic residential architecture hinged upon site respect; shading was provided by the proximity of housing units and projections (ledges) built into their external facades ensured that the pathways were shaded. Trees and plants in interior courtyards also provided shade.

Respect for Users: The human factor plays an important role in the design of Islamic homes; Islamic social customs, traditions and culture are reflected in the design's fulfillment of the need for privacy and respect of neighbors. This is manifested in the inward orientation of homes, the separation between *haramlek* and s*alamlek* and the isolation of the entire home from passersby in the street, which is realized by limiting the number of openings and using *mashrabeyas*. In

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addition, the use of solid, robust local natural building materials provided protection against natural catastrophes.

Cohesive Design: The architectural design of Islamic homes attempts to apply the principles and cohesiveness of green architecture. It makes use of natural construction materials available in the local environment, employs inner courtyards, space orientation and shading to control temperatures, *malqafs* (windcatchers) to ventilate spaces that do not face north, *shokhshekhas* (skylights) to complete the cycle of air movement, and wood *mashrabeyas* to attenuate strong sunlight, control humidity levels, regulate natural ventilation and provide privacy.

The above summary presentation of green architecture principles featured in Islamic architecture shows the extent to which Islamic architecture interacts with the local environment and how it makes use of resources available in the environment to build homes that both ensure the comfort of their users and preserve natural resources.

PROPOSED MEASUREMENT MATRIX

The research proposal depends on formulating environmental measurement criteria for the model measurement matrix that include methods for gauging how the historic Islamic architectural repertoire is used to achieve the goals of green architecture. The proposed matrix assigns overall assessment ratings (strong > 70% - medium > 50% - weak < 50%), depending on the degree of application of measurement criteria. The criteria are:

1. Site selection, planning and organization
2. Form of the construction bloc and building
3. Orientation
4. Cross-section
5. Ceilings
6. Openings
7. Construction and finishing materials
8. External envelope (walls) treatment
9. Building appliances

Formulation of the proposed measurement matrix is based on an analytical study of Islamic architectural trends that produced an environmental architectural repertoire and solutions (identified according to the overall measurement criteria assessing architectural design elements), combined with an assessment of the degree to which they concur with green architecture tendencies and with the historic Islamic elements and repertoire that apply these tendencies. The matrix may be applied to measure the degree to which historic and modern buildings featuring Islamic elements and repertoire concur with the principles of green architecture. It may also be used as a reference tool for applying green architecture principles and tendencies when using the Islamic architectural repertoire and elements, as follows:

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Table 1: Proposed Measurement Matrix

Measurement Factors (Islamic architecture elements and repertoire)	**Building Terms (Case Study)**
Site selection, planning and organization: 1. Use of natural energy resources 2. Use of local construction materials 3. Use of water storage tanks and rainwater drainage conduits 4. Unified planning and separation of functions (residential, commercial) 5. Internal courtyards and thick walls, to reduce noise levels 6. Use of windows, fountains, trees and public gardens	Site selection, planning and organization
Building / building bloc form: 1.Shading and size of inner courtyards, to control temperature, lighting and ventilation 2. The *takhtaboosh*, placed between the main courtyard and sunny gardens 3. Projections (ledges) on upper floors and facades	Form of the building bloc / building
Orientation: 1. Inner courtyards and the distribution of spaces around them 2. The *takhtaboosh* and the *maq3ad*; principal northward-facing spaces 3. Main entrances overlook the courtyard 4. Wide openings in the main internal facades 5. To regulate lighting and ventilation, *mashrabeyas* are used to enclose openings 6.Extrenal facades are almost solid, with very few openings 7. The inner courtyard is aligned in a north-east or north-west direction 8. *Malqafs* are used to draw northerly winds into spaces that do not face north	Orientation
Cross-section: 1. Using the courtyard as a principal element of design 2.Horizaontal section of an irregular bloc	

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containing several open spaces 3. Creating spaces facing north, such as the *takhtaboosh*, to ensure constant air circulation between areas of different pressure 4. Using spaces such as *iwans* for protection against external elements 5. Dividing spaces into private and public ones, according to degree of seclusion and susceptibility to noise	Cross Section
Ceilings: 1. Use of *khoshkhanas*, *shokhshkhas* and *malqafs* as principle design elements for ventilation and overhead lighting 2. Using the difference in the height between spaces for ventilation and lighting purposes 3. Double wood ceilings 4. Using wood ceilings for insulation 5, Use of domes and vaults in ceilings	Ceilings
Openings: 1. Using *mashrabeyas* to enclose openings to provide shade on external facades and to regulate the passage of light and heat 2. Using openwork plaster and etched wood units 3. Openings are oriented inwards and are narrow on internal walls and wide on external walls 4. Use of wide openings on internal facades and narrow openings on external facades 5. Use of wide openings in internal facades that overlook the courtyard (they should be narrow on internal walls and wide on external walls to increase ventilation and lighting and provide a broader view)	Openings
Construction and finishing materials: 1. Use of local building materials such as mud-brick, limestone, red brick and wood 2. Using wood to cover surfaces, in *mashrabeyas* and openings 3. Using limestone, light color stone and coarse surfaces in lower floors, and brick and baked clay in upper floors	Construction and finishing materials

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Treatment of external envelope (walls): 1. Using limestone and mud in construction 2. Building ledges on upper floor facades to provide shading for lower floors 3. Using openwork plaster units in walls to promote ventilation 4. Using medium-size inner courtyards and increasing the ratio of surrounding walls to courtyard width to promote shading	Treatment of external envelope (walls)
Building appliances (lighting methods – electrical appliances – sanitary appliances – waste management – fire protection systems – electricity generation – other architectural details) 1. The use of *malqafs* for ventilation 2. Dependence on natural resources for ventilation; use of *malqafs*, *shokhshekhas*, *qamareyas*, internal courtyards and *mashrabeyas* 3. Using solar energy for lighting (reflected rays) 4. Using leftover wood to make *mashrabyas* 5. Functional use of sanitary appliances (such as heating room to heat water) and efficient water consumption - Each house is equipped with a water tank. 6. Installing ducts in walls to clear away water and rain 7. Use of fountains 8. Using grey water in fountains and *salsabeels*	Building appliances (lighting – electrical appliances – sanitary appliances – waste management – fire protection systems – electricity generation – other architectural details)

The criteria above were identified based on a study of green architecture aspects in design principles of historic buildings and on an assessment of the extent to which green architecture principles and designs are applied; the building's architectural design (form and orientation), building envelope design (walls, ceilings and openings), and structural design (construction materials, methods of construction).

THE EGYPTIAN GREEN PYRAMID RATING SYSTEM

b) The Green Pyramid rating system in Egypt and its scores (strong > 70% - medium > 50% - weak < 50%), assigned according to the extent of application of rating criteria, which include:
1. Site sustainability

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2. Energy efficiency
3. Water efficiency (minimization and efficiency of water use)
4. Resources and construction materials
5. Indoor environment quality (ventilation and lighting quality, acoustics control)
6. Innovation, inventiveness and flexibility of management and maintenance
7. Reduction of pollution and recycling of waste

The following equation is used to calculate the overall percentage of Green Pyramid criteria met: total percentage of criteria met / the number of criteria.

ANALYZING RESIDENTIAL BUILDING EXAMPLES IN EGYPT

This section of the paper provides an analytical review of a number of historic Islamic residential buildings. Buildings are rated according to the Egyptian Green Pyramid system, and the extent to which they apply green architecture principles using Islamic architectural terms and techniques is assessed. In order to be rated on a purely scientific basis (unaffected by architectural style), residential buildings whose design is representative of green architecture were selected, regardless of architectural style. We have therefore chosen case studies from among projects that were awarded first prizes in the Toshka green architecture competition sponsored by the Organization for Energy Conservation and Planning. The purpose of the competition was to design a flexible residential unit that is capable of growing. One of the conditions was to avoid being influenced by a specific architectural style. A number of Eco- friendly residential buildings are studied, analyzed and rated according to both the Egyptian Green Pyramid system and the proposed measurement matrix to assess the extent to which they apply green architecture principles by using Islamic architectural solutions and repertoire. Selected buildings represent architects' attempts to apply environmental concepts to their designs, to underline the value of Islamic architecture and to encourage the design, within the context of modern technology, of modern architectural buildings that are suitable to, and in harmony with, the surrounding environment. The competition looked for the most deserving examples of contemporary architecture and honored those that provide a contemporary re-interpretation of ancient architectural lessons and demonstrate efforts to resolve local environmental problems. The Hassan Fathy Prize aims at advancing contemporary Egyptian architecture and commemorating the memory of Egyptian architect Hassan Fathy, the precursor of sustainable development theories and one of the pioneers of Egyptian architecture.

Historic Residences

Zeinab Khatoun House

- Architectural description: The building's design plan is an inward-facing one. The building is composed of two blocs; a two-storey building and a three-storey one. Spaces designed for visitors are separate from those intended for use by residents, with separate entrances for each. The building features the following architectural elements:

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1. Entrance: This is an oblique entrance in accordance with social custom. It has a wood beam ceiling. To the right of the entrance is a small passage with three doors; the first door opens unto a rectangular room with a wood ceiling, and the second opens unto the uncovered rectangular courtyard.[1]
2. The side entrance vestibule: A rectangular corridor covered partly with single vaults and partly with intersected vaults. Ventilation openings are located between the two ceiling types[2].
3. Main courtyard: For privacy purposes, most of the building's spaces open unto this courtyard, which serves to regulate temperature and to provide natural lighting and ventilation. It also works with the small, uncovered inner courtyard to create a permanent airflow in the building and to reduce temperatures in heat spots \ islands, while the different pressure levels in the courtyards create a cooling and ventilation system. The courtyard leans to the northeast at a 17-degree angle. Over 82% of its floor area and 77% of its wall area are shaded in the daytime on June 21[3], thus regulating temperature and lighting, especially during the peak hours. The courtyard is square, with a costly water fountain at its center.[4]
4. The *maq3ad*: Overlooks the courtyard and faces north to provide natural ventilation.
5. The large hall: Located on the first floor, it consists of a square *durqa3a* with a wood ceiling and a *shokhshekha* at its the center. The *durqa3a* is flanked by *iwans* covered with beamed wood ceilings[5] that serve as heat insulators. The ceiling of the hall is lower than that of the *durqa3a* to enhance lighting and speed up the ventilation process. Spaces in the building are arranged according to their exposure to noise, and the *iwans* provide protection against external elements.

Figure 1: Floor Plan, Ground Floor of the Zeinab Khatoun House
Source: Assem Mohamed Rizk, *Atlas al 3emara al islameya al qebteya belqahera*, Vol. 10, Madbouly Bookstore, 2003

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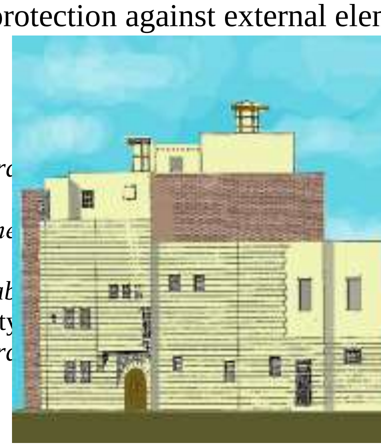

[1] Mohamed, Assem, *Atlas al 3emara al islameya al qebteya belqaher* ... ore
[2] Ibid.
[3] Abdel Reda, Shahd, 2011, *tatbeeq ossos al3enara alkhadra' letarshe* ... *ıneya*, Masters dissertation, Faculty of Engineering, Cairo University
[4] Mustapha, Hossam Al Din, 2005, *derassa ta7lileya makan lelthawab* ... *ı al far3ounya wa al3emara alislameya bemasr*, PhD. dissertation, Faculty ... sity
[5] Mohamed, Assem, *Atlas al 3emara al islameya al qebteya belqaher* ... ore

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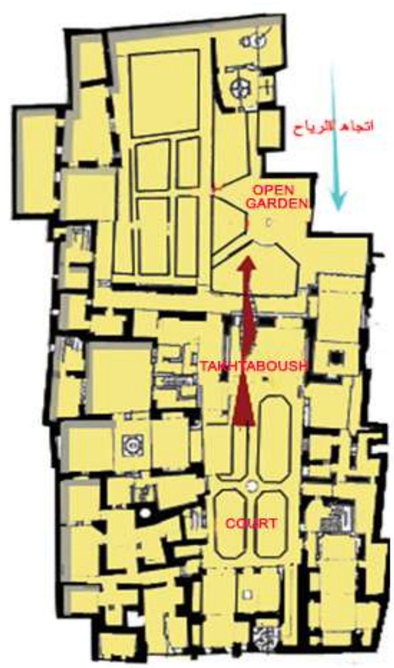
6. The bath: This consists of three rectangular rooms of varying size. A *khoshkhasha* covers the bath's heating room[1] and provides both lighting and ventilation. In addition, s*alsabeels* use steam to cool the bath.
7. *Malqafs*: serving the large and small halls are located on the roof[2]. Their function is to entrap the cool air and propel it into the halls. Together with the *shokhshekha*, they ensure a continuous airflow, making use of the upward flow of warm air.
8. Façade features: The house is composed of two external stone facades and the main internal facades with their wide openings. The first external façade features a main entrance, several lower windows and a number of upper windows in the midst of which is a wood *mashrabeya*. The second façade, facing northwest, is a small one. To provide protection against the sun, it is plain, with no ornamental or architectural features[3].

Figure 3: A Façade of the Zeinab Khatoun House
Source: Assem Mohamed Rizk, *Atlas al 3emara al islameya al qebteya belqahera*, Vol. 10, Madbouly Bookstore, 2003

9. Openings: *Mashrabeyas* overlooking the courtyard and surmounted by *qamareyas* face southward to minimize the sun's rays[4]. Upper openings allow the warm air to flow out of the building and the cooler air to flow in. They also ensure that natural lighting reaches the furthest corners of the internal spaces.[5]
10. Construction materials: Materials with a low level of thermal conductivity mostly derived from the local environment; stone is used for the ground floor and light colored brick for the upper floors.

Al-Suheimi House

- Architectural description: With a floor plan interspersed by open spaces, the building faces inward; an oblique (to provide protection against external elements) passage from the entrance leads into the courtyard.
    1. The courtyard: Located in the center of the house, it faces northeast and serves to moderate indoor temperature and to provide lighting and ventilation. Indoor spaces are arranged around the courtyard according to their privacy and acoustic insulation needs.
    2. The *takhtaboosh*: This is located between the shaded indoor courtyard and the sunny private garden. Since the



[1] Abdel Reda, Shahd, 2011, *Tatbeeq Ossos al 3emara al khadra' let… akaneya*, Masters dissertation, Faculty of Engineering, Cairo University
[2] Mohamed, Assem, *Atlas al 3emara al islameya al qebteya belqahe…* e
[3] Ibid.
[4] Abdel Reda, Shahd, 2011, *Tatbeeq Ossos al 3emara al khadra' let… akaneya*, Masters dissertation, Faculty of Engineering, Cairo University
[5] Ibid.

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air pressure is different in each of the two areas, the air flows from the courtyard, passing through the *takhtaboosh*.

3. The halls: For protections against external elements, the halls of the house each consist of two *iwans* separated by *durqa3a*s of different heights, used to promote ventilation. Ornamental gas lanterns hang from the ceilings.
4. The *maq3ad*: This is a hall with an uncovered north-facing façade that overlooks the courtyard and is used in the summertime.
5. The bath: Its ceiling is decorated with tiny square and round shaped openings covered in colored glass. As a water conservation measure, the bath contains a special closet for the water tank.
6. The openings: Most of the windows in the house overlook the inner courtyard. *Shokhshekhas* and *malqafs* make use of the upward flow of warm air to ensure continuous air circulation indoors. Upper openings provide ventilation and lighting and some are covered in colored glass.
7. Construction materials: Low thermal conductivity local materials were used; wood for *mashrabeyas* and stone for building thick walls that enhance heat and sound insulation. The surface area of west and east-facing facades are reduced, projections are built into facades to provide shade and light color materials are used to deflect the sunlight.
8. Site organization: The use of fountains and trees in the courtyard, building the private garden and raising humidity levels
9. Internal facades: These are the main facades of the house. The number and size of the openings in them regulate lighting and ventilation, according to the functional and climatic needs of the various indoor spaces. Most of the openings in the internal facades are large ones.

Figure 4: Ground Floor Plan, Al-Suheimi House
Source: http://wahmed.kau.edu.sa/

It is apparent, from all the above, that the functional, environmental, economic and social dimensions of design, execution and operation in both buildings facilitate the control and reduction of maintenance and operation costs. By using natural energy resources and materials, creating suitable climatic solutions and distributing cooling loads, they promote the use of resources that are locally available in the environment to ensure thermal comfort and provide natural lighting and ventilation.

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Table 3: Summary Analysis of the Zeinab Khatoun and Al-Suheimi Houses, Based on the Measurement Matrix and Green Pyramid Criteria, Source: Researcher

Zeinab Khatoun						**Al-Suheimi**					
Measurement Criteria	Degree of Application		Green Pyramid Criteria	Degree of Application		Measurement Criteria	Degree of Application		Green Pyramid Criteria	Degree of Application	
Site Selection	89 %	Strong	Site Sustainability	70 %	Average	Site Selection	90 %	Strong	Site Sustainability	85 %	Strong
Building Form	80 %	Strong	Energy Efficiency	70 %	Average	Building Form	90 %	Strong	Energy Efficiency	85 %	Strong
Orientation	90 %	Strong	Water Efficiency	50 %	Average	Orientation	90 %	Strong	Water Efficiency	60 %	Average
Cross Section	89 %	Strong	Construction Materials & Resources	70 %	Average	Cross Section	90 %	Strong	Construction Materials & Resources	70 %	Average
Ceilings	80 %	Strong	Indoor Environmental Quality	80 %	Strong	Ceilings	70 %	Average	Indoor Environmental Quality	85 %	Strong
Openings	70 %	Average	Innovation / Inventiveness & Renovation and Maintenance	40 %	Weak	Openings	80 %	Strong	Innovation / Inventiveness & Renovation and Maintenance	70 %	Average
Construction & Finishing Materials	90 %	Strong				Construction & Finishing Materials	80 %	Strong			
Wall Treatment	70 %	Average	Waste Reduction & Recycling	50 %	Average	Wall Treatment	80 %	Strong	Waste Reduction & Recycling	60 %	Average
Building Appliances	70 %	Average				Building Appliances	80 %	Strong			
Overall Rate of Application	80 %	Strong	Overall Rate of Application	65 %	Average	Overall Degree of Application	85 %	Strong	Overall Rate of Application	75 %	Strong

The analytical study of historic buildings based on the measurement matrix (i.e. using historic architectural elements and repertoire as an approach to applying green architecture principles) and their assessment according to Egyptian Green Pyramid rating system criteria leads us to conclude the following: <u>the higher a building's rate of application of the measurement matrix (i.e. the building features a greater percentage of historic elements), the greater the application of green architecture principles is (i.e. a higher Green Pyramid criteria application rate)</u>.

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Green Buildings

First Prize Winning Model in the Toshka Green Architecture Competition, First Example, Designed by Architect Mamdouh Mattar

- Architectural Description: A housing unit featuring a number of elements[1], including:
  1. Entrance: The concept behind the housing unit is applied by placing the greater part of the unit underground. To minimize sunlight, the rectangular building bloc faces east west and most of the building's spaces face north.
  2. Cross-Section: Cross-section of a building bloc containing numerous open spaces, with few urban heat islands; the rooms, separated according to the need for privacy, are arranged around the courtyards, which are the principal source of lighting and ventilation.
  3. Main Courtyard: Inner courtyards are used to reduce exposure to sunlight and increase shading. The ground floor overlooks a main courtyard where plants provide shade. An uncovered stairway in the courtyard leads to a secondary courtyard. The guest quarters, located on an upper level and separated to meet privacy needs, overlook this courtyard[2].
  4. Walls: 80 cm-thick load-bearing walls offset the effect of the sun's rays. The walls are white to deflect the sun's rays.
  5. Roofs: Domes are used to provide shade; roofs are made of stone and built in the traditional manner.
  6. Façade features: According to the design, most of the building is underground, which reduces the area of surfaces exposed to the sun. The main facades are the indoor facades, which have wide openings. To heat and cool water, the parts of the building that face south use solar energy derived from an energy complex. To reduce water consumption, the complex uses both subterranean and rainwater.
  7. Openings: Very large wall openings are used in combination with the *malqafs* opposite them to speed indoor air circulation. To combat the effect of the sun's rays, openings are treated with Colestra.

Figure 5: Ground Floor Cross-Section of the First Example
Source: Heba Abdel Mohssen, *Al3emara al khadra'a, al e3tebarat al bee'eya wa al enssaneya fi al tasmeem*, Master's Dissertation, Faculty of Engineering, Institute of Environmental Studies and Research, Ain Shams University, 2000

[1] Multiple authors, 1999, Green Architecture Competition, Applied Green Architecture Design Model, Architecture Competitions, *3alam al bena'* Magazine, Issue no, 214

[2] Ibid.

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8. Construction Materials: Natural materials are used, such as stone and hollow brick, and, as finishing material, sprayed coarse-textured coatings to combat the effect of sun.
9. Site Organization: Evergreen trees and shrubs surround the building, reducing the amount of sunshine that reaches it[1] and minimizing noise levels. Sanitary appliances are used.

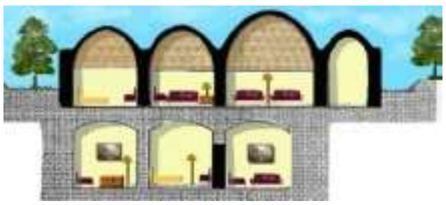

Figure 6: Section a – a, First Example
Source: Previous source (Figure 5)

Figure 7: Section b – b, First Example
Source: Previous source (Figure 5)

Figure 8: Section c – c, First Example
Source: Previous source (Figure 5)

First Prize Winning Model in the Toshka Green Architecture Competition, Second Example, Designed by Architect Magdy Mohamed Ibrahim

- Site: Toshka
- Architectural Description: The unit's design concept is based on the principle of thermal insulation and keeping indoor temperatures cool in the summer and warm in the winter. The building's central courtyard is a building solution suited to the climatic conditions of the region,[2] and it features many other innovative environmental solutions. It consists of:
    1. The central courtyard provides natural lighting and ventilation to the indoor spaces arranged around it. It is covered with concrete crossbeams, which form a pergola on which climbing plants grow. To regulate air humidity levels, water sprinklers are installed above the concrete pergola that covers the courtyard. Canvas fabric, stretched

Figure 9: Cross-Section, Ground Floor, Second Example
Source: Multiple authors, 1999, Green Architecture Competition, Applied Green Architecture Design Model, Architecture Competitions, *3alam al bena' Magazine*, Issue no, 214

[1] Ibid.
[2] Ibid.

beneath the sprinkles, is dampened by the water sprayed by the sprinkles, and the hot air passing through it absorbs the water vapor and cools the air.[1]

2. Building Facades: To ensure permanent heat insulation, the design uses natural soil, which has insulating properties, for the building's walls. The eastern and western facades of the unit (which in this case function as retaining walls) are therefore coated with natural soil. Solar cells are used to generate electricity.
3. Walls: Stone load-bearing walls (on reinforced concrete strip foundations) are used, and they also function as retaining walls. For thermal conductivity, the designer uses a low, 50 cm-thick stone wall as a nocturnal TROMB wall; at night, the wall radiates the heat, derived from solar energy that it has stored, into the building's interior spaces, providing the warmth needed in the winter[2].

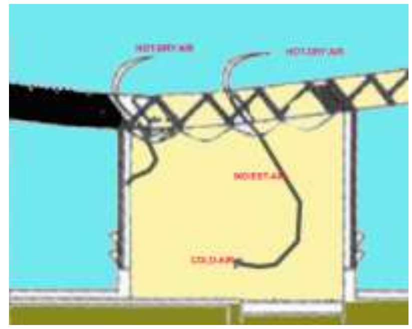

Figure 10: Study Explaining How to Increase Humidity Level in the Courtyard
Source: Previous source (Figure 9)

4. Roofs: The roof is made of reinforced concrete that is poured on-site (in a large site, individual blocs may be poured). After it is installed, the concrete roof is insulated using a 40 cm-thick layer of mud. Green grass is then cultivated to absorb the sun's rays and deflect light. Furthermore, observing the flutter of grass on rooftops makes it possible to allow sunlight into the building during the winter and to shade building facades and keep the sun out of the building during the summer. The location of the water tanks on the highest point of the concrete rooftop, behind the solar collectors, helps to ensure that the water pressure is suitable for use in the indoor water taps[3] and to reduce energy consumption.

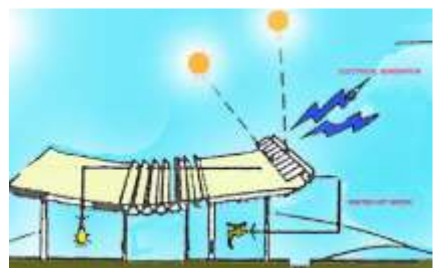

Figure 11: Environmental Solutions in the Second Example
Source: Heba Abdel Mohssen, *Al3emara al khadra'a, al e3tebarat al bee'eya wa al enssaneya fi al tasmeem*, Master's Dissertation, Faculty of Engineering, Institute of Environmental Studies and Research, Ain Shams University, 2000

5. Openings: To cool the building in the summertime, air is drawn into the unit through the high-pressure, shaded area above the concrete pergola. Inside the unit, the hot air collects high up in the spaces that have upper openings and sloping roofs, forming an area of low-pressure. To warm the building in the winter, the

[1] Ibid.
[2] Ibid.
[3] Ibid.

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upper openings in rooms are closed. Sun enters the courtyard, whose opening is also closed.

6. Use and Function of Sanitary Appliances
7. Construction Materials: Reinforced concrete was used as a roofing material. Stone (readily available on the site) was chosen to build the walls because of its high capacity for storing solar heat. All the windows and doors are made of wood, which helps to control air humidity levels. These construction materials were chosen because of their resistance to the effects of external elements and because their manufacture and use require little energy.
8. Site Organization: The design concept for this multi-unit complex is based on creating areas of varying air pressure, thereby generating air circulation that promotes cooling, as well as on the shade provided by the thick tree growth in the central area[1].

Figure 12: Multi-Unit Complex (Second Example)
Source: Multiple authors, 1999, Green Architecture Competition, Applied Green Architecture Design Model, Architecture Competitions, *3alam al bena' Magazine*, Issue no, 214

Table 4: Summary Analysis of the First and Second Examples of First Prize Winning Models, Based on the Measurement Matrix and Green Pyramid Criteria
Source: Researcher

First Prize Winner (First Example)						**First Prize Winner (Second Example)**					
Measurement Criteria	Degree of Application		Green Pyramid Criteria	Degree of Application		Measurement Criteria	Degree of Application		Green Pyramid Criteria	Degree of Application	
Site Selection	85 %	Strong	Site Sustainability	90 %	Strong	Site Selection	70 %	Average	Site Sustainability	90 %	Strong
Building Form	60 %	Average	Energy Efficiency	75 %	Strong	Building Form	60 %	Average	Energy Efficiency	75 %	Strong

[1] Ibid.

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Orientation	80 %	Strong	Water Efficiency	70 %	Average	Orientation	55 %	Average	Water Efficiency	80 %	Strong
Cross Section	70 %	Average	Construction Materials & Resources	85 %	Strong	Cross Section	70 %	Average	Construction Materials & Resources	75 %	Strong
Ceilings	50 %	Average	Indoor Environmental Quality	85 %	Strong	Ceilings	0 %	Weak	Indoor Environmental Quality	85 %	Strong
Openings	70 %	Average	Innovation / Inventiveness & Renovation and Maintenance	70 %	Average	Openings	50 %	Average	Innovation / Inventiveness & Renovation and Maintenance	70 %	Average
Construction & Finishing Materials	75 %	Strong				Construction & Finishing Materials	60 %	Average			
Wall Treatment	75 %	Strong	Waste Reduction & Recycling	70 %	Average	Wall Treatment	75 %	Strong	Waste Reduction & Recycling	65 %	Average
Building Appliances	75 %	Strong				Building Appliances	75 %	Strong			
Overall Rate of Application	65 %	Average	Overall Rate of Application	80 %	Strong	Overall Degree of Application	65 %	Average	Overall Rate of Application	80 %	Strong

The analytical study of green buildings based on the measurement matrix and their assessment according to Egyptian Green Pyramid rating system criteria leads us to conclude the following: Buildings with an equal rate of application of Green Pyramid criteria, have a very similar (almost equal) rate of application of measurement matrix criteria. To realize a strong application rate of green architecture principles, average use was made of historic architectural elements and repertoire without necessarily adhering to the Islamic style.

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Existing Environmentally Friendly / Eco-Friendly / Buildings

Beit Halawa: Winner of the first cycle (1980) of the Aga Khan Award for Architecture (Cycle theme: Searching for contemporary uses of traditional architectural language)

- Architectural Description: The house consists of two floors and its indoor spaces are arranged around three sides (North, East and South) of an inner courtyard. The house faces north-west, and is partially shaded. Cool air blows into it through the *malqaf* (wind trap), and it has a small garden as well as a servants' backyard. In other words, the house has an inward-facing design.

Figure 13: Cross-Section, Ground Floor, Beit Halawa Source: www.archnet.org

1. The *maq3ad*: An open area overlooking the beach, its location between the backyard and the garden provides a permanent supply of cool air.
2. The *malqaf* (wind trap): faces the sea breeze
3. The *iwan*: is located on the ground floor and faces east to provide protection against external elements
4. The ceilings: are vaulted with wooden beams
5. The oblique entrance: serves to separate the outdoors from the indoors, enhances thermal and acoustic insulation and provides varying degrees of privacy for different indoor spaces[1]
6. The *mashrabeyas*: ensure privacy and regulate natural lighting. Arches and large openings are used in internal and north-facing walls.
7. Construction materials: The sandstone used to pave the courtyard helps to keep it cool in the summer. The structure is built of stone with plaster finishing. Light color materials with low thermal conductivity levels that are easy to use, manage and maintain are used.

Figure 14: Section 1, Beit Halawa
Source: Previous Source (Figure 13)

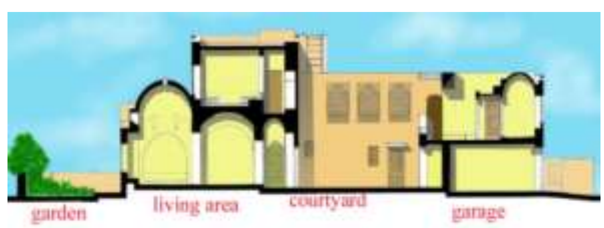

Figure 15: Section 2, Beit Halawa
Source: Previous Source (Figure 13)

[1] Serag Al Din, Ismail, 2007, *Al tagdeed walta'seel fi 3emarat al mogtama3at al islameya, tagrebat ga'ezat aga khan lel3emara,* Bibliotheca Alexandrina

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8. Construction: Traditional construction methods (that depend more on manual labor than on energy resources) were used[1].
   Use and function of sanitary equipment

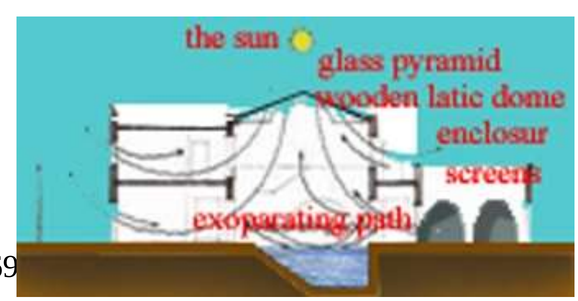
Al Alayli House: is the winner of the 2009 Hassan Fathy Award for Architecture. The theme for that year was, 'Identity in Contemporary Egyptian Architecture' and the reasons why this house was chosen for the award are the following:

Figure 16: Alayli House Façade
Source: www.bibalex.org

First: The design revives the Egyptian identity by using innovative methods to incorporate traditional elements into contemporary architectural concepts.
Second: The design achieves a tangible overall balance between indoor spaces and outdoor gardens.[2]
Third: Some specific concepts of sustainability are applied.
Fourth: The design avoids pretentious use of traditional architectural elements to symbolize a local identity; it is based on a simple structure that is environmentally harmonious.

- Architectural Description: The building consists of:
  1. The courtyard: The courtyard design is open to a number of external spaces, and underlines the principle of multiplying space activities and enhancing social interaction through its inward orientation. Spaces are divided into public and private ones. The perforated wooden dome, covered with a pyramid-shaped glass roof, collect sunlight and promote ventilation provide practical climatic conditions.
  2. The walls: The design uses hollow double walls; the cavity between the exterior and interior walls acts as a thermal and acoustic insulator[3].
  3. Roofs: Small shrubs that provide insulation from the sun cover the roofs.
  4. Finishing: Light colors are used on external facades (to

Figure 17: Cross-Section, Ground Floor
Source: Previous Source (Figure 16)



[1] Ibid.
[2] www.bibalex.org
[3] Ibid.

deflect the sunlight) as well as on interior walls (to increase lighting).

5. *Mashrabeyas*: Used to enclose openings overlooking the courtyard, they serve to regulate natural lighting and ventilation.
6. Openings: The building's openings face north. Upper floor openings are large and shaded by ledges built into the wall above them.
7. Site organization: Wood pergolas, a swimming pool and tree serve to control lighting and reduce temperatures. The house is surrounded by **arcade** that supply shade,[1] diffuse the sun's rays and provide protection against external elements.

Figure 18: Cross- Section, Al Alayli House
Source: Previous Source (Figure 17)

Table 5: Summary Analysis of Beit Halawa and the Al Alayli House, Based on the Measurement Matrix and Green Pyramid Criteria
Source: Researcher

Beit Halawa						**Al Alayli House**					
Measurement Criteria	Degree of Application		Green Pyramid Criteria	Degree of Application		Measurement Criteria	Degree of Application		Green Pyramid Criteria	Degree of Application	
Site Selection	60 %	Average	Site Sustainability	85 %	Strong	Site Selection	65 %	Average	Site Sustainability	90 %	Strong
Building Form	85 %	Strong	Energy Efficiency	75 %	Strong	Building Form	95 %	Strong	Energy Efficiency	60 %	Average
Orientation	75 %	Strong	Water Efficiency	60 %	Average	Orientation	70 %	Average	Water Efficiency	50 %	Average
Cross Section	80 %	Strong	Construction Materials & Resources	80 %	Strong	Cross Section	85 %	Strong	Construction Materials & Resources	40 %	Weak
Ceilings	65 %	Average	Indoor Environmental Quality	80 %	Strong	Ceilings	20 %	Weak	Indoor Environmental Quality	85 %	Strong
Openings	60 %	Average	Innovation /	70 %	Average	Openings	60 %	Average	Innovation /	60 %	Average

[1] Ibid.

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Construction & Finishing Materials	80 %	Strong	Inventiveness & Renovation and Maintenance			Construction & Finishing Materials	40 %	Weak	Inventiveness & Renovation and Maintenance		
Wall Treatment	90 %	Average	Waste Reduction & Recycling	65 %	Average	Wall Treatment	60 %	Average	Waste Reduction & Recycling	60 %	Average
Building Appliances	65 %	Average				Building Appliances	40 %	Weak			
Overall Rate of Application	75 %	Strong	Overall Rate of Application	75 %	Strong	Overall Degree of Application	60 %	Average	Overall Rate of Application	65 %	Average

The analytical study of existing environmentally friendly buildings based on the measurement matrix and their assessment according to Egyptian Green Pyramid rating system criteria leads us to conclude the following: Measurement matrix and Green Pyramid criteria application rates can be very similar in a single building. The relative rates can be almost identical and the degrees of application equal. That is, when the rate of application of the measurement matrix rises, the rate of application of Green Pyramid criteria also rises, so that the two rates are equal. However, because the two rates are directly proportional, it is almost impossible for the measurement matrix application rate to rise and the Green Pyramid application rate to drop to a level that is beneath it. We can thus consider the measurement matrix a principal practical approach to the application of both green architecture principles and tendencies, and Green Pyramid criteria.

RECOMMENDATIONS

Most Important Recommendations for Practical Application:

1. Focusing increased attention on a building's architectural design stages (from design concept formulation and site selection, to detailed building design, choice of construction materials and selection of environmental solutions), and using the measurement matrix as a practical approach to the application of green architecture principles.
2. International architectural models and trends should not be adopted unthinkingly, but only after deep thought and serious consideration.
3. Making use of traditional architectural solutions that are suitable to local environmental conditions to provide thermal comfort, natural lighting and ventilation and to successfully design a green home
4. It is important to ascertain that architectural designs fulfill environmental needs and are in harmony with social conditions.

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5. The importance of using traditional historic architectural design solutions to resolve environmental issues

Most Important Recommendations for Architecture Education:

1. Raising environmental awareness among individuals and institutions and developing / upgrading education curricula
2. Promoting appreciation and consideration of heritage architecture and the green architecture concepts and solutions it embodies, particularly within the architectural education system
3. The importance of in-depth study of traditional historic architecture so as to make genuine use of it - beyond simply reproducing or imitating it
4. The study of green architecture must be intensified to make this subject an essential component of building design

Most Important Recommendations for the Roles Played by the State and by Institutions:

1. It is essential for institutions to favor green architecture buildings and to encourage the acquisition of experience in this field, making green architecture essential to the building design.
2. The importance of integrating and consolidating local environmental principles into Egyptian construction law and systems
3. The role of universities in assessing projects and their effect on the environment must be activated.
4. The importance of recognizing and respecting modern principles of historic architecture in society
5. The importance of assessing the environmental impact of construction projects and promoting the adoption of green architecture principles

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