Impact of Dynamic Facades on Thermal Performance of Office Buildings

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Abstract

With a thoughtful insight into Arab cities and the technological evolution impacts on their contemporary architectural designs, especially in their office buildings, it is noticed that there is lack of using a clear and specific scientific methods in dealing with the thermal transfer through the skins of those buildings is clearly apparent, resulting in the intensity of the cooling system used for achieving the thermal comfort of the occupants of this vacant area, thereby increasing the energy consumption rates within these buildings.

So there is a need to find a new method to enable improving the thermal performance of the office buildings in Arab cities through using the dynamic facades system, to achieve that a virtual office building subject to the open offices systems with glass facades in the hot, dry climate region of Greater Cairo was studied using the parametric design tools in order to achieve a distinguished dynamic façade, whereas it was applied to the southern side of the buildings, the consumed heating and cooling loads were studied before and after the addition of this façade by using the environmental simulation techniques, and it is found that this technology saved 43% of the energy consumed by the cooling loads, which basically contributes directly to reduce energy consumption within the office buildings.

Keywords: Dynamic Facades, office buildings, Energy loads, Parametric Design, Simulation tools, Thermal Performance.

1. Introduction

Thermal performance of Office Buildings is one of the most important standards of successful design for the building, where employees spend a great part of the day in work, therefore the amount of thermal comfort inside the workplaces has a great impact on their health and state, which consequently affects their work performance and execution. So, in a study that is conducted by (Seppanen, Fisk et al. 2004) [1], on the relation between performance in work and temperature in indoor places, which in turn affects the Thermal comfort, which shows that as the temperature measure of indoor places is more than the proper measure of Thermal comfort inside the place, as the place occupants capability is decreased in work performance by 2% per one Celsius degree. Building façade is considered one of the most important contributors in energy budget and comfort parameters in any building, as it is an insulator for the internal environment from the external one. This research aims to achieve a Thermally comfortable environment for occupants of these buildings and to reduce energy consumption that is used in cooling and heating. This is increased in importance due to coinciding with the presence of energy crisis, environmental pollution, and climate change that is resulted from excessive energy use in these buildings. This increasing demand for energy is due to office building facades, wherein hot arid climates like Egypt, façade components are responsible for up to 45% of cooling loads [2]; as a result there is a need to design more efficient Office Buildings, which aims to reduce solar energy gain and to decrease Thermal stress as a vital issue. In the light of technological development in architecture field, it becomes necessary for the architect to keep pace with this development, because architect cannot only go to conventional methods of using known opening ratios or using fixed conventional breakers, where continually varied temperature dynamics requires to be encountered by dynamic systems that are able to respond through sensing devices that stimulate them on time of respond and circulation. This is done by the discovery of feasibility and design capabilities of dynamic facades that keep pace with the continuous climate changes. In study conducted by (Sinziana Rasca,2014) [3] on impact of dynamic facades on energy requirements in buildings in several sites of different climate, the study applied dynamic façade on different building sizes (commercial- administrative); sizes ranged from small-size buildings XXS which area is estimated by (384 m2) to large-size buildings XXL with area of (6000 m2). Results concluded that dynamic façade systems have a positive impact on the energy requirements of buildings, generally in most climates around the world. The study recommended to conduct an experiment on climates that are not included in the research, where most studies of dynamic facades considered the impact of façade movements on the lightening of indoor places, but we noticed that these researches do not consider the impact of dynamic facades on thermal performance inside the buildings. So, a hypothetical administrative building will be designed, in a dry hot climate region in Great Cairo territory. This building follows open office system with glass facades, study of solar path by Ladybug tool, heating and cooling loads of the building in its main state by Honeybee tool, and then designing dynamic façade aided by parametric design tools using Grasshopper tool, and to apply this proposed dynamic façade on southern facade as it is the most façade in which sun movement prolongs, so it is subject to more kinetic stress than the two eastern and western facades. Furthermore, to study of heating and cooling loads after the addition of the dynamic façade by using the Honeybee tool and comparing results before and after the façade addition to reach the research objective.

2. Theoretical background

2.1. Thermal performance in Office Buildings:

The thermal performance of Office Buildings is considered one of the most significant standards of successful designs, where it takes heat flow magnitude between these buildings and the external surrounding environment, where building components of walls, windows, and used materials affect the healing flow to the building inside. This research aims to achieve a thermally comfortable environment for occupants of these buildings, to reduce energy consumption that is used in cooling and heating. This is increased in importance due to coinciding with the presence of energy crisis, environmental pollution, and climate change that is resulted from excessive energy use in these buildings.

Thermal performance in buildings indicates theThermal comfort ratio, which is felt by occupants in the internal spaces of the building. Both (J. Nayak and J. Prajapati) defined the thermal performance of building meaning as "modeling process to exchange energy between the building and the surrounding environment" [4], and the different range in temperature between the building and its surrounding environment is the main driver of energy flow all over the building. In the following, factors affecting the thermal performance will be considered, and to illustrate the heat transfer mechanism between facilities and their surrounding environment, in addition, to discuss the thermal comfort as a scale of thermal performance, and to provide an overview on the impact of the thermal performance on the energy consumption.

2.1.1. Factors affecting the thermal performance of buildings:

Some of the most important factors affecting thermal performance of buildings are magnitude of heat entry and exit through the building components, internal heat loads generated by the building occupants, as activities performed by them, and heat flow magnitude carried by air during respiration process; this means that the heat flow of facilities depends on a large number of factors that can be summarized as follows [5]:

- Design variables of (building orientation- shading)
- Used materials characteristics (density- specific heat- connectivity)
- Weather data (sun rays- wind speed)
- Building use data (exchange of building internal air- entry of air from outside)

2.2. Concept of Practice the movement in architecture:

Practice the movement in architecture engineering is defined as building with mobile elements (motor devices) in the site, or transformable or configurable structures. Facilities with mobile elements are integral construction structures that move with floor, walls, and ceiling, and they are of most common mobile facilities and easiest design, either in architecture, construction, or mechanics, such as rotary and sliding buildings. Transferable structures are such as mobile buildings and structures, or folding, sliding, rotary, expandable, or larger-area spreadable ceiling. It is considered a suitable strategy for buildings that need re-formation, upon changeable conditions needs and requirements, which are mostly functional or environmental. While in terms of change in configuration, it is a change that happens in the site itself without affecting the area in which it works [6]. In the following, there is an illustration of a general framework of the circulation approach classification in architecture.

2.2.1. Static approach:

It is a hypothetical circulation that achieves aesthetic goals or trials to attract intention. This type of hypothetical circulation is applied during the design stage using digital models, which enable designers to amend freely in the design stage.

2.2.2. Dynamic approach:

Systems under the dynamic approach are featured by the quick development of technology and mechanics, which enable facilities to respond to the surrounding changes, either they are external such as climate, or internal such as space occupant needs. This approach is divided into two circulation types [7].

- Spatial movement:

It is known as a small scale, by folding, sliding, rotation, expansion, and transformation.

- Non-spatial movement:

It is known as microscale, where motion occurs by a change in color, texture, light transmittance, and topography.

2.3. Definition of dynamic facades

"Dynamic facades are defined as response-quick facades, where they show the ability of understanding and learning from their surroundings, and adjusting their behavior accordingly. Building casing is not inert, but it transforms dynamically to regulate the internal environment reducing the energy requirements. From the ideal view, it includes methods of energy generation" [8]. The ability of dynamic facades depends on changing the characteristics and behavior on macro- or micro- scale, as it is classified by Loonen [9].

2.4. Reasons for dynamic facades movement:

Considering the research field, we find that dynamic facades are changing by time, instead to be fixed. Façade elements can be programmed to respond to climate factors of temperatures, wind, and solar radiation, and for energy efficiency improvement, or for aesthetic reasons such as artistic formation or to serve as live banners [10].

2.5. Importance of dynamic facades in raising thermal performance efficiency in buildings:

The need for buildings that respond to climate changes in the surrounding environment and to adapt with it becomes an urgent issue. To do so, it must be characterized by the flexibility to be able to encounter the climate change risk which affects the whole world [11]. Continuously changing temperatures dynamics require to be encountered by dynamic systems that are able to respond by signals sent on time of response and movement.

3. Methodology

The proposed methodology of this research used parametric modeling and simulation of the thermal performance of the Office Buildings. Methodology is divided into two consecutive stages; where first stage concentrates on preparation of study model and analysis of thermal performance of the main model, and the second stage concentrates on designing a dynamic façade, and model analysis and thermal performance comparison before and after adding the dynamic façade in the selected opening ratios, which would be for each month throughout the year in work hours from 8 am to 6 pm. The simulation process aims to reduce the energy loads resulted from cooling, by selecting optimum opening ratios among the proposed alternatives in the early design stage.

3.1. First stage methodology: Building in the main state:

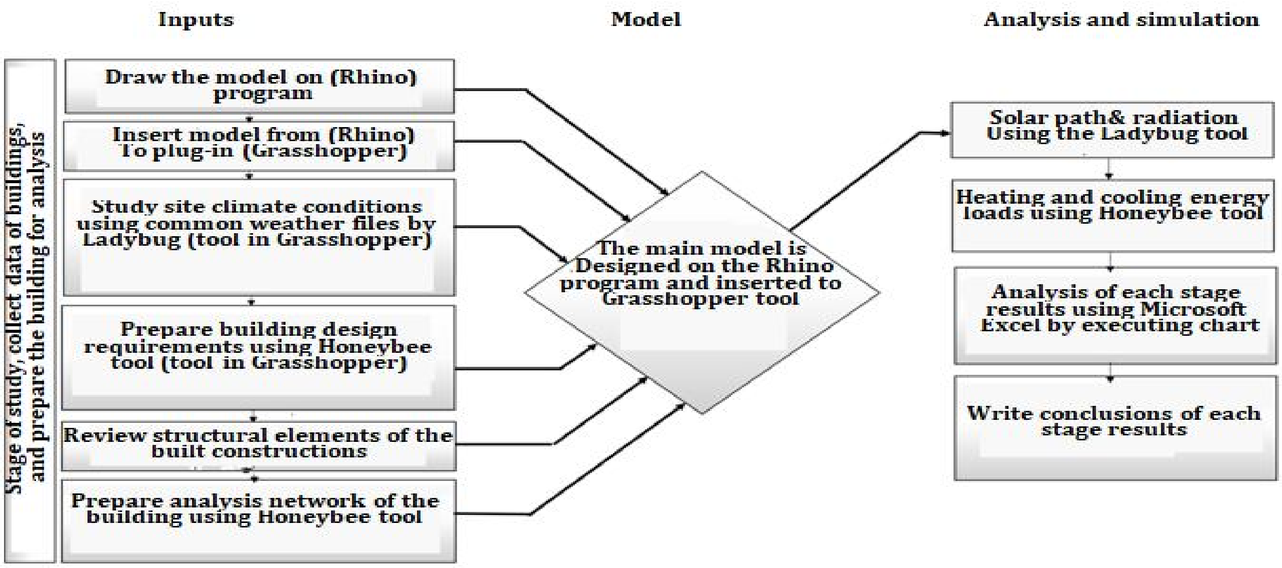


Figure 1: shows building design methodology and evaluation using simulation programs. (by researchers)

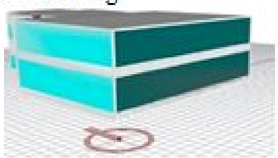
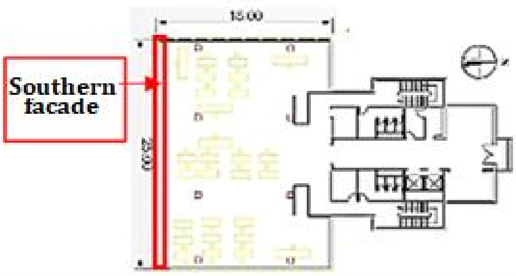
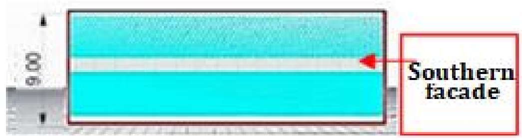
3.1.1. Preparation of study model:

Preparation of the model includes several stages, which are as follows:

First stage:

In this stage, the model is drawn on (Rhino) program, and to identify its characteristics, as shown in Table 1:

Table 1: shows model characteristics prepared for the study. (by researchers)

□ Model characteristics:	
▪ Space type:	▪ Orientation:
An office area with open space is specified in the hypothetical administrative building. 	Southern (proposed dynamic façade is applied on the southern façade due to its subject to a high percentage of thermal stress).
▪ Area:	▪ Floor numbers:
The Office area is 375 m2 	The building has consisted of two levels 

Second stage:

Additionally, to identify the climate conditions using the Ladybug tool. (As shown in table 2).

Third stage:

In this stage, the model is inserted from the (Rhino) program to plug-in (Grasshopper), and to specify design and space requirements using the Honeybee tool. In the following, there is an illustration of climate conditions and design and space requirements. (As shown in table 3 & 4).

Table 2: Climatic data specified to simulate the model of study. (by researchers)

□ Specify climate data:	
▪ Location:	▪ Weather data:
A case study is selected to be in Cairo city, Egypt, at coordination of (30°03′45″ North, 31°14′58″ East) [12].	The simulation uses weather files to recover data of the building site identified for this study purpose. the simulation was conducted using EnergyPlus Weather File (EPW) of Cairo.
▪ Sky state:	▪ Date and time:
Cairo is featured by sunny clear sky through the year approximately. It belongs to the arid subtropical climate according to Köppen climate classification (Peel ‘ Finlayson et al. 2007) [13]. Sky state is obtained through simulation using the (EPW) weather file of Cairo.	The study considers every month of the year. Time from 8 am to 6 pm was specified to know the consumed energy amount of heating and cooling load in work hours.

Table 3: Design requirements for the proposed design sample for study model. (by researchers)

□ Design requirements:	
▪ Opening ratio- the window to wall ratio (WWR):	▪ Biosphere:
Window to wall ratio (WWR) of the southern façade is 75%.	It is assumed the non-presence of neighbored buildings or trees around the building under study.

▪ Shading system		
In the main case, it is no shading system on the building.		
▪ Used construction materials		
First: the Climate region of Cairo is extracted in the Honeybee tool, which is 2B according to the classification of ((ashraeClimateZone). And then, extraction of the used construction materials for the building of (walls, ceilings, windows, floors) from the structural library of Honeybee tool, which is Honeybee-Call From EP Construction Library (CallFromEPConstrLibrary).		
▪ properties of the proposed construction materials		
Construction material	Thermal transmittance (U-value)	Thermal resistance (R-value
1- External wall ASHRAE 90.1-2004 EXTWALL MASS CLIMATEZONE ALT-RES 1-2	0.983626	1.016646
2- Windows: ASHRAE 90.1-2004 EXTWINDOW CLIMATEZONE 1-2	5.84	0.171233
3- Ceilings: ASHRAE 189.1-2009 EXTROOF IEAD CLIMATEZONE 2-5	0.229604	4.355327
4- Floors: ASHRAE 189.1-2009 ATTICFLOOR CLIMATEZONE 1-8	0.199447	5.013852

Table 4: Space requirements of the proposed sample of study model. (by researchers)

□ Space requirements:	
▪ Occupation table:	▪ Program:
The occupation table has selected to be from 8 am to 6 pm for 5 work days, which are work hours for many private companies in Egypt.	Space use has specified. It is an open space office.
▪ Used devices:	
Occupants perform regular office works, including work on the computer.	

3.1.2. Preparation of the building for analysis and presenting the results of each stage:

- Ladybug tool: To specify the solar path and the largest amount of solar radiation located on the building casing for every month, which is a tool in Grasshopper (as shown in figure 2):

Grasshopper window Rhino window

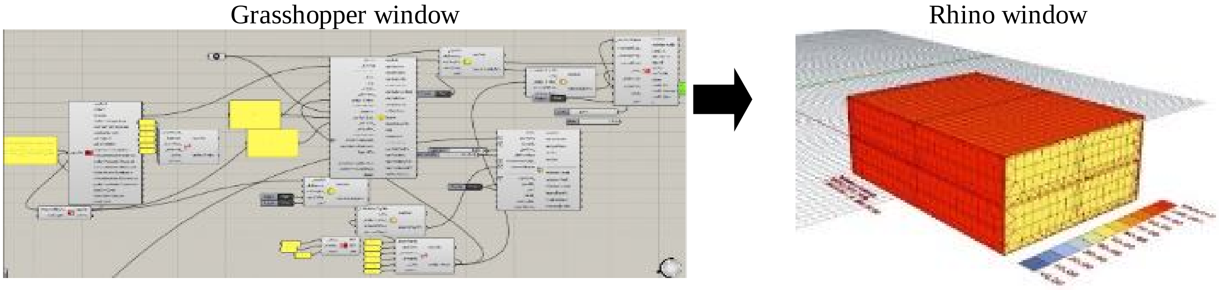


Figure 2: Shows work procedures in Grasshopper tool using Ladybug to build analysis network on the building casing, and results are presented on the Rhino window (by researchers)

- Honeybee tool: To calculate cooling and heating loads. It is a tool in Grasshopper (as shown in figure 3).

Grasshopper window Rhino window

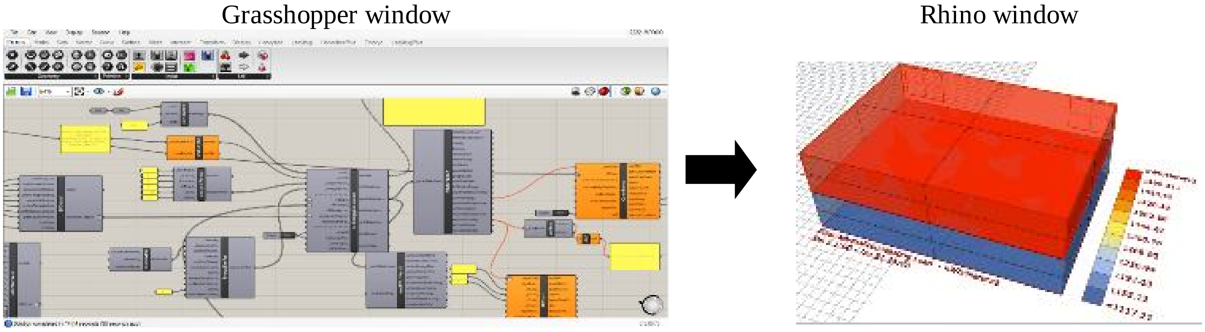
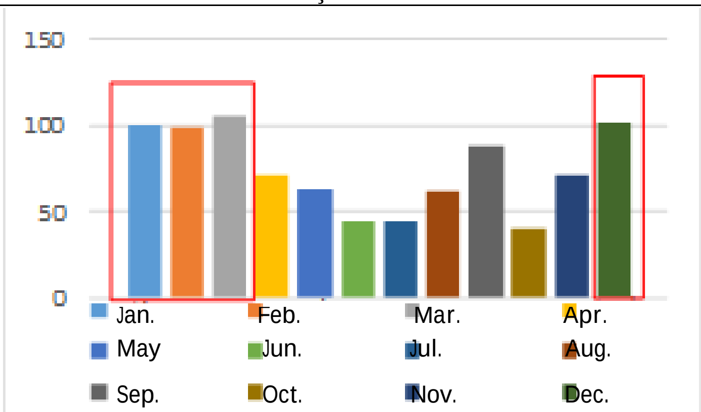
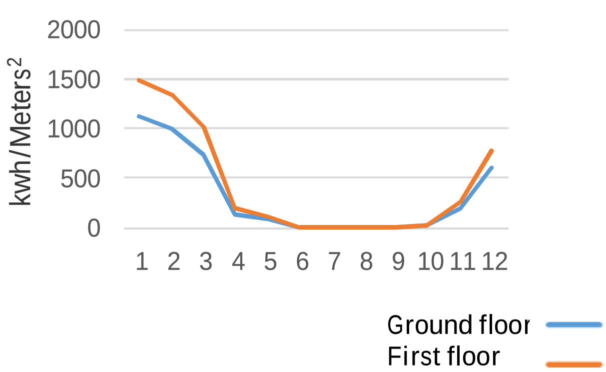


Figure 3: Shows work procedures in Grasshopper tool using Honeybee to build analysis network on the internal space, and results are presented on Rhino window (by researchers)

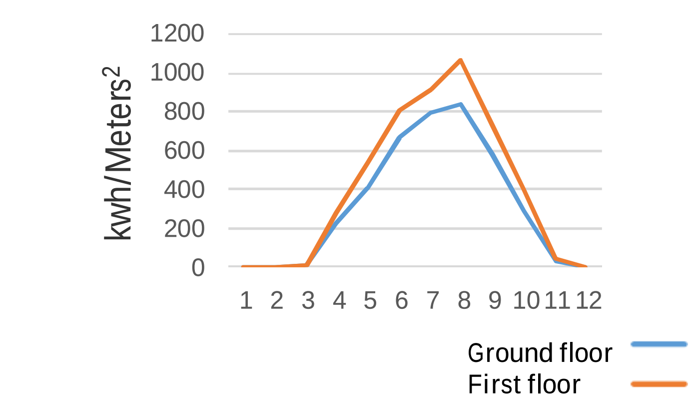
After finishing the steps of building analysis using ladybug & Honeybee tools the results analyzed (as shown in table 5):

Table 5: Analysis of results extracted from the Ladybug tool and Honeybee tool for the main model. (by researchers)

<table>
<tr><td colspan="2">▪ Analysis of results extracted from Ladybug:</td></tr>
<tr><td>Solar radiation on southern façade surface Kwh/m2</td><td>Result:</td></tr>
<tr><td>


</td><td>We notice that solar radiation concentration falling on the southern façade increases in winter season than in summer season, due to sun slop angles, where they are the nearest in winter (40°-60°) than in summer (80°-90°).</td></tr>
<tr><td colspan="2"></td></tr>
<tr><td colspan="2">▪ Analysis of results extracted from Honeybee:</td></tr>
<tr><td>Heating loads comparison between ground and first floors Kwh/Meter2</td><td>Result:</td></tr>
<tr><td>


</td><td>1- From this diagram, it is shown that heating loads have the highest values in Jan. period, and the lowest values in Jun., Jul., Aug., and Sep. months.
2- It is also shown that heating loads are increased on the first floor than on the ground floor as a result of an increase in the surface area exposed to the external environment.
3- It is also shown that heating loads are maximum in Jan., and they are graded until they end in Jun., and then start increasing again from Oct. and ending by Dec.</td></tr>
<tr><td>Cooling loads comparison between ground and first floors Kwh/Meter2</td><td>Result:</td></tr>
</table>



1- It is shown that cooling loads have the highest values in Aug. month and the lowest values in Jan. month.
2- It is also shown that cooling loads are increased in the first floor than in the ground floor as a result of exposing the building ceiling to direct solar radiation, and increased surface area exposed to the external environment, which transfers temperatures from outside to inside.
3- It is also shown that cooling loads are maximum in Jan., and they are gradually increased till their maximum in Aug., and then gradually decreased until ending in Dec.

3.2. Second stage methodology: The building after the addition of the dynamic façade:

This step is to identify the design requirements, on which the success of study administrative building dynamic façade design can be measured, where kinetic comfort in the administrative space is located between 22-24 Celsius degree [14]. This step must be conducted at an early stage to determine whether the dynamic façade design strategy will work to improve building thermal performance or not. Analysis after the addition of the dynamic façade to the study model includes several stages (as shown in figure 4).

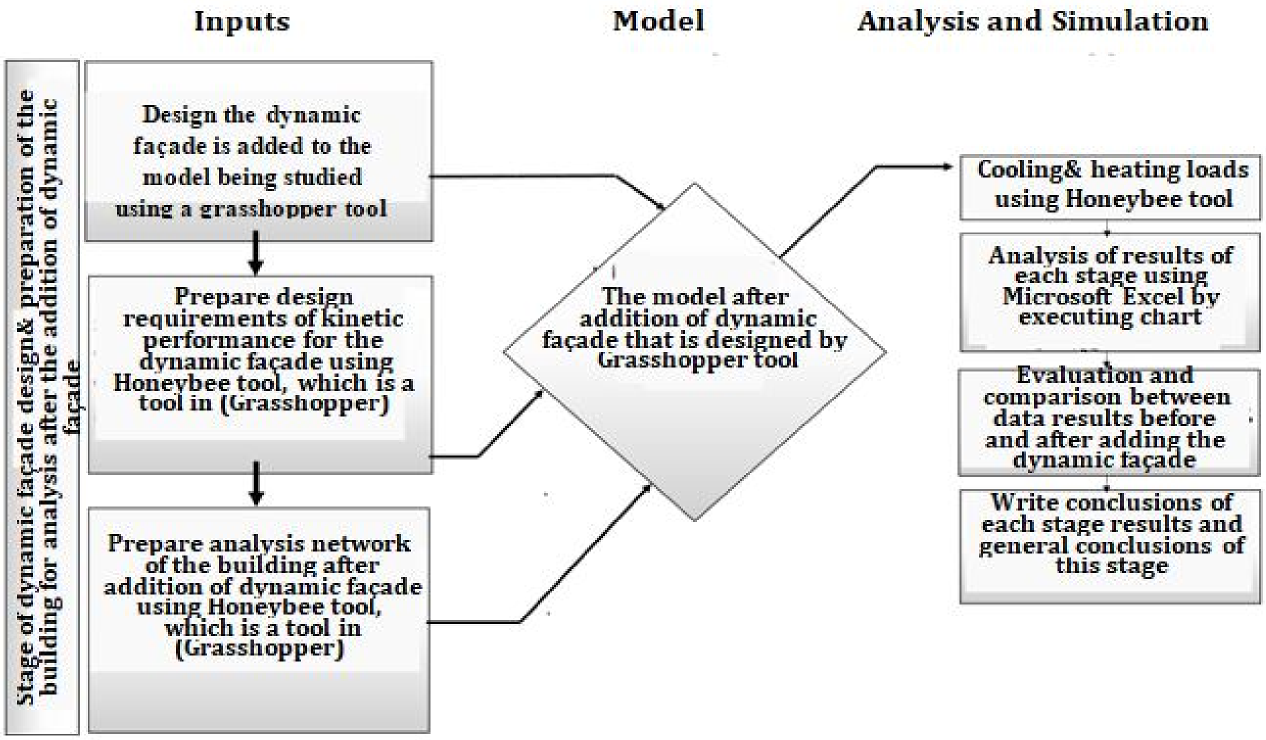


Figure 4: Shows a dynamic façade design methodology and evaluation using simulation programs. (by researchers)

3.2.1 Parametric design of the dynamic façade:

First: Design idea of the dynamic façade:

The idea is inspired by the sunshade system, where sunshade is considered one of the most common objects sued by people to protect themselves from the sun. Sunshade causes change in the geometric form of the casing so that it becomes adaptable with the surrounding climate changes. (as shown in figure 5).

Figure 5: It shows the design idea of the dynamic façade inspired by the sunshade

Second: To specify the parameters and characteristics of the dynamic unit:

-Design parameters of the dynamic façade. (as shown in figure 6).

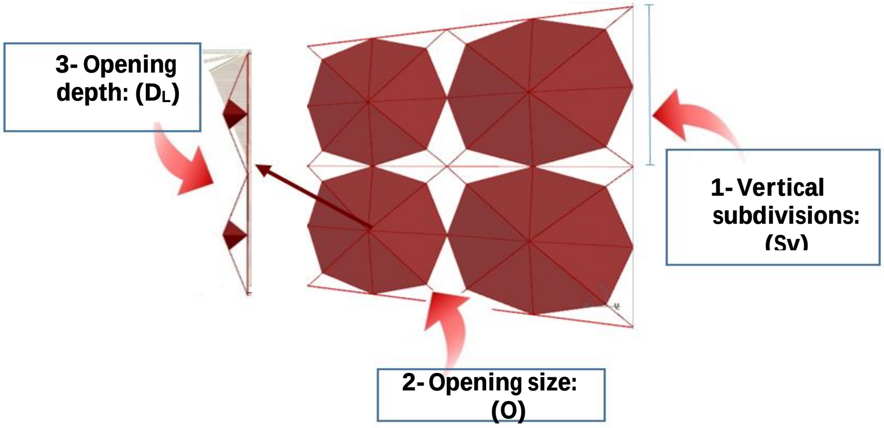


Figure 6: shows design parameters used to form the typical unit

First parameter: vertical subdivisions (Sv):

The dynamic façade consists of a typical unit that is repeated on network measures 4.5 * 5.0. The network is provided by a mathematical equation that links between vertical and horizontal subdivisions with each other. It is assumed that the ratio between vertical and horizontal subdivisions equal to 1:1. The first parameter can be amended to be in the ratio of 2:1, where the number of horizontal and vertical subdivision numbers can be controlled allowing different sizes of rectangles, which work as a base to generate the dynamic façade unit (as shown in Figure 7).

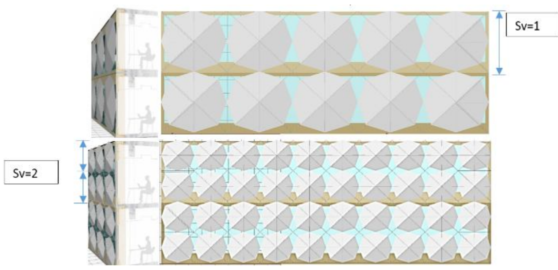


Figure 7: Different formations resulted from the first parameters (vertical subdivision values),

(by researchers)

Second parameter: Opening size (O):

The unit has consisted of eight triangular surfaces. Each surface is established from the diagonal line between hidden rectangle angle points and center points. And then four points of central points are established. This allows generating the eight surfaces. The eight surfaces are controlled by the number bar (Slider) by transferring the showed four points. These points movement to the central point direction identifies the opening size to be considered as a second parameter "O", (as shown in Figure 8).

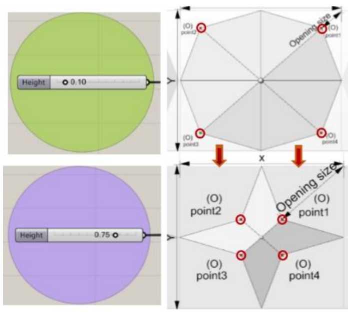
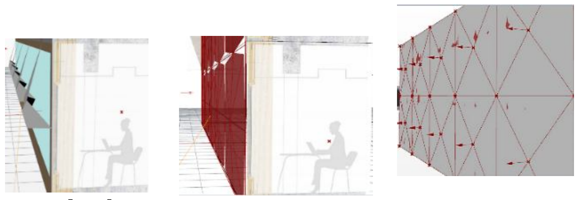


Figure 8: Points controlling the second parameter (opening ratio), (by researchers) .

Third parameter: Typical unit depth (Skin depth) (DL):

The third parameter controls the skin depth "DL" of the dynamic façade by moving these four points in the y-direction of the façade. Façade depth "DL" is regulated by the number bar (slider), which is the same bar that controls the opening ratio, where it is linked with mathematical equation as percentage of unit depth D. opening depth is linked with the unit depth reversibly, i.e. as unit size increases as vector length decreases, and vice versa. (as shown in Figure 9).



Unit depth is 80 cm | Unit depth is 10 cm | Y vector is in the middle of the unit

Figure 9: the Third parameter shows the skin depth of .the dynamic façade, (by researchers)

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3.2.2 Exploration of different alternatives of the typical unit design:

The three parameters control the typical unit causing a change in the dynamic façade shape; for each parameter certain values to be selected from upon the mathematical equations and the slider as shown in Table (6).

Table 6: Parameters of the typical unit of dynamic façade, (by researchers).

Unit parameters			Min.	Max.
Parameter number	Parameter definition	Symbol		
Parameter 1	Vertical subdivisions	(Sv)	1	2
Parameter 2	Opening size	(O)	.10(x)	.80(x)
Parameter 3	Unit depth	(DL)	.10(-x)	.80(-x)

This parametric model allows quick exploring all typical unit shapes without the need to re-draw each parameter individually using conventional modeling methods because it saves time and effort in the preparation of all solutions by changing number bar (slider) as shown in Figure (8). Results will be analyzed after inserting the dynamic façade and comparison among four cases by fixing the first parameter, which is the vertical subdivisions in a ratio of 1:1, and changing the second (opening ratio) and third (unit depth) parameters, which are linked by reversible relation as previously mentioned, they will be controlled by the slider as shown in Figure (11).

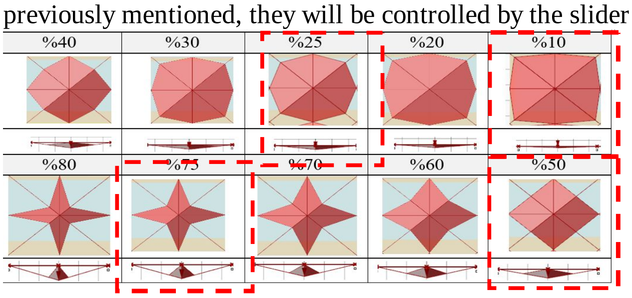


Figure 10: It shows the relation between opening ratio in the dynamic façade and sunshade depth. (by researchers)

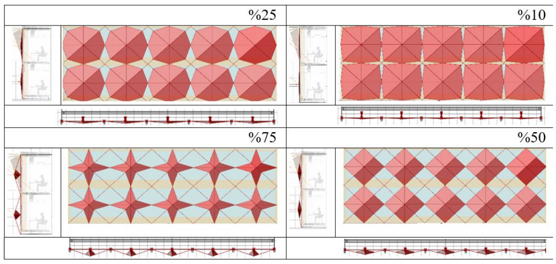


Figure 11: Proposed relations that will be studied and to analyze their data. (by researchers)

3.2.3. Building preparation and presentation of each stage results:

- Honeybee: Heating and cooling loads (as shown in figure 12)

Grasshopper window Rhino window

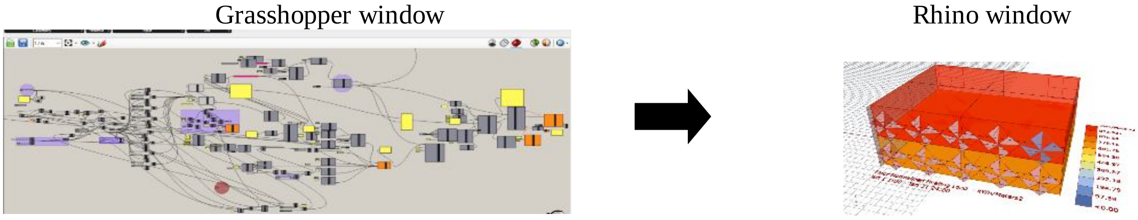


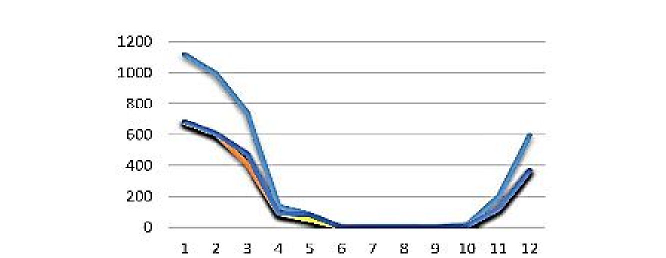
Figure 12: Shows work procedures in the Grasshopper tool using Honeybee to analyze the internal space, and results will be presented on the Rhino window. (by researchers)

After analyzing the building using honeybee tool the results are analyzed (as shown in table 7).

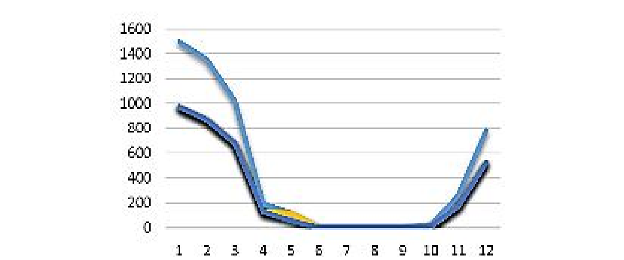
Table 7: Analysis and comparison of thermal performance for the model before and after the addition of the dynamic façade with the selected opening ratios. (by researchers)

Analysis and comparison of heating loads of ground and first floors Kwh/ Meter2

Heating loads of ground floor



Heating loads of first floor

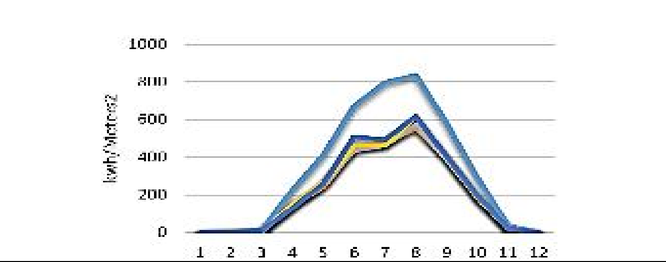


Opening ratio75% Opening ratio50% Opening ratio25% Opening ratio10% Main state before façade

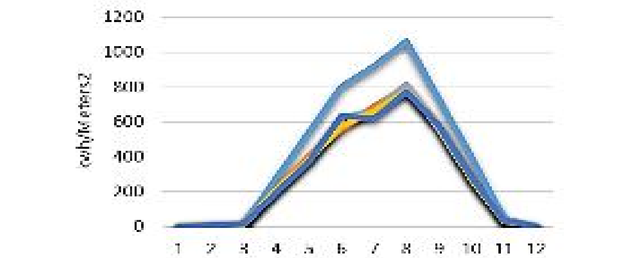
Conclusion:
Heating loads results are highly converged after addition of the dynamic façade with the proposed opening ratios, which motivates thinking functionally to make use from sun rays in winter months (Dec.- Jan.- Feb.- Mar.) to lighten the internal space, where the higher opening ratios, the higher benefit ratio from sun rays inside the space.

Analysis and comparison of cooling loads of ground and first floors Kwh/ Meter2

Cooling loads of ground floor



Cooling loads of the first floor



Opening ratio75% Opening ratio50% Opening ratio25% Opening ratio10% Main state before façade

Conclusion:
From the previous results, we find significant differences in the consumed cooling loads in every month after addition of the dynamic façade with the proposed opening ratios, which allows the designer to select the best opening ratios for the dynamic facades in every month according to the extracted results from Honeybee tool to reduce the consumed cooling loads.

3.2.4 Conclusion of the best opening ratios to save cooling loads for each month:

In this stage the extracted results for the model before and after adding the proposed dynamic façade to extract the optimum cooling loads saving ratios in hot monthes (as shown in figure 8,9)

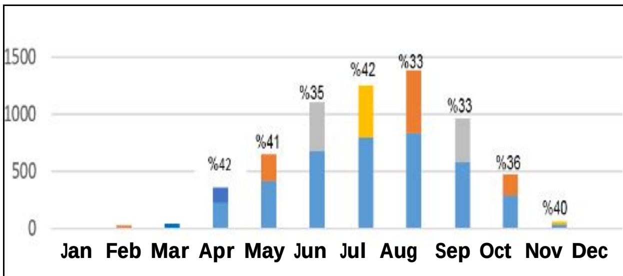
Table 8: Shows a comparison of saving ratios in energy loads for the proposed opening ratios of the dynamic façade in %. (by researchers)

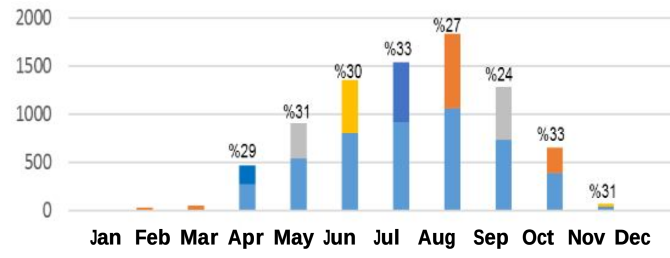
Month	Saving ratio %	Opening ratio 10%		Opening ratio 25%		Opening ratio 50%		Opening ratio 75%	
		Ground floor	First floor	Ground floor	First floor	Ground floor	First floor	Ground floor	First floor
1-31 Jan.	Heating loads	39.8	34.9	38.97	34.91	38.97	34.91	38.95	34.89
	Cooling loads	-------	--------	---------	--------	--------	--------	--------	-------
1-28 Feb.	Heating loads	39.11	35.8	39.11	35.83	39.11	35.83	39.09	35.81
	Cooling loads	-------	--------	---------	--------	--------	--------	--------	-------

1-31 Mar.	Heating loads	36.0	33.5	36.05	33.51	36.05	33.51	36.02	33.49
	Cooling loads	32.5	22.9	42.55	23.45	35.28	26.15	24.55	13.89
1-30 Apr.	Heating loads	-------	--------	---------	--------	--------	--------	--------	-------
	Cooling loads	34.30	23.28	38.22	27.85	34.04	22.97	42.43	29.41
1-31 May	Heating loads	-------	--------	---------	--------	--------	--------	--------	-------
	Cooling loads	41.37	25.49	36.94	31.32	35.49	29.73	36.93	31.31
1-30 Jun.	Heating loads	-------	--------	---------	--------	--------	--------	--------	-------
	Cooling loads	33.65	30.68	35.01	22.41	31.21	28.16	24.11	20.72
1-31 Jul.	Heating loads	-------	--------	---------	--------	--------	--------	--------	-------
	Cooling loads	39.34	25.02	41.68	27.91	42.07	28.39	38.04	32.98
1-31 Aug.	Heating loads	-------	--------	---------	--------	--------	--------	--------	-------
	Cooling loads	33.96	25.74	31.70	23.2	26.3	27.5	26.29	27.48
1-30 Sep.	Heating loads	-------	--------	---------	--------	--------	--------	--------	-------
	Cooling loads	30.5	21.5	32.7	24.0	29.5	20.39	30.04	20.93
1-31 Oct.	Heating loads	-------	--------	---------	--------	--------	--------	--------	-------
	Cooling loads	36.37	32.60	35.81	32.02	36.19	32.42	33.79	29.87
1-30 Nov.	Heating loads	-------	--------	---------	--------	--------	--------	--------	-------
	Cooling loads	36.59	26.35	39.76	30.03	40.25	30.61	36.0	25.73
1-31 Dec.	Heating loads	38.66	32.88	38.65	32.87	38.65	32.87	38.62	32.83
	Cooling loads	-------	--------	---------	--------	--------	--------	--------	-------

Table 9: Comparison between the best opening ratios for the dynamic façade in peak months, with the model in its state, and extraction of final results and saving ratios in cooling loads from this stage. (by researchers)

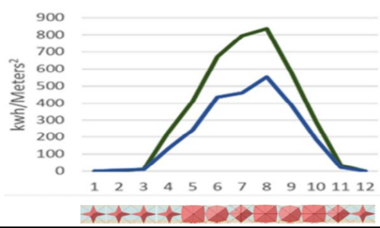
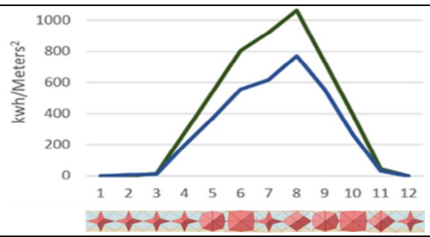
The best opening ratio in each month to reduce cooling loads in summer and making use from sun rays in winter	
Ground floor	First floor





Dynamic façade75% Dynamic façade50% Dynamic façade25% Dynamic façade10% Main state

Comparison of cooling loads

Ground floor	First floor
	
Proposed ratios For ground floor — Ground floor before façade	Proposed ratios For ground floor — Ground floor before façade

Conclusion:

- From the previous results, we find the dynamic façade leads to saving in the consumed energy of cooling loads, where the highest saving in consumed energy reaches 42% for the ground floor, and 33% for the first floor in July, and reaches average saving of the consumed cooling loads upon peak month numbers that showed 37.75% for the ground floor, and 29.75 for the first floor.
- Due to the heating load results are converged, it is decided to make use from sun rays in lightening the office space, by increasing the dynamic façade opening ratios to 75%.

4. Results:

- Climate change that we are witnessed today has become requiring non-conventional solutions, which exceed fixed shading strategies and the known opening ratios. That is because the continuously changed temperatures require to be encountered by dynamic systems that are able to respond through signals informing the suitable time of response and circulation.
- Facades are considered one of the most important casing elements that contribute to the energy budget, and they have a big role in building protection against external climate effects.
- Circulation approach in architecture is classified into the static approach, which expresses hypothetical circulation that achieves aesthetic goals, and dynamic approach makes facilities able to respond to changes, either they are external like climate or internal like designer needs.
- The efficiency of the dynamic façade opening ratio is different in every month, where the internal space needs shading in some months and needs ventilation or lightening in other months, hence the importance of circulation in dynamic façade emerges.
- There is an effective impact in using the dynamic façade in saving cooling loads in the Office Buildings, where the highest saving in energy consumed in cooling reaches 42% for the ground floor and 33% for the first floor in July.
- Additionally, installing the dynamic façade at distance from the main building façade has helped in the improvement of ventilation inside spaces, therefore reducing the cooling load.
- Heating loads are highly converged, which motivates thinking functionally to make use from sun rays to lighten the internal space, where the higher opening ratio, the higher benefit ratio from sun rays.
- Parametric design and simulation tools provide designers conducting experiments on the façade extensively to reach the best opening ratio and typical unit size, which reduces the cooling loads in every month.

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