Original Article

Sustainable vision of kinetic architecture

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ABSTRACT **Architecture has always been part design and part science, but, once again, we are in an era where the two have great potential to help one another. A design-science marriage will be key as both scientists and designers strive to push their respective fields forward. Each can provide insight into the other as designers can help scientists think 'outside of the box' while scientists bring newfound technologies and theories to design disciplines – including the architecture process. By incorporating motion into architecture, designers give occupants another dimension by which to interact with their surroundings. Architects can not only communicate motion, but can also engage occupants in what it means to have transition and morphing states of architecture. When done properly, kinetic architecture can inspire, surprise and even touch the soul. This introduction to kinetic architecture highlights its purposes and benefits, and provides strategies for designing and constructing moving building elements that optimize sustainability in architecture. This article proposes an initial conceptual framework for the exploration of the sustainable engaging attributes of kinetic architectural structures. It will serve as one of the first attempts to understand, define and frame kinetic architecture from a complex adaptive environmental approach. The article also attempts to bring together the camps of performative, responsive and adaptive environments under the rubric of kinetic architecture.**
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INTRODUCTION

Since the early twentieth century, artists and architects alike have been incorporating movement into design to explore its possibilities to introduce the element of time, to reflect the importance of machine and technology in the modern world and to explore the nature of the vision. In this way, movement has either been produced mechanically by motors or by exploiting the movements of people, air, water, and other kinetic forces in space (Zadinac, 2009).

Kinetic architecture relies on the design of buildings in which transformative and mechanized structures aim to change the shape of buildings so as to match the needs of people on the inside and adapt to the elements on the outside. Although a considerable amount of time and effort has been spent on building 'intelligent homes' in recent years, the emphasis has now shifted on developing computerized systems and electronics to adapt the interiors of a building to the needs of its residents, while responding and adapting to its external surroundings and communicating to the outside world (Zadinac, 2009).

DILEMMA OF STUDY

Architecture evolved in the belief that the static, permanent forms of traditional architecture were no longer suitable for use in times of major change. Kinetic architecture was supposed to be dynamic, adaptable and capable of being added to, reduced, or even being disposable (Maria, 2008).

The notion of motion in architecture has to be examined through virtual and physical methods, to investigate, explore and propose how motion can be suggested, depicted or physically incorporated into buildings or structures. The goal is to link past practices related to kinetic form with motion-based emerging technologies in a meaningful way and project into the inherent architectural possibilities (Kostas, 2008).

The area of kinetic architecture, that is the integration of motion into the built environment, and the impact such results have upon the aesthetics, design and performance of buildings may be of great importance to the field of architecture. Although the aesthetic value of virtual motion may always be a source of inspiration, its physical implementation in buildings and structures may challenge the very nature of what architecture really is (Kostas, 2008).

WHAT IS KINETIC ARCHITECTURE?

Kinetic Drawing holds energy; moving one part creates a movement all over the drawing. They hold energy and are unstable. Giving or applying influence will cause unforeseen reactions and eventually lead to ruin, but mankind has got used to this process; new environments have been built on the fundamentals of previous environments over and over (Stan, 2006). They can be found inside and outside buildings, and nature holds many of them. It needs only an eye to see them, an artist to build them (Stan, 2006). When they are visible in the interior spaces as well as in the surroundings of the building, we will realize a great variety of drawings inside the building as well as in the nature (Stan, 2006).

Kinetic Architecture lies in creating spaces and objects that can physically re-configure themselves to meet changing needs, whereby an adaptable architecture is formed. At this intersection, there exists an unexplored physical architecture tuned to address today's dynamic, flexible and constantly changing needs. Kinetic design depends on motion for its effects (Zadinac, 2009).

The best kinetic architecture is that which presents new architectural alignments and contrasts. Such new juxtapositions allow occupants to experience environments anew. When architecture can morph to renew experiences in real-time, then kinetic architecture has a better chance of doing its job (Maria, 2009).

INTERACTIVE FORCES IN KINETIC ARCHITECTURE

Kinetic interaction within architecture can greatly impact one's experience. A designer embedding kinetics can often provide for a new kind of awareness (Maria, 2009).

Buildings are confronted with many forces during their life cycle starting from the design phase extending to the operating system. The final project involves the design of a building in which motion is an essential part of the program.

There are methods through which kinetic architecture can influence building form as a result of forces either during the design process or during the operating of the building. The final impacts of these forces are (as seen in Figure 1):

Figure 1: Forces in kinetic architecture and architectural response.

Static movement:
The forces applied during the design process using computer-aided programs through commands that cause building design modifications (movements) during drawing phase only.

Dynamic movement:
Incorporating technologies into buildings in which transformative mechanized structures change with climate, need or purpose.

KINETIC ARCHITECTURE FOR SUSTAINABILITY

This section will focus on dealing with sustainability through the applications of a kinetic system in architecture. Vernacular architecture must react with the forces modifying their forms. These forces can be enhanced, either during the design process that relies on static movement, or during the life of the building offering dynamic movement. Such examples improve the impact of kinetic forces in dealing with sustainability:

Static movement

In architecture, the notion of motion is often represented as an abstract formal configuration that implies relationships of cause and effect. Deformation, juxtaposition, superimposition, absence, friction and exaggeration are just a few of the techniques used by architects to express virtual motion and change. These attempts are based on the idea that perpetual succession is not only conceived directly through physical motion but also indirectly through formal expression (Maria, 2008).

(a) *DRAW*

1. Polyline: Multi curve linear

Pearl River Tower in Guangzhou:
Skidmore, Owings & Merrill won the architectural competition for the Pearl River Tower in Guangzhou (Figure 2).

The 303 m/69 storey office tower started construction in July 2006, and completion was scheduled for Fall 2009. The building is designed to be one of the most environmentally friendly buildings in the world as it can produce more energy than it consumes. Among

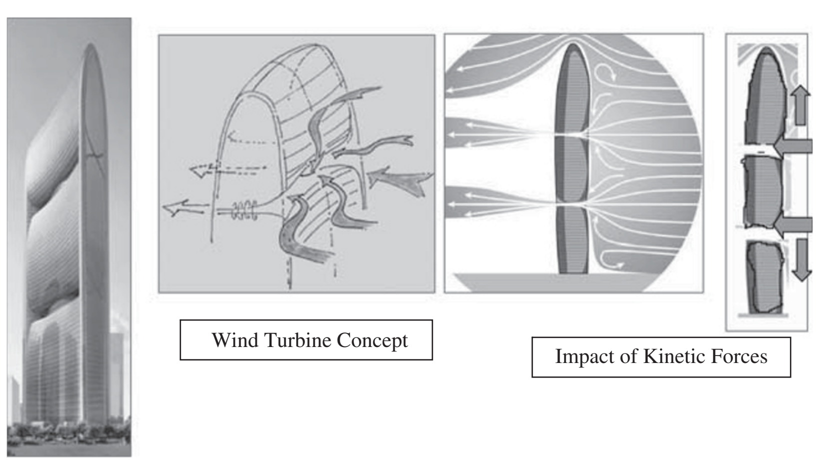

Figure 2: Pearl River Tower.

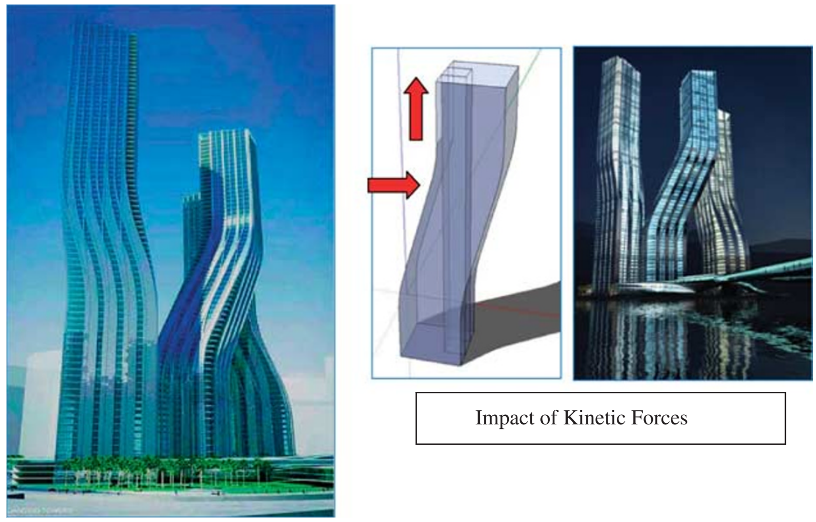

Figure 3: Dancing Towers.

its features are turbines that turn wind into energy for the HVAC system, a solar collector for more power generation and a rainwater collection system, part of which is heated by the sun to provide hot water. The building is cooled, in part, through heat sinks and vertical vents. The turbines do more than generate electricity. The openings through which the wind flows help reduce the overall wind load on the skyscraper.

Dancing Towers:
Zaha Hadid' Dancing Towers are planned to be located in Dubai's business bay development area (see Figure 3). The project was launched (2008) and, when complete (2012), will consist of three interlinking towers containing offices, apartments and a hotel. The towers, which share a single podium, will form the centerpiece of the Business Bay development.

The plan consists of three buildings that rise up from the ground bending and intertwining with each other to create fluid animation of the forms.

Dubai's Dancing Towers consist of three towers, an 84 storey office tower, and two 68 storey residential and hotel towers.

The three towers are conjoined two by two, the offices and the hotel at the base and the hotel and the residential tower at the top. Through these adjacencies, the towers are strategically organized in a symbiotic relation, sharing certain segments of the program.

On the seventh level, the floor plates of the hotel and the office towers merge creating a link to the Hotel Business Centre (part of the offices tower) with meeting rooms, office facilities and services for guests.

2. Circle

The New Shanghai Super Tower:
The New Shanghai Super Tower, Gensler Architects (Figure 4) is a small site of 30 370 m^2. Once finished, the massive building will be a steel structure that rises to 632 m with a 565.6 m tall central core made of concrete. The building will be 127 storeys, with an internal area of 558 803 m^2 and feature offices and retail space. It will also feature a luxury hotel.

The building will feature a double skin that encloses an interior 'bioclimatic' atrium. The Atrium will be planted with trees as high as 10 m tall, which the firm suggests will

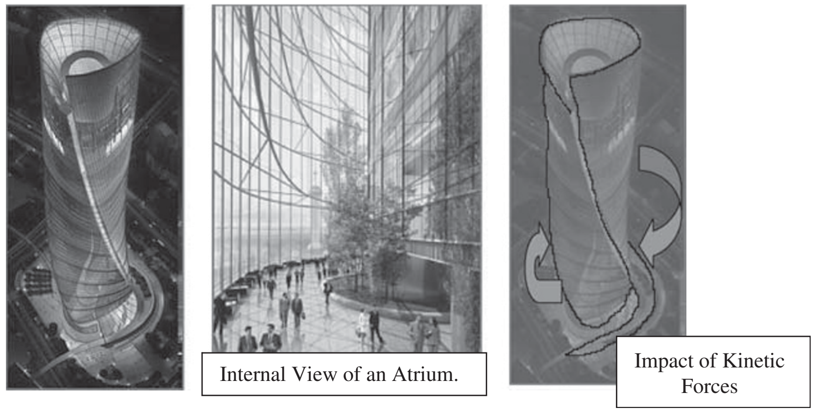

Figure 4: The New Shanghai Super Tower.

turn the Atriums into a 'bioclimatic' tower, and the trees will help to regulate the cooling of the building.

The Atrium is designed to twist around the building's core. According to Gensler, this '[reinforces] the impression of movement and dynamism that symbolizes Shanghai's success as a world city and the emergence of modern China'.

The design is composed of eight major levels that are tiered using floor-plates, approximately the shape of triangles, to enable the building to have the large vertical Atriums behind. This design allows each of the eight levels to have a front with an outer glass façade wrapped around it and create the large vertical Atrium spaces behind. The top will have a viewing platform and observation areas. These areas will have a large open space inside the tower, open to the elements. This design element is to pay homage to the void located near the top of the Shanghai World Finance Centre.

The Shanghai Tower is organized as nine cylindrical buildings stacked one atop another. The inner layer of the double-skin façade encloses the stacked buildings, whereas a triangular exterior layer creates the second skin, or building envelope, which gently rotates as it rises. The spaces between the two façade layers create nine atrium sky gardens.

Sustainable strategies:
In accordance with the goals of the Shanghai Tower Construction and Development Co., Ltd, the tower will be one of the most sustainable tall buildings in the world. Working closely with Thornton Tomasetti and Cosentini, Gensler adopted a fully integrated design approach ensuring all design decisions uphold a sustainable intent.

The façade's taper, texture and asymmetry work in partnership to reduce wind loads on the building by 24 per cent, offering considerable savings in both building material and construction costs.

In addition, the building's spiraling parapet collects rainwater, which is used for the tower's heating and air conditioning systems. Wind turbines located directly beneath the parapet generate on-site power. The landscaped atria improve indoor air quality and create comfortable places for people to linger.

Sustainable highlights:

- The twisting, asymmetrical shape of the tower reduces wind loads on the building by 24 per cent, reducing the structural load on the building.

- Innovative skin technology is one of many sustainable design and renewable energy systems in the tower. The circular inner glass skin uses 14 per cent less glass than a square building of the same area, and minimizes energy consumption.
- The double-skin façade's vertical atria create thermal buffer zones. It also improves indoor air quality while creating desirable places for people to linger. These public amenity floors also reduce the number of vertical trips each building occupant must make.
- The building's spiraling parapet collects rainwater, which is used for the tower's heating and air conditioning systems. The spiral shape facilitates vortex shedding and creates an asymmetrical surface to reduce wind loads on the building. Wind turbines located directly beneath the parapet generate on-site power.
- Shanghai Tower's owners aim to register for a high level of building certification from the China Green Building Committee and the US Green Building Council.

(b) *MODIFY*

1. Cut: Subtracting

Co-Op Canyon:
Standard Architecture's conceptual design, Co-Op Canyon, has recently received an honorable mention for the Re:Vision Dallas competition (see Figure 5). The competition provided participants with the opportunity to create an innovative and sustainable prototype for an urban community. Standard's radical approach focused on how the residents could potentially gain equity through participation in construction, agriculture, maintenance, education and conservation programs central to the sustenance of the community.

Co-Op Canyon creates a sustainable, zero carbon space fit for 1000 users. Inspired by the cliff dwellings of the Anasazi Indians, the Co-Op features terraced urban conditions, which overlook a lush urban canyon. The dwelling terraces are lined with front yard gardens that host native plants varying in color and texture, while backyard gardens emphasize the ends of the terraces. The garden allotments, in addition to communal farms, are dispersed throughout the terraces allowing residents to grow, exchange and share canyon-grown produce.

The Canyon walls are relatively thin, which allows ample natural light and air circulation within the dwellings. At street level, the porous walls form the threshold between the community and the urban context linking the terraced canyon floor to the streets of Dallas.

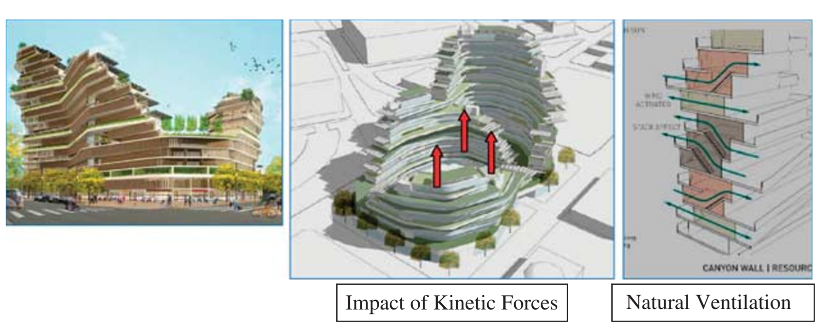

Figure 5: Co-Op Canyon.

Figure 6: Soaring green skyscraper.

Soaring green skyscraper for New York:
Daniel Libeskind recently unveiled a soaring green skyscraper for New York that is constructed of mostly glass and stands to be the city's tallest residential structure at 900 feet (see Figure 6). Dubbed the 'New York Tower at One Madison Avenue', the 54-storey apartment building features a series of '*sky gardens*' cut out from its facade that provide green space and terraced balconies for residents. Terraced gardens are becoming quite popular as a means for people to have an outdoor connection, fresh air and even a place to grow their own food.

There is a certain competitiveness involved in designing a skyscraper that drives designs to be bigger, better, greener and more innovative. Often, the designs for skyscrapers are unveiled and promoted extensively by very proud architects.

As for the other green amenities, few details have been released. We can most likely expect the residential project to have great indoor air quality and be very energy and water efficient, thanks to the insular effects of sky gardens. No word as to whether this project would seek LEED certification.

2. Copy: Adding

Houses Stacked in the Sky – Amazing Skyscraper in New York:
Herzog & de Meuron in Basel, Switzerland, is 57-storey residential building in the Tribeca area and will house 145 residences, each with its own unique floor plan and private outdoor space (see Figure 7). This typology makes the building look like a *stack of houses*, each floor stacked on top of the other, each one slightly askew to create dramatic cantilevers away from the traditional skyscraper form. This is a wonderful concept. The tower will appear to be resting atop his sculpture, and will be the first

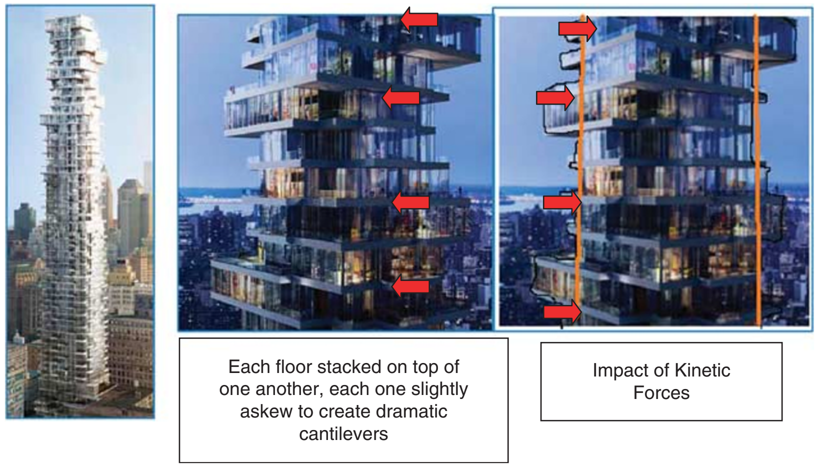

Figure 7: Houses stacked in the sky.

permanent public artwork for the artist in New York City. With articulated surfaces, dramatic cantilevers, profiled slab edges, profusion of balconies, expanses of glass and views from downtown Manhattan to as far as the Atlantic Ocean.

This structural arrangement of floor plates, at 56 Leonard Street, will create an irregular flurry of cantilevered terraces up and down the building, making plays of light and shadow that give the tower a shimmering, animated appearance on the skyline and widely varying interiors. The building's dramatic nine-storey crown contains its apex penthouses – eight occupying full floors and two occupying half floors – and will appear on the Manhattan skyline as a chimerical geometric sculpture of stacked, glimmering glass volumes. Ranging in size from approximately 3650 to almost 6380 square feet, these areas embrace the outdoors through expansive private terraces of up to 1700 square feet. Penthouses are accessed by private elevator. Soaring window walls rise to 14 feet and open on to panoramas of the city and sky.

3. Offset

Solar Wind Pavilion:
Michael Jantzen's experimental designs are a fascinating amalgamation of art, architecture and environmental sustainability (see Figure 8). The visionary architect's design for the Solar Wind Pavilion is no exception. Planned for the California State University at Fullerton, the Solar Wind Pavilion is an impressive integration of wind power generation, solar energy and rainwater harvesting, all combined into a gathering place for students and faculty for special events, studies, relaxation and meditation.

The proposed structure will be built using lightweight, high strength, composite concrete. The canopy roof would be covered with frosted glass shaded by a series of concentric louvered rings and a large digital projection display screen would be placed at the center of the canopy roof. The pavilion could accommodate a gathering of 300 people.

The pavilion harvests energy from the natural environment, which could be used to power the university. A vertical axis wind turbine mounted atop the structure would convert wind energy into electrical energy; it could be used directly or stored in batteries, placed at the base of the pavilion, for future use. Photovoltaic cells, arranged in four large rings mounted at four concentric shade louvers, would also harness solar energy to produce electricity, while the canopy roof would collect rainwater.

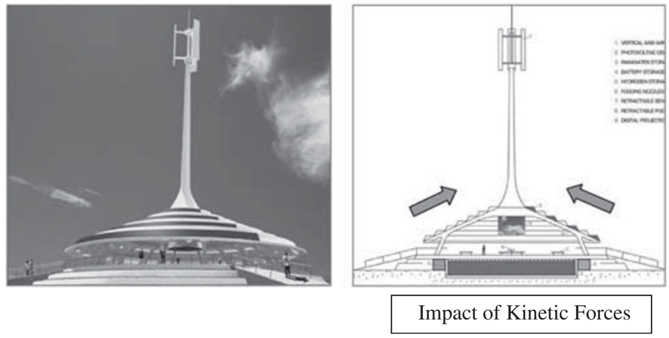

Figure 8: Solar Wind Pavilion.

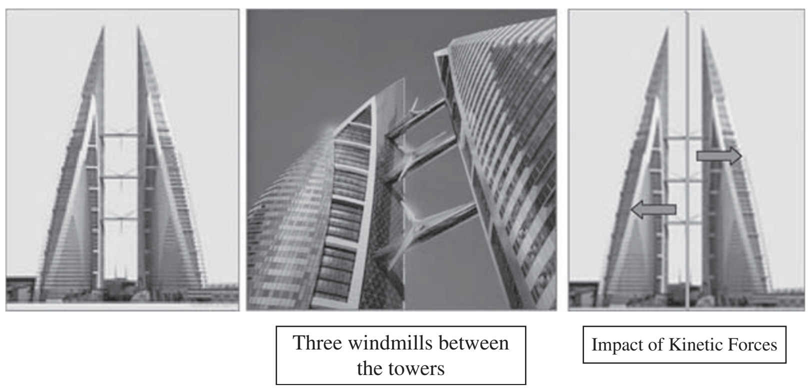

Figure 9: Bahrain World Trade Center.

4. Mirror

Bahrain World Trade Center:
The Bahrain World Trade Center (WTC) is two 240 m tall twin towers (see Figure 9). The construction started in 2004 and was completed at the end of 2006. These twin towers are the second tallest buildings in Manama, Bahrain, with 50 stories full of offices, apartments and a shopping mall with 150 shops. The towers are designed by the famous architect WS Atkins & Partners, with assistance from Danish Norwin & Rambøll. With three windmills between the towers, they produce 15 per cent of the power they consume.

The Bahrain WTC is the first large-scale building that will introduce the use of wind power to supply the needs of the building.

The plan remodeled a hotel and a shopping mall in a prestigious area near the Arabian Gulf.

The two buildings that make up the complex are inspired by the shape of the sails of ships that use wind energy to surf like the WTC uses wind energy to supply the needs of the activities taking place inside it.

The project also aims to show the world that countries of the United Arab Emirates, known globally for its oil production, also have launched renewable energy.

The two towers are joined by three bridges that support each of the three wind turbines erected at the project. All of the buildings were designed to optimize the passage of wind through the area where the turbines are placed, increasing its natural rate by up to 30 per cent. Other projects that sought to incorporate wind power failed because of high costs incurred to implement the technology.

In the case of the Bahrain WTC, the plan was carried out because the conventional design supports three windmills, 29 m in each diameter. Although these turbines were designed to minimize vibration and noise, they are, but, a small variation of windmills used in wind farms, and therefore the budget required to be devoted to scientific research was minimal.

The three windmills running at full capacity can provide between 11 and 15 per cent of the energy the building demands, which amounts to between 1100 and 1300 MW per year.

5. Stretch

Norman Foster's entertainment center in Kazakhstan:

Situated in the capital of Kazakhstan, Astana, the Khan Shatyry entertainment center will become a dramatic civic focal point (see Figure 10). The soaring structure, at the northern end of the new city axis, rises from a 200 m elliptical base to form the highest peak on the skyline of Astana.

The 100 000 m^2 center's unique concept – to provide a sheltered environment embracing an urban-scale internal park, shopping and entertainment venue – was developed in response to the harsh climate and extreme weather in both winter and summer.

Held by a mast, the vast tent-like cable net structure is clad in ETFE, a material that allows light to wash the interior spaces, while sheltering them from extreme weather conditions.

A park steps up the height of the building in undulating terraces providing public space and green oases for the visitors.

A tropical water park weaves its way through the landscape; and its wave pools, river and waterfall are lit by roof lights that are seamlessly integrated into the design. The highest terrace is a viewing deck, which will offer dramatic views over the park.

At the core of the building is a large flexible space that will form the cultural hub of the center, accommodating a varied program of events and exhibitions. Complemented by 40 000 m^2 of retail space with a wide range of cafes, restaurants, cinemas as well as ample covered car park facilities, the Khan Shatyry will offer leisure facilities for all.

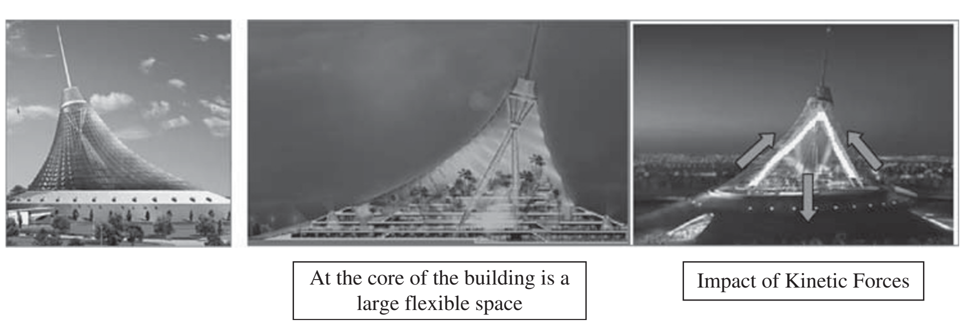

Figure 10: Entertainment Center.

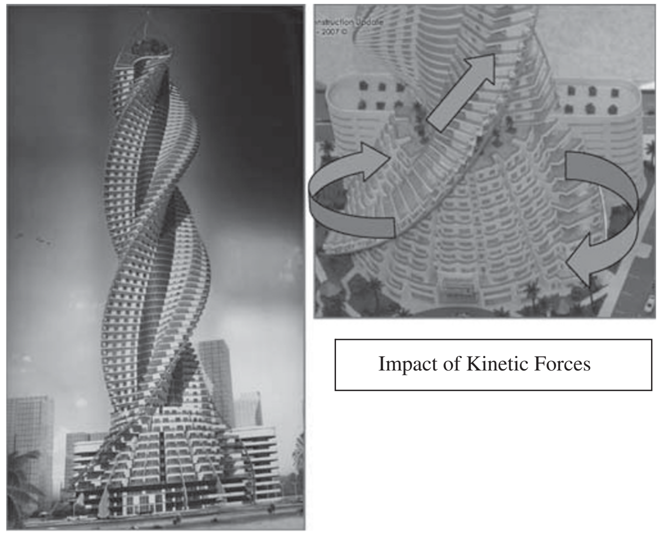

Figure 11: Diamond Tower.

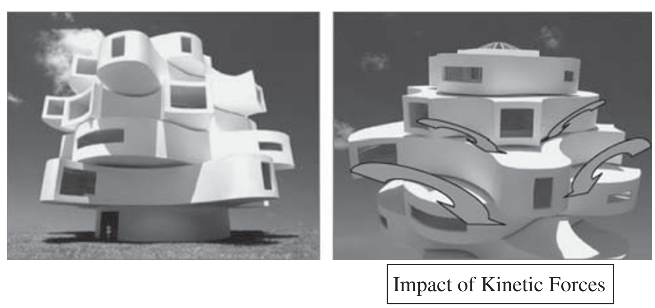

Figure 12: Wind Shaped Kinetic Pavilion.

6. Rotate

Diamond Tower:
Al-Masart Company has started its work on a project to build an innovative residential tower in Jeddah, Saudi-Arabia (see Figure 11). Referred to as the Diamond Tower, this twisted residential structure is one of a kind and will occupy approximately 80 floors. The Diamond Tower is expected to be 350 m tall (1149 feet/85 floors) and will comprise of approximately 300 residential units.

Wind Shaped Kinetic Pavilion:
Fusing art, architecture and renewable energy, California-based Michael Jantzen's Wind Shaped Pavilion is literally head-turning (see Figure 12). The pavilion is a proposal for a large fabric structure that rotates in segments around a central support frame, generating enough electricity as it moves to light the pavilion at night. Just think of the opportunities available in the building, the pavilion large enough that every level becomes an apartment or a commercial space, and the view from inside changes at the whims of the weather!

The interior structure is made of cob (clay and straw), a tried-and-true green building approach that lends itself to customized shaping of walls and ceilings.

The project is a building of six floors that can move itself exploiting the aeolian current to generate and store electric energy that can be used, for example, for the illumination.

The building is covered in a light wrapping and it is hinged around a central nucleus, the only space opened at all heights. In the intentions of this designer, the Wind Shaped Pavilion should show itself with an initial disposal of floors perfectly aligned, which the wind then alters. The shape of every single floor has been projected with the intention to favor the direction of the wind and then, the circular motion.

Dynamic movement

Challenging past practices, architecture today finds itself in a position to revisit its traditional kinetic aesthetics with new technological innovations. Through the use of sensors, actuators and microcontrollers, actual controlled motion can be designed, integrated and implemented in, on or across buildings. The traditional problem of motion, stasis and order are challenged, redefined and transformed by new spatio-temporal possibilities and strategies opened up through technological innovation, in particular robotic technologies and new approaches to mobility, portability and nomadic culture (Maria, 2008).

By combining motion, green energy and efficient construction, the Dynamic Tower will change architecture as we know it, and will start a new era of Dynamic Living (David, 2008).

Physical motion, other than in doors, windows, elevators or escalators, is not commonly present in buildings. In fact, the form and structure of the average building suggests stability, steadiness, sturdiness and immobility. Yet, although motion may suggest agility, unpredictability or uncertainty, it may also suggest change, anticipation and liveliness (Maria, 2008).

(a) *PARTIALLY*

1. Components

The Suite Vollard:
The Suite Vollard apartment building in Curitiba, Brazil, was the first building in the world to spin its 15 floors (see Figure 13). What is unique is that it is an apartment building, where each unit has the ability to rotate to get a 360 degree panoramic view of the city.

Each apartment has its own independent engine system, which can be engaged with a remote control. A complete clockwise or counterclockwise 360° turn takes 1 hour and the system is equipped with a programming timer. I would have all my dinners facing the West to catch the beautiful sunsets.

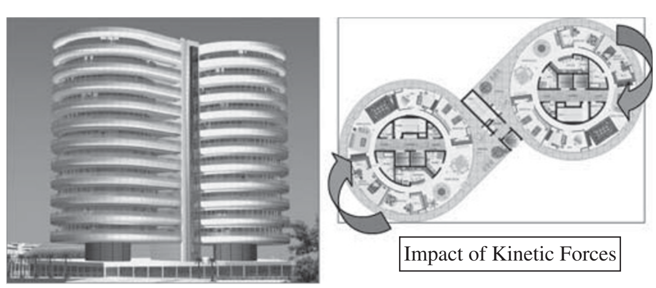

Figure 13: The Suite Vollard.

Figure 14: The Devonshire Building.

2. Elements

The Devonshire Building:
The Devonshire Building, DEWJOC Architects, University of Newcastle, is a very green building that automatically opens and closes banks of shade on its south facing façade (see Figure 14). The 'intelligent' system tracks the amount of sunlight entering the windows and takes into account the time of day and season. The key architectural aim was to design a building that would incorporate as much natural daylight as physically possible. The blinds help manage overheating, and they are backed up by a geothermal cooling system. To top it all off, the building has solar modules on its roof that generate 25 kW of power.

Sustainable solar shading for science structure:
The Devonshire Building is a landmark six-storey edifice in the heart of University of Newcastle's campus. It is home to the Institute for Research and Sustainability and the Regional E-Science Centre, and is therefore a pioneering construction embracing recycled materials, renewable energy and solar power reflecting the University's commitment to the environment.

Climate responsive:
Levolux were brought in to provide solar shading to the glazed southern elevation of the building. Levolux 400 mm aerofoil fins were fitted to steel 'bow trusses' and are motorized to operate in banks controlled by light sensors and a Levolux Multicontroller. The louvers are also climate responsive and allow optimization of daylight and solar penetration according to the time of day and the season.

On the southern elevation, Levolux also installed a newly designed, extruded aluminum 'J' tread 'walk-on' brise-soleil system, attached to the steelwork behind the aerofoils. A galvanized walkway was fitted on the north elevation.

A fluid aesthetic façade solution
Steve Halsall, project architect with The Dewjoc Partnership comments: 'The prime objective to the building design was the integration of the solar shading with the façade design. Levolux took up the challenge by taking on a proactive role in the design development of the solar shading system, which has resulted in a fluid aesthetic façade solution'.

Figure 15: Dynamic Tower.

(b) *TOTALLY*

Dynamic tower:
Set to be constructed in Dubai, this skyscraper designed by architect David Fisher rotates by wind power. But not as a whole – this building rotates by individual floor creating what Fisher calls 'dynamic architecture' (see Figure 15).

Dynamic architecture marks a new era in architecture. This new approach, based on motion dynamics, is, in fact, a challenge to traditional architecture that until now was based on gravity.

Dynamic Architecture buildings keep modifying their shape. As each floor rotates separately, the form of the building changes constantly; you may not see the same building twice.

In addition to the horizontal turbines, the building is to be fitted with photovoltaic panels on the roof – generating approximately 7 million dollars worth of electricity every year, according to Fisher.

The Dynamic Architecture tower in Dubai will have 200 apartments and hence four turbines that can take care of their energy needs. The surplus clean energy produced by the remaining 44 turbines can light up the neighborhood of the building.

CONCLUSION

Developing a stronger design science approach is important. Opening the lines of communication between design and science disciplines is critical. Each can inform the other in exciting new ways – where science can find creative solutions and design can develop more innovative creations. The renewed advent of design science is here – and the architectural process is a key contributor (Maria, 2008).

Today's life is dynamic, therefore the space we are living in should be dynamic as well, adjustable to our needs that change continuously to our concept of design andour mood. Kinetic buildings can follow the rhythms of nature and can change direction and shape from spring to summer, from sunrise to sunset and adjust themselves to the weather so, buildings will be alive (David, 2008).

Kinetic architecture will allow architects to develop realistic consideration of human and environmental conditions. The result will be architecture of unique and wholly unexplored applications that address the dynamic, flexible and constantly changing activities of today and tomorrow.

Adaptive response to change must intelligently moderate human activity and the environment and build on the task of enhancing everyday activities by creating architecture that extends our capabilities.

It is difficult to see if advanced kinetic architectural systems are far on the horizon or inevitably in the very near future. To extrapolate the existing into a future vision for architecture is a conundrum residing in the hands of architects directing the future of their profession. Therefore, architects need to grasp a vision that will harness technology transfer from 'outside' fields and prevent contradictions in human interaction with the built environment.

ONLINE REFERENCES

David, F. (2008) Architecture, residential/dynamic architecture, http://plusmood.com/category/architecture/residential/, accessed 25 May 2009.

Kostas, T. (2008) Kinetic architecture, course website locator: 2309, Harvard Design School, http://courses.gsd.harvard.edu/2309, accessed 13 June 2009.

Maria, L.L. (2008) Sensing architecture, design science: The ideal architecture process, http://sensingarchitecture.com/708/design-science-the-ideal-architecture-process/, accessed 3 June 2009.

Maria, L.L. (2009) Sensing architecture, kinetic architecture lifting the human spirit through experience, http://sensingarchitecture.com/229/kinetic-architecture-lifting-the-human-spirit-through-experience/, accessed 13 June 2009.

Stan, C. (2006) Kinetic drawings by and invited artists, http://www.meetinginzdonov.nl/index.php?id=101, accessed 25 May 2009.

Zadinac (2009) Free essays on kinetic architecture. *Kinetic Architecture*, 21 March, http://www.antiessays.com/free-essays/41104.html, accessed 3 June 2009.