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Extreme and Adaptive Design (EAD)

Design Extremo e Adaptativo

Maria Giovanna Trotta
maria.trotta@itesm.mx
Tecnológico de Monterrey. Avenida General Ramón Corona 2514, Nuevo México, 45138 Zapopan, Jalisco, Mexico.

Luis Adolfo Márquez Valdés
luismarquezv@itesm.mx
Tecnológico de Monterrey. Avenida General Ramón Corona 2514, Nuevo México, 45138 Zapopan, Jalisco, Mexico.

Abstract
The design process is influenced by several variables and is based upon diverse resources. Time and budget determine the limitations of the strategies which define product development. Designers are increasingly facing new challenges/problems, for example, they must consider the brief, new local and global changes, new trends, and the knowledge and technological tools available to satisfy, anticipate or guide the needs of the users. Formal and informal approaches are used to gather information, gain better understanding and reduce the distance between users and designers in order to identify the best opportunities. Decision-making is based on different tools depending on whether the demand is local, national or international. The paper describes EAD (Extreme Adaptive Design), a design methodology with the aim of providing sustainable bio-inspired solutions which can be used for developing new design concepts related to the anticipation of extreme weather conditions due to potential natural disasters. Visionary designers or students can use the methodology for a better understanding of present and future global challenges, for managing conceptualization within the parameters of efficiency, for stimulating systemic reasoning and for developing new bio-inspired solutions.

Keywords: sustainability, biomimicry, eco-design.

Resumo
O processo de design é influenciado por diversas variáveis e é baseado em vários recursos. O tempo e o orçamento determinam as limitações das estratégias que definem o desenvolvimento do produto. Os designers estão cada vez mais enfrentando novos desafios/problemas; por exemplo, devem considerar as breves mudanças locais e globais, as novas tendências e os conhecimentos e as ferramentas tecnológicas disponíveis para satisfazer, antecipar ou orientar as necessidades dos usuários. Abordagens formais e informais são usadas para coletar informações, obter uma melhor compreensão e reduzir a distância entre usuários e designers, a fim de identificar as melhores oportunidades. A tomada de decisão baseia-se em diferentes ferramentas, dependendo se a demanda é local, nacional ou internacional. O artigo descreve EAD (Extreme Adaptive Design), uma metodologia de projeto com o objetivo de fornecer soluções sustentáveis de bio-inspiração que podem ser usadas para desenvolver novos conceitos de design relacionados com a antecipação de condições climáticas extremas devido a potenciais desastres naturais. Designers visionários ou alunos podem utilizar a metodologia para uma melhor compreensão dos desafios globais presentes e futuros, gerenciar conceituação dentro dos parâmetros de eficiência, estimular o raciocínio sistêmico e desenvolver novas soluções bio-inspiradas.

Palavras-chave: sustentabilidade, biomimética, eco-design.

Introduction

According to the IPCC (Intergovernmental Panel Climate Change), global warming will cause high variability in climate systems and differences in changes between locations (Collins *et al.*, 2013). In line with the statements about climate, more rapid changes will take placed in the atmosphere and in the earth, all with different scales of speed and degree. At the end of the 21st century, climate change resulting from high thermal energy will mean the acceleration of the water cycle, alteration of the CO_2 and nitrogen cycles (altering the equilibrium between the living world and soil, water and atmosphere) and consequently increasing pollution, floods, desertification and other phenomena.

Natural disasters have been part of human history from the dawn of time. Nowadays, the exponential growth of population, cities, agriculture, and industries is creating both the causes and the impacts of "natural" disasters.

Natural disasters are the result of anthropogenic climate change, where humans are adding more energy to the earth and removing protections through the construction of sprawling settlements. Natural disasters are part of a complexity of phenomena which are increasing the vulnerability of the social, economic, physical, environmental and political systems which interplay in the scientific field of disaster risk management, disaster management theories, and disaster management cycles (Van der Waldt, 2013).

According to the United Nations International Strategy for Disaster Risk Reduction, disasters happen due to the combinations of hazards to which people vulnerable to risk are exposed (UNISD).

The IPCC assessment report declares that patterns of physical disasters around the globe are variable, but the frequency of hydro-meteorological extreme events has increased.

In Figure 1a we can observe the damage in billions, the percentage of people affected and the number of people killed (World Economic Forum, 2015). The percentage of natural disasters is 87%, of which 70% is comprised of earthquakes and tsunamis.

If we see Figure 1b, the top 10 columns show countries affected by disasters, with the blue circles showing the magnitude of the damage.

In order to understand the magnitude of natural disasters, the graph shows the economic damage in billions of the Honshu tsunami in 2011. This is followed by hurricane Katrina in 2005, the earthquake in Wenchuan in 2008, and finally the earthquake in Kobe in 1995 (Anderson, 2008).

Understanding systemic needs during disasters is absolutely vital in order to prepare and address appropriate solutions. The understanding of megatrends is also extremely important in order to develop sustainable solutions for the future.

It is widely understood that population growth, for example, in Europe, is accompanied by an increase in the number of elderly people; Europe currently has the largest elderly population in the world (United Nations, 2011), and this is significant because the needs of the old are different from the needs of the young. Another mega-trend is related to urban overcrowding (Goldstone, 2010), which increases dependency on imported food as a result of land in urban areas becoming increasingly inaccessible for agriculture (FAO, 2009). People in general are becoming increasingly aware of the impact of climate change, as is their awareness of the economic consequences resulting from it. Adaptation to climate change is becoming an increasingly important part of future projections for the majority of cities around the world (Field *et al.*, 2012). However, not everyone understands exactly which parts of the world will be most affected by climate change.

Risk management related to climate change is associated with the concepts of vulnerability and exposure coupled to increasing losses; this contrasts with the concept

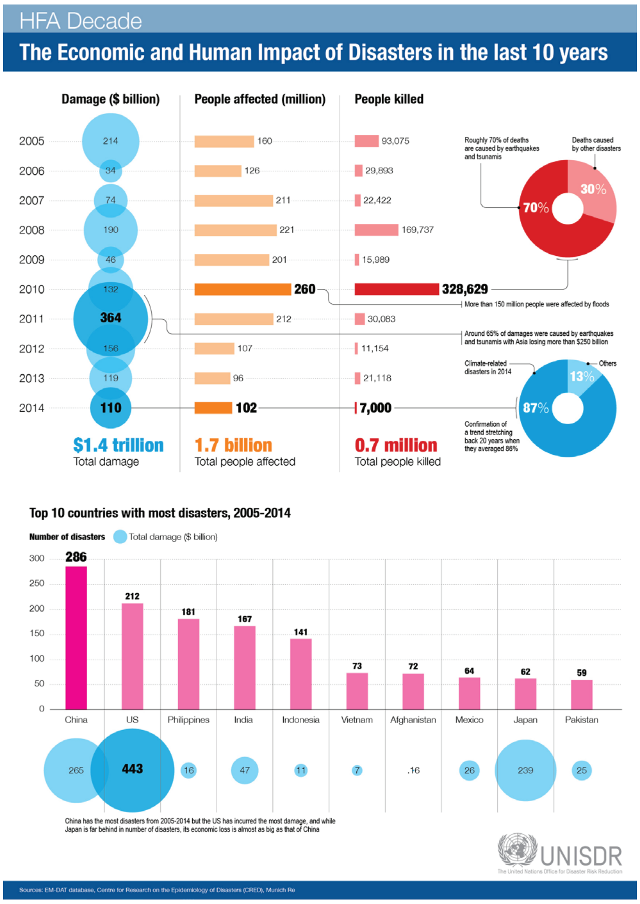

Figure 1. (a) The economic and human impact of disasters in the last 10 years. (b) Top 10 Countries with most disasters, 2005-2014.

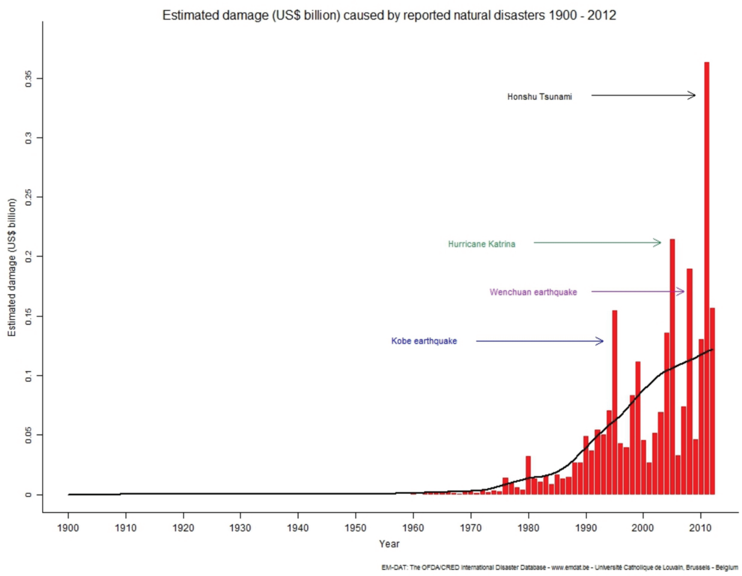

Figure 2. Estimated damage caused by reported natural disasters (1900-2012) (World Economic Forum, 2015).

of sustainable development, described in the Brundtland Commission, which should guarantee the safeguarding of resources for future generations (Brundtland *et al.*, 1987).

Economically-guided decisions like the destruction of mangrove swamps, cutting down of forests for building materials or for intensive agriculture and the covering of road surfaces with impermeable materials contribute to the removal of patterns of protection, the interruption of the water cycle and inadequate drainage.

It should be stated, however, that climate change will also lead to benefits for some people, who will speculate, make investments and take decisions based on environmental, social, geo-political, economic and technological climate-change forecasts.

Managing disaster risks requires hypotheses to be drawn up based on historical data. However, these hypotheses could be affected in terms of certainty by diverse factors; for example, the relevance of their connections with the systems on which they are based.

In Figure 3, the interconnection of global risks can be observed.

If we take a hurricane as an example of an extreme weather event and try to evaluate the multiple effects associated with this phenomenon in cities around the world, we could try to imagine the sequence of events which would occur in order to gain a better understanding of the resources, energy and information available.

Emergency management involves a set of programs and variables which can be considered and confronted before, during and after a disaster. The entities involved could be private, local government, or state. Communication systems provided by technology or manuals could form part of the strategies aimed at mitigating the severity of the event.

As can be observed in Figure 4, the steps of a comprehensive emergency management plan are the following: (a) Preparedness; (b) Incident; (c) Recovery; (d) Mitigation (Alexander, 2002).

(a) *The preparedness* takes place immediately before a disaster and consists of planning, organizing, equipping, training, exercising, creating, evaluating and improving.
(b) *The response phase* starts with the disaster or when a communication announcing the disaster is given. It includes activating resources and coordinated actions in order to reduce the impact, protect the population, and limit the damage;
(c) The recovery phase is related to rescuing, lifesaving, and restoring infrastructures like water, sewerage and electricity in the short or long term.
(d) The mitigation step is directed towards changing human leadership and concentrates on planning, being effective, reducing risks for citizens and protecting structural and non-structural properties.

The managers of the emergency can be different, and include volunteer organizations, public health bodies, local operators, and local enforcement (Rubin, 2007).

In the Hazard Vulnerability Analysis, the vulnerabilities of communities will be prioritized based on the relevance of: (a) exposure; (b) social and (c) physical vulnerability.

We are focusing on cities, because large communities, built environments, the economy, networks, technology, pollution and so on are located in urban zones.

A truly sustainable community should be exposure-resilient and consider prevention along with environmental supervision, quality of life, economic strengths, and a fair inheritance for future generations.

Typically in natural disasters, rain, floods, wind or earthquakes are not responsible for the majority of lives lost; fatalities are due mostly to building collapse or flying debris.

In an emergency, information-management is extremely important; information can be received by systems and transferred to other systems in order to work effectively. This can be seen in Figure 5.

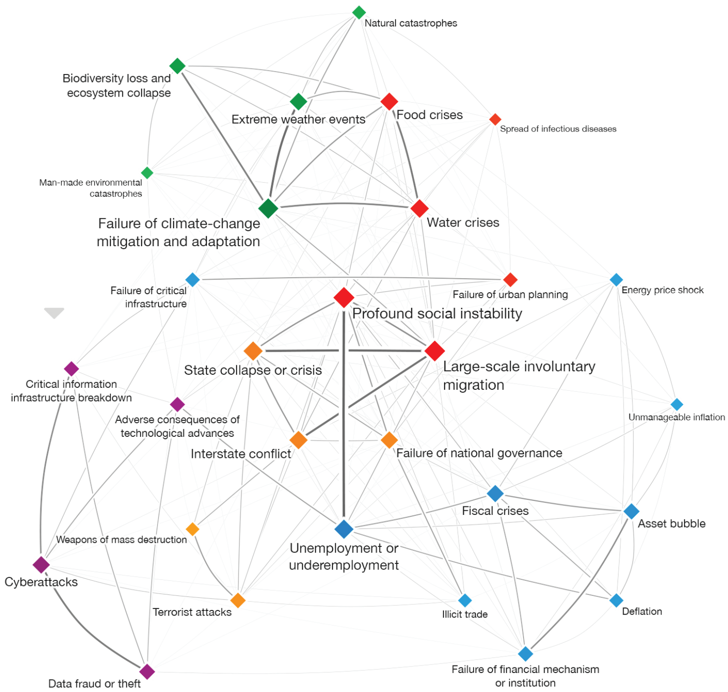

Figure 3. Global Risk Interconnection Map (World Economic Forum, 2015).

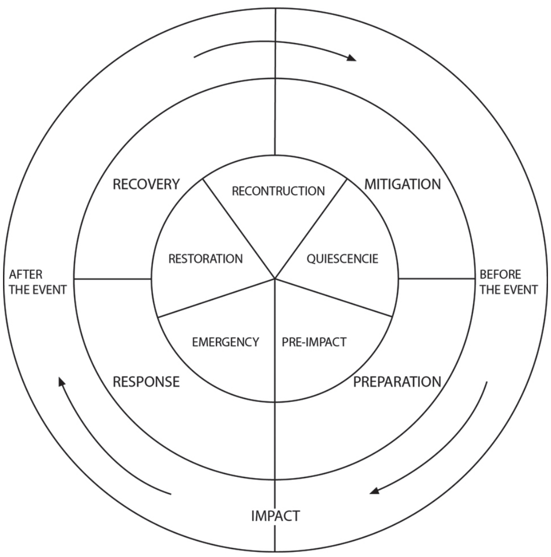

Figure 4. Comprehensive emergency management steps.

On October 23th 2015, Mexico faced the strongest hurricane ever measured in the western hemisphere. The city of Guadalajara and the cities on the west coast were directly in the path of hurricane Patricia.

An emergency was declared in Guadalajara due to the likelihood of heavy rains and strong winds (National Hurricane Center). The University of Guadalajara Institute of Astronomy and Meteorology warned about the fury of Patricia, which quickly became a powerful hurricane that was anticipated to be a Category 3 by the time it reached Jalisco. The danger of Patricia is comparable to that of the anticipated hurricanes Kena and Odil.

Hurricane force wind fields can cause hazardous conditions and significant destruction along coastlines thousands of miles away from their epicentre. Hurricane Patricia had wind speeds of 201 mph before making landfall, subsequently slowing to 130 mph as it moved across Mexico. Weather forecasts estimated that the hurricane caused rainfall of 500 mm.

In Jalisco thousands of Mexicans and foreign tourists took refuge in hurricane shelters, schools and other structures prior to Patricia making landfall. The hurricane subsequently followed the path outlined in Figure 6 before blowing itself out in Texas, where it caused significant precipitation (Todd *et al.*, 2016).

Fortunately, in contrast to what had been predicted, Patricia failed to reach a category three hurricane but instead presented as a tropical storm, causing a much lower impact in terms of water quantity and duration when compared with other, similar storms which have caused rainfall of more than 180mm over a three-day period.

However, if Patricia had made landfall at the strength predicted, it would have caused severe disaster, probable loss of life and innumerable material losses. It could have resulted in the city collapsing for several days, with unprecedented consequences.

In terms of geo-water location, Guadalajara has a unique position because it is located close to Lake Chapala, the nation's largest lake. Chapala is the major supplier of water to Guadalajara and lies in the Atemajac (Figure 7) Valley, which has a natural slope suitable for drainage and soil composed mainly of pumice materials (better known locally as 'Jal'). This allows it to function as a drainage area for the Santiago river canyon (known as Canyon Oblatos). The drainage area has a depth of between 250 and 500 meters, which means that neither the sewerage sanitation system or rain drainage should be affected (Figures 1 and 2). Unfortunately, floods are

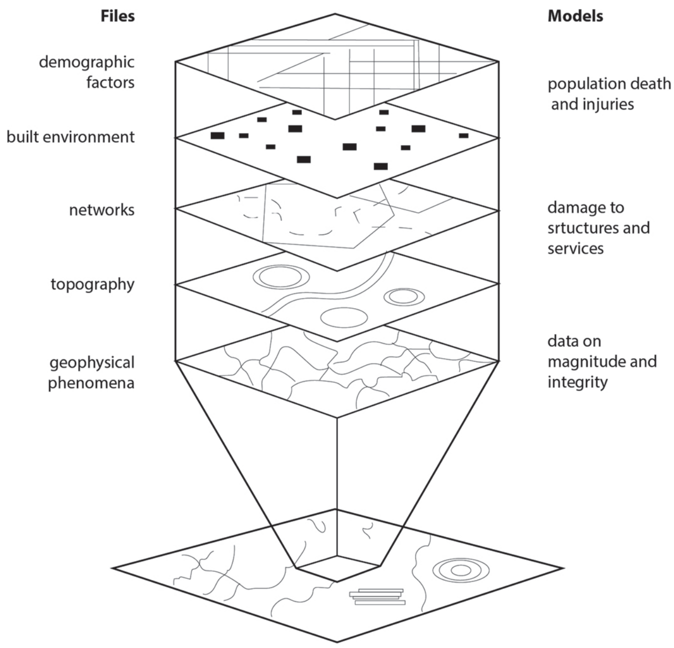

Figure 5. Geographic Information System to develop predictive models of Hazards.

Figure 6. Path of Hurricane Patricia.

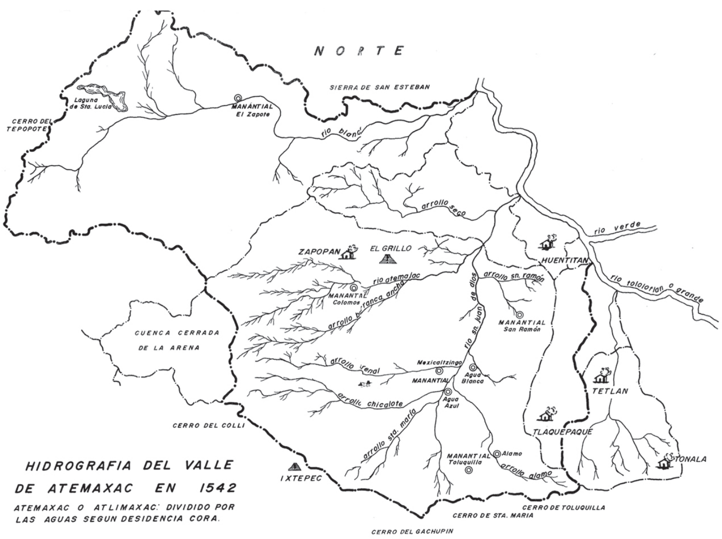

Figure 7. Plane Atemajac Valley in 1542.

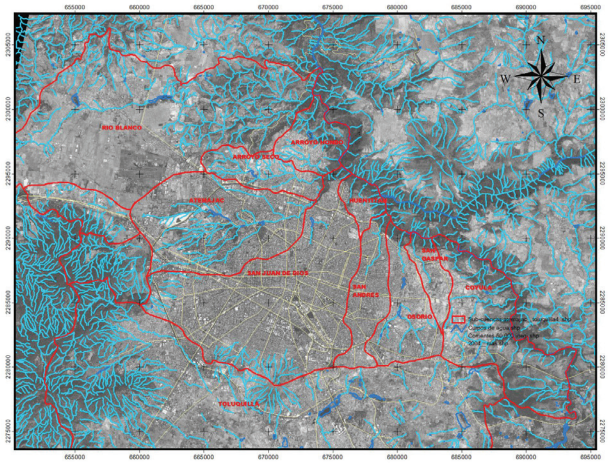

Figure 8. Metropolitan Area of Guadalajara, Basin map.

only one of the three problems affecting the community, the others being the rule of law and traffic congestion.

Floods in this region are not the result of natural conditions but are instead due to the haphazard urban development, which began in the 1970's, when a process of unbridled urbanization began, which, in the space of 40 years, multiplied the built environment area by six while the population only tripled; this speaks of a land-hungry and inefficient model that gave rise to urban sprawl (Figure 9). The suburbs, particularly as they are less densely-built than the centre of the city, could have been constructed with water-sensitivity in mind. However, this has not been the case; the urban model employed has given preference to the private car. This has resulted in a significant area being dedicated to roads and parking lots and a lack of green areas and open spaces. In Guadalajara the average is three meters of green area per capita compared to the ten meters suggested by the WHO (World Health Organization).

The lack of green filtration areas are a sign that many of the natural watersheds have become urbanized, generating a drastic change in the coefficients of runoff and rainwater filtration. Whereas previously rainwater was deposited on highly-permeable rural land, it is now deposited on roads, reducing the capacity of groundwater replenishment and increasing the risk of flooding. What were previously two natural advantages therefore are now two issues in urgent need of resolution (Figure 10), and this urgency is compounded by the spectre of climate change.

The paper describes the principles, phases, and application of a bio-inspired design methodology when developing a refuge with the main goal of protecting and rescuing people. Cities have been selected from diverse countries which are experiencing changing conditions in order to allow the study of distinctive climate conditions and local resources. The methodology works with projections to anticipate, approximately 35 years hence, the catastrophic climate events which could occur and develop efficient conceptual solutions.

Bio-inspired design focuses on eco-efficient solutions to human problems and has the aim of preserving the equilibrium for all living things.

As part of the Climate Change course in the design school of Monterrey Tech Campus Guadalajara, 3rd semester students are guided by the professor in the use of tools and methodologies that might be useful in the development of new sustainable design solutions.

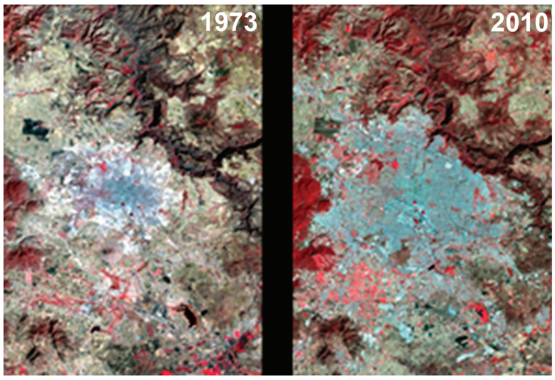

Figure 9. Metropolitan Area of Guadalajara, growth of Atemajac Valley.

Figure 10. The water situation in the region of Guadalajara. Source: *The Informer* (2014).

Method

Students select a specific problem related to future climate disasters in a specific global location, a location which is characterized by certain resources and extreme weather conditions (temperature, humidity, wind, pressure, solar radiation, precipitations). The impact of the exercise is intensified by the:

(a) Use of biological knowledge from natural systems to assist in the design of new artifacts;
(b) Proposal of a functional approach for the interpretation of different problems related to climate disasters;
(c) Focus on efficiency by using diverse strategies;
(d) The analysis and visualization of future scenarios, combined with forecasted trends.

The methodology is divided into the following steps:

(1) Selection of the specific problem;
(2) Data collection (about the problem, the environment, regulations, people, economy and existing solutions);
(3) Strategy definition (functions; level of innovation; technology; 6R; WBCSD eco-efficiency parameters, budget);
(4) Decision about parameters (TRIZ principles, bio-inspired design, materials, energy);
(5) Definition of the proposal;
(6) Analysis, Simulation, Evaluation;
(7) Implementation.

During step 1, students select a relevant, specific problem related to climate change with the help of different databases (NASA, the Wuppertal Institute, EPA, ISTAT, etc.).

Then, for step 2, which involves data collection, students research more specifically: (a) human needs, analyzing bibliographic and on-site information by considering culture, age, gender, education, equality, safety, population growth habits and so on; (b) environment, by looking for biodiversity, renewable resources, pollutants, climate characteristics (Tº, precipitation, radiation and so on); (c) economy: industries, services, employment, debt, governance, income distribution; (d) existing solutions (patent database).

Figure 11. Shelter, analysis and data collection.

Subsequently, during step 3 students analyze and select the best sustainable strategy to use in terms of: (a) functions (verbs, which represent the significance of the system); (b) budget; (c) level of innovation (incremental, differential, radical); (d) technology (same domain, different field, experimental); (e) WBCSD eco-efficiency parameters (reduction of toxicity; increased service-intensity of goods and services, reduction of materials and energy, greater durability, maximum use of renewables, improved recyclability);

During step 4 students make decisions about (a) the parameters, how to reduce weight, decrease toxicity, recycle, rethink the product, facilitate repairs, and make a more robust design; (b) TRIZ principles, (c) bio-inspired solutions, (d) materials, and (e) sources of energy;

Then, for step 5, students define the design proposal.

Subsequently, for step 6, students analyze, simulate, and evaluate by using (depending on the time available) (a) a Finite Elements Analysis, (b) an LCA (Life Cycle Assessment), or (c) multi-criteria decision making.

Finally, for step 7, students implement the changes they have suggested.

Study

Considering the steps previously outlined, students will then formulate a more simplified approach in which the general concept is defined, as shown in Figure 11. The geometrical strategy makes reference to the compactness of hexagonal structures, trying to have as little surface area as possible and armor-plating the most effective structure.

Based on effectiveness, the students decided to use modules to facilitate the assembly but employing radial symmetry (articulating modules around a vertical axis) in order to provide significant resistance to the impact and pressure of winds, as shown in Figures 12 and 13.

The selection of materials aims to combine strength with the buffering effect of vibrations, thus avoiding the structure being affected and those sheltering inside suffering discomfort.

Conclusions

Tackling climate change and developing solutions for improved wellbeing takes a long time. Through the ex-

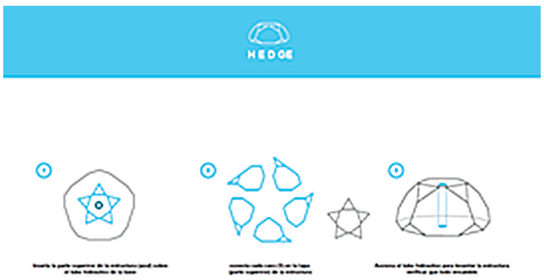

Figure 12. Shelter, parameters, mechanisms and effective design strategy.

Figure 13. Shelter, measures and effective design strategy.

ercise described above our intention is to bring students closer to the dynamics of the issue and view climatic phenomena on both a global and local scale.

Climate change is an extremely challenging phenomenon, and the environmental systems involved, such as the hydrosphere, cryosphere, biosphere, atmosphere, geosphere and Anthropos-sphere, are particularly complex. Today's natural disasters offer an insight into future scenarios, and the systemic vision of eco-design can offer a specific view of tomorrow's challenges. By focusing on particular challenges and maintaining the systemic vision of eco-design, creatives, inventors, engineers, architects and designers can employ this methodology to help find new ways to develop more sustainable solutions.

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