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A SWOT Analysis of Responsive Shading Systems with Umbrella Concepts

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ABSTRACT

The aim of this research is to analyze and to explore the responsive components, mechanism, and design parameters of responsive shading systems associated with umbrella concepts. In this context, a SWOT analysis has been carried out to identify situational strengths and weaknesses, as well as broader opportunities and threats, which hoped to generate further discussion about the prospects of responsive umbrella-like structure.

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A SWOT ANALYSIS OF RESPONSIVE SHADING SYSTEMS WITH UMBRELLA CONCEPTS

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Abstract

The aim of this research is to analyze and to explore the responsive components, mechanism, and design parameters of responsive shading systems associated with umbrella concepts. In this context, a SWOT analysis has been carried out to identify situational strengths and weaknesses, as well as broader opportunities and threats, which hoped to generate further discussion about the prospects of responsive umbrella-like structure.

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1. Introduction

In the context of rapid technology development, solutions for responsive facades can offer more flexible architectural solutions providing better use of natural light and contributing to saving energy. This kind of thinking is deeply embedded in various sustainability rating systems [1, 2]. In this context, the buildings envelopes became the locus of technological innovations, in which buildings are increasingly supported by the application of sensors and actuators as well as the mechanisms that control and activate an intelligent response to the physical environment and to a different pattern of use [3-5].

This could theoretically be buildings envelopes consisting of movable systems that respond automatically to various conditions. The purposes of these systems vary, as do the technologies adopted and the motivations of exploration. Therefore, if we accept that sustainable design is one of the main necessities in today's architecture, this paper investigates how this issue can be properly responded by use of responsive systems. However, responsiveness as a general approach can be achieved at different scales. To limit this broad scope, the paper explores the potential of

responsive shading systems with umbrella concepts to create a form of architecture that responds and adjusts itself to its occupancy and the environment. While responsive shading system is successful in capturing the core of recent research practices, it does not provide us with details needed to understand the situational strengths and weaknesses, as well as broader opportunities and threats associated with these emerging classes of building. In this context, this paper investigates this knowledge gap by applying a SWOT analysis, which hoped to generate further discussion about the prospects for responsive umbrella-like structures.

2. Background Research

The earliest thought of responsive architecture was born in the late 1960s. In the mid-70s, the term 'responsive architecture' was coined by Nicholas Negroponte when spatial design issues were beginning to be explored, mostly due to advances in cybernetics, artificial intelligence, and digital technologies [3, 6-7]. A lot happened in the next two decades, William Mitchell in 1995 argued that these technologies decomposed traditional building types and predicted that the future of architecture will witness a growing domination of software over materialized

form [8]. With more consideration being paid to energy use of buildings, the building envelope have begun to utilize sensor-based automated response to environmental conditions [3].

As architects before responsive systems are implemented, the biggest challenge is to design responsive architecture that achieves the design aims by choosing an alternative that suits the design parameters. These parameters let the designer decide how responsive systems can change their configurations in real time by reacting to environmental changes, avoid monotony, and retain a high degree of novelty. Based on the design aim, design parameters are covered: a) visual performance in the form of illuminance, distribution, glare, and directivity; b) energy saving related to lighting energy and thermal comfort; c) energy harvesting in the case of integrated building concepts with other renewable wind or solar technologies; and d) visual comfort including outdoor view, social performance, and appearance. By customizing these parameters, responsive architecture can decrease energy usage, improve comfort, and increase the sustainability of the built environment [3, 9].

Recently, ever-increasing architectural designs are trying to apply responsive shading systems, especially with umbrella concepts due to their efficient mechanism in terms of various designs and performance parameters. Before the study investigates SWOT analysis associated with responsive systems, certain architectural applications of the umbrella concepts are presented in the following section.

3. Responsive Shading System with Umbrella Concepts

Growing interests in sustainable design have led architects in the direction of utilizing umbrella concepts in their shading systems. In addition, Selkowitz and Lee [10] suggested that manual process of

shading systems might work effectively in small projects. But in a larger building with many occupants and the integration of façade and lighting systems, more reliable automated controls are essential.

On later construction practices, several responsive structures attempt to apply automated shading systems with umbrella concepts (see Table 1). In the expressions of the designers, they came up with the idea from umbrellas, which are those practically basic methods utilized for shading and protection. This category includes a change in the geometric morphology of the envelopes by making them adaptable to be reconfigured to meet changes. This is the case with the automated shading system of the Surya shading screen, Conjoined Media Towers, Al Bahar Towers, CJ Research Centre's Kinetic, and the new façade of Madrid Pavilion. In addition, the folding of different membranes is also evolved from the umbrella concept; a fine case is the adaptable cover of the courtyards of the Prophet's holy mosque, Kingdom of Saudi Arabia (KSA) [11-16].

Ideally incorporating the umbrella concept with building envelopes requires design to be integrated across various disciplines. Based on Hathaway [17], the determination for curtain walls, shading devices, glass, and windows systems requires critical analyses of the buildings site and the solar orientation, in addition to the weather, wind, and context within its built environment.

The analysis of the mentioned case studies equipped with umbrella concepts is given in Table 2. The objective of this analysis has been to collect information about the responsive shading systems. It focuses on responsive building elements, especially an overview of umbrella materials, components, mechanism, and supportive systems.

Considering this analysis, it found that pattern system and features of umbrella concepts have evolved quickly in the last decade. The introduction of new materials and technology has allowed designers to propose effective responsive solutions that could be shown within the six case studies. Much of this success is due to the introduction of innovative materials such as technical fabrics, composite materials, but especially to the use of smart materials and technologies. This is the case of using PTFE (Polytetrafluoroethylene), which was used in two cases—the honeycomb shell of Al Bahar Towers and the large umbrellas for the Prophet's holy mosque. In addition to the other effective materials which used or fabricated specifically in other cases. These materials are self-cleaning, lightweight, highly flexible, and enables everyday opening and closing.

Another very interesting aspect in the evolution of umbrella concept is its integration with lighting technologies. The integration of umbrella materials with LEDs represents another step forward towards design research for enhancement of expressive possibilities of architectural elements and thus of the architectural practice. A significant example is REX Designs Conjoined Media Towers.

Finally, architects have always used umbrella screening as an architectural element to be mounted on a surface or a facade. However, from an urban perspective, this umbrella concept can able to qualify an urban-scale sculpture and to make an aesthetic contribution to its surroundings, this is the case of Surya shading screen.

Table 1: General information and mechanism analysis of the responsive shading systems with umbrella concepts. Adapted from [11-16]

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Category	The Surya shading screen, USA.	Conjoined Media Towers, Middle East.	Al Bahar Towers, Abu Dhabi, UA E.	CJ Research Centre's Kinetic, South Korea.	Madrid Pavilion, Shanghai Expo, China	Prophet's holy Mosque, KSA
Building type	Urban-scale sculpture	Office	Office	Office	Office	Religious/ Mosque
Climate	Hot-humid	Hot-arid	Hot-arid	Humid-continental	Humid-subtropical	Hot-desert
Mechanism	Comprising of variably dimensioned umbrellas that generate a series of unique flourish pattern.	Responsive sunshades can quickly be deployed from the cavities embedded between floors within minutes.	Series of transparent umbrella-like modules open and close in response to the sun's path.	Depending on a single linear actuator that accumulates the pleated membrane like an umbrella.	The idea is to make each umbrella controllable by a pulley to allow people to adjust the light levels.	12 large umbrellas provide shading during the day and ventilation and cooling during the night.
Design parameter	- Shading oriented strategy - Blocking glare and reflections	- Solar shading - Filtering light - Media wall - Iconography	- Solar shading. - Reducing glare. - Improving daylight	- Solar shading - Light filtering - Reducing glare	- Solar shading - Improving daylight - Blocking strong wind	- Solar shading for the Muslim pilgrims - Visual comfort

Table 2: Analysis of the responsive components in the case study buildings. Adapted from [11-16, 18]

Category	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Sitting	Elevations	External facades	External facades	External facades	External facades	Translucent ceiling
Pattern (system & features)	Staggered repetition of scaled rectangular shields.	Radial repetition of semi-triangular shapes.	Repetition of crystalline honeycombs shell system.	Repetition of steel strips shading system.	Repetition of steel star-sticks with aerodynamic shape.	Repetition of equal bell-shaped suspension-tensioned membranes.
Materials	Giant aluminium sunscreen	LEDs integrated material	Stretched PTFE panel	Perforated pleated metal	Perforated Corten steel	Stretched PTFE membrane
Supportive structure	Umbrellas' stems supported by ring-shaped frame which reinforced by intervention cantilevers above the street through a giant tripod.	The building's elevations are clad in large retractable umbrellas supported and installed between the floors of stone-clad towers.	The honeycomb shell operates as a curtain wall, sitting two meters outside the buildings' exterior on an independent steel frame.	Each unit is set between floors in groups of three ribbons, allowing the windows to be fully covered or exposed.	Aluminium framing system supported between floors to allow each umbrella to be controlled by a pulley operable from the inside.	There are two different heights of umbrellas affixed to freestanding columns which allow overlapping and covering the entire area effectively.

In addition, this responsive umbrella-like structure is not a fixed idea, but an evolving concept to be redefined with changes in environmental situations. Concerning design parameters attained from those analyses, umbrella-like structures achieve a good performance-based design, particularly for external building envelopes with an interesting façade, an efficient shading system, reducing solar gain, reducing glare, and providing privacy. The investigation of the umbrella concepts reveals how architects, engineers, and other industry professionals can achieve more responsive architecture with integrated collaboration and recent technologies. Dependent upon these developments, umbrella-like structures can provide architects by the means to produce more sustainable ideas. However, to form a clear analysis about the responsive shading systems with umbrella concepts, there is a need to look at the other sides of these technological innovations. In the following

section, potentials and limitations of responsive umbrella-like structures are presented.

4. A SWOT Analysis of the Current Practice of Responsive Umbrella-like Structures

How have responsive architecture become? Below a SWOT analysis has been carried out to help identify some of the key factors, which hoped to generate further discussion about the prospects for responsive umbrella-like structure.

Strengths. Architects should realize that responsive systems have altered the course of architecture. Incorporating cutting edge technology, responsive umbrella-like structure can adapt to its surrounding. The brain of the responsive system can be programmed to learn how to do this based on the different control mechanisms.

In the absence of the users, even for a short period, the intelligently responsive shading system can operate the physical building automatically for maximum efficiency, even when it is unoccupied [19]. As shown from the case study analysis, it is important to passively decrease heat loads in the building— suitably controlled solar shading is one of the most effective solutions. This is the most significant issue especially in hot climate architecture. Besides offering effective shading oriented strategy, umbrella-like structures have other related strengths as:

- Providing the basic functions of shelter and privacy, while reducing glare and improving daylight penetration.
- Resulting a piece of responsive architecture that both radically cuts carbon emissions and presents an elegant new aesthetic.
- Producing buildings that reflect the technological and cultural conditions of our time.
- Enhancing visual comfort, the umbrellas work as blooming flowers programmed to fold and unfold in minutely delayed sequence to avoid collision between their moving parts.

Weaknesses. The following discussion concerns potential weaknesses of responsive umbrella-like structures in relation to the extra time, experience, cooperation, and resources which are generally required in such structures. The most significant beings are:

- There is a general lack of experience in different operation and management processes. High standard of building construction management is required for these structures.
- Poor cooperation among the design team. In this context, the different members of the design team need to understand both the embedded responsive systems and the role of different professional fields.

- These structures always associated with higher costs, first costs including installation and operating costs including maintenance during the lifetime of the building. These costs should be included in any economic considerations. On the other hand, the energy saving potential should be considered as a competitive alternative.
- Risks about the increased loads of supportive frames and structures.
- Optimization problems, implementing responsive systems requires continues optimization based on experience, measurements, and simulations.
- There are concerns that some systems may contravene current noise regulations.
- Lack of occupant training, education, and responsibility.

Opportunities. As stated throughout this study, the opportunities offered by innovations in science and technology and the demands for sustainable buildings will continue to produce more intelligently responsive architecture. In this context, the major two opportunities are:

- The sustainable opportunities raised by umbrella-like structures that can respond to sunny, shady, hot, or cold conditions would suggest that these structures possess the means to produce spaces that respond to environmental conditions.
- There is another opportunity related to architectural practice. While architecture does not readily require technical expertise, it may be evident that architects are interested in such experience to take place. Consequently, this practice changes when the opportunity to access real-world data collected by responsive technology presents itself to the discipline. This shift empowers architects to conceptualize a new architecture that could tie user needs and environmental situations directly to the architectural form. In this context, responsive technologies provide architects with important aesthetic opportunities,

allowing the new formal and performance-driven behavior to become a part of an architect's formal vocabulary. However, this shift has included further weight to the architectural profession [7, 20- 22].

Threats. Barriers to the implementation of responsive umbrella-like structures arise from several factors, technological and non-technological. Inquiries to the construction community allow the identification a set of barriers, especially in non-advanced countries, as the following:

- Risks about physical environmental conditions of building surroundings as well as wind loads and pressures.
- Lack of specific construction regulations, standards, and laws.
- Poor availability of reliable performance data concerning both energy and comfort issues due to the unexpected failure of sensor technologies or simulation programs.

After a SWOT analysis, the final decision will be made after extensive studies and discussions among investors, designers, users, and other stakeholders who possess different cultural and scientific backgrounds.

The requirements for a successful application include not only the technical ability to achieve responsiveness but also effective in dealing with people's needs and the environmental conditions. These requirements seem to be more important than the technical ones. Furthermore, to increase the benefits of such an approach and to reduce human intervention, a responsive space must act on its own; it must have the ability to sense and respond to a variety of stimuli without human intervention [23].

5. Conclusions and Future Perspectives

Although scientific research and development work in this important area of architecture is still in its infancy, an

examination of the present responsive umbrella concepts reveals many advantages in the realization of more sustainable buildings. Producing buildings that reflect the technological and cultural conditions of our time. However, novel design and construction strategy are needed to ensure that architects and engineers can guarantee, comfort, security, and safety concerns of employees, customers and other users of these emerging classes of building. A responsive umbrella concepts may easily provide flexibility for a variety of uses, but it must also keep its occupants safe while performing their tasks. In this concern, it is of great importance to carry out detailed SWOT analysis after extensive studies, researches, and discussions among different professionals. This study just highlights the umbrella concepts and encourages conducting more comprehensive analysis about their potentials and limitations, which hoped to generate further discussion about the prospects of responsive umbrella-like structure.

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