ENVIRONMENTAL RETROFITTING: THERMAL EVALUATION OF THREE LIGHT STRUCTURE DESIGN SCENARIOS FOR TRANSITIONAL SPACE IN ALEXANDRIA UNIVERSITY, EGYPT

[1]AMR A. BAYOUMI, [2]AHMED M. SOLIMAN, [3]TAREK A. FARGHALY, [4]ZEYAD T. EL SAYAD

Department of Architecture, Faculty of Engineering, University of Alexandria, Alexandria, Egypt

Abstract - Current overwhelming of heat and energy facing the health of the urban and architecture environment is considered a significant dilemma. In responding to this problem, architects and designers relying more now on quantitative and qualitative methods to approach the environmental aspects within architectural design scenarios. In spite of the complexity and uncertainty of current methods and tools used by architects to investigate environmental aspects, most of these studies are lack of the vital issues to translate these findings into architectural proposals which can effectively retrofit to existed urban environment.

As part of multi-tiered research project which was dedicated to study environmental performance of existed transitional spaces in Educational buildings from urban to building scale, the paper focused to study Egyptian Revival building in Alexandria University. As multi-tiered study which was done from studying the urban fabric to the studied courtyard building within three years (2013-2015). The paper had three main goals: firstly, reviewing/examining the abilities and limitations of digital simulation methods used in this study to retrofit an existed courtyard building in Alexandria University. Secondly, applying simulation process as evaluating method for design decisions by comparing three Light Structural Models (LSM) to realize the appropriate design to existing courtyard building. Finally, propose an initial simulation indicators related to simulation findings to be used as part of aggregation of Environmental Retrofitting of Educational Buildings Index (EREBI) in Egypt.

The paper settled that however the reviewed limitations of digital simulation methods, optimized simulation processes through continuous nurturing data from field measurement data can be helpful method for predicting future design scenarios. Thus, a number of limitations in such studies can be reduced or partially avoided. And the simulation results can be used for EREBI indicators to aid architects, stakeholders, and decision makers to be used as integrative method for taking decisions.

Index Terms - Building Simulation, Environmental Indicators, Retrofitting Design, Transitional Spaces

I. INTRODUCTION

What and why retrofitting existing courtyards of Educational Buildings?

The rising dilemma of that contemporary buildings are becoming more energy consuming and devastating to the surrounding environment [1]. Let many studies to be conducted recently to seek more precise and integrative knowledge to improve environmental performance by retrofitting design strategies. By quoting the famous English architect Lord Norman Foster, "*The challenge (was) to relate the new building to the old, but at the same time to produce a building that signify (ed) its own age with integrity.*" – Foster and Partners, Carre d'Art, Nimes [2]. This retrofitting challenge required to be faced by have continuous retrofitting activities such as economic analysis, risk assessment, social observation, etc [3], which let many countries to put significant effort for developing retrofitting strategies. For instance, Queensland (Australia) government seek increasing environmental and energy performance of their existed governmental buildings by investing around 8 million dollars for retrofitting strategies [3]-[4].

In this paper, it focuses on one of the required retrofitting activities which is environmental building performance analysis. As this research is part of retrofitting design strategy of Alexandria University. It examines the effect of changing design of Light Structure Models (LSM) on internal thermal and air flow performance in courtyard space. Furthermore, the study aims to decrease the challenges of data gathering, simulation process, and to support straight forward interpretations through continuous feedback management process.

II. THE EGYPTIAN CONTEXT

Egyptian civilization was known for its advanced architecture with its remarkable geometries [5]. Egyptian architecture with its grandeur and power looking usually used as Reviving architecture for governmental, organizational, cultural, and educational buildings, these revival buildings have architectural elements defined through a hierarchy of transitional spaces which support social, cultural, and environmental aspects. As stated by Petruccioli [6] and Salama [7], transitional spaces such as courtyards evolve and ensemble as a main characteristic of traditional buildings within an evolutionary paradigm of a society changes through time and cannot restricted to one form. Thus, transitional spaces act as 'dynamic containers and paths' in which they decrease the complexity of architecture form in their physical characteristics [6]-[7].

In Egypt, courtyard has its role as private space in Egypt, as there is a current emphasis on the development of climate sensitive outdoor transitional spaces, particularly with the present energy crisis, poverty and overpopulation. Historically, Egyptian Temples named houses consists a number of hierarchical rectilinear courtyards [8]. Courtyards

were used for a number of uses such as educational, recreational, and cultural uses [8].

These courtyards were considered as part of Egyptian architecture system. As some researchers such as Lloyd [9] described this Egyptian system as Egyptian Labyrinth especially in theological buildings such as pyramids and temples. The hierarchy of transitional spaces described in temples as a number of courtyards sided with one wall or arcade in between hypostyle halls, and surrounded with twisted paths which had limited accessibility to hidden champers, as some of these spaces cannot be entered or leaved without a guide [9].

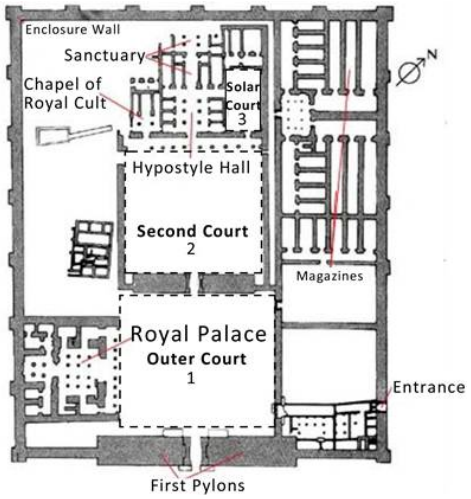


Fig. 1 Seti Temple Plan (source: http: http://www.touregypt.net/featurestories/seti1temple.htm)

As shown above, Seti Temple had three hierarchical courtyards which separated by other types of transitional spaces such as Pylon gates, Arcades, and Hypostyle Halls.

The reviving concept of this Egyptian architecture system was mimicked partially in some Egyptian educational buildings. This is apparent in Alexandria University which its buildings are an Egyptian revival style mimicking the Egyptian transitional spaces such as courtyards and arcades.

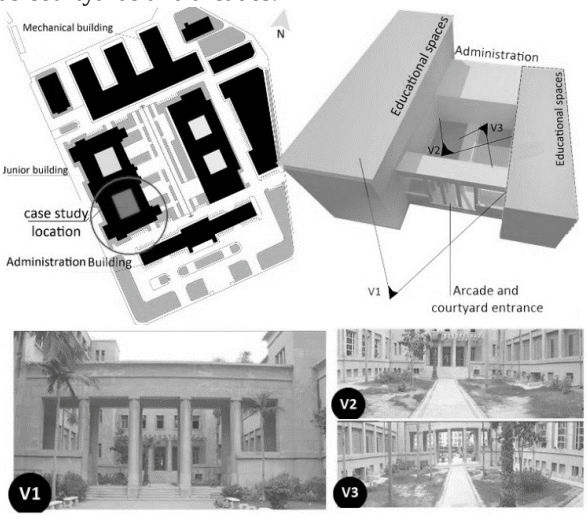


Fig. 2 Existed case study of courtyard building in Alexndria University

In existed case study, a hierarchy of transitional spaces used in the educational buildings which can be used as extensive social, recreational, and cultural gathering spaces. The case study is located at the southwestern zone of the educational building. Number of observational and computational studies were undergone in this studied courtyard building.

III. OBSERVATIONAL VS COMPUTATIONAL METHODS

Today, many observational and computational methods have their own paradigm which affect the investigating and interpreting the environmental performance in buildings. This is according to the geographic scope can be appeared in studies such as Urban Heat Island (UHI) studies and Thermal indoor studies.

From previous reviewed studies such as Mirzaei [10]; Abohela [11]-[12]; Gan [13]; Winsberg [14], observational and computational methods have their abilities and limitations, these reviewed studies are summarized as shown in table I.

Table I: Abilities and limitations of Observational and Computational Methods

	Observational Methods	**Computational Methods**
Used method in this study	**Field Measurement Method**	**Digital Simulation Method**
Abilities	-Show **higher accuracy** and realistic results - Easily to interpret results.	-**Less time** consumed -Can Predict future scenarios. -Predict flow field in details. -Low cost. - Greater availability to architects for fast design decisions. - High visualization results.
Limitations	- Highly consuming in time. - Based on current situation and cannot predict future design scenarios. - Operating costs are high.	-**Low accuracy** results -**Complex** and can even puzzled experienced users. - High computational power and budget. - Many assumptions applied in selecting boundary conditions or turbulence models.

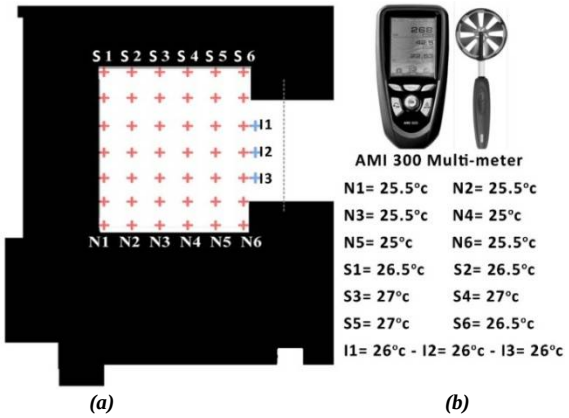
Field measurements are now developed to trace parameters like temperature, air velocity, turbulence fluctuations and pollution concentration with high accuracy rates. However, this ability to have accurate results, field measurement approach has several limitations. The reading process of measurement

devices around a study area is generally time-consuming task and very expensive. Moreover, field measurement devices are only limited to a number of existed parameters which simultaneously measured. This indicates that it cannot establish all the three-dimensional spatial distribution of the values and cannot predict its future changing potentials inside a selected zone [10]. Thus, approximations are often done to estimate these values for unreachable places. In addition to these limitations, it is necessary to carry out the measurements for extended time frame to can reduce the effect of unpredictable errors (e.g. pedestrians, biodiversity change, and vehicles).

On the other hand, yet according to Mirzaei [10], simulation approaches have been widely advanced in the last two decades and this can let researchers to solve large complex problems. However, computational methods can be used to create design scenarios and visualizing results to be validated. That approach has limitations such as it is computationally consuming. This therefore leads to limitation of building highly detailed geometries and highly refined grids which leads in many cases to inaccurate results. To enhance progress of applicable tools, model integration has been proposed in order to take advantage of studied courtyard building. Thus, field measurement tools used as nurturing data source for simulation process.

IV. FIELD MEASUREMENT STUDY

As observational methods usually consume more time than computational methods, field measurements were done within 3 years. The measurements had been gotten through using E-instrument multi-meter sensor to find out temperature and air velocity ranges in site. These ranges are summarized by taking mean rates in October, November, and December as they are the mostly active months for using educational buildings as observed. In this study, it focuses on October readings. This data is used for main purpose which is to nurture simulation model and to find out potential problems within the simulation study.



(a) *(b)*

Fig. 3 (a)Tracing grid points; (b) Multi-meter sensor and traced air temperature at selected points

Field measurements were done by using E-instrument multi-meter sensor. In which the accuracy of temperature is around ±0.4% of reading ±0.3°C, and accuracy of air velocity is ±3% of reading ±0.1m/s and ±1% of reading ±0.3m/s [15]. Within rectilinear grid, a 45 tracing points in the studied zone. The measurements are done between 9:00 clock to 11:00 clock diurnal. Thus, the traced data are visualized in mean values.

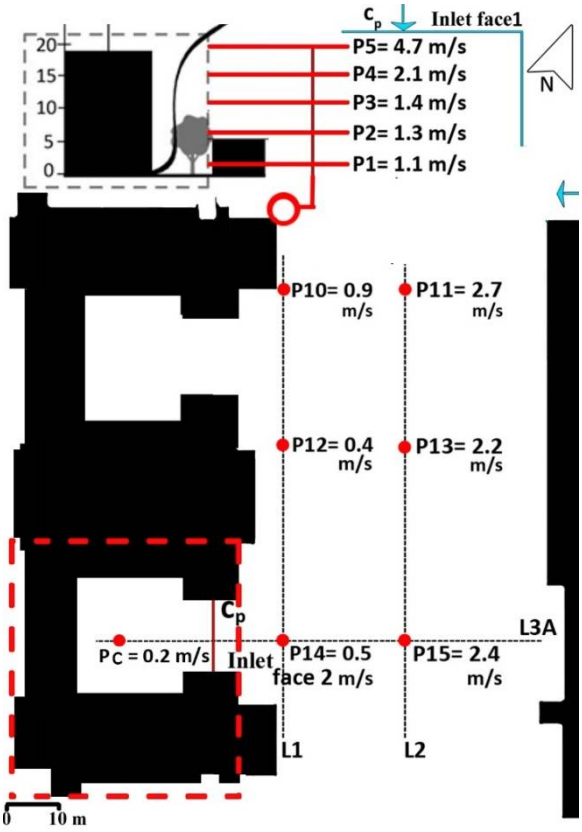


Fig. 4 Traced air velocity

As shown above, six points are indicated as S points and N points at Southern Façade (SF) and Northern Façade (NF) respectively. In October, the traced temperature ranges from 25°c to 27°c. As temperature increases at Southern Façade (SF) and decreases at Northern Façade (NF). Where the air velocity ranges from 0.2 m/s to 4.7 m/s. Traced values are used as input and guiding data for simulation process using Autodesk CFD.

V. COMPUTATIONAL MODEL

Broekhuizen [15] stated that Autodesk CFD abilities can be user friendly, interoperable and more accurate for architects if it compared to other tools such as design builder and flow design [15]-[16].
In this study, Autodesk CFD is directly integrated with Autodesk Revit. As model created in Revit with neglecting small model features which are less than 0.5 m, the model then is exported to Autodesk CFD.
Autodesk CFD was used to do meshing manually to control grid size. The CFD process consists of 3 main

steps which are: model setup, boundary conditions, meshing, and iteration process.

A. Model Setup, Boundary Conditions and Meshing Process

The 3d model is simplified with reducing details of windows and doors, and removing landscape elements in Autodesk Revit. The dimension of the courtyard is about 21 x 24 m.

The boundary conditions process of this model is essential part in CFD. It is defined as virtual vital conditions to be wholly or partially fulfilled as part of the model boundary to let a set of differential equations to be solved within defined setting of conditions [17].

A number of defined boundary conditions based on traced data is settled in the CFD process. Firstly, the inlet turbulent is indicated according to the vertical air velocity profile and the stream wise turbulent intensity as:

$$k_z = a((I_{U.Z})(U_Z))^2 \text{ [18]}$$

Where k_z is the roughness height, Z is the height coordinate, I_U is the stream wise turbulence intensity, a is taken as 0.5 by assuming that the square of the standard deviation of turbulent fluctuation in the longitudinal direction ($\sigma^2 u$) to be much larger than the value of the other two directions ($\sigma^2 v$ and $\sigma^2 w$) which are assumed to be approximately equal ($\sigma^2 u >> \sigma^2 v \approx \sigma^2 w$) [18]-[19].

The initial setup included the bottom of the domain to be a non-slip wall with standard wall functions, top and side considered symmetry, outflow indicated as pressure outlet at pressure=0 and velocity inlet of piecewise linear data input from the field-measurement data. Wall boundary condition is assigned with different heat fluxes depending on surface temperatures that were recorded by field-measurement tools.

Table I: Abilities and limitations of Observational

Boundary Conditions	Element	Material	Specification and input properties
Velocity input	Northern inlet face	Air	Air speed: Piecewise linear at z=1m, *v*=1 m/s(measured in site), at z=4m, *v*= 5 m/s, at z= 8m, *v*=7 m/s, at z=11 m, *v*=9m/s
wall	Ground		non-slip wall
	surface		-Input of measured temperature (Piecewise linear)
Top and side walls	Top and side surfaces	Air	Symmetry
Pressure outlet	Southern face	Air	Air Pressure=0
wall	Building structure volumes	Brick for walls and concrete for roofs	Brick wall - convective heat transfer coefficient: I3 w/m^{2}K; Concrete roof- Heat flux: 76 w/m^{2}k

As another vital part of boundary conditions, turbulence is vital to calculate the growth of air flow pattern. As many researchers (Abohela [11], Ramponi and Blocken [18] and Daniel Micallef et al [20]) found out that Menter's Shear Stress Transport (SST) k- Ω is a stable turbulent model. which is a hybrid combination between k-epsilon model and Wilcox k-omega, as Wilcox model is sensitive to near the wall simulation while k-epsilon is ideal for predicting flow in distant regions from wall [20]. This hybrid combination gives ideal agreement with observational data for air velocity in central open spaces [11]-[18]-[20].The SST k- Ω requires fine grid near wall, as in flow region between the laminar sublayer and the fully turbulence region the function of Intelligent Wall Formulation (IWF) is used which not count for roughness effects. According to Bani [19], IWF can be advantageous to SST k- Ω with limited computational cost.

The governing equations can be summarized as:

1. Turbulent Kinetic Energy (TKE):

$$\frac{\partial k}{\partial t} + U_j \frac{\partial k}{\partial x_j} = P_k - \beta^* k\omega + \frac{\partial}{\partial x_j}\left[(\nu + \sigma_k \nu_T)\frac{\partial k}{\partial x_j}\right]$$

2. Specific Dissipation Rate:

$$\frac{\partial \omega}{\partial t} + U_j \frac{\partial \omega}{\partial x_j} = \alpha S^2 - \beta \omega^2 + \frac{\partial}{\partial x_j}\left[(\nu + \sigma_\omega \nu_T)\frac{\partial \omega}{\partial x_j}\right] + 2(1 - F_1)\sigma_{\omega 2}\frac{1}{\omega}\frac{\partial k}{\partial x_i}\frac{\partial \omega}{\partial x_i}$$

3. F1 (Blending Function):

$$F_1 = \tanh\left\{\left\{\min\left[\max\left(\frac{\sqrt{k}}{\beta^* \omega y}, \frac{500\nu}{y^2 \omega}\right), \frac{4\sigma_{\omega 2} k}{CD_{k\omega} y^2}\right]\right\}^4\right\}$$

As inside boundary layer: F_1=1; In free stream: F_1=0 [20].

CD_{KW}:

$$CD_{k\omega} = \max\left(2\rho\sigma_{\omega 2}\frac{1}{\omega}\frac{\partial k}{\partial x_i}\frac{\partial \omega}{\partial x_i}, 10^{-10}\right) \quad [21]$$

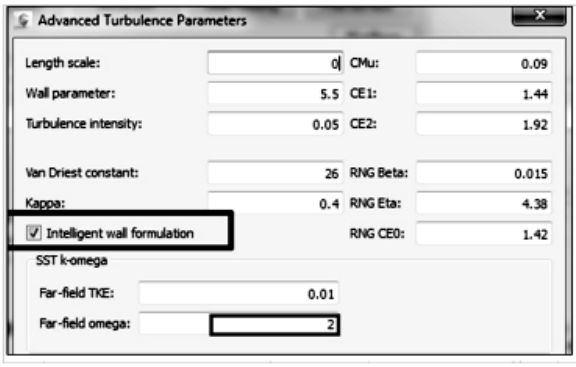


Fig. 5 SST k-omega turbulent parameters used for calculations

As shown above, the IWF is selected and Far-field omega is settled as two. There are five discretization schemes available in Autodesk CFD. As discretization scheme accuracy is based on its order [22], so the initialized values are based on discretization scheme of ADV 5. According to Autodesk [23], using ADV 5 while keeping the y+ values above 11.225 to act exactly within the classical law of the wall function which is considered important to not leading to poor performance [22].

Another factor affecting simulation process was the grid cell generation/meshing which is a process of defining the resolution of studied geometries. Fig. 6 shows hierarchical meshing of refined mesh used for the study model. The meshing process was undergone through meshing sensitivity analysis which shows that 471,458 grid cells could lead to good simulation performance without excessive computational loads. After setting up the boundary conditions and meshing, the iteration of simulation was running up till it converged after 445 iteration process.

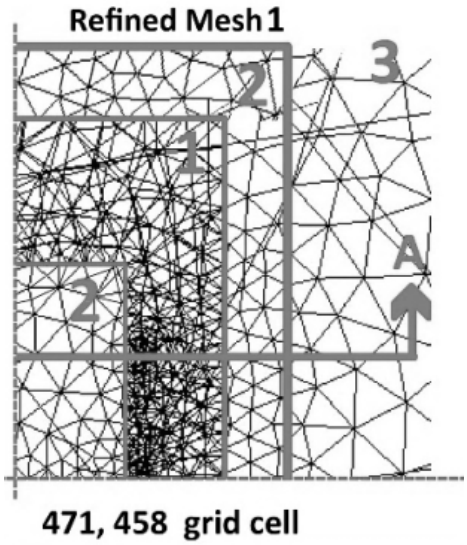


Fig. 6 Hierarchical refined mesh of the model

B. Existed and Retrofitted Computational Results

The LSM retrofitting design is based on retrofitting the height of the courtyard building as a first stage. As a previous study, simulation results were obtained to find out the optimum retrofitted building height. It was shown that increasing northern building height from 11 m to 18 m don't show significant changes in thermal flow. The results show more dynamic ranges of simulated temperature more than field measured data. As simulated CFD temperature displays ranges of temperature more than 3°c, despite the fact that observed temperature differences didn't range more than 2°c.

As shown in results, the retrofitted case showed slight increase of temperature at wall surfaces, while a relatively similar decrease of temperature rates at the central zone of courtyard.

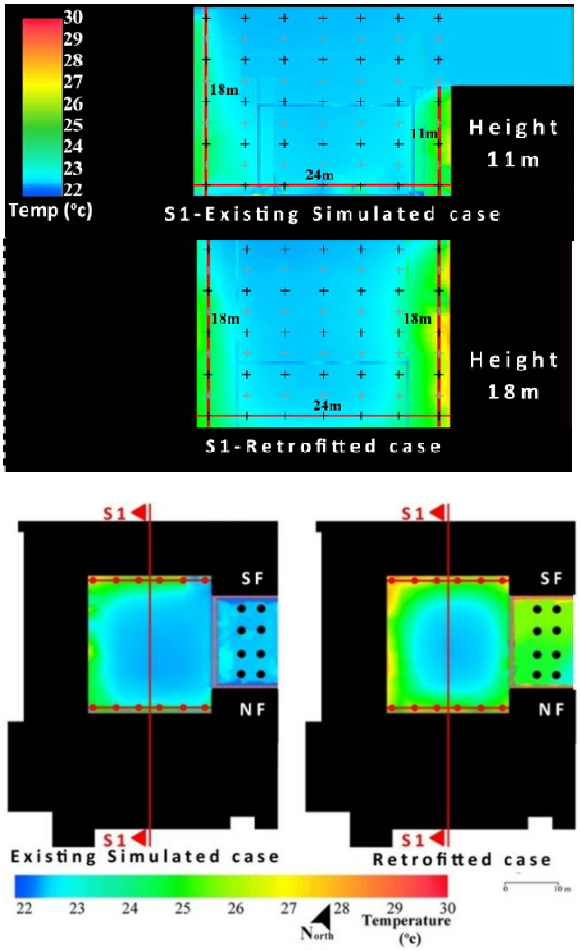


Fig. 7 Thermal simulation results of existed and retrofitted height of case study

These results were used to indicate the simulated building conditions before the initial setup of LSM cases.

C. LSM Cases

According to transfer these computational results and numerical findings into architectural design decisions. Mimicking the traditional Egyptian concept of

Clerestory openings as inlet surfaces, through three LSM cases which proposed as: (1) Case A: is a flat surface with a height of 4.5 m. of side-lit; (2) Case B: is a vault shape with 2.5 m. side-lit and curvature of 4.5 m high; (3) Case C: is a pitched roof structure with 2.5 m. side-lit and triangular roof of 4.5 m high.

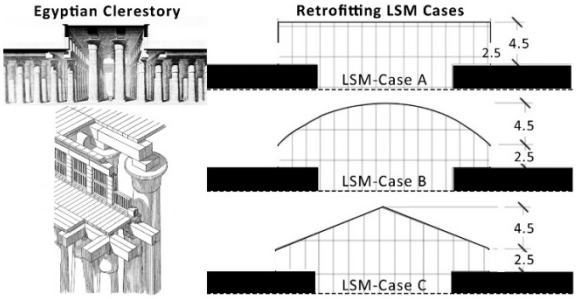


Fig. 8 The three retrofitted LSM cases

D. LSM Boundary Conditions and Meshing process

The CFD grid structure of these three models were built-in by 1,800,000 tetrahedral grid cells for each case study with a no more than 10,000 grid cells change for each case. As mentioned in computational process, the hierarchy of the sizing of the unstructured grid cells provide flexibility in meshing regular and irregular geometries. This hierarchy is based on decreasing grid no. at the outer surfaces of the courtyard building.

The computational process acquired a range from 400 to 500 iterations to solve it. Thus, after convergence of iteration process is done, the results of the three light structures are analyzed and compared.

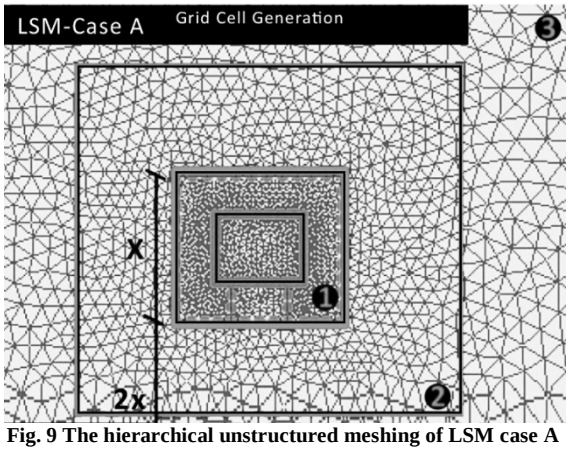


Fig. 9 The hierarchical unstructured meshing of LSM case A

VI. EVALUATION OF LSM RESULTS

The evaluation of LSM simulation results indicated through defining levels of comfort. However, there are difficulties to define certain levels of comfort within a number of changing factors. Previous studies show through fixing certain parameters can let level of comfort index be achievable in Air Flow Pattern (AFP) and thermal performance [23]-[24]-[26].

AFP study shows that air velocity is characterized by fluctuating readings. Thus, as stated by Soligo [24] and Penwarden [25], Beaufort scale was recommended to indicate levels of comfort [24]-[25]. Penwarden [25] described the scale as air velocity decreases more than 0.4 m/s or increases more than 10.7 m/s, discomfort can be felt by pedestrians. As shown in figure 10, interpreted measurement ruler based on Beaufort scale description.



Fig. 10 Air velocity- measurement ruler based on Beaufort scale

Otherwise, temperature comfort criteria are considered more complex to be determined as many studies indicated [26]. As the comfort rates can change dramatically through many changing factors such as location, season, weight, age, gender, and activity [26]. Nicol [27] suggests that adaptive thermal approach can be more appropriate. This approach is indicated when no dramatic changes in air velocity or functional activities, then comfort temperature changes should be as narrow as $\pm 2^{o}$c [27]. As long as changes slow in temperature, users then can adapt easily to the seasonal changes of temperature [27]-[28]. So according to traced temperature, it was considered that decreasing temperature at lower zones with limited change of range temperature from 25^{o}c to 27^{o}c is targeted as comfort levels in the studied month.

After several hours of iterations, S1-section plots was taken to compare the three cases. The sections are divided by two tracing lines which are S_G and S_C. S_G is a graph line at height of 1.5 m. at ground level, and SC is a graph line at height of 19.5m at the mid of Clerestory. Focusing more in this study on S_G values to find the AFP and thermal performance affecting the users of the transitional space.

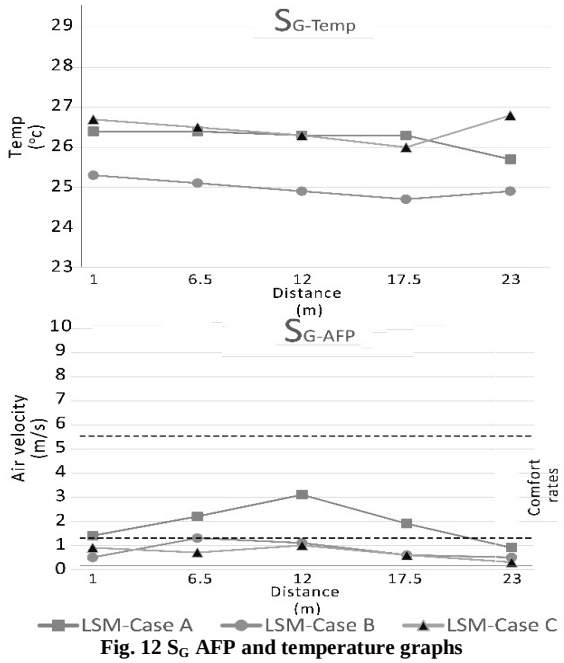


Fig. 12 S_G AFP and temperature graphs

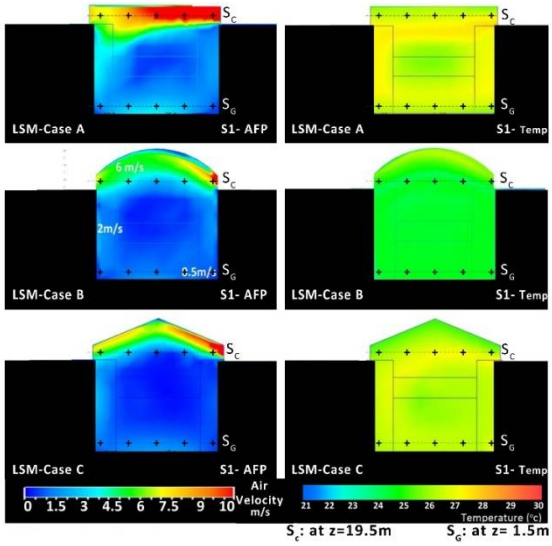


Fig. 11 Air Flow Pattern and Temperature in the three cases

Simulation results of the three cases can be summarized as:

LSM -Case A: The flat roof case shows that the temperature in the court ranges from around 25°c to 28.7°c. Temperature rates increase at the top zone near LSM surface and at the lower zone near ground surface. Moreover, the air velocity increases near LSM to reach about 10 m/s, while at the middle zone of the space a large eddy with low air velocity is shaped by a range of 0.05 m/s to 0.2 m/s. This scenario shows that comfort air velocity can be achieved near external walls because air velocity reaches from about 4 to 5 m/s, but at the roof level can have discomfort air velocity levels. There is also high fluctuation of temperature levels at the mid zone of the studied space.

LSM -Case B: The vault roof case shows that the air temperature ranges from 24.5°c to 26.5°c which is less fluctuating rates than case A and considered within the ±2°c. To sum up, the temperature rates increase only at the top zone near light structure surface, and the air velocity reaches about 7 m/s adjacent to the LSM surface, while at the middle zone of the space a large eddy with low air velocity is shaped by a range of 0.09 m/s to 0.5 m/s. This scenario shows that comfort air velocity can be achieved near external walls because it reaches about 2 to 3.5 m/s.

LSM -Case C: The pitched roof case shows that internal simulation shows that the air temperature rates ranges from 25°c to 28°c which is nearly similar to case A but has higher temperature than case B. The temperature rates increase at the level of the side-lit surface of the light structure, and the air velocity near to the inlet of the light significantly decreases from 10 m/s to 6.5 m/s , while at the middle zone of the court a large eddy with low air velocity is formed by a range of 0.1 m/s to 2 m/s.

S_G graphs are used to show the AFP and temperature differences between the three cases. Temperature graph shows the less temperature fluctuation of case B, and the better AFP performance of case A.

As shown above a number of findings can be summarized as:

1. The air velocity at ground level in the three cases is ranging from about 0.3 m/s to 3 m/s. Case A shows exceptional air velocity which ranges more than 0.4m/s, this means that case A can have more potentials of comfort ventilation rates in adjacent spaces than case B and case C.
2. LSM cases show that it can be dramatic increase of air velocity at the clerestory level in which it can reach to about 10 m/s with low turbulent effect. These findings can be a startup for further future studies of examining using wind turbines in such case.
3. The Thermal results showed that case B is more effective thermally than case A and case C. While the AFP results show that case A was slighter performed better than both case B and case C. Therefore, it is recommended to exclude case C of pitched roof as retrofitting design potential.

VII. TOWARDS EREBI FRAMEWORK

Indicators are used to measure the performance, as defined by Shen [29] they should be selectively essential elements to give a clear view of the status of green architecture practice. Researchers such as Tarabieh [30], Zhang[31], and Shen[29] specified that indicators should characterize by the following: (1) Their quantified ability; (2) Assisting pilot tools used for making decisions and policies; (3) Performance tools related to indicate how methods can be effective in existed and future studies.

Moreover, as recommended by Shen [29] at the beginning of proposing environmental indicators such as EREBI, it would be more effective to start with a short list of indicators and later on more indicators can be added or removed as another retrofitting studies would be investigated.

The focus of the EREBI framework is on retrofitting design of educational buildings and its effect on social behavior and environmental performance. This purpose is limited by political, economic constraints which are the main drives for buildings design decisions. So this study focuses only on the environmental aspect of retrofitting design decisions of LSM shape.

It is important to assert that any try to apply a set of such indicators through certain objectives to all communities and contexts could be arguable. While sharing generating indicator practices from different practices and context can enrich the overall view of green communities [31].

These findings used for schematic retrofitting design proposals in transitional spaces in Alexandria university. The study shows some limitations of the used simulation method such as limitation of available computational power which leads to decreasing the

modeling resolution and neglecting some details of the real built environment.

However, these limitations can affect the results. Simulation can be supportive to Architecture design scenarios as it is the best method to visualize and predict future scenarios. Thus, there is an increasing need for understanding the complex phenomenon shaping the simulation process to integrate with the design process in current practice, which this research is contributed to.

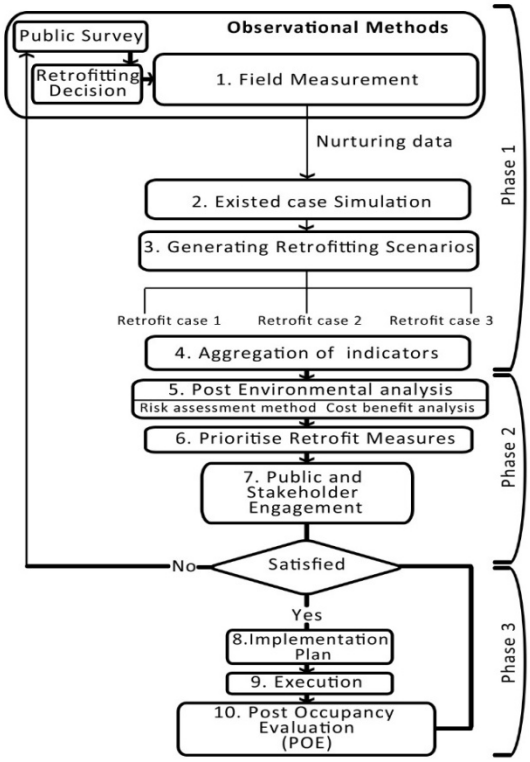


Fig. 13 EREBI Framework

The suggested EREBI framework consists of ten steps within three main phases of retrofitting strategy:

Phase one based on using observational and computational methods for environmental retrofitting strategy. In this phase, the first step is observational stage through public survey and in-site field measurement. Second step is nurturing field measurement data to build existed simulation models. Third step is to generate retrofitting scenarios. After repeating the three steps for every indicator, then fourth step of aggregation of retrofitting indicators related to previous scenarios is taken place.

Phase two is by getting outside the box of environmental retrofitting, by examining other dimensions. As fifth step is related to other studies such as risk assessment and cost benefit analysis. Then Sixth step is dedicated to prioritizing the environmental, risk, and economic measures. Finally, the public stakeholders and decision makers would decide whether a satisfied retrofitting strategies are proposed or not.

Phase three is about Execution and post occupancy phase. As if retrofitting design has been satisfied, implementation plan would be settled down as step eight. The ninth step is integrative execution of the retrofitting project. Finally, the Post Occupancy Evaluation (POE) is settled as tenth step which can be observed by surveying and interviewing users of retrofitted building.

Thus, EREBI framework is suggesting to be a compromising solution between different observational and computational methods. If so, this framework can be used as organizing and feeding back the retrofitting design research in existed educational buildings in Egypt.

REFERENCES

[1] S. Roaf, D. Crichtonand F. Nicol, "*Adapting buildings and cities for climate change, A 21st Century Survival Guide*", ISBN: 978-1-85617-720-7 Elsevier, second edition 2009.

[2] A. ElSeragy, A. ElNokaly, Proposal of Sustainable and Eco-exurban Communities at the Western Desert Development Corridor in Egypt. Available:http://eprints.lincoln.ac.uk/8497/1/CSAAR%202008%20Full%20paper%201%20revised.pdf (accessed 5 Jun 2017)

[3] Z. Ma, P. Cooper, D. Daly, and L. Ledo, Existing building retrofits: Methodology and state-of-the-art. Energy and buildings, vol. 55, pp. 889-902, 2012.

[4] Queensland Government, Climate Q: Toward a Greener Queensland: Improving Energy Efficiency in Existing Government Buildings. Available:http://www.climatechange.qld.gov.au/pdf/factsheets/8govlship-b1.pdf (accessed 9 Jan 2017).

[5] Petruccioli, Attilio. "The Arab City: Neither Spontaneous nor Created." In Environmental Design: Journal of the Islamic Environmental Design Research Centre 1-2, pp. 22-33. Rome: Dell'oca Editore, 1997-1999.

[6] A. Salama, "A Typological Perspective: The Impact Of Cultural Paradigmatic Shifts on The Evolution of Courtyard Houses in Cairo," METU JFA, vol. 23, no. 1, pp. 41-58, 2006.

[7] J. Kenrick, *"Ancient Egypt Under the Pharaohs"*, vol. 1, Digitized version from University of Toronto in 2007, 1852.

[8] A.B. Lloyd, "The Egyptian Labyrinth", The Journal of Egyptian Archaelogy, published by Egypt Exploration Society, vol. 56, pp 81-100, 1970.

[9] P.A. Mirzaei, and F. Haghighat. "Approaches to study urban heat island–abilities and limitations." Building and Environment, vol. 45, no.10, pp.2192-2201, 2010.

[10] I. Abohela, "Effect of Roof Shape, Wind Direction, Building Height and Urban Configuration on the Energy Yield and Positioning of Roof Mounted Wind Turbines," PhD thesis, The University of Nottingham, Nottingham, UK, 2012.

[11] I. Abohela, N. Hamza, and S. Dudek, "Assessment of wind flow within the built environment." Built and Natural Environment Research Papers, pp.81, 2011.

[12] G. Gan and S. B. Riffat, "Numerical simulation of closed wet cooling towers for chilled ceiling systems." Applied Thermal Engineering, Elsevier, vol.19, no.12, pp.1279-1296, 1999.

[13] Winsberg, E.B., "Science in the age of computer simulation," The university of Chicago press, Chicago and London, ISBN-13: 978-0-226-90204-3, 2010.

[14] E-instrument, Multi-meter Multifunctional IAQ Monitor AMI 300 manual, 2013. Available: http://www.solutionsdirectonline.com/einstruments/pdf/e-instruments-ami300-manual.pdf (accessed: 4 November 2016)

[15] Broekhuizen I. Integrating Outdoor Wind Simulation in Urban Design : A Comparative Study of Simulation Tools and their Benefits for the Design of the LTU Campus in Luleå [Internet] [Dissertation]. 2016. Available from: http://urn.kb.se/resolve?urn=urn:nbn:se:ltu:diva-54838

[16] D. Paksi, 'The Concept of Boundary Conditions', copyright of POLAN Y I A NA, 2014/1-2. (23): pp. 5–20. Available: http://uberty.org/wp-content/uploads/2016/10/boundary-conditions.pdf

[17] R. Ramponi and B. Blocken, CFD simulation of cross-ventilation for a generic isolated building: Impact of computational parameters, Building and Environment, 53:34 , 48, July 2012, ISSN: 03601323. doi:10.1016/j.buildenv.2012.01.004. Available: http://www.sciencedirect.com/science/article/pii/S0360132312000013

[18] R.K. Bani, Validation of Atmospheric Boundary Layer CFD Simulation of A Generic Isolated Cube: Basic Settings for Urban Flows,IBPSA.Available: http://www.ibpsa.org/proceedings/BSO2016/p1021.pdf (accessed 9 Jun 2017)

[19] D. Micallef, V. Buhagiar, S. P. Borg, Cross ventilation of a Room in a Courtyard Building, Energy & Buildings, Volume 133, 1 December 2016, pp. 658–669. Available:

[20] http://www.sciencedirect.com/science/article/pii/S0378778816309124

[21] Autodesk, online essay entitled: "SST K-Omega Turbulence Models", (February 2017), Available: https://knowledge.autodesk.com/support/cfd/learn-explore/caas/CloudHelp/cloudhelp/2017/ENU/SimCFD-Learning/files/GUID-0F5C4828-9F91-46B6-A16A-2578D72DCFCC-htm.html (accessed 15 April 2017)

[22] A. Sayma, "*Computational Fluid Dynamics*" Abdulnaser Sayma & Ventus Publishing Aps. ISBN: 978-87-7681-430-4. https://kosalmath.files.wordpress.com/2010/08/computational-fluid-dynamics.pdf, 2009.

[23] Autodesk, online essay entitled: "What does the Intelligent Wall Formulation mean to the turbulence model is k-epsilon in Simulation CFD", (November 2014), Available: https://knowledge.autodesk.com/support/cfd/troubleshooting/caas/sfdcarticles/sfdcarticles/Intelligent-Wall Formulation-k-epsilon.html [accessed at 11 May 2016].

[24] ASHRAE, "ASHRAE Handbook Fundamentals, I-P Edition, American Society of Heating, Refrigerating and Air-Conditioning Engineers," ISBN 1-931862-70-2, 2005.

[25] M.J. Soligo, P.A. Irwin, C.J. Williams, and G.D. Schuyler, A comprehensive assessment of pedestrian comfort including thermal effects. Journal of Wind Engineering and Industrial Aerodynamics, vol. 77, pp. 753-766, 1998.

[26] A.D. Penwarden, A.F.E. Wise, Wind environment around buildings, Building Research Establishment Report, HMSO, 1975.

[27] A. K. Mishra, and M. Ramgopal, Field studies on human thermal comfort—an overview, Building and Environment Jounal, vol. 64, pp. 94-106, 2013.

[28] J. F. Nicol, and M. A. Humphreys, Adaptive thermal comfort and sustainable thermal standards for buildings, Energy and buildings Journal, vol. 34, pp. 563-572, 2002.

[29] M. A. Humphreys, and J. F. Nicol, An adaptive guideline for UK office temperatures, in J.F. Nicol, and M. A. Humphreys, O. Sykes, S. Roaf (Eds.), Standards for Thermal Comfort: Indoor Air Temperature Standards for the 21st Century, E and FN Spon, London, 1995.

[30] L. Y Shen, J. J. Ochoa, M. N. Shah, X. Zhang, The application of urban sustainability indicators- A comparison between various practices, Habitat International Journal, Elsevier, vol. 35, pp.17-29, 2011.

[31] K. Tarabieh, and A.M. Malkawi, Building an Urban Energy Performance Framework: Integrating Spatial Analysis and Building Simulation Tools for Campus Planning, IBPSA, Building Simulation Conference, 2007.

[32] K. Zhang, K., X. He, and Z. Wen, Study of Indicators of Urban Environmentally Sustainable Development in China, International Journal of Sustainable Development, vol. 6, no.2, pp.170-182, 2003.

★★★