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Evaluating Double Skin Glass Façades in terms of Life Cycle Cost for High-Rise Buildings in Egypt

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Abstract. In high rise buildings the glass façades systems are often preferred due to the low maintenance, being rain screen as well as being lightweight, aesthetic, and durable. In the other side this system cannot be setup with openings such as windows for ventilation due to wind effect at upper floors. Therefore, this system increases cooling loads and ventilation systems. A double skin glass façade system has been developed to solve all these problems. Although the façades are often considered one of the measurable indicators for the cost efficiency, however cost of the double skin façades need guiding rules.

The aim of this paper is to present a quantitative evaluation methodology that could be used to determine cost optimal level for standard double skin glass façades alternatives based on enhancing building performance. The paper concentrates on the initial costs in addition to the maintenance costs, salvage costs and the annual costs along the life cycle period for the façade.

The paper has generated standard double skin glass façades alternatives that are common used in the building construction industry based on an extensive literature review, concerning double façade components. In addition, variables that affect the quantitative evaluation process are identified. Then, these standard double skin glass façades alternatives are subjected to a proposed quantitative evaluation methodology, which is used to find out the total present value life cycle cost (TPVLCC). The present value method (PVM) along the life cycle period for the façade is applied, consequently the research results support the decision-making for investors, architects, façade engineers and specialists to choose the cost optimal level for double skin glass façades.

Keywords: Double skin glass façades, Quantitative evaluation, cost optimal level, present value method.

1. INTRODUCTION

Double skin glass façades are composed of two glass skins with a large cavity in between, working as a thermal buffer zone that decrease the surface temperature of the skins, lowering rate of heat transfer between surface of the inner skin [1]. The winds acting on high-rise building do not permit external shading devices to fix on the surface. However, sun-shading system in the intermediate cavity can have almost the same effect as an external installation, and it will be much more efficient than interior shading devices in room [2]. The investment made for the façade is also expected to be economical from owner point of view. In Central Europe, these façades are about twice the cost of conventional curtain walls [3].

The extra costs are racked up by the expense of engineering façade and the unfamiliarity with these systems, which leads to higher installation costs.

According to literature, only a few studies investigated double skin façades practicability. Martinez, Patterson, Carlson, & Noble [1] presented two online surveys among building façade professionals for (over) than 300 building projects, the first survey was to identify façade retrofit practices and the second survey was to identify levels of design, and construction thinking. The results showed that, the major stage of professional involvement was during the execution stage with 47% followed by the planning stage and material supply with 38% additionally, (over) than 60% of responders had direct façade experience with curtain walls. Which indicate the underlying motivations that shaped the façade retrofit projects and understanding of the practice of façade retrofitting.

On the other hand, there are a considerable amounts of publications that have been considering the façade's cost in construction field. Othman [2] applied value management methodology during preparing tender documents phase on five-star hotels projects, the findings indicate an increase's efficiency, quality and reduce the total costs. Which helped in selection suitable finishing materials for hotel spaces, in addition, Spickova & Myskova [3] presented comprehensive information about the Life Cycle Costing (LCC) method then applied the LCC into the practical cost's management. To provide and present the alternative approach for how to achieve long-term minimum value of total costs from strategic point of view. Another paper by Ebbert & Knaack [4] is studied the integration of services into the building envelope to an office-high rise built in 1970, through a thermal simulation , the results showed that an energy saving of 75% is possible, this integration has been provided economically feasible and individually adaptable solutions in renovation.

It was clear from the literature review there are few researches that have been investigated cost optimal level for the double skin glass façades in terms of the life cycle cost. Therefore, this paper aims at investigating the results of applying a quantitative evaluation methods on standard double skin glass façade alternatives that could be used to determine cost optimal based on enhancing building performance, with respecting the life cycle costing (LCC).

2. METHODOLOGY

This paper is divided into two main phases. The first phase is divided into two consecutive stages, the first stage is presented an extensive literature review concerning the double skin glass façades components, from this literature a standard double skin glass façades alternatives groups were identified. The second stage, three selected alternatives groups were investigated from the economic point of view. The pricing of this process is based on a survey and interviews with three constructing façade firms in Egypt.

In the second phase, a quantitative evaluation methodology is demonstrated. The present value method (PWM) is chosen for evaluation as a tool for costs calculations along life cycle period, as it is widely accepted in scientific researches concerning the value management. This method is composed of 3 consequent steps, namely as the following: determination for the initial costs, the maintenance costs, salvage costs and the annual costs, Then converting the costs to present value, to find out the total present value of life cycle cost (TPLCC) for double skin glass. Finally, the quantitative evaluation method is applied for all the alternatives to find out the cost optimal level for double skin glass façades to select with different budgets [4] and [5].

2. FIRST PHASE: REVIEW OF GENERATING STANDARD DOUBLE SKIN GLASS FAÇADES ALTERNATIVES

The first phase is divided into two consecutive stages. The first stage is used for generating standard double skin glass façades based on the components of the new façade in relation to the existing one.

According to the literature concerning double skin façades components have been widely investigated , Oesterle [5] gave the most comprehensive definition of any double skin façade that DSF is consists of multi layered façade envelope, which has an external and internal layer that contains a buffer space used for controlled ventilation and solar protection. Moreover, Another research paper made by Ding, Hasemi, & Yamada [6] defined that DSF is composed into three layers namely, external skin layer, inter-mediates space with adjustable thermal control device and internal skin layer, where the outer layer (glazing) provides protection against weather and improved acoustic insulation against external noise. In addition, and a classification made by Poirazis [7] focusing on the structural system by breaking it down into a hierarchy of substructure as the following: Primary structure: loading bearing core, all columns, walls, and floors. Secondary structure: which are not part of primary structure like consoles (metal service floors, partitions, roof structure). Tertiary structure: all structure which are part of the secondary structure, but not critical to the stability of the second structure likes a material façade construction. As a result of this literature, façade retrofitting components are divided into five dimensions namely: supportive structure, façade glazing system type, façade material, façade glazing position and façade performance type.

Supportive structure: Poirazis [7] presented a comprehensive classification for the supportive structural system for the DSF. The result shown that the Supportive structure system was classified into three types cantilever bracket structure, suspended structure, frame structure and carrying by the floor. In addition, Ebbert & Knaack [4] presented a comprehensive classification for the anchoring systems based on the position of new façade component in relation to the original façade, Anchoring system was classified into five categories as the following: Replacement: system suspended per floor and connected to a defined point to the floor or columns, Additional exterior layer: system suspended per roof with supportive structure connected to a defined point to the floor or columns, Additional interior layer: system carried by the structural floor and supported by the walls, Exterior upgrade: System connected to existing structural façade and Interior upgrade: System connected to existing structural façade.

Façade glazing system type: Barau [8] presented an evaluation systemized the curtain wall system types into six types according to the constructional material, anchorage system, tolerance view and profile material type, based on basic factors such as safety, economic, and environmental constraints to enlighten designers and contractors on the choice of curtain wall type selection. The result shown that the utilized curtain wall type is the best design solution choice, and the second choice was the structural glazing type because of its high construction cost in case of glass fins or tension cables supportive structure.

Façade materials: Poirazis [7] focused on the types of glazing panels and their thickness for DSF. The results showed that the most common panel types used for DSF are usually at the external skin is found tempered single pane or can be laminated, at the internal skin is found tempered double or triple pane with thermal insulation, the gaps between the panes are filled with air, argon or krypton with thickness is normally 9, 12, 16 mm, etc. or found laminated filled with polyvinyl butyral (PVB) or resin with thickness is normally 0.38, 0.76, 1.52 mm. Another research by Lopez, Frontini, Bonomo, & Scognamiglio [9] presented an analytical study about the external ventilated cladding systems solution for existing or new construction façade used at public façades based on given examples from different façade system, components material. It was found that numerous cases that used for additional layer method is glass, and for upgrading method is aluminum compost panels cladding then concrete panels. In addition, Hammad [10] presented a thermal simulation aiming to reduce the cooling loads at an educational building's façade by exploring low energy strategies. A simulation for different construction composition resulted the using aluminum composite panel as an external material has the big influence at decreasing the heat capacity.

Façade glazing position: A simulation for evaluating energy efficiency for both single and double skin glass façade is applied by Cetiner & özkan [11] on clear, reflective and low-E glass types with one glass thickness 6 mm for all types. It was found that for external skin the double skin glass façade formed with the low- E glass is about 22.84 % more energy efficient than the single skin glass façade with a cavity width 900 mm and white aluminum venetian blind with a thickness of 0.2 mm position near external skin in the cavity. The slats forming the blind are 16 mm wide, and the slates distance from each other is 12 mm with angle 45degree.

Façade performance type: Rezazadeh & Medi [12] presented a comparison between different types of naturally ventilated double façade and base case (curtain wall). The result shown that the Shaft- box type with 100 cm wide cavity had the highest total hours of comfort which was 677 hours, the box window type which was 650 hours, the corridor type which were 643 hours, and multistory type façade which was 640 hours, respectively.

TABLE 1. Summary of literature review about double façades components

Double façade components	
Façade supportive structure	

Supportive structure system type	Galvanized carbon steel Cantilever bracket structure and suspended structure.
Supportive structure material	
Anchoring system	Suspended and connecting to the existing main façade structural system.
Façade glazing system type	Unitized
Façade material	
Glazing frame material type	aluminum
Glazing material type	Single glazing: 0.06 mm clear glass Double glazing: 0.06 mm reflective and low-E glass with air space 0.016
Façade glazing position	
	Double glazing for the external skin is more efficient than single glazing, With 900 mm Cavity width with Shading devices (Venetian blinds) is positioned near external skin cavity.
Façade performance type	Shafted – box type

3.1. Double skin Glass façades alternatives compositions

Double glass façades alternatives are first grouped depending on different positions of the single or double glazing and using solar control device as shown in **fig. 1**, then according to the literature review of double skin façade glazing position at **TABLE 1** above, group (I) from single skin, in addition the groups (IV) and (V) from double skin is chosen for investigation from the economic point of view.

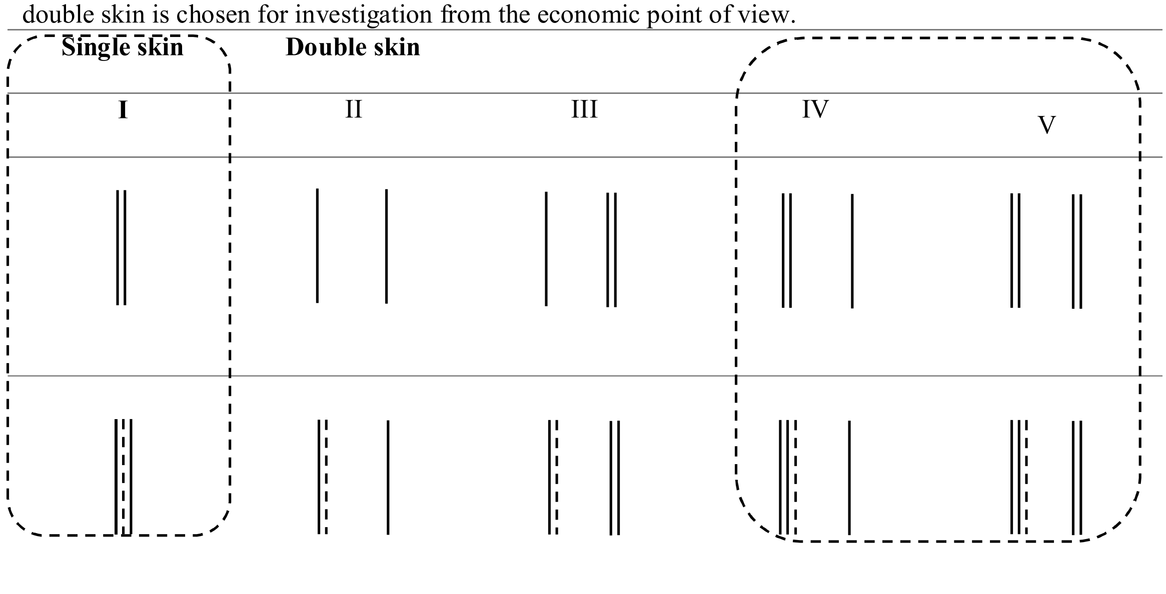

FIGURE 1. Skin glass façades alternatives compositions

Then all possible alternatives compositions are formed as a result of combination of these alternatives with the most three usable glasses types, according to the literature review of double façades glazing materials at table (1). Then the façades are coded according to a code system developed which is composed of letters and numbers indicate the position of the glass/ glazing type and whether using or not using a solar device, as shown in **TABLE**

2. For example, DS31Y is an alternative with five columns which defines a double skin façade with a double low-e glass on external skin, single clear glass on internal skin, and a solar control device in its cavity.

TABLE 2. Alternatives coding

COMPONENTS VARIABLES				
Position of glazing types		Position of glass types		Using solar control device
	D	1		
S		2	2	N
			3	
AN EXAMPLE: DS31Y				
D: Double glazing S: Single glazing		1: Clear glass 2:Reflective glass 3:Low-E glass		Y: YES N:NO

3.2. Variables affecting the quantitative evaluation process

The Second stage is used to identify the variables affecting the quantitative evaluation process, which are economic variables, double skin glass façades materials selection and the bill of selected materials with technical specs, description, and installation. The data of this process is based on the survey and interviews with three constructing façades firms in Egypt.

3.2.1. Economic factors

Which are considered as:

- Life period: It is assumed to be 25 years.
- Inflection rate: It is assumed to be 10%.
- Interest rate: It is assumed to be 8.5 % with constant rate without escalation.

3.2.2. Double skin glass façades materials selection

Double skin glass façades material selection is directly influenced by the resulted from **TABLE 1**. All the available technical data sheets from the survey is studied, then the best material's façade vendor company is selection from the economic point of view, as shown in **TABLE 3**.

TABLE 3. Summary of literature review about double skin glass façades materials selection

Double façade material	Type Vendor company	
Supportive structure system type	Galvanized carbon steel Cantilever bracket structure , and suspended structure- **Local made**	
Supportive structure material		
Glazing frame system type	unitized	**Schuco** frame**-** cross section USC 65
Glazing frame material type	aluminum	
Glazing material type	Single glazing	0.06 mm- **Sphinx** clear glass
	Double glazing	0.06 mm - **Sphinx** Solar lite reflective and Sphinx Silver low-E glass with air space 0.016

Shading devices	**Sucho** Venetian with thickness 0.2 mm, the slats forming the blinds are 16 mm wide and the distance between the slats is 12 mm, the angle of the slats is 35 degree.

3.2.3. Bill of selected material with technical specs, description, installation for double skin glass façades alternatives.

This step is to specify the technical specs, description, installation and composition with selected materials for the double skin glass façades as shown in **TABLE 4**, and to find out the material's unit price per meter for every component. All unit prices should include the following general instructions as shown:

1- All fixed, movable scaffold, cranes and all necessary works to finish the item according to the drawings, technical specifications and consultant engineer instructions.

2- Submittal for the structure calculations sheets if needed, all certificates and catalogues for review and approval prior commencement of site work.

3- Adhesive materials and electrostatic coat for the substructure, fixing anchor and bolts if needed.

TABLE 4. Bill of selected materials, technical Specs, description, installation for double skin glass façade alternatives

Double skin glass façades alternatives bill of materials		
Supply and install prefabricated unitized system per meter along the façade by Schuco Company with cross section type USC 65. The system is composed of large subdivided modular units, providing shafted façade concept ventilation that are fabricated, assembled and glazed in the factory, each unit assembled by interlocking with each of the units adjacent to it, each unit is designed to permit movement due to temperature changes, wind seismic events, and long-term movement of structure, at least five floors to support the ventilation concept. This system can be fixed by 900 mm supportive carbon steel galvanized cantilever structure with electrostatic coat by the unit brackets that can adjusted along three axes. System should include the following: Aluminum venetian blinds with thickness of 0.2 mm, the slats forming the blind are 16 mm wide, and the distance between the slats is 12 mm. the angle of slats is 35 degree. For corner connections: must be manufactured with miter joints, butyl rubber must me sealant with EPDM silicon to ensure not only the sealant property, but also to decrease the pollution on the glass surface. For service use: a walkway grating steel galvanized fixed on the supportive structure. For air controlling: an aluminum frame with ventilation flaps glass louvers fixed at the top, while fresh air flaps aluminum sheet at the bottom of the façade.		
Bill of selected material		Unit price
Code	Material	LE
S1	Sphinx single glazing 6mm clear glass.	300
S2	Sphinx single glazing 6mm reflective glass.	400
D1	Sphinx double glazing 24 mm clear glass with 16 mm air space	600
D2	Sphinx double glazing 24 mm reflective glass with 16 mm air space	800
D3	Sphinx double glazing 24 mm Low- E glass with 16 mm air space	1000
	Schuco unitized frame, along the façade with, cross section USC 65 for single glazing	2600

	Schuco unitized frame, along the façade with, cross section USC 65 for double glazing	3000
	Galvanized carbon steel cantilever with walk way grating per floor.	100
	Schuco Aluminum Venetian blinds	1000
Salvation (resale) costs = 40% from Initial costs Schuco unitized frame for single glazing = 40%*2600= 1040 LE Schuco unitized frame for single glazing = 40%*3000= 1200 LE		
Repair every 5 years: Silicon, rubber repair and Carbon steel Cantilever polish = 15% from initial cost		
Cleaning every 2 month: External glass by suspended scaffold with 4 meter long = 30 LE monthly = 180 LE Price/Year Internal glass by walk way grating = 15LE= 60 LE Price/Year Total cleaning price per year= 240 LE		
Cleaning costs are considered fixed price for all alternatives.		

2. SECOND PHASE: PRESENT VALUE OF LIFE CYCLE COSTS

The second phase is applied using a present value method (PW) to determine the total present value life cycle cost which composed of three sequence steps, namely as the following: determination for initial costs, maintenance costs, salvage costs and the annual costs [4], [5] and [6]. The pricing of this process is based on the survey and interviews with three constructing façade firms in Egypt as the following:

4.1. Determination for the initial cost for double skin glass façades

Determine the unit costs for supply and install double skin glass façade per square meter for all the components, averaging the values taken through survey and interviews with three constructing façade firms in Egypt.

Equation (1): $CI= \sum m= tc\ (Am \times Mm)$

Where CI is the initial cost; m the number of components, tc is the time period required to complete the construction, Am is the area of components, Mm is the total of workmanship, vehicle and material costs of every component per square meter and ∑ is the summation.

4.2. Determination for maintenance costs for double skin glass façades

The maintenance cost composed of repairing and replacement cost, Maintenance process times averaging for 5 years after starting, consequently along the life cycle of the material

Equation (2): $CM= CI \times M\ \%$

Where CM is the maintenance cost, CI is the initial cost and M % is the maintenance percent per square meter.

4.3. Determination for salvage costs for double skin glass façades

The salvage cost around 40% from the initial cost.

Equation (3): $CS= CI \times S\ \%$

Where CS is the Salvage cost, CI is the initial cost and S % is the Salvage percent per square meter.

4.4. Determination for annual cleaning costs for double skin glass façades

Where cleaning process times averaging from 2 to 6 times per year

Equation (4): $ACCL = CCL \times n \times t$

Where ACCL is the Annual cleaning cost, CCL is the cleaning cost per time, n is the cleaning times per year and t is the life cycle period (number of years).

4.5. Determination for total present value of life cycle costs of double skin glass façades

There are regularly paid every year in the assumed life period of the façade, so these costs which will be paid in the future must be converted to the present values, which is influenced by two factors which are present value factor PVF and present value of annuity factor PVAF.

Present value factor

Equation (5): $PVF = 1 / (1 + r)^{t}$

Where PVF is the Present value factor, r is the inflation rate, t is the life cycle period and number of years.

Present value of annuity factor

Equation (6): $PVAF = i \times t$

Where PVAF is the Present value of annuity factor, i is the interest rate, t is the life cycle period and number of years.

Future value

It is used for calculating the future maintenance cost, which took in consideration the inflation rate along the life cycle period.

Equation (7): $FV = PV \times (1 + r)^{t}$

Where FV is the future value, PV is the Present value, n is the times per year, r is the inflation rate and t is the life cycle period (number of years).

5.4.1. The present value maintenance costs

It is assumed that maintenance cost changed in the life cycle period.

Equation (8): $PVCM = PVF \times FV$ every 5 years

Where PVCM is the Present value maintenance cost, PVF is the present value factor FV is the future value every 5 years.

Equation (9): $TPVCM = \sum PVCM$ for each life cycle period every 5 years

Where TPVCM is the total Present value maintenance cost, Where PVCM is the Present value maintenance cost.

5.4.2. The present value salvage costs

Equation (10): $PVCS = PVF \times FV$ after ending life cycle period of 25 years

Where PVCS is the Present value maintenance cost, PVF is the present value factor FV is the future value after ending life cycle period of 25 years

5.4.3. The present value cleaning annual costs

It is assumed that cleaning costs do not change in the life cycle period.

Equation (11): $PVACCL = PVAF \times ACCL$

Where PVACCL is the Present value annual cleaning cost, PVAF is the present value of annuity factor and ACCL is the annual cleaning cost.

5.4.4. The total present value of life cycle costs

It is the summation of the initial cost, present value of life cycle costs for maintenance and present value of life cycle costs for annual costs.

Equation (12): TPVLCC= CI +PVCM – PVCS + PVACCL

Where TPVLCC is the Total Present Value Life Cycle cost, CI is the initial cost, PVCM is the present value maintenance cost, PVCS is the present value salvage cost and PVACCL is the present value cleaning annual cost.

3. QUANTITATIVE EVALUATION FOR COST OPTIMAL LEVEL OF DOUBLE SKIN GLASS FAÇADES ALTERNATIVES

To compare the results of double skin glass façades alternatives in this paper, the evaluation of this paper can be viewed in **TABLE 5**, and is calculated according to equations (1) to (12) as the following:

TABLE 5. Quantitative evaluation for cost optimal level of double skin glass façades alternatives

NO.	CODE		CI	CM				PVCM	PVCS	PVACCL	TPVLCC	
		EQ.		15% CI					40%CI		CI+PVCM -PVCS+ PVACCL	
		FACTOR		5Y	10Y	15Y	20Y		25Y	25Y		
		PVF		0.62	0.39	0.24	0.15		0.09			
		PVAF								1.7		
I	D1N	FV	3600	540	594	653.4	718.7		1440	180		
		PV	3600	334.8	231.7	156.8	107.8	831.1	129.6	306	4607	1007 (28%)
	D1Y	FV	4600	690	759	834.9	918.4		1840	180		193 (16.1%

											)
		PV	4600	427.8	296	200.4	137.7	1061.9	165.6	306	5800	1200 (26.1%)
	D2N	FV	3800	570	627	689.7	758.7		1520	180		
		PV	3800	353.4	244.5	165.5	113.8	877.2	136.8	306	4846	1046 (27.5%)
	D2Y	FV	4800	720	792	871.2	958.3		1920	180		195
		PV	4800	446.4	308.8	209.1	143.7	1108	172.8	306	6041	1241 (25.9%)
	D3N	FV	4000	600	660	726	798.6		1600	180		
		PV	4000	372	257.4	174.2	119.8	923.4	144	306	5085	1085 (27.2%)
	D3Y	FV	5000	750	825	907.5	998.3		2000	180		195
		PV	5000	465	321.7	217.8	149.7	1154.2	180	306	6280	1280 (25.6%)
IV	DS11N	FV	6500	975.0	1072.5	1179.8	1297.7		2600.0	240		
		PV	6500	605.4	413.5	282.4	192.9	1494.2	234.0	408	8168	1668 (25.7%)
	DS11Y	FV	7500	1125.0	1237.5	1361.3	1497.4		3000.0	240		194
		PV	7500	698.5	477.1	325.9	222.6	1724.1	270.0	408	9362	1862 (24.8%)

	DS12 Y	FV	6600	990.0	1089.0	1197.9	1317.7		2640.0	240		
		PV	6600	614.7	419.9	286.8	195.9	1517.2	237.6	408	8288	1688 (25.6%)
	DS12 N	FV	7600	1140.0	1254.0	1379.4	1517.3		3040.0	240		193
		PV	7600	707.8	483.5	330.2	225.5	1747.1	273.6	408	9481	1881 (24.8%)
	DS21 N	FV	5700	855.0	940.5	1034.6	1138.0		2280.0	240		
		PV	5700	530.9	362.6	247.7	169.2	1310.3	205.2	408	7213	1513 (26.5%)
	DS21 Y	FV	6700	1005.0	1105.5	1216.1	1337.7		2680.0	240		194
		PV	6700	624.0	426.2	291.1	198.8	1540.2	241.2	408	8407	1707 (25.5%)
	DS22 N	FV	6800	1020.0	1122.0	1234.2	1357.6		2720.0	240		
		PV	6800	633.3	432.6	295.5	201.8	1563.2	244.8	408	8526	1726 (25.4%)
	DS22 Y	FV	7800	1170.0	1287.0	1415.7	1557.3		3120.0	240		194
		PV	7800	726.5	496.2	338.9	231.5	1793.0	280.8	408	9720	1920 (24.6%)
	DS31 N	FV	6900	1035.0	1138.5	1252.4	1377.6		2760.0	240		
		PV	6900	642.7	438.9	299.8	204.8	1586.2	248.4	408	8646	1746 (25.2%

												)
	DS31 Y	FV	7900	1185.0	1303.5	1433.9	1577.2		3160.0	240		194
		PV	7900	735.8	502.6	343.2	234.4	1816.0	284.4	408	9840	1940 (24.6%)
	DS32 N	FV	7000	1050.0	1155.0	1270.5	1397.6		2800.0	240		
		PV	7000	652.0	445.3	304.1	207.7	1609.1	252.0	408	8765	1765 (25.2%)
	DS32 Y	FV	8000	1200.0	1320.0	1452.0	1597.2		3200.0	240		194
		PV	8000	745.1	508.9	347.6	237.4	1839.0	288.0	408	9959	1959 (24.5%)
V	DD11 N	FV	7200	1080.0	1188.0	1306.8	1437.5		2880.0	240		
		PV	7200	670.6	458.0	312.8	213.7	1655.1	259.2	408	9004	1804 (25.1%)
	DD11 Y	FV	8200	1230.0	1353.0	1488.3	1637.1		3280.0	240		194
		PV	8200	763.7	521.6	356.3	243.3	1885.0	295.2	408	10198	1998 (24.4%)
	DD12 N	FV	7400	1110.0	1221.0	1343.1	1477.4		2960.0	240		
	DD21 N	PV	7400	689.2	470.7	321.5	219.6	1701.1	266.4	408	9243	1843 (24.9%)
	DD12 Y	FV	8400	1260.0	1386.0	1524.6	1677.1		3360.0	240		194
	DD21	PV	840	782.4	534.4	365.0	249.3	1931.	302.4	408	10437	2037

	Y		0					0				(24.2%)
	DD13 N	FV	760 0	1140. 0	1254. 0	1379. 4	1517. 3		3040. 0	240		
	DD31 N	PV	760 0	707.8	483.5	330.2	225.5	1747. 1	273.6	408	9481	1881 (24.8%)
	DD13 Y	FV	860 0	1290. 0	1419. 0	1560. 9	1717. 0		3440. 0	240		194
	DD31 N	PV	860 0	801.0	547.1	373.7	255.2	1976. 9	309.6	408	10675	2075 (24.1%)
	DD22 N	FV	760 0	1140. 0	1254. 0	1379. 4	1517. 3		3040. 0	240		
		PV	760 0	707.8	483.5	330.2	225.5	1747. 1	273.6	408	9481	1881 (24.8%)
	DD22 Y	FV	860 0	1290. 0	1419. 0	1560. 9	1717. 0		3440. 0	240		194
		PV	860 0	801.0	547.1	373.7	255.2	1976. 9	309.6	408	10675	2075 (24.1%)
	DD23 N	FV	780 0	1170. 0	1287. 0	1415. 7	1557. 3		3120. 0	240		
	DD32 N	PV	780 0	726.5	496.2	338.9	231.5	1793. 0	280.8	408	9720	1920 (24.6%)
	DD23 Y	FV	880 0	1320. 0	1452. 0	1597. 2	1756. 9		3520. 0	240		194
	DD32 Y	PV	880 0	819.6	559.8	382.4	261.1	2022. 9	316.8	408	10914	2114 (24%)
	DD33 N	FV	800 0	1200. 0	1320. 0	1452. 0	1597. 2		3200. 0	240		
		PV	800	745.1	508.9	347.6	237.4	1839.	288.0	408	9959	1959

			0					0				(24.5%)
	DD33Y	FV	9000	1350.0	1485.0	1633.5	1796.9		3600.0	240		194 (9%)
		PV	9000	838.2	572.5	391.0	267.1	2068.9	324.0	408	11153	2153 (23.9%)

4. ANALYSIS AND CONCLUSIONS

As a result of calculations. It is now clearly seen from table (5) the following:

- The single composition, which is coded as D1N formed with using of double low-E glass has the lowest initial costs and total present value life cycle costs. The double skin composition, which is coded as DD33N formed with the using of double low-E glass on external and internal skin, has the highest initial costs and total present value life cycle costs.
- The present value life cycle costs increases the initial costs by about 23.9% to 28%.
- Using the venetian blinds increases the present value life cycle costs by about 9% to 16.1%.
- The difference between the lowest initial costs for composition D1N to the highest initial costs for composition DD33N is about 3.5%.
- The difference between the lowest total present value life cycle costs for composition D1N to the highest total present value life cycle costs for composition DD33N is about 2.2%.

The proposed quantitative evaluation methodology makes a guideline rules for making economically efficient decision in a double skin façades for the investors, architects, façade engineers and specialists. In addition, this method also makes a guideline rule for generating a skin façades alternatives coded groups.

In the future studies, determining more limits for life cycle costs and standardizing the cost efficient selected materials for alternatives components.

6. References

[1] A. Martinez, M. Patterson, A. Carlson and D. Noble, "Fundamental in façade retrofitt practice," *Procedia engineering,* pp. 934-941, 2015.

[2] A. Othman, Value Management Approach between Increasing Quality and Reducing Costs, Applying Methodology during Tender Documents Phase, Cairo, Egypt.: Ain Shams University, 2013.

[3] M. Spickova and R. Myskova, "Costs efficiency evaluation using life cycle costing as strategic method," *Procedia Economic and Finance,* vol. 34, pp. 337-343, 2015.

[4] T. Ebbert and U. Knaack, "Office refurbishment by means of façades with integrated building services”," *TMU-ARCH.SAKURA,* pp. 227-234, 2013 B.

[5] E. Oesterle, Double Skin Façades: Integrated Planning, Building physics, Construction, Aerophysics, Air-conditioning and Economic viability, Munich, London: Persel, 2001.

[6] W. Ding, Y. Hasemi and T. Yamada, "Natural ventilation performance of a double-skin façade with a solar chimney," *Energy and Buildings,* vol. 73, pp. 411- 418, April 2005.

[7] H. Poirazis, double skin Façade: A Literature Review, electronic version ed., Sweden: Lund University, 2004.

[8] L. Barau, Systematic Evaluation of Curtain Wall Types, Gazimagusa, North Cyprus.: Eastern Mediterranean University, 2010.

[9] C. Lopez, F. Frontini, P. Bonomo and A. Scognamiglio, "PV and façade systems for building skin, Analysis of design effectiveness and technological features.," in *29th European Photovoltaic Solar Energy Conference and Exhibition*, 2014.

[10] H. Hammad, Integrating active thermal mass strategies into buildings assessment of energy consumption in educational buildings in Egypt, Cairo, Egypt.: Ain Shams University, 2017- A.

[11] I. Cetiner and E. özkan, "An Approach for the Evaluation of Energy and Cost Efficiency of Façades," *Energy and Buildings,* vol. 37, pp. 673-684, june 2005.

[12] N. Rezazadeh and H. Medi, "Thermal behavior of double skin façade in terms of energy consumption in climate of north of Iran- Rasht," *Space Ontology International Journal,* 2017.

[13] Design Builder, "Importing CAD Data," June 2019. [Online]. Available: https://support.designbuilder.co.uk/index.php?/Knowledgebase/Article/View/6/3/importing-cad-data.

[14] T. Herzog and W. Lang, Using multiple glass skins to clad buildings, Architecture record, UK: McGraw-Hill, 2000.

[15] F. kreith and Y. Goswani, Energy Managment and Conservation Handbook: Economic Methods, 2nd ed., CRC press, 2016.

[16] H. Marshall and R. Ruegg, Energy Conservation in Buildings: An Economis Guidebook for Investment Decision, Online ed., Washington, USA: National Bureau of standards Handbook 132 (NBS), 1980.