SJFA
الدورية العلمية لكلية الفنون الجميلة - جامعة الإسكندرية
Scientific Journal of the Faculty of Fine Arts Alexandria University
Print ISSN: 2356-8038 Online ISSN: 2535-227x
جامعة الإسكندرية
ALEXANDRIA UNIVERSITY

Affordable Housing Retrofitting Strategies through Coupling Simulation Method Criteria

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ABSTRACT

Nowadays many of social housing in Alexandria are often obsolete with inadequate condition that represent through the comfort conditions, energy consumption and structural conditions moreover the lack of the minimum aspects of the architectural aesthetic elements. over 50% of the Egyptian population live in informal settlement. Alexandria has a great share of these slums, while it contains more than 36 informal setlements. The residential sector consume about 47% of all the electricity consumption. The government constructing a large concrete blocks without concerning about the environmental issues during the decision making or design buildings more energy efficient. Also this buildings with old energy technologies affects the overall energy consumption in the city. this research aims to state the significance of choosing the appropriate software in decision making for retrofitting strategies of building energy and micro climate simulation through formulating a strategic framework of concentration area, selection and assessment criteria applied of different architect friendly softwares, concluding by applying the passive design strategies reaching the most effictive thermal comfort techniques through coupling method in order to simulate the building energy and micro climate by eQuest which employs DOE-2.2 and Designbuilder which employs Energyplus along with the micro-climate tools such as CityBES and ENVI-met respectively as the most architect friendly use softwares.

KEYWORDS: informal settlements, microclimate simulation, energy simulaiton, retrofitting systems, passive systems

1.INTRODUCTION

Informal settlements were described through a numerous varied definitions, and each of them was based on some of the characteristics that characterize slums, in terms of being illegal, unplanned and marginal areas. Recently the slums were frequently mentioned as it is a global concern to reflect the depth of this phenomenon in its housing and population dimensions.

Slum areas are described as areas that constructed by self-efforts, they are built in the absence of law in settlements which have not been planned. That can be environmentally and socially insecure which is characterized by a low level of basic services and lack of facilities. Resulted in a segment of society whose values and principles are decreasing in the face of the overwhelming need for food, housing, clothing and sense of security [1]. Over 50% of the population in Egypt lives in informal areas [2]. Alexandria has a great share of the informal settlements as over two third of the population lives in slums distributed through all the city districts as shown in table 1 [3].

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The annual demand for residential units in Egypt ranges between 200 thousand to 300 thousand housing units, to meet the needs of population growth and internal migration, the government housing sector providing 27.4% of this requirement. The private sector also provides the same rate of 27.4%, while random housing fills 45.2% of this requirement, making the largest reliance on the need to meet the need for random housing [3].

Table 1. Informal settlements distribution in Alexandria [3]

Name of the District	Size in Km^2	Total population/year	Number of informal areas	Average Density P/Km^2	Safe / unsafe
El Montaza	82	1,585,572/2018	9	19,336	Safe
Sharek (East)	35	1,158,822/2018	5	33,109	Safe
Wasat (Middle)	68	543,405/2018	2	7,991	Safe
El Gomerk	4.7	156,780/2018	2	33,357	Safe
Gharb (West)	20.1	356,613/2018	8	17,741	unsafe
Sub Total	**209.8**	**2,801,192**	**26**	**13,351**	
El Amriya+ El Agamy	1555.5	617,384+ 608,674 /2018	5+ 4	788	Safe + unsafe
Borg El Arab	534.7	133,543/2018	1	250	Safe
Total	**2300**	**5 ,225,979/2019**	**36**	**2,272**	

1.2 Problem Statement

By 2014 Egypt has a total electricity capacity of 174.9 Billion kWh, all the distributed amount is 146.6 Billion kWh, the residential sector consume 63.5 Billion kWh compared to 2018 the residential sector consume 83.4 Billion kWh with increasing ratio 7.6%. The total electricity of residential houses increases from 36.6% to 42.4% with loss of 7.7% of generated energy and 3.2% self-consumption by the station, with a total up to 53.3%. However the government implementing new electricity generation stations through renewable and non-renewable sources that only the whole consumption payback covers 63% of total cost while increasing the cost by average 30% between 2019-2020 in order to cut all the governmental financial support by 2025.
The problem is the increasing gap between the energy consumption and energy production due to the new urban communities.

1.3 Research aim and objectives

This research aims to the significance of choosing appropriate software in decision making for retrofitting strategies of the building energy and micro climate simulation considering the occupants' thermal comfort for the new residential complex determining the appropriate simulation software testing the retrofitting system, through the following objectives:

- Determining the meteorological parameters affecting the occupants' thermal comfort.
- Considering the retrofitting strategies of building and micro-climate.
- Applying the energy simulation through different software by a concentration areas, selection and assessment criteria.
- Determining the architect friendly software.

2. The Meteorological Parameters Affecting The Occupants' Thermal Comfort

The need to achieve a good indoor environmental quality (IEQ) as a result of thermal, visual, acoustic comfort and indoor air quality. The awareness increased that an adequate design of the indoor environment, where people work and live, requires a synergic approach to all facets involved in full compliance with sustainability. IEQ strictly affects the overall building energy performances and exhibits an antagonistic relationship with respect to the energy saving requirements [4].

Thermal comfort is defined by the opinion of people who occupy a space, depending on the subjective feeling related to temperature, it refers to the perception of occupants, and should be modified as possible to avoid situations of discomfort or thermal stress. Thermal comfort must be guaranteed as a neutral condition, thermal comfort described through seven points thermal sensation scale between the Predicted Mean Vote (PMV) and Occupants' sensation as shown in Table 2 [5].

Table 2. The 7-point thermal sensation scale [5]

PMV vote	+3	+2	+1	0	-1	-2	-3
Sensation	Hot	Warm	Slightly warm	Neutral	Slightly cool	Cool	Cold

Physiological equivalent temperature (PET), where the exchange between human body and environment is evaluated and, in relation to the different equilibrium situations, is defined as a perceived equivalent temperature by a subject, PMV and Percentage People Dissatisfied (PPD%), which is related to the felling and judgment of people as shown in Fig.1 [5].

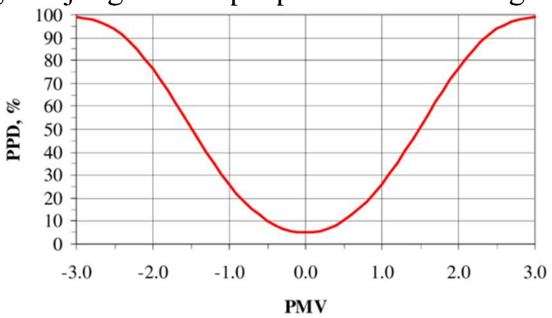

Fig. 1 Thermal sensation scale [5]

Physical parameters of indoor environment is related to the air volume enclosed in the building, this is an open system that:

– Exchanges mass, because of the air passage through doors and windows, and air leakage, which causes as well the movement of indoor pollutants, such as dust and CO_2,

– Exchange energy, because of the difference in temperature between indoor and outdoor spaces, because of heating due to the sun or to the presence of people, or to the variation in latent heat due to absolute, specific and relative humidity as shown in Table 3 [6].

Table 3. The variables influencing the indoor environment [6]

The variables influencing indoor environment					
Air temperature, measured in °C	Mean radiant temperature (MRT) measured in °C	Absolute humidity, measure in gv/m^3	Specific Humidity measured in gv/kga	Relative humidity (RH), measured in percentage (%)	Air velocity (v), measured in m/s

3. STRATEGIES FOR ENERGY RETROFITTING

The design that maintains a comfortable temperature within the building using the climate and natural elements to get the optimum benefit and to reduce or eliminate the independence on mechanical systems for heating, cooling and lighting, is called 'Passive Design'. There are two crucial measures for passive design to be beneficial and effective: climate and comfort. To get the maximum benefit of energy retrofitting for a building it's needed to combine different strategies [7].

Analytical considerations to Design an Energy efficient Building in order to get the optimum benefit of the retrofitting strategy, needs to consider the following:

A. Building orientation

Building orientation governs the passive technologies implementation within the design. It also governs the window sizing and locations, which will affect both lighting space conditioning within a building. Proper orientation can lead to significant reduction in lighting and space conditioning load if coupled with passive design technologies [8].

B. Building shape

Well-designed passive building produces less air pollution and greenhouse gasses, and thus it contributes to a more sustainable environment. Good passive buildings not only conserve energy, but also account for hidden environmental benefits. Massing of the building blocks help achieve thermal and visual comfort. Building blocks channelize or obstruct the wind flow, also act as shading devices for surroundings. Building blocks design and geometry can influence the wind flow and velocity [9].

C. Material selection

Choice of material depends on the outside climate around the building. However, the properties of material used, which governs their usage, can be noted as three different properties. Color, insulation property and assembly type. Finishes color will vary the amount of heat and light absorbed and reflected. Lighter the color greater reflectivity while darker the color more absorbing property. In addition, the insulation property plays an important role in material selection. Good insulation is required to reduce heat exchange between the internal and external space [10].

4. MICRO-CLIMATE LEVELS

Many urban and suburban areas experience elevated temperatures compared to their outlying rural surroundings, this difference in temperature is what constitutes an urban heat island (UHI) [11].
According to the characterization in different layers of urban heat island is divided into three categories surface urban heat island (SUHI), canopy urban heat island (CUHI) and boundary urban heat island (BUHI), The BUHI is relatively hard to detect due to temperature difference from sensors mounted on tall towers, balloons and aircraft and climate model simulation has been usually used to understand the characterization of BUHI. Canopy urban heat island is usually quantified by air temperature records from urban and rural stations The heterogeneous time series of air temperature records usually result in uncertainties of warming trend induced by urbanization process, Satellite-based land surface temperature (LST) is widely used in the monitoring of SUHI and can provide detailed information in regards to surface temperature variation over various land cover types as shown in Fig. 2 [12].

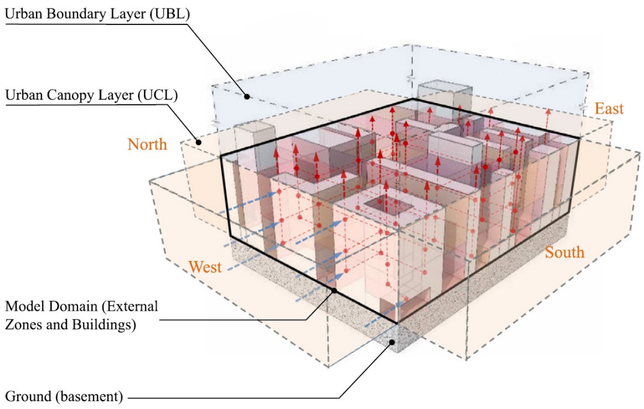

Fig.2 Schematic depiction of the urban microclimate levels [12]

Elevated temperatures from urban heat islands, particularly during the summer, can affect a community's environment and quality of life. Most impacts are negative and include:

- Increased energy consumption
- Elevated emissions of air pollutants and greenhouse gases
- Compromised human health and comfort

In order to set a strategic criteria to control urban heat island in micro scale for energy consumption reduction needs the following:

1. Providing green spaces and vegetation in different layers of buildings
2. Using albedo materials on external surfaces of buildings
3. Providing void decks at ground level or at mid-span, variation of building height and arrangement of openings in building to face the prevailing wind can create natural ventilation.
4. Providing appropriate orientation of building and site for preventing sun radiation, encouraging air movement and natural ventilation.

5. BUILDING INFORMATION MODELING

A limited number of building energy simulation tools are integrated with building information modeling (BIM) through Industry Foundation Class (IFC) and Green Building XML (gbXML), additional efforts such as manual model check and modification for defining thermal zones are requested to generate reliable energy models. Simulation results into the design decision is still considered difficult. Typically, energy simulation tools provide a large quantity of numerical results presented in tables or charts [13].

Existing building energy simulation tools aim to evaluate energy performance and thermal comfort during a building's life cycle. Specifically, DOE-2 and EnergyPlus have been widely used at multiple stages of a building's life cycle due to their functionality of exchanging data with other tools through standard data formats as described in the "Building Energy Software Tools Directory"

The research surveyed more than two hundred software about evaluation of the performance of each tool in different categories such as graphical representation of results, easy learnability, short learning curve, flexibility of use and navigation, simple input options, flexible data storage, providing online support and training courses, providing weather data within the tool, and interoperability.

5.1 Selection Criteria for Energy Simulation Softwares

Developed criteria for assessing the architect-friendliness of the building information modeling (BEM) tools, this evaluation criteria consisted of five concentration areas as shown in table 4 [13].

Table 4 five concentration areas for evaluation criteria of the BEM tools [13]

Concentration areas				
Data Input	Data Output	Graphical User Interface	Usability	General

The first part focused on achieving quick and straight forward data input, as well as graphical representation of the geometry, while the second part focused on the interpretation of output results and the capabilities of parametric analysis. The third section stressed the importance of the Graphical User Interface (GUI) through clear and flexible navigation instead of using command line interface (CIL), the fourth section incorporated the usability for minimal and quick feedback, and a general section based on the overview of most commonly used BEM tools and the different developed selection criteria as shown in table 5 [14].

Table 5 Selection criteria for BEM tools [14]

Selection criteria				
Usability and Information Management of Interface	Integration of Intelligent Design Knowledge base	Accuracy of tools and the ability to simulate detailed and complex building components	Interoperability of building modelling	Integration with building design process.

The selected BEM tools for this research have higher penetration within the architectural practice, in addition to their integration with BIM tools. Also, defined the following assessment criteria from as shown in table 6 [15].

Table 6 Assessment criteria for BEM tools [15]

Assessment criteria				
Usability	Interoperability	Support Options	Information Management	Computing Capabilities

5.2 User friendly energy Softwares for architects

These software helping choose the most applicable software to be used by architects, depends on the software source availability, and the results validation. Using more than one software covering the microclimate simulation and building energy simulation combined together to give a holistic overview of energy performance. Emphasizing on test and assess the performance of the most commonly used BEM tools, by applying the previous criteria for (concentration areas, selection criteria, and assessment criteria) as shown in table 7.

Table 7 User friendly software for building energy simulation. Source: the researcher

Energy simulation Softwares	AUTODESK GREEN BUILDING STUDIO Autodesk Green Building Studio (GBS)	Energy Plus	DesignBuilder Designbuilder (DB)		Selection criteria
Validation	DOE-2.2 + ASHRAE Standard 140 Validation	ANSI/ASHRAE Standard 140-2001 IEA SHC Task 22 HVAC BESTest	ASHRAE 90.1 , LEED , IRS tax credit		
Concentration areas					
Data Input	• power the energy analysis of the new Autodesk Energy simulation plugin Autodesk Insight 360, as well as Form It 360 • uses DOE-2.2 energy simulation engine, • integrated with Autodesk modeling tools such as Autodesk Revit • Read all building geometry data produced by gbXML, enabled BIM, and 3D-CAD.	• EnergyPlus reads the data dictionary (Energy+.idd) and the input data file (in.idf) prior to doing anything else. • The input data file is the primary file that EnergyPlus uses to create the building simulation. • The only additional files are referenced by certain objects (such as fuelFactors object and TDV files in the DataSets directory.	• The 3-D modeler improved gbXML BIM import to fully support courtyard voids and providing full 2-way interoperability export with other modeling tools. • The HVAC module to support fluid to fluid heat exchanger, zone water-to-air heat pumps, and waterside economizers. • Employs EnergyPlus simulation engine, also allows both external and internal airflow simulation.	I/V	Usability and Information Management of Interface
Data Output	GBS uses the DOE 2.2 dynamic thermal whole building energy simulation engine to estimate building energy use and operating costs; which are based on the effects and interactions of building form, materials, systems, usage, and climate.	it forms the analytical basis for most energy efficient standards such as ASHRAE 90.1, and for both free and commercial building energy modeling tools. Utilizes thermal zones and component-based HVAC system, in conjunction with the building geometry description and weather data to assess both water and energy use of the building.	Full integration between energy, daylighting and comfort analysis tools provides a holistic view of performance impacts of design decisions such as shading and glazing areas on daylight performance and cooling loads. Optimise daylight availability using the trusted Radiance and Daysim engines.	II/V	Integration of Intelligent Design Knowledge base
Graphical User Interface	Create geometrically accurate data input files for EnergyPlus using the gbXML schema.	Energy Plus is a console-based program; however, it lacks an integrated (GUI).	Quickly model concept designs and easily develop your model as the design evolves. High-quality graphic outputs help you quantify performance,	III/V	Accuracy of tools and the ability to simulate detailed and complex building components
Usability	Ability to design high performance buildings at a fraction of the time and cost of conventional methods, Optimize energy efficiency and to work toward carbon neutrality earlier in the design process.	E+ is a whole building energy simulation program that engineers, architects, and researchers use to model both energy consumption for heating, cooling, ventilation, lighting and plug and process loads and water use in buildings.	1) Designbuilder package for Engineers, and 2) Designbuilder package for Architects. use a single model to do the loads, energy and comfort, daylighting and CFD modeling all in one place	IV/V	Interoperability of building modelling
General	GBS supported standards: (Energy + , DOE-2, eQuest, gbXML)	Free, open source, and cross-platform. Its development is funded by (DOE) Building Technologies Office (BTO). Along with OpenStudio.	Developed by the US Department of Energy, and it is widely accepted and reliable for thermal and energy simulation.	V/V	Integration with building design process
Official website	https://gbs.autodesk.com/GBS/	https://energyplus.net/	https://designbuilder.co.uk//		

	Usability I/V	Interoperability II/V	Support Options III/V	Information Management IV/V	Computing Capabilities V/V
Colors	•	••	•••	••••	•••••
Strength Degree	Week	Moderate	Good	Very Good	Excellent
	Assessment criteria				

The US department of energy formerly hosted over two hundred energy simulation tools, the previous table 7 shows the user friendly software for building energy simulation, also there are more software like eQuest, Autodesk Insight Solar, Indoor Climate and Energy, and more selected according to the previous criteria. Reliably generating high quality BEM using current tools remains difficult. Although much of the process has been automated, intervention by the user to simplify models, choose among representations with subtle differences, and correct errors. Also there are software dedicated for the micro-climate simulation as shown in table 8.

Table 8 User friendly software for Micro-cliamte simulation. Source: the researcher

Concentration areas	Energy simulation Softwares	(IES-VE) Integrated Environmental Solution – Virtual Environment	Envi-met	CityBES (City Building Energy Saver)		Selection criteria
	Validation	ASHRAE Standard 140 / BESTEST / EU EN13791	ASHRAE Standard			
	Data Input	Ability to import building geometrical data from a commonly used BIM tools in addition to gbXML, IFC, and DXF files. includes 11 modules, ModelIT for geometry creation and editing, SunCast for shading visualization ApacheCalc for loads analysis, ApacheSim for thermal analysis, Apache HVAC, MacroFlo for natural ventilation, MicroFlo for 3D CFD. FlucsPro/Radiance for lighting design, DEFT for model optimization, LifeCycle for LC energy and cost analysis, and Simulex for building evaluation.	The new ENVI-met plugin for Rhino Grasshopper has been developed in the Ladybug Tools. By the use of this plugin, the user is able to convert Rhinoceros 3D designs to ENVI-met model areas and run ENVI-met simulations without even opening the ENVI-met software suite. This makes the usage, especially for architects who commonly utilize Rhinoceros 3D for their designs in the first place, much easier. - Modeling 3D buildings with Rhinoceros and Grasshopper to - Integration with plugins of Grasshopper, such as Gismo (GIS plugin for Grasshopper)	Three layers of the software :first the data layer, the Algorithms and software layer including weather data , And combined data in 3d city models (CityGML, GEOJSON) that includes building stock data , geographical information system (GIS), Database for a selected location (ECMs, utility rates, codes and Regulations), secondly the software layer includes EnergyPlus, OpenStudio and CityBES, finally the use cases layer provides examples of potential applications related to energy.	I/ V	Usability and Information Management of Interface
	Data Output	IES-VE provide a variety of output data formats such as tabular, graphical, photorealistic images and detailed populated reports that match green building rating systems templates	Solar analysis, Air pollutant dispersion, Building Physics(Façade, temperatures vegetated walls) Interaction between the outdoor microclimate with indoor climate Green & blue technologies	Provides a set of features to support Building energy efficiency analyses including energy retrofit analysis, energy benchmarking, urban energy planning, and building operation improvements	II / V	Integration of Intelligent Design Knowledge base
	Graphical User Interface	IES-VE is one of the hardest to learn tools, which require training to master because of its relatively complex suite	The new NetCDF converter allows users to visualize simulation results using a wide range of different visualization tools in addition to the well-known LEONARDO application.	CityGML, as the data schema to represent and exchange 3D city models. Also provides 2D building footprint GeoJSON format, building height, type, and year of built	III / V	Accuracy of tools and the ability to simulate detailed and complex building components
	Usability	IES-VE employs Apache dynamic simulation engine for its thermal and energy simulation, Radiance for lighting simulation, MacroFlo and MicroFlo for airflow and CFD simulation.	ENVI-met only simulates part of the spatial environment, boundary conditions are required for the lateral and vertical borders of the 3D model.	CBES allows users export the retrofit analysis results to CSV format for further analysis. Also generates sub-hourly load profiles to support the analysis of district energy systems.	IV / V	Interoperability of building modelling
	General	an integrated suite of in-depth building performance analysis tools, linked together by a common user interface and central integrated data model.	Allows to create living conditions in a constantly changing environment. With interactive tools doaspect of the microclimate complex and analyze how designs perform.	A free user friendly web app modeling urban buildings using detailed EnergyPlus models. Excellent 3D GIS visualization.	V / V	Integration with building design process
	Official website	https://www.iesve.com/	https://www.envi-met.com/	https://citybes.lbl.gov/		

Assessment criteria	Usability I/V	Interoperability II/V	Support Options III/V	Information Management IV/V	Computing Capabilities V/V
Colors	•	••	•••	••••	•••••
Strength Degree	Week	Moderate	Good	Very Good	Excellent

6. CONCLUSION

Energy efficient buildings aim to reduce the overall energy consumption necessary for their operation. High-performance buildings are designed to improve the overall building performance, besides energy usage, such as improving occupants' thermal, visual and acoustic comfort. Quantifiable predictions can help in identifying strategies and methods to improve building energy efficiency and the overall building performance.

Passive design is about taking advantage of natural energy flows to maintain thermal comfort. Passive technologies are systems which rely on natural resources and help to achieve comfort levels without relying on artificial energy. Choice of passive design techniques is majorly dependent on local climate where the project is located. The techniques are sustainable and use abundantly available natural resources. Integration of such techniques help transform building envelops into living organic creations to sustain human life within.

Urban heat islands refer to the elevated temperatures in developed areas compared to more rural surroundings. UHI are caused by development and the changes in radiative and thermal properties of urban infrastructure as well as the impact buildings can have on the local micro-climate.

7. RECOMMENDATIONS

In order to test the retrofitting systems to reach the most energy efficient scenarios required to use the coupling simulation method by combining the results from the building energy simulation and micro-climate simulation based on the selection, assessment criteria and concentration areas in order to choose the most appropriate simulation software providing the relatively most accurate results for the occupants' thermal comfort through passive design strategies by using eQuest which employs DOE-2.2 and Designbuilder which employs Energyplus along with the micro-climate tools such as CityBES and ENVI-met respectively as the most architect friendly use software.

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الملخص

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Print ISSN: 2356-8038 Online ISSN: 2535-227x

استراتيجيات التعديل التحديثي للإسكان بأسعار معقولة من خلال معايير أسلوب محاكاة الاقتران

يوساب مجدى[1]، وائل كامل[2] ، عادل المنشاوى[1]

الملخص

في الوقت الحاضر ، غالبًا ما يكون العديد من المساكن الاجتماعية في محافظة الإسكندرية بالية مع ظروف غير ملائمة تمثل من خلال الشعور بالراحة داخل المباني واستهلاك الطاقة والظروف الانشائية للمباني علاوة على عدم وجود الحد الأدنى من العناصر الجمالية المعمارية. يعيش أكثر من 50٪ من سكان مصر في مناطق عشوائية. الإسكندرية لديها نصيب كبير من هذه الأحياء الفقيرة ، في حين أنها تحتوي على أكثر من 36 موقعا غير مخطط. يستهلك القطاع السكني حوالي 47٪ من إجمالي استهلاك الكهرباء. وما تقوم به الحكومة ببناء كتل خرسانية كبيرة دون القلق بشأن القضايا البيئية أثناء اتخاذ القرار أو تصميم المباني بشكل أكثر كفاءة في استخدام الطاقة. كما أن هذه المباني ذات تقنيات الطاقة القديمة تؤثر على الاستهلاك الكلي للطاقة في المدينة. يهدف هذا البحث إلى توضيح أهمية اختيار البرنامج المناسب في اتخاذ القرار لاستراتيجيات التعديل التحديثي. لبناء الطاقة ومحاكاة المناخ من خلال صياغة إطار استراتيجي لمنطقة تركيز ومعايير الاختيار والتقييم المطبقة على برامج معمارية مختلفة ، واختتم بتطبيق استراتيجيات التصميم تعتمد علي مصادر طبيعية للطاقة تصل إلى تقنيات الراحة الحرارية الأكثر فعالية من خلال طريقة الاقتران من أجل محاكاة طاقة المبنى والمناخ الجزئي من خلال **eQuest** الذي يستخدم **DOE-2.2** و **Designbuilder** الذي يستخدم **Energyplus** مع أدوات المناخ مثل **CityBES** و **ENVI-met** على التوالي ومن البحث تعتبر هذه أكثر برامج للاستخدام المعماري.

الكلمات الدالة: العشوائيات, محاكاة المناخ, محاكاة الطاقة, انظمة التحسين لاستهلاك الطاقة, الانظمة الصديقة للبيئة.

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