AN APPROACH FOR SUSTAINABLE AFFORDABLE HOUSES DESIGN IN EGYPT

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Abstract
Achieving sustainability is an important factor to be considered in the architectural design process, there is an important need to consider sustainability in affordable houses design. The research problem is the presence of many affordable houses in Egypt without considering the terms of sustainability, and also the increasing the numbers of these projects in Egypt. By studying the current situation of most affordable houses projects in Egypt, a lack of achieving sustainability requirements appear, which led to the need for an approach to meet these requirements in affordable houses design. The research includes a theoretical study of the sustainability requirements when designing new affordable houses, with concerning about achieving the design requirements for users, considering the project cost and applying the requirements of sustainability to be matching with the local environment. The search includes an analytical study of some international case studies that include some of sustainability applications, determining the advantages and the latest international ideas in the field of sustainable affordable houses. The analytical study includes also a local affordable houses project in Cairo in Egypt identifying the most important shortcomings in sustainability achievement in this project. The research aims to propose an approach to achieve sustainability in the affordable houses design and to be applicable to apply to the projects in Cairo, Egypt, where the research concluded a design approach to achieve sustainability of affordable houses projects in Cairo in Egypt considering of the local factors, matching with local environment and international developments.

Keywords
Sustainable design, affordable houses, sustainable houses design, affordable houses design, and sustainable design
AN APPROACH FOR SUSTAINABLE AFFORDABLE HOUSES DESIGN IN EGYPT

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ABSTRACT: Achieving sustainability is an important factor to be considered in the architectural design process, there is an important need to consider sustainability in affordable houses design. The research problem is the presence of many affordable houses in Egypt without considering the terms of sustainability, and also the increasing the numbers of these projects in Egypt. By studying the current situation of most affordable houses projects in Egypt, a lack of achieving sustainability requirements appear , which led to the need for an approach to meet these requirements in affordable houses design. The research includes a theoretical study of the sustainability requirements when designing new affordable houses, with concerning about achieving the design requirements for users, considering the project cost and applying the requirements of sustainability to be matching with the local environment. The search includes an analytical study of some international case studies that include some of sustainability applications, determining the advantages and the latest international ideas in the field of sustainable affordable houses. The analytical study includes also a local affordable houses project in Cairo in Egypt identifying the most important shortcomings in sustainability achievement in this project. The research aims to propose an approach to achieve sustainability in the affordable houses design and to be applicable to apply to the projects in Cairo, Egypt, where the research concluded a design approach to achieve sustainability of affordable houses projects in Cairo in Egypt considering of the local factors, matching with local environment and international developments.

KEYWORDS: Sustainable design, affordable houses, sustainable houses design, affordable houses design, and sustainable design.

RESEARCH OBJECTIVE
The research aims at providing an approach for achieving sustainability in affordable houses design in Cairo, Egypt.

RESEARCH METHODOLOGY
The research is based on theoretical study and applied study, where the theoretical study included the theoretical approaches and basis of affordable houses to achieve the sustainability in residential buildings, and the applied study included an analysis of some international case studies with the analysis of the most important elements of affordable houses projects and the most important international trends in this field ,with an analysis of an affordable houses project in Cairo, Egypt ,explaining the existing problems of this project. All previous elements led to conclude the approach to achieve sustainability in affordable houses project which will be applicable in Cairo, Egypt.

1. INTRODUCTION
Affordable houses is a topic that receives an international interest where it works to provide housing units for some people who do not able to get a house at market prices, there are many international experiences in the field of affordable housing with a reasonable cost while providing the required services, international trends are working towards achieving sustainability in affordable houses to maximize its
benefits to the affordable houses users and the community while some of international projects received LEED certification as a result of some strategies in these projects.

2. AFFORDABLE HOUSES DEFINITION:
Affordable houses are houses that achieve the requirements of low income people who cannot meet their requirements through the open market (Myerson, 2008) where they fit their income to provide these families with the suitable houses for their income (Disney, 2007). In the United States, houses are considered affordable for families when their expenses for housing do not exceed than 30% of their total income (Wikipedia, 2012). Affordable houses design are linked with some principles such as selecting the suitable site with the required infrastructure, determining the area of unit carefully considering the cost reduction methods and community considerations and designing effectively of typical floor plans while minimizing of wasted areas with effective design of circulation areas, as well as the optimum use of spaces, the simple design of the typical floor plans and efficient selection of suitable materials with suitable prices and appropriate use (Ehmann, 2014), and also selecting of inexpensive structure systems, studying the total cost carefully, analyzing the reasons that may raise the cost, that may be related to design or construction methods, trying to create innovative solutions to decrease the cost and studying to what extent users can accept these buildings when completed (Duncan, 2000).

3. SUSTAINABLE DEVELOPMENT
Sustainable development is defined as the provision of the requirements at the present time with no prejudice of individuals in the future to provide with their requirements (Dalal, 2002) where sustainability can be defined as working on a future that takes into account the environmental, social, and economic aspects (Magwood, 2017).

4. SUSTAINABLE DEVELOPMENT AND AFFORDABLE HOUSES
According to the previous definitions the affordable houses which are suitable for low-income people, if they are designed and addressed with solutions that reduce operating costs, energy and resource consumption, and they can provide the inhabitants with their living needs, taking into account of social, economic and environmental aspects, of the present and future, they can be considered as sustainable houses (Ehmann, 2014). Therefore, houses is provided to people with low incomes to be matching with their financial potential to provide them with the required needs, these buildings are sustainable and take into account the different dimensions of social, environmental and economic sustainability and has the efficiency of consumption of energy, materials and water during the life cycle of these buildings (Owen, 2017).

4.1 Multi Family Affordable Houses and Sustainability
International trends have emerged towards achieving sustainability in multifamily affordable houses, with the emergence of many innovative ideas and architectural solutions to achieve sustainability and conserving energy in these buildings, (Ehmann, 2014) in Louisa project in Portland which is 16-storey residential building that completed in 2006, there’re many sustainable solutions such as using bamboo flooring, using of recycled carpets, finishes are made from local materials, balconies are used for shading devices on the facades and some other treatments to protect against external noise, making the interior spaces quiet where the project consumes about 40% of the energy consumption compared with any other project of the same size and area. The Acqua Vento project in Alberta was completed in 2006 and holds a LEED certification, the project works on collecting rain water and recycling gray water, the project also uses solar panels to produce energy where the project reduced water consumption by 60% and reduced energy consumption by 50% compared to another similar local project (Yudelson, 2009). In the Helena apartment building in New York, which was completed in 2005, the project contains a sewage treatment plant in the building, micro turbines to produce electricity, solar panels modules that produce about 13 kilo Watt of energy, the project also includes methods to reduce energy consumption that leads to decrease the energy consumption which led to a decrease in energy consumption of the building about 33% compared to the consumption of any other building of the same size and functions, the project also purchases the rest of energy needed from outside its site, of energy that generated by renewable energy techniques and the project has received a LEED certification. (Yudelson, 2009).

5. PRODUCTION OF MATERIALS AND SUSTAINABILITY
The production of some building materials causes a bad effect to the environment because this production generates a great amount of pollutants, gases and a large amount of carbon dioxide (Bredenoord, 2016), therefore, it is better to use materials that do not produce pollution when produced, or to use other natural materials whose production do not cause pollution, that will be preferred in the terms of sustainability, such as timber, stone, bamboo and any other natural materials (Moya, 2016).
6. AFFORDABLE HOUSES AND COST

The economic dimension is one of the main factors of sustainability. The economic dimension contains the cost of affordable houses which is not limited to the initial costs of building construction and finishing, but also it includes the operating costs which include the maintenance processes (Ehmann, 2014). In order to the building to be sustainable and efficient as an affordable house, the operating costs should be as low as possible to be suitable for users who are a low-income people (Martin, 2015). The prices of the equipments and tools that are used in buildings to meet sustainability requirements may raise the initial cost of the sustainable projects, but during the occupation of the project, the operating cost will be low which is appropriate for affordable houses for low income inhabitants (Matt, 2017). The project in Hunziker Areal, Zurich in Switzerland is an example for an affordable houses project, it includes a non-profit system to provide the actual cost to inhabitants, and the total cost contains the initial cost which includes land and construction cost and running cost which includes maintenance, operating and management cost (Owen, 2017).

6.1 Planting and Economic Support to Inhabitants in Sustainable Affordable Houses

The plants in landscape areas should be selected from the local environment to be compatible with the local climate and soil. It’s required to select the plants which need least water consumption as well as these plants and landscape areas don’t require much maintenance. In affordable houses projects, there are new solutions to plant fruits and vegetables to be used as a food for the inhabitants with a consideration of how to provide with the required water in a sustainable way (Fontan, 2016).

7. DURABILITY AND SUSTAINABLE AFFORDABLE HOUSES

Durability and the minimum maintenance required are necessary elements to be considered in affordable sustainable houses to continue for long periods, if the building needs frequent maintenance and repairs which will cost a lot, it is not considered a sustainable building. It is necessary to study the quality of construction, materials, finishing materials, systems, installations and equipments as well as the continuity for a long time without the need for large maintenance works, and take into account the impact of climate factors on the building to reduce the large maintenance work (Kibert, 2016). Multiple large maintenance works of buildings for short periods will increase the operating cost and can affect the affordability and sustainability of building, therefore, the quality and continuity of the long-term building should be considered with the selecting of structural system and materials that to be durable and do not need multi maintenance. (Fontan, 2016).

8. TECHNOLOGICAL DEVELOPMENT AND ENERGY DEVICES FOR SUSTAINABLE HOUSES

Technology has contributed to the development of used devices to achieve sustainability whereas technological development has contributed to the improvement of energy generating tools as well as energy conservation. For example, the shapes and sizes of solar panels have developed and their prices had decreased that makes them suitable for the sustainable affordable houses projects, as well as the emergence of air condition system that is using solar energy for its process, and the development of solar water heaters in their sizes and efficiency, and also the development of wind turbines which makes them smaller sizes and more efficient which is commensurate with sustainable houses (Matt, 2017).

9. SOCIAL SUSTAINABILITY

Social sustainability in affordable houses works to create the suitable houses for users and to improve the level of living of these people, so that they can interact effectively with larger urban regions. When starting to design a sustainable affordable housing project, it is necessary to understand the social aspects of the community that will use this project and to deal with these aspects positively, because users will make a community with certain characteristics, the types of expected users must be identified. It’s necessary to make a social study, survey and collecting social information on the expected users, and utilizing of the prior social data for these communities and also to collect information on their lifestyle, behavior, culture aspects, traditions, habits, activities, beliefs, social life, participation among the inhabitants, coexistence with others, the extent of social development and level of education of these users (Ehmann, 2014). The design must consider these social aspects identifying the requirements for social services, and providing with required services such as transportation, social communication with the community and other required social services, because the lack of interest of social sustainability by the designer affects negatively to the success of the project, it may lead to unexpected feedbacks by users according to their behavior, habits or culture, so the designer must take into account these social requirements, community needs and users requirements at the decision making stage (Eriksson, 2016). The body of (ASHA) which is a branch from the International Finance Corporation (IFC) that provides funding and consultancy for sustainable buildings for housing projects worldwide such as Vietnam, Indonesia, Brazil, and India, has prepared a study in the field of sustainable social aspects of the residents in sustainable housing projects, some recommendations according to inhabitants’ types suggest that in some cases
maybe there’s a need to add some activities and services such as shopping centers, retail stores, open spaces, child care, transportation and some spaces in buildings for social activities (Yu, 2015).

9.1 Inhabitant’s Behavior and Energy Conservation

There’s a relation between inhabitants behavior and energy conservation, Aune proved that the consumption of energy and materials in families is an expression of inhabitants’ behavior and lifestyle of using the energy and materials in their houses (Støa, 2012). The British researchers Chaplles and Shove identified four different models of comfort and activities in houses, these models are related to the behavior and habits of people, they found that each model has a different effect on consumption of energy and resources in houses (Støa, 2012). By working to make some development in behavior and lifestyle of users, that will improve obtaining sustainability and reducing energy consumption, as an example the Hunziker project in Zurich reduced its monthly energy required to 2000 watts of electrical power by encouraging inhabitants to adapt and change their lifestyles and habits to a sustainable way, as well as motivating them to use bicycles instead of other means of transportation. (Owen, 2017).

9.2 Affordable House area and the social factor

Some trends are working to reduce the unit area of the affordable houses to reduce the cost of construction, however, the determination of the residential unit area must be linked with the nature of the society which will live in this housing project to be accepted by users and trying to fulfill their requirements (Cleary, 2012). Some studies and data must be prepared such as survey studies and statistical data on the target population, the expected average number of family members for users, the target society, social and behavioral nature of users, the priorities for the use of the house internal spaces for users, the internal activities in the house and the expected income of the population to pay on housing. In order to determine the optimal area of the house (Støa, 2012), the distribution of internal spaces and the number of rooms in the residential unit (Scott, 1997).

10. THE BENEFITS OF SUSTAINABLE AFFORDABLE HOUSES

Sustainable affordable houses benefits include achieving the required houses for low income inhabitants while achieving sustainability including environmental, social and economic dimensions (Barrie, 2006), the economic dimension includes providing housing for the low income people in affordable prices with the required services, it also works to improve energy efficiency, decreases the consumption of materials and resources, and minimizes water consumption, this reduces the operating costs to the inhabitants as a result of sustainability procedure (Magwood, 2017). The social dimension includes providing the required comfort for users, providing the required social activities, providing a suitable social life, supporting the required social care, increasing the quality of life, enhancing the integration among the community parts and strengthening the local community by supporting a part of its component of those who need of affordable housing (Wells, 2008). Environmental dimension includes the optimal dealing with the existing climate, reducing the negative impact on the environment, improving air quality and internal environment, reducing carbon emissions, preserving the environment, dealing optimally with environment to achieve the desired benefits, minimization the pollution with good waste management and minimizing of pollutants which leads to create of a healthy life for the people (Moxon, 2012).

There are other benefits when living in sustainable houses, people who live in a less polluted, less noisy and healthier environment in sustainable houses will live in a good health that will lead to better productivity, higher quality in work and a greater sense of satisfaction and comfort which will lead to a great benefit especially for low-income people (Magwood, 2017), it is also a step towards less polluted cities as sustainability practice will also develop inhabitants behaviors as well as the use of local materials will enhance local production capacities which enhancing local employment opportunities and local income (Wahlstrom, 2014), the conserving of energy and water consumption will reduce the required burden on infrastructure services, which leads to reduce the need for the establishment of more power plants, water purification plants, sewage and gas plants, thus reducing the cost of required utilities when establishing of new affordable houses projects as well as the use of renewable energy will reduce pollution and reduce the cost of energy (Barrie, 2006).

11. MAIN OBSTACLES TO ACHIEVE SUSTAINABILITY IN THE AFFORDABLE HOUSES.

The sustainability achievement in affordable housing projects may face some obstacles such as the lack of interest by designers and decision-makers for sustainability without considering it as one of the project’s main objective, the lack of understanding on how to achieve sustainability in affordable houses projects for designers, the lack of knowledge, benefits, basis, importance of sustainability, and sustainable livelihoods for some users, the lack of information for the decision makers about the importance of sustainability in affordable housing.
projects (ICAST, 2017) and Lack of conscious funding that supporting the sustainability. Some decision makers may believe that sustainability devices may increase the initial costs of the project (Martin, 2015) as well as some of equipment or devices to achieve sustainability may be not available in the local market (ICAST, 2017).

12. INTERNATIONAL CASE STUDIES FOR SUSTAINABLE AFFORDABLE HOUSES:

12.1 Via Verde residential project, New York City, USA

Via Verde is located in New York city in USA, which is a residential affordable and sustainable project, it completed in 2012 and contains 222 flats in different height building parts (as shown in Fig. 1, 2 &3). The project won the competition of new housing in New York which expresses social housing aiming to create sustainable and healthy living (Wadman, 2014). The project considered a step towards the sustainable affordable housing and also it awarded LEED Gold certification (Archdaily, 2014).

![Fig. 1 Via Verde project](Reference: Wadman, 2014)

![Fig. 2 Solar panels on façade](Reference: Wadman, 2014)

![Fig. 3 Shading devices](Reference: Wadman, 2014)

12.1.1 Planning and Design

The architectural design of the building consists of four sides surround an internal courtyard (as shown in Fig. 4 & 5) which contains plants and landscape elements. The inner courtyard starts from the first floor level. The retail stores that provide the commercial services locate under the courtyard in the ground floor level. The courtyard is used as a community space. The project total area is 294000 sq. feet, it contains 277000 sq. feet for residential area, 7500 sq. feet for commercial and community area and 40000 sq. feet for green spaces (Archdaily, 2014).

![Fig. 4 project site plan](Reference: Matkins, 2014)

![Fig. 5 Ground floor plan](Reference: Matkins, 2014)

The architectural design includes different residential apartments types like units with one bedroom, units with two bedrooms (as shown in Fig. 7) and units with three bedrooms (as shown in Fig. 6). Most of apartments are overlooking to the inner courtyard (Archdaily, 2014). The project oriented to best direction to maximize favorite wind with considering the sun radiation effects. The project is designed to take into consideration the site borders and shape and also the adjacent areas and surrounding environment, it is inspired from the place and nature (Matkins, 2014).

![Fig. 6 Examples of one, two and three bedrooms units](Reference: Matkins, 2014)

![Fig. 7 One bedroom and two bedrooms units.](Reference: Matkins, 2014)
12.1.2 The relation with the environment

The design of the project is inspired by the characteristics of the surrounding nature and the city.

12.1.3 Social dimension

The Via Verde project contains an indoor place for community activities for all residents as a common space that is designed in the penthouse floor (Archdaily, 2014). The project works to provide outdoor spaces for recreational activities as well as social activities and works to integrate the project with nature and to be a kind of sustainable housing that has positive healthy aspects and affordable (Matkins,2014). The project also include amphitheater for the social gathering and activities.

12.1.4 Sustainability features:

The project is featured by green roof with plants which connect inhabitants with the nature in addition to that the stepped terraced roofs are planted with some fruits and vegetables for the inhabitants. (Matkins, 2014).

12.1.5 Passive solar design

Window openings allow good ventilation of all rooms and for internal spaces. Natural light is enough for spaces during the day. Shading devices and balconies are working to give the required shades to protect from sun radiation (as shown in Fig. 3) and also residential units contain high insulation system for building.

12.1.6 Water consumption

An advanced system was used for rainwater by adding external high tech rain screens covers the facades that deflect the majority of rain water and reduce the infiltration of water vapor during the rain, LEED body considered this system is a good feature when awarding LEED certification to the project. The recycling process of rainwater is made to irrigate the plants on roofs. Green roofs can suck rainwater, it connects the residents with nature and to protect the facade from solar radiation because it contains evergreen plants. Residential units contain water conserving systems (Matkins, 2014).

12.1.7 Materials

Bamboo is used in interior finishes which is a natural material. There’s no use for any paint that contains any harmful material to human health.

12.1.8 Energy

- The building provides more than 30% energy saving than a similar building.
- Solar panels had been added to generate electricity (as shown in Fig. 2) (Wadman,2014).
- The project is equipped with Energy saving devices.
- All building corridors and stairs have provided with motion sensors to control lighting for conserving electricity. One of the reasons that be credited by LEED was to encourage residents to use stairs instead of elevators to decrease electricity consumption (Wadman,2014). The use of ceiling fans led to decrease the use of air condition machines. Residential units contain energy efficient lighting.

12.1.9 Recycled materials

About 20% of the materials used in the construction of the building, were from recycled materials (Matkins, 2014).

12.1.10 Recycling waste

About 80% of the waste from the construction process had recycled and residents are encouraged to support recycling operations by giving them the best way of recycling the waste (Matkins, 2014).

12.1.11 Indoor air quality:

The paints used are not harmful to health and do not contain (VOC) volatile organic compound.

12.1.12 Social dimension

In the seventh floor there’s a landscape area used for sports and social activities.

12.1.13 Healthy living

The project is designed to be healthy and environmentally friendly to the residents, that works to address health problems for them so the project deals with the health problems of the residents, the project is located in a district characterized by the highest rates of asthma therefore the project worked to deal with this health problem by increasing the sports activities of the residents. Walking on foot is considered an important health issue, so the project encourages residents to walk to the metro station, which is just a few minutes walking and also other daily services and public school complex are located nearby where people can reach through walking on foot because many residents don’t own a car.
(Wadman, 2014). The project also encourages residents to use bicycles making a storage place for their bicycles, and also there is a center for sports and fitness (Matkins, 2014), as well as the project contains a health center, about 5500 sq. feet locates in ground floor level (Matkins, 2014).

12.2 Sierra Bonita Apartments in Hollywood, USA.

The project is affordable houses, consists of 42 units for low income special needs people (as shown in Fig. 8), it locates in West Hollywood, its area is 500,000 sq. feet which completed in 2010 (Goodwin, 2012).

12.2.1 Planning and design

The floor plan is a rectangular shape with an inner courtyard. The residential unit is a space used as a bedroom, a space for living area, bathroom and kitchenette, some units are overlooking to the inner courtyard while others are overlooking to the main street with balconies which are covered by some panels to protect from direct solar radiation (Goodwin, 2012). There are two strips of solar panels on the southwest facade and roof to generate electricity (as shown in Fig. 9). The design takes into account some aesthetics in facades and doesn’t give the feeling that the building is for low-income people (Lubell, 2010).

12.2.2 Sustainability: The building has some sustainability features as the following:

- **Passive solar design**

  Panels on balconies of main façade offer the suitable shading to protect from direct solar radiation for the residential units (as shown in Fig. 12) (Architizer, 2012). The project contains inner courtyard which is planted by bamboo plants to create a nature environment which is used for a suitable shading, natural ventilation, air quality and good air circulation (as shown in Fig. 13) (Lubell, 2010). Solar panels on roof provide a shading area on roof to be used by inhabitants. Large windows provide the maximum daylight and have some shading devices to reduce heat acquisition (Architizer, 2012).

- **Materials**

  The louvers in ceiling are manufactured from recycled materials.

- **Energy**

  Solar panels are on roof and façade which can provide all the electricity required for the common areas of the building (as shown in Fig. 10 & 11). The roof includes solar water heaters that provide all required hot water. All units have energy saving devices. All energy saving elements, and renewable energy systems can reduce the required operating costs for low-income residents (Goodwin, 2012).

The project has a positive impact on the surrounding area (Goodwin, 2012).
-Social dimension

The design of the building allows spaces for the social activities for residents in roof and courtyard.

12.3 Los Vecinos Solar Affordable Housing in San Diego , USA

Los Vecinos building is a multifamily affordable housing in San Diego, USA, achieved Platinum LEED certificate in 2009, (as shown in Fig. 15 & 16) and also it awarded of excellence Sustainable Communities Champion in 2009, and awarded E.A.R.T.H Workers (Environmental And Restoration That Helps) of San Diego in 2009. The architectural design of the building consists of three stories with U shaped, surrounds a courtyard from three sides, many apartments have oriented to the inner courtyard which includes a green area and some landscape elements. The building contains a recreation area and a community center to create a kind of interaction for the inhabitants (Martinez, 2010).

The building works to meet sustainability requirements where it’s considered an important goal for the architectural design for indoor and outdoor. U-shaped design helped to take advantage of natural day light and natural ventilation (solaripedia, 2010).

12.3.1 Sustainability features:

The project is sustainably designed for affordable housing, the design of the building reduces the amount of carbon emissions and reduces the consumption of public utilities such as electricity, gas and water, which reduces the required bill amount for the residents (solaripedia, 2010). This led to get a platinum LEED certificate. The building has a range of sustainability techniques, which include:

- Renewable energy:
  The building contains Photovoltaic panels on its roof which generate about 90% of the usage required electricity of the project (solaripedia, 2010).

- Energy saving:
  The residents receive monthly reports on consumption rates, and energy conservation methods, with an explanation of the methods used to reduce consumption. This project is featured by energy saving systems (solaripedia, 2010).
  The project is prepared by a good insulation system for walls and roofs, the use of tank-less hot water and the use of Low E glass (low emissivity glass) in windows which works to increase the efficiency of thermal insulation of windows (Viro, 2017), that to decrease the energy consumption (SDGE, 2009). The project used tankless water system for providing hot water, this system works on decreasing the water consumption (Martinez, 2010). All lightings are compact fluorescent units (Martinez, 2010).

- Water efficiency:
  All units in the building contain low-water- devices and valves to reduce water consumption, to (solaripedia, 2010). All planting in landscape consume minimum water . As a result of the use of artificial turf and a certain high efficient type of irrigation system, the reduction of water consumption has reduced to 50 %, and also the project uses a special efficient plumbing system that decrease the consumption of water by 20-30% (SDGE, 2009). Rain water is collected for irrigation (Martinez, 2010).

- Ventilation:
  Ventilation types are natural ventilation and a system based on fans fixed on ceiling (solaripedia, 2010).

- Building Materials:
  The building was built on the site of an old hotel that was demolished and recycling about 75% of its waste in the construction of the new building (SDGE, 2009). Approximately 50% of the waste was recycled during the construction process and recycled materials were reused in construction works (solaripedia, 2010). Other recycled materials have recycled to be used in countertops, artificial plants and for floor finishing instead of using new materials (SDGE, 2009). Recycled materials were reused to make art pieces by local artists to use in interior design and also doors made from reusable materials (solaripedia, 2010).

- Recycled Materials:
  Recycled materials have used in construction and finishing materials.
-Indoor air quality:
  The presence of a system for the air exhaust outside for the undesired air and using air filters, the project systems are improving of internal environment by using natural materials for floors finishes and using of materials for paint with no VOC (Volatile Organic Compound) (solaripedia, 2010). All insulation materials are formaldehyde-free. The project works to provide a healthy environment for the residents.

-Sustainable Social dimension:
  Training courses have conducted to the residents to raise their awareness of the sustainable lifestyle, the concept of efficient use of energy, and the ways to conserve the environmental components and reduce pollution, while educating program to children and adults on how to achieve their requirements through the sustainable life (solaripedia, 2010), and how to decrease the utility bill by conserving the resources (SDGE, 2009). Also there’re training programs for the managers of the sustainable buildings (Martinez, 2010).

-Decreasing pollution:
  The site is close to means of mass transportation, therefore it encourages the residents for walking and cycling to use mass transportation instead of using cars, which helps to reduce the pollution (SDGE, 2009). All interior spaces are free of smoking (Martinez, 2010).

12.4 Step Up on Fifth project in Santa Monica, California, USA.
The Step up on Fifth is an affordable housing project (as shown in Fig. 17 & 18), it’s in Santa Monica in California, USA, the purpose of the project is to contain the homeless people, it contains of 46 units. The design of the building envelope is for sustainable purposes. The project had awarded LEED Gold certification.

Fig. 17 Exterior façade
Reference: Arch daily, 2010
Fig. 18 Exterior envelope
Reference: Arch daily, 2010
Fig. 19 Typical floor plan of the project
Reference: Arch daily, 2010

12.4.1 Planning and Design
The architectural design of the building (as shown in Figure 21) is an E shape surrounds of two internal courtyards. The retail units locate under two courtyards level. The project consists of 5 typical floors, ground floor and basement floor for car parking. Some of units are directly oriented to the inner courtyards.
The design of units consists of one space for living and sleeping, bathroom and a small kitchenette.

12.4.2 Social dimension of sustainability
Each floor in the Step up on Fifth project includes a community room overlooking to the inner courtyards, which is considered the area for the social activities of all residents.

12.4.3 Some Sustainable strategies
The project contains many sustainable strategies like:
  - Passive solar design strategies
    The design of the project takes into account the passive design requirements like:
    The building oriented to control the required sun radiation, cooling and required shades (as shown in Fig. 20 & 21) (Arch daily, 2010) and also the shape of building controls the desired and undesired wind and encourages the natural ventilation.
    - Internal courtyard (as shown in Fig. 22) plays an important role in passive solar design.
    - The study and design the distribution of natural lighting and natural air ventilation.
    - The design of the external façade to achieve the maximum natural lighting, shading devices had been added on the southern facades and minimizing the windows and openings in western facades (Arch daily, 2010).
    By using these strategies, the building has achieved 50% more efficient than other building.
  - Energy saving
    - The building is equipped by energy saving devices, systems and tools to decrease the energy consumption which are working through construction and occupancy phases (Arch daily, 2010).
    - The exterior envelope was designed to make the required shading for the building.
    - The use of thermal insulation in walls, roofs, and exterior envelope, and also the use of double glazing windows to prevent heat transfer to inside or outside to conserve the energy during cooling or heating process for the interior spaces. All windows are using low-E coating (low emissivity coating) for glass to improve the energy efficiency and protect for thermal transfer through glass.
-The project has the potential to achieve sustainability requirements and lower energy consumption than is better than the required rates in California state by 26% (Arch daily, 2010).

**Fig. 20 Shading devices**

**Fig. 21 Shading devices on facades**

**Fig. 22 Inner courtyards**

**-materials**: The construction waste was transferred to a recycling station to be recycled and reused in another process. The recycling rate of the project is 71%, which used in insulation, flooring, concrete and carpets.

**-Water**: The use of low consumption valves for water and low flow in toilets and water saving system, with the rain water management to be reused (Arch daily, 2010).

### 13. AFFORDABLE HOUSES IN EGYPT

There are several affordable houses projects in Egypt, most of them are focusing on reducing the construction cost of the residential unit without considering to reduce the operating cost.

#### 13.1 Future housing project in the Third Settlement, New Cairo city as an example for affordable houses:

Future Housing projects aim at providing affordable houses for low-income people, these projects was established in many new cities in Egypt such as New Cairo, Sixth of October, Al-Obour, Al-Shorouk, Tenth of Ramadan, Sadat and New Minya. Future housing project in New Cairo (as shown in Fig. 24 & 25) locates in the Third Settlement, its site area is 7 feddan and consists of several buildings which have the same architectural design type, facades and height. All buildings have five floors height. The architectural design of residential units (as shown in Fig. 23) has two types, first one consists of three bedrooms, living area, kitchen and bathroom while the second one consists of two bedrooms, living area, kitchen and bathroom. Residential buildings are oriented in two different directions, with the use of grass and some trees in landscape areas (Hasan, 2018).

**Fig. 23 Typical floor plan**

**Fig. 24 Site plan of New Cairo project**

**Fig. 25 Future project in New Cairo**

#### 13.2 Project disadvantages in terms of sustainability in affordable houses:

There’re many disadvantages in this project as the following:

**13.2.1 Creative solutions**

The absence of any innovative or creative solution towards achieving sustainability in this affordable houses project, whether in mass, facades or other elements in buildings.

**13.2.2 Design considerations**

The site is far from mass transportation and also adjacent buildings are not connected that does not reduce the total areas of the exterior walls. There are a small number of units in each floor for each building and large residential units’ areas, the units are three bedrooms units with living area, kitchen and bathroom and two bedrooms units with living area, kitchen and bathroom, with the absence of one-bedroom units or studio units making the unit expensive for low-income inhabitants (Hasan, 2018).

**13.2.3 Passive solar design**

- The project design did not take into account of the preferred orientation of openings in buildings.
- The building design does not contain an internal courtyard.
- The absence of thermal insolation of exterior walls and also the absence of any architectural solution to protect the facades from solar radiation as there are no shading devices on the southern, western or southwestern facades, as these facades need protection from solar radiation in Cairo also the glass in windows is not double nor (Low E glass) that does not protect from outdoor temperature.
- Good natural ventilation is not considered, the design doesn’t include the means for air ventilation and spaces have a deep depth and this may not allow adequate natural light to reach the depth of spaces.

13.2.4 Energy
- There’s no generation of renewable energy neither by solar panel nor by wind turbines, no presence of power saving systems and no use of solar energy in water heating.
- There's neither use of LED lighting nor sensors to decrease the energy consumption.

13.2.5 Operating cost
The operating and maintenance cost has not taken into account.

13.2.6 Water consumption
- Buildings do not contain a system for recycling and reuse of wastewater in toilets and also the absence of a system for collecting rainwater and also buildings do not contain special valves and water consumption devices that provide the suitable flow rates to control the water consumption.
- The existing green areas are natural grass where they consume a large amount of water and there's no use of artificial turf and also plants that consume little water are not selected.

13.2.7 Materials
- Recycled materials are not used in buildings, neither in construction work nor in finishes.
- Materials that can be recycled were not used
- The used finishing materials were expensive and not durable.

13.2.8 Social dimension
- There are no spaces for social activities for the inhabitants.
- The project did not take into account to support inhabitants socially and healthily.
- The absence of any workshop to teach the inhabitants to live in a sustainable way.
- There's no use of roofs to grow plants or vegetables that can feed the residents.

13.2.9 Recycling process
- The absence of any recycling system for the waste.
- The waste resulted from the construction stage had not recycled.

14. THE ELEMENTS THAT SUPPORT THE PROPOSED APPROACH
The proposed approach is based on the analysis of the theoretical study and the applied study to conclude of the most important ideas, elements and international trends that can be applied in affordable houses in Cairo, Egypt to achieve sustainability. The proposed approach takes into account the operation and maintenance cost, social aspects of the inhabitants, environmental aspects, energy saving, water consumption, the use of local materials and other sustainability requirements.

15. AN APPROACH FOR SUSTAINABLE AFFORDABLE HOUSES DESIGN IN EGYPT
The proposed approach is as the following:

15.1 Aesthetic aspects
The creative and aesthetic aspects of the design to be desirable for inhabitants must be taken into account.

15.2 Creative solutions to achieve sustainability
Innovative and creative solutions must be added for the roofs, internal spaces and facades design to achieve sustainability in affordable houses.

15.3 Location
- The selecting of the location must be close to public transportation to facilitate easy access by walking to reduce the cost of transportation for the inhabitants and also to be near to the commercial and educational services to be possible to reach by walking for the residents without using cars, to reduce pollution and also many residents do not own cars.
- The selected location must be serviced by the necessary infrastructure.

15.4 Design considerations
The use of connected buildings to reduce of external facades areas with increasing the number of residential units in each floor.

Unit design
Increasing the use of studio apartments that include an area for bed, an area for living, bathroom and kitchenette, and also increasing the use of one bedroom apartments that include bedroom, living area, bathroom and kitchenette, because these units have less space and less price.

15.5 Passive solar design strategies
Considering passive solar energy such as:
- Good thermal insulation of external walls, roofs and openings.
- Windows and external doors must be sealed to prevent thermal leakage.
- Good natural ventilation.
- Maximum use of natural daylight.

**Courtyards**

Taking into account the presence of internal courtyards in residential buildings with considering the best courtyards proportions to achieve the appropriate amount of shades as well as courtyard can be uses as a multifunction space for the users.

**Orientation of buildings**

Taking into account the building orientation to control the required sun radiation and desired wind while considering the required protection from undesired sun radiation and wind.

**Facade and building envelope**

- Achieving maximum natural light while considering the facade orientation.
- The uses of required shading devices for western, southern, south western and south eastern facades and also the use of double glazing windows.
- The use of low E glass (Low emissivity glass) in windows to increase the thermal insulation.
- The use of solar panel on external facades.

**15.6 Economic factors**

- Minimizing the running cost as much as possible (cost of electric, water supply, gas supply, maintenance and transportation) where units are for low income people.
- Selecting of appropriate low cost structural systems and finishing materials which don't make pollution to the environment.
- The use of roofs in planting of vegetables and fruits as well as the use of trees in outdoor landscape areas which produce fruits that can be used as a food for the residents.

**15.7 Water consumption efficiency**

- The use of water efficient consumption equipments.
- Collecting the rainwater to be recycled for irrigation and bathrooms.
- Increasing the use of artificial turf for landscape areas to reduce water consumption.
- The selected plants should use low water consumption and need less maintenance.
- Preparing of a system to recycle of sewage water and reusing in toilets and irrigation.
- The use of low water flush equipments and valves to reduce the water consumption.
- The use of a sustainable type of irrigation system that reduces the water consumption.

**15.8 Materials**

The use of materials with the following requirements:

**Local materials**

- The use of local materials with low cost.
- The use of materials which require the least maintenance.

**Recycled materials**

- The use of recycled materials in construction and finishing like using of recycled steel for construction and recycled wood, bricks, doors, windows and other materials for finishing.
- The use of recyclable materials.

**Sustainable materials for healthy living and decreasing the pollution**

- The paints must be VOC-free (Volatile Organic Compounds).
- All materials used must be formaldehyde free.

**Durable construction and materials**

- The use of durable construction as well as finishing materials, systems and equipments must be durable and don't need much maintenance.

**18.9 Roofs**

- Adding solar water heaters and solar panels on roofs.
- Planting the buildings' roofs with vegetables and fruits.
- Using the roof area for social activities for the inhabitans or as a multifunction space.

**15.10 Energy**

The following requirements must be considered:

**Renewable energy**

- The use of solar panels in roofs and facades to generate electricity.

**Energy saving**

- Achieving a good level of Energy efficiency.
- The use of tankless solar heaters for providing hot water.
- All equipments must include energy saving devices.
- The number of floors must not exceed than four or five floors to reduce the need for elevators for reducing of the energy consumption.

**Artificial lighting**
- Controlling lighting by sensors to decrease the energy consumption.
- The use of energy saving lighting units (LED lights to reduce energy consumption.

### 15.11 Sustainable operations
- Ensuring that the process of construction does not make a bad effect to the environment and does not produce a large amount of waste.
- Sustainable waste management should be considered for the project.

### 15.12 Recycling process
- Prepare a recycling system for the waste.
- Transferring of waste during construction to recycling stations.

### 15.13 Social sustainability
- Considering social situation of the target inhabitants to support them socially, healthily and economically.
- The design must include a space for the social activities for inhabitants.
- It is possible to add an activity that has an economic return to the residents.
- Internal courtyards can be used as activity spaces for the inhabitants.
- Providing training workshops to the inhabitants on the different ways to achieve sustainability, reducing the consumption of resources and water and working to reduce the costs, and also how to deal in a sustainable manner with their houses and deal with the waste.
- Providing training workshops to project managers on sustainable management for affordable houses.
- Taking into account the inhabitants culture.
- Supporting the lifestyle in a sustainable manner.

### 16. CONCLUSIONS
- Some of affordable houses projects in Egypt don’t take into account the energy saving, reducing water consumption, passive solar energy strategies, the use of recycled materials and other requirements to achieve sustainability.
- The research provides an approach to achieve sustainability in affordable houses in Cairo, Egypt, based on the theoretical study and analysis of the latest international case studies for sustainability achieving in affordable houses whereas this approach is applicable for the local situation in Cairo.
- One of the important elements in sustainable affordable houses projects is to decrease the running cost which will be very effective to the low income inhabitants as well as the initial cost of construction.
- Most of recent international affordable houses projects are working for achieving sustainability requirements that includes: reducing running costs, reducing maintenance cost, reducing energy and water consumption, maintaining the resources, achieving passive solar design applications, generating renewable energy and reducing negative impacts to the environment.
- International affordable houses projects aim at strengthen the social dimension as a part of sustainability whereas they provide a space for social activity in these projects. In some projects there’s the use of roofs or internal courtyards for social activities for the inhabitants for preparing the required workshops for the inhabitants to teach them to live in a sustainable manner.
- The creative and innovative solutions in architectural design to support sustainability requirements are important elements of the international sustainable houses projects.
- The research provides some of architectural solutions that have been applied internationally to meet the sustainability requirements.

### REFERENCES