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Reconsidering the Transparency of Contemporary Architecture and Sustainability Through Development of Glass Technology

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ABSTRACT

This study is anchored on the exploration of the evolving concept of transparency in contemporary architecture, with a spotlight on the integral role of advancing glass technology. It primarily addresses the question: How has glass technology redefined transparency to foster sustainability in contemporary architectural designs? The core objective is to delineate the enhancements in glass materials enabled by modern technological techniques, specifically focusing on glass envelopes and their contribution towards achieving the three pillars of building sustainability: environmental, economic, and social. Utilizing an analytical methodology, this research first elucidates the notion of double transparency, the indicators of architectural sustainability, and the leading-edge technologies in the glass industry. Subsequently, a comprehensive review of contemporary architectural transparency literature is undertaken, shedding light on its sustainability aspects. The study further includes an analysis of the application of glass technology in avant-garde architectural projects recognized by LEED awards. This examination aids in the construction of a theoretical framework that illustrates the environmental, economic, and social sustainability indices actualized in contemporary architecture, following the application of the double transparency concept through novel technological techniques. In conclusion, this research underscores the efficacy of advanced glass technologies, including glass envelopes, double facades, and smart glass. These technologies have demonstrated their capabilities in managing facade shading to minimize heat gain, controlling light transmittance into spaces, and conserving energy to the lowest feasible level, thereby curtailing overall energy consumption. Consequently, they present a compelling case for the advancement of sustainable architectural practices.

1. INTRODUCTION

Sustainability, pivotal to architecture, has profound implications for both individual livelihoods and the stewardship of nature's resources, both present and future. The application of the transparency concept, denoted by the extensive use of glass facades that transform buildings into complete glass enclosures, has blurred the boundaries between internal and external spaces. However, this has engendered several challenges, including a rise in thermal gain within building masses and the resultant necessity for prolonged air conditioning operation to maintain thermal comfort. Furthermore, escalating economic costs and the erosion of a sense of belonging have been observed, as transparent facades have pervaded all building types, including historically significant structures. This encroachment has precipitated a discord with the traditional landscape, fostering a sense of disconnection and miscommunication with the observer.

With technological evolution, enhancements in glass materials have surfaced, altering their behavior and properties through various treatments that control permeability. Examples of these developments include smart glass and digitally controlled tinted glass, which offer a spectrum of opacity to transparency. These advancements facilitate light transmittance control, serving both aesthetic and practical considerations.

The emergence of new glass execution techniques has precipitated a shift towards the concept of double facades, such as the glass envelopes technique. This transition has given rise to the notion of double transparency, which creates a dynamic physical field between the interior and exterior, redrawing the boundary and controlling it based on considerations of permeability. This approach serves the achievement of sustainability indices in alignment with environmental, economic, and social standards — a topic the study seeks to elucidate in detail.

The research posits that architectural sustainability can be realized through contemporary glass facades. It also explains the current trend among designers to increasingly adopt double facades, glass envelopes, and smart glass to enhance building efficiency and rationalize energy consumption, thereby reducing costs. Furthermore, this approach seeks to amplify the social, cultural, and symbolic values of architecture.

2. CONCEPT AND ASPECTS OF SUSTAINABILITY

The World Commission on Environment and Development (WCED), led by then Norwegian Prime Minister Gro Harlem Brundtland, in 1987 drafted a definition of sustainability as meeting the needs of the present without compromising the ability of future generations to meet their own needs [1].

Sustainability has three aspects: the first is represented by the environmental aspect and emphasizes the close link between the building and the surroundings, so the building is environmentally friendly by achieving natural ventilation, natural lighting, and the introduction of high technology to reduce the heat load on the building [2]. The second aspect is the economic aspect and focuses on reducing construction and maintenance costs and the energy consumed by the building, reducing the waste of materials and raising the productivity rates of users. The use of natural daylight in office buildings, for example, reduces operating energy costs in the long run [3]. As for the third aspect, it is represented by the social aspect and focuses on achieving the lowest level of social exclusion, the best social relations, guaranteeing the highest limits of justice, improving the lifestyle of individuals for all groups, increasing their productivity in the workplace, and making them more satisfied, less stressful and healthier [4]. As shown in Figure 1, the Krishna Singh Center building in Philadelphia, as it was classified as an environmentally, economically and socially efficient building because of its ability to generate energy from the sun and thus reduce energy consumption as well as achieving an increase in labor productivity due to its ability to provide comfort and a suitable atmosphere [5].

Figure 1. Krishna P. Singh center for nanotechnology, designed by Weiss/Manfredi [5]

3. TRANSPARENCY BETWEEN TRADITIONAL AND CONTEMPORARY CONCEPTS

The traditional concept of transparency has been associated with having the property of transmitting light so that the objects are illusory and completely invisible and can be seen through the object. When the architecture of modernity in the 20th century like “The Glass House” by Mies Vandrieu as shown in Figure 2a, adopted the raw glass material on the entire building, architecture became complete glass structures, reflecting the intellectual openness, the industrial revolution and the lack of boundary between the inside and the outside. That is why traditional transparency has been called "tremendous transparency" [6], but the sophisticated technological potential and material revolution that contributed to modifying and changing the behavior of pure glass and changing its optical characteristics and operational methods enabled the glass to disperse or reverse the falling light rather than pass and transmit light across it altogether like “the Knight Center Represent” as shown in Figure 2b, that was the main reason why the traditional concept of transparency has turned into a variety of concepts as "disturbance of transparency," "disruption of transparency," "transparency tensions, “and "double transparency [7]." Thus, the biggest shift of the concept is the transcendence of glass materialism, which has turned its unilateral concept into duality and juxtaposition between the two opposites to the point where today's architecture is described as scenography after the boundaries between the inside and the outside have been dismantled [8]. Diagram 1 has shown the transform concept of “Traditional Transparency” to “Duplication Transparency”.

(a) The glass house by Mies van der Rohe represents the transparency of modern architecture [9]

(b) A double-skin glass facade envelops the Knight Center represent duplicated transparency [10]

Figure 2. The development of transparency in architecture through time [9, 10]

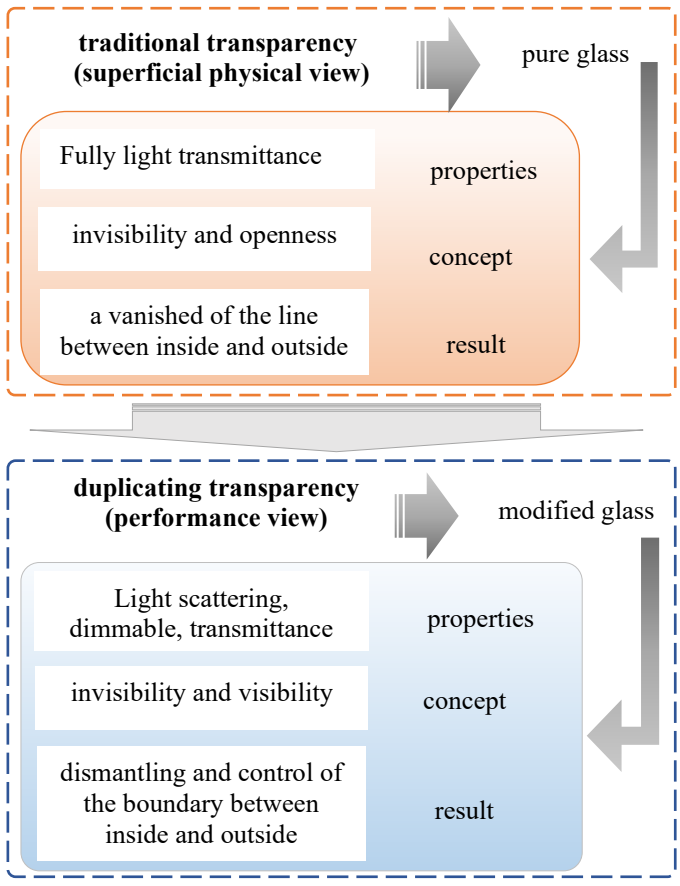

Diagram 1. Transform concept of “traditional transparency” to “duplication transparency”

4. GLASS PROBLEMS ASSOCIATED WITH SUSTAINABILITY ASPECTS

The traditional concept of transparency that modern architecture has focused on and applied across enormous glass structures has encountered many problems, most notably the modernist boredom of glass rectangular cans that has rendered modernity irresistible to the language of communicating with society, as well as other aspects associated with glass material as weak durability of glass structures and its lack of resistance to weather conditions and its high cost. But the highlight of the transparent buildings was what was called "thermal crime," because pure transparent glass is a simple barrier between the external and interior environment that leaks heat inland, achieving the highest rates of thermal gain, particularly in Mediterranean climate countries [7]. Transparent buildings also faced a negative attitude and great objection when glass architecture was adopted in tandem with conservative and historical buildings because of the contradiction of modern glass with historical hardness to the point where glass architecture was accused of being split from context and denying historical values [8]. And in architectural discourse, transparency has been treated as a design mechanism or tool that erases the fact that meanings do not precede narratives conveyed by transparency because they plan the appearance to control a specific view of things, which confirms their ability to modify how we see things and thus modify our ideas [11]. It was the tool of modernity in highlighting the principles and ideas of modernity and proclaiming the establishment of a healthy social democratic society, but later it turned out to be the exact opposite, and transparency was associated with non-aesthetic provisions based on the representative aspect of its application because of the potential of glass to reflect the sky, to the point where the building became so absent as to fade out of nowhere due to the erosion of the boundaries between the internal and external environment, which achieved a sense of insecurity [8].

5. SUSTAINABLE IMPROVEMENT ACCORDING TO ADVANCED TECHNOLOGY

With the scientific and technological progress, it was possible to distinguish the improvements in the glass structures to become more efficient, and they were represented by:

5.1 Material additions to the glass to modify its behavior

Where the glass is added or coated with metallic oxides were adopted, causing passing light to bend, absorbed or partially reflected, to give various aesthetic values that created a state of contradiction where the facade was neither fully transparent nor blurred, destabilizing the image of self and space, Developing glass into different types such as (annealed - thermally enhanced - coated -supported by compression membranes - hybrid glass chips) As well as modifying the flat model of glass via bending technology to achieve single or double bent glass, corrugated glass or glass tubes that are connected to an exoskeleton and considered structural elements [12] and adding smart materials to the glass to convert it into live glass that senses the weather data and opens and closes in such a way that it controls the CO_2 level as well as high performance aspects, particularly control of air quality inside [13]. European Investment Bank, Luxembourg City, Luxembourg as shown in Figure 3, is considered the first building in Europe to receive the highest environmental assessment according to the Construction Research Foundation in Europe as the transparent design succeeded in constructing a building that achieved the lowest thermal gain rates in summer and exactly vice versa in winter that could fill offices with daytime light, provide maximum daylight and transparency, promote interaction and social networking, and serve as a prime example reflecting a progressive approach to sustainability, particularly after its superiority in maintaining natural temperatures and light ventilation at a comfortable level and throughout the whole year [14].

Figure 3. The European investment bank headquarters in Luxembourg, photo by Forgemind Archimedia [15]

5.2 Development of glass technologies (Transparent skins and glass fins)

Advanced technology has also provided sophisticated glass architectural techniques that have achieved sustainability indicators, particularly after the evolution of the relationship (crust-structure) to create so-called transparent leather, as they have been able to adjust the transparent surface to meet environmental requirements to protect buildings from overheating or to reduce heat leakage [7]. Smart Transparent Cladding Technology with Smart Glass Adoption which was achieved by adopting a thin electric membrane introduced the fusion state of visual display with heating and cooling after transparent cladding was able to assemble lighting and energy on the surface through a printing process similar to that of ink jet [16]. Glass Fins technology, by introducing patch formulations, point fixing systems and steel plates between glass layers with the development of several glass fin adhesion details were able to provide kinetic support in the structure [15]. As well as the visual effects that affect their transparency, they spread and disperse light to reduce the glare or distribute it evenly without reducing the total light. Painted glass fins can be equipped with daylight-regulating motors inside the building, acting as light reorientators and shading devices depending on the time during the day, making them a functional element capable of adapting the facade to light due to their ability to change the facade behavior [17]. As show in Figure 4, the Tefken Oz Levent Istanbul, Turkey, by Altensis represents the first commercial and administrative building to be certified gold LEED by the American Council on Green Buildings thanks to its glass facade that combined low emission properties with solar energy control to reduce winter heat loss and avoid summer excess heat gains [18]. As well as its role as decorative aesthetic constructions, that changed the appearance of the facade as a result of distorted reflections and thus produced varied effects of variable transparency within the facade as a whole [7].

Figure 4. The Tefken Oz Levent Istanbul, Turkey, by Altensis, 2011 [19]

5.3 Electronic control of glass

By introducing the electronic structures of glass surfaces and combining physical environments in immaterial, incandescent facades were realized that were able to achieve light sculptures photosynthesis. In broad daylight, aluminum panels appear opaque and light-reflective, and at night they disappear completely to appear fully illuminated, transparent glass crystals. And so, the facade is transparent, but it looks opaque, and vice versa, the wires are transparent when operating, and when combined with the physical structure of the building, they sparkle into a creative visual scene, varied in transparency, thanks to technological control of light, to show light with a variety of scenes [20]. Thus the visible appearance of the building's skin and components varies as the sun develops over the course of its daily trajectory, the interior changes completely at night or at dusk allowing for transparent or skewed images thanks to the development of new material that challenges the traditional physical transparency by transparent liquid crystal screens, although they are physically transparent, they serve as support for image displays, thus achieving impressive augmented reality effects that allow the design of responsive shapes that are easily interactive through touch screen techniques, as they allow bending because of the superior flexibility of the thinness of the technologically developed glass [21], as in the Wind Tower by (Toyo Ito) as show in Figure 5, it provides a changing scene of light and colors at night against A transparent tower during the day through the response of the electronic system in the glass to the movement of wind and sound waves to the noise in the site [22].

Figure 5. Wind tower by Toyo Ito [22]

6. PREVIOUS STUDIES

This is Some specialized studies dealing with the achievement of sustainability in contemporary glass buildings will be reviewed.

6.1 Kang and Park (2021)

The study focused on what it called "poetic transparency" for describing the visual influences, sensation and sense of contemporary transparent leather that it considered (the store of human experiences) and (a model for creating architectural sustainability) in the depth of the internal and external boundaries for its ability to integrate (visual perception, empirical perception and environmental perception), and discussed representative shifts achieved in the application of transparency in contemporary architecture, indicating that they require reconsideration and examination of their phenomena as ideas verified through application, The study therefore adopted an analysis of selected SANAA projects and their visual and environmental performance according to weather or location of the Sun and their experiments that challenge traditional concepts of horizontal and vertical motion based on the interaction between spaces and their ability to create a three-dimensional world that exploits the reflective and transparent capabilities of glass to deepen and intricate the spatial place and to create spaces for people to come together to learn, read and communicate with each other.

The study clarified the cognitive aspects achieved through transparency, in particular the perception of the natural environment and bringing knowledge of it to architecture through glass and opaque surfaces, open spaces, light ceilings, glass volumes, introducing air, water and light into spaces to experiment with the five senses to perceive the building by cutting depth and introducing nature physically and psychologically, focusing on the buffer zone between (outside and inside of the design) [23].

6.2 Alqalami (2020)

The study addressed the continuity of the cultural and social values of architectural heritage identity in local heritage facades as a sustainable social dimension embodied by digital technology techniques represented by photovoltaic cells to apply transparency in contemporary architecture, as well as its role in reducing damage related to environmental sustainability to improve energy efficiency in building performance. The study focused on modifying the physical properties of architecture in order to transform into a transparent textile screen that adopts sustainable local materials such as wood and its dynamic traits through the disruptive pattern of facades that allows light to penetrate to behave like "bay screen" reflecting the values (temporal-spatial-cultural) by adopting (smart dynamic glazing) as glass is essentially a transparent material with BIPP photovoltaic and solar cells integrated with it to generate electricity to create a new transparent shell that enables wide optical choices and effects of color, light, shade, intensity and opacity as well as their role as influential characteristics in efficiency, performance, permeability and visual expression to express aesthetic and functional ideas and environmental and social specificity. The study concluded that the transparency achieved in contemporary architecture by intelligent elements brought architecture to a state of equilibrium in the application

of the diverse ideas embodied in the “bay screen" which reflected the values of (elegance and environmental, social and cultural sustainability) [24].

6.3 Blandini (2021)

The study focused on the performance aspect of glass material in architecture through its analysis of the most prominent high-performance glass buildings (Etihad, New House, Vienna, Grand Egyptian Museum, Cairo Museum, Dubai, Kuwait International Airport) that no longer only adopt aspects of thermal insulation but also improve the adaptation aspects of the building as a whole according to the surrounding conditions to actively interact with environmental changes. The buildings have adopted sophisticated technological techniques such as fins, glass panels and duplicate transparent leather, some of the buildings also adopted the use of selective coating and custom silk printing that are considered the best at the level of third-generation glass facades, that have faced current and future challenges between perceived transparency, energy targets and daylight by adjusting the glass facade behavior that actively interacts with changes in sunlight over different periods, others focused on punching techniques through digital simulation techniques to achieve the greatest isolation and highest light transmission, as well as the issue of resilience to the challenges of explosion in the Kuwait Airport building by promoting a plan to implement the dismantling process and recycling the various components once the building is dismantled, the latter adopted complex iterative calculations to improve the pre-stress forces While continuing to respect the twist limits of the double insulated glass unit to provide protection from direct sunlight, especially in the hot summer period. The study indicated that analysis of the building's life cycle became mandatory in the future in order to be more accurate in assessing the energy involved and the overall energy balance during the life span of the building by focusing on transparent facades [25].

6.4 Sadeghi et al. (2015)

The study focused on the symbolic meaning of transparency that ignores the cultures of countries, but contemporary architecture managed to achieve a symbolic transparent building with meaning. The study was based on an analysis of three projects of transparent architecture in London considered to be its contemporary symbolic icons (Gherkin Tower, London City Hall, Shard Tower). The study considered that the forms were essentially symbolic in that they were attributed to formalities associated with ideas such as "global patterns," "past experiences," "functional aspects," "context" and "user perspectives," symbolizing (traditions - religion - values of society - cultural, heritage or civilizational values - national values). But the features are independent of the form, so the geometric character is one thing and the feature is another thing. As for the study it asserts that the meaning persists with form even if it becomes transparent, forcing recipients to think about meaning, and that transparent buildings attract people because they achieve a strong relationship between (form and meaning). The study therefore concluded that the symbolic meaning of a transparent building is not only associated with intensive use of glass in the facade but also to the pattern of its architectural shape, each transparent building has a symbolic meaning associated with its community over time [26].

7. ELABORATION OF THE THEORETICAL FRAMEWORK

After an analysis of past studies and applied practices of contemporary transparency, it can be found that glass has taken a sustainable approach in contemporary architectural practice, reflecting the shift in the application of the concept of duplication of transparency. The theoretical framework for research, which explains the vocabulary of sustainability in its aspects (environmental, economic and social), can be presented as shown in Table 1.

Table 1. Theoretical framework of sustainability through dublicating transparency

Main Terms	Secondary Terms	Indications
Indications of Sustainability	**Environmental indications**	- Shade Level Control. - Controlling the level and directing the light. - Sensing weather data and controlling facade opening and closing. - Regulating the level of light inside the building. - Carbon dioxide control. - Indoor air quality monitoring. - Air temperature control. - Controlling the amount of energy for natural.
	Economic indications	- Increasing structural efficiency. - Increasing economic efficiency. - Reducing cost Increasing durability.
	Social indications	- Optical permeability control to achieve photosynthetic aesthetics. - Visual Scene Control for facade. - Interaction with transparent screens by projection. - Introducing knowledge of nature into the building. - A sense of openness, liberation and integration with nature. - Creating a communication language with community. - Harmony with historical & heritage buildings. - Reinforcing the values of the temporal and spatial context. - Deepening and intensifying spatial beauty to create functional spaces (learning/reading/meeting).
Advanced Technological Capabilities of Glass	**Adding to glass**	- Coating of glass with metallic oxides. - Adding smart materials to the glass.
	Developing glass into different types	- Annealed - Thermally reinforced - Reinforced with compressive films - Hybrid glass chips
	Adjusting the flat model of the glass	- Bending - Corrugation - Tubular formation
	Developing glass technologies	- Transparent skins - Glass fins
	Electronic control of glass	Optical glass facades

(Source: The researchers)

8. PRACTICAL STUDY

After analyzing previous studies, the vocabulary of the theoretical framework will be applied to contemporary architecture projects that have adopted the advanced technological capabilities of glass to apply double transparency. These were represented by four pioneering projects as they won awards and achieved LEED standards, represented: (the Avignon TGV Station, USGBC granted the 9-storey Daimler Trucks North America (DTNA), Nile House, Elm Park Development, Strasbourg station). The research will analyze the description of those projects to measure the vocabulary of the theoretical framework, as follows: Contemporary architecture of the 21st century introduced the so-called "environmental approach to transparent design," bypassing the surface structural use of glass to contribute contemporary transparency to sustainable performance especially with regard to the environmental and energy considerations that today have become a fundamental standard of design in our society which has a growing awareness of the importance of reducing carbon footprint, for example (TGV Station) in Avignon as show in Figure 6, which has a strong summer sun, a transparent northern facade of cold-bent double modules was adopted, a technique that achieved pressure equation and excessive environmental design [27].

Figure 6. The Avignon TGV station [27]

USGBC granted the 9-storey Daimler Trucks North America (DTNA) as show in Figure 7. Corporate a platinum level certificate, the agency's highest rating given to solar performance of glass facades that achieved a 26% VLT visible light permeability against the solar heat acquisition coefficient (SHGC) of 0.19 and the lowest energy consumption [28].

Figure 7. USGBC granted the 9-storey Daimler Trucks North America (DTNA) [29]

The (Nile House) building with transparent facades and ceiling as show in Figure 8, is an integrated design that has created efficient solutions in terms of energy saving considerations as the building has been able to increase natural ventilation in peak time thanks to the shading strategy while reducing glare in the offices that have achieved natural lighting and allowed the sky to be seen, as well as the potential for transparency in creating fun gathering spaces [30].

Figure 8. Nile House [31]

The glass building within Elm Park's development plan as show in Figure 9, represents a performance element with its duplicate facade that is no longer just an additional component of the building, it was designed in conjunction with the opposite facade and its role goes beyond the function of glass as it can extract hot air because it also stimulates ventilation. During the day, the duplicate facade absorbs hot air. During the night, fresh air flows in order to make the most of the thermal mass. The building thus confirmed the effectiveness of the duplicate facade as architectural logic merged with technical considerations in asserting the overall design process, integrating with the surrounding landscape and moving between the natural and artificial surroundings with the highest efficiency [32].

Figure 9. Elm Park development [33]

It is remarkable at the Strasbourg station as shown in Figure 10, the radical change in the orientation of the facade, as its transparent glass facade faces south instead of north, but it represents a new technical and architectural design that reflects technical knowledge, as the overlap area between the new envelop and the roof of the current building was used to extract hot air and the inlet air is at a low temperature and thus the cooling effect is enhanced by natural ventilation thanks to glass printing with a variable glazing pattern of up to 75% coverage of the upper parts of the envelope to reduce solar gain within the void by controlling the invisible energy spectrum and low-emission electrical coating on the inner side to reduce thermal radiation in the inner space which increases the sense

of comfort that depends not only on absolute temperature but on the psychological aspects of perception and on heat exchange between air and the skin of space occupants. Curved glass panels are not hot-bent but cold-bent using innovative cold-bent glass technology. The building embodies that a dream of complete transparency is now possible thanks to a prudent design that combines all the technical, environmental and architectural variables combines all the technical, environmental and architectural variables [32].

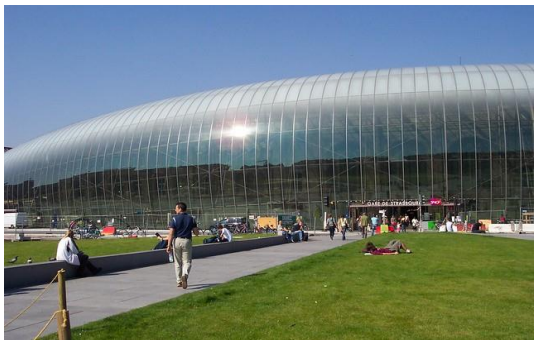

Figure 10. Strasbourg station [34]

9. THE RESULTS OF THE PRACTICAL STUDY

After applying the detailed theoretical framework on the selected projects as shown in Table 2, it was reached to achieve the percentage of achievement of each indicator as shown in Figure 11.

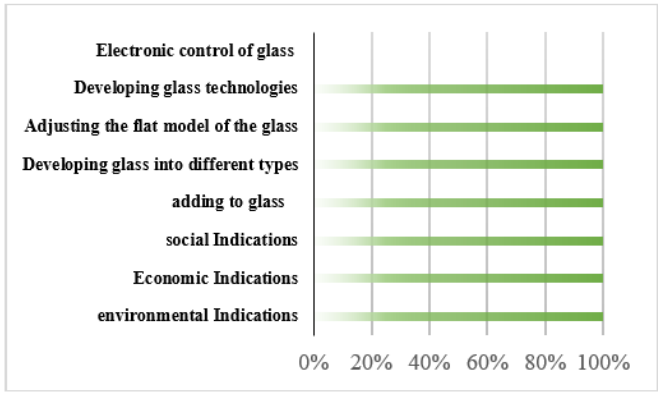

Figure 11. The results of measuring the indicators of the theoretical framework on the selected projects

Table 2. Measuring the indicators of the theoretical framework on the selected projects

Main Terms	Secondary Terms	Indications	Case 1	Case 2	Case 3	Case 4	Case 5
Indications of Sustainability	Environmental indications	- Shade Level Control.	*	*	*	*	*
		- Controlling the level and directing the light.		*	*	*	*
		- Sensing weather data and controlling facade opening and closing.			*	*	*
		- Regulating the level of light inside the building.			*	*	*
		- Carbon dioxide control.			*	*	*
		- Indoor air quality monitoring.	*	*	*	*	*
		- Air temperature control.	*	*	*	*	*
		- Controlling the amount of energy for natural.	*	*	*	*	*
	Economic indications	- Increasing structural efficiency.	*	*	*	*	*
		- Increasing economic efficiency.	*	*	*	*	*
		- Reducing cost Increasing durability.	*	*	*	*	*
	Social indications	- Optical permeability control to achieve photosynthetic aesthetics.					
		- Visual Scene Control for facade.	*	*	*	*	*
		- Interaction with transparent screens by projection.	*	*	*	*	*
		- Introducing knowledge of nature into the building.			*	*	*
		- A sense of openness, liberation and integration with nature.	*	*	*	*	*
		- Creating a communication language with community.	*	*	*	*	*
		- Harmony with historical & heritage buildings.			*		
		- Reinforcing the values of the temporal and spatial context.	*		*	*	*
		- Deepening and intensifying spatial beauty to create functional spaces (learning/reading/meeting).	*	*	*	*	*
Advanced Technological Capabilities of Glass	Adding to glass	- Coating of glass with metallic oxides.	*	*	*	*	*
		- Adding smart materials to the glass.				*	*
	Developing glass into different types	-Annealed	*	*	*	*	*
		- Thermally reinforced		*	*	*	*
		- Reinforced with compressive films	*		*		
		- Hybrid glass chips					
	Adjusting the flat model of the glass	-Bending	*				*
		- Corrugation	*				*
		- Tubular formation		*	*	*	
	Developing glass technologies	- Transparent skins	*	*	*	*	*
		- Glass fins					
	Electronic control of glass	Optical glass facades					

(Source: The researchers)

10. CONCLUSIONS

- The shift to duplicate transparency allowed achieving a diverse character of contemporary architecture depending on the contextual conditions, in contrast to traditional transparency, which added a unified character to architectural output in isolation from context. The main reason for this is that the point of view of transparency is no longer the same as the previous materialistic view.

- The application of the concept of duplicate transparency

has contributed to the development of diverse solutions to achieve sustainable design, commensurate with the specificity of the spatial context (environmentally, economically and socially).

- Duplicate transparency, thanks to the modification of the behavior of the glass, ended the thermal crime that was attributed to the modernist transparent structures. Transparency today conducts and controls to achieve the adaptation of glass facade with the data of the environment, and this means that transparency today goes beyond the issue of achieving the highest isolation and steps forward to achieve a performance response for the building as a whole.

- Transparency today is linked to the efficiency of the building, particularly with its robustness, thanks to the new capabilities that have ended the poor stability and permanence of the glass due to its physical outlook, as well as the possibilities of dismantling, transporting and recycling it even under the most destructive conditions.

- Transparency today achieves symbolic aspects and embodies meaningful values for the purpose of communicating with society in order to achieve social sustainability by synthesizing multiple features of transparency (partial-color-light) with symbolic formal patterns to publicize the renewal and updating of symbols and maintain their permanent effectiveness.

- Duplicating transparency represents a new architectural concept and technical design that reflects technical knowledge that increases (environmental, economic psychological) values, therefore it represents essential concept of wise design that integrates all technical, environmental and architectural variables to achieve sustainability in architecture.

- On environmental indicators of sustainable, duplicating transparency practice transcend the surface structural use of glass to contribute to sustainable environmental performance (especially with regard to environmental and energy considerations).

Where duplicating transparency modification of the behavior of the glass, ended the thermal crime that was attributed to the modernist transparent structures. Transparency today controls to achieve the adaptation of the glass facade with the data of the environment. This means that contemporary transparency goes beyond the issue of achieving the highest isolation and transcend in order to achieve a performance response for the building as a whole, to the point of controlling the indicators of the internal space, in order to reach the best health aspects.

- For achieving efficiency within the economic aspect: duplicating transparency is linked to the efficiency of the building, especially related to its durability, due to new capabilities that ended the weakness of stability and durability of glass according to physical view, as well as the possibilities of dismantling, transporting and recycling it. While the feeling of psychological comfort is enhanced by enriching the symbolic aspects and the embodiment of values that achieve meaning and deepen communication with society. This was achieved by synthesizing the multiple characteristics of transparency (partial - color - light) with symbolic formal patterns to announce the renewal and updating of symbols and maintain their permanent effectiveness.

- Diversified architectural product is achieved by transforming from the application of traditional transparency to the adoption of double transparency (where the shift from the unified character of architectural production in isolation from the context to the diverse character allowed by modifying the behavior of glass and the development of its implementation techniques that achieve efficient structures within all aspects and considerations of sustainability environmental, economic and social).

11. FUTURE RESEARCH DIRECTIONS

- The possibility of conducting research on the role of double transparency in promoting the values of heritage and historical buildings.

- The possibility of conducting research on the role of smart glass in raising the efficiency of administrative buildings.

- Conducting research on the role of double transparency in promoting spiritual values in religious buildings.

- The possibility of conducting research on the role of glass fin in raising the marketing of commercial buildings.

- The possibility of conducting research on converting glass facades into a renewable source of energy generation.

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