Envisioning infrastructure to reduce disaster’s impact to cities during the climate change area being elements of smart cities

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Abstract. The paper explores the possibilities of architectural design to benefit human condition, which encompasses physical environment of safe life during the climate change era and predicted disasters. The first part deal with the problem of natural disasters and hazards during the climate change era and human beings react to them. The second part presents, among others, results of the research program undertaken at West Pomeranian University of Technology in Szczecin by authors. The program is focused on adaptive built environments and envisions new solutions based on advanced digital technology. Presented design contains a systemic solution the problem of disaster security in high-urbanized areas. This is a proposal of active infrastructure to reduce disaster’s impact to urban environment through using personal flying evacuation equipment and safe landing site. The conclusion emphasizes the significance of integrated approach to design i.e. interdisciplinary collaboration between architects, structure, material and environmental engineers. Preventing loss of life and mitigation of damage is a challenge for coastline communities. The methods of solving the “tsunami problem” hold inherent social issues that make planning for disaster a complex problem requiring structural engineering and architectural design directing attention to the solutions. This study highlights the problem of coastal societies and serves as a useful background for further research on the possibilities of redefining sustainable and human friendly design.

1. Introduction

Global climate change has already had observable effects on the environment. The increasing impact of natural disasters over recent decades has been well documented. This constitutes a serious threat to global security. Effects that scientists had predicted in the past are now occurring: in particular changes in frequency, intensity and location of weather events like floods, storms and droughts. The most frequent way human beings react to natural disasters is relocation to other places. Human mobility is a primary mechanism to cope with extreme weather events [1]. Recently, architects and structural engineers, urban planners, health and physical scientists have started to work on specific solutions how urban environment should interact in the face of global climate change, natural disasters and other hazardous events [2].

The following study is an application of an experimental approach in recently re-opened discussion on possibility and advisability of creating a systemic solution to resolve the problem of disaster.
security in urbanized areas. It envisions a new infrastructure to reduce disaster’s impact to cities through implementation of advanced technologies and materials of the tomorrow.

2. Climate action – natural disasters and hazards

The increasing impact of natural disasters and hazardous events over recent decades has been well documented. Natural disasters are defined as complex events “concentrated in time and space, in which a community experiences severe damage and disruption of its essential functions, accompanied by widespread human, material or environmental losses, which often exceed the ability of the community to cope without external assistance” [3]. However, one form of external assistance is the online disaster-response community (ODRC) that is comprised of formal and informal networks of people acting as sensors collecting, processing, and delivering information where it is needed [4].

The changes that will occur as a result of climate change over the next 10 years will have a huge impact on the lives of hundreds of millions of people. Recorded natural disasters have doubled from approximately 200 to over 400 a year over the past two decades. Recent research shows that only in 2008 about 20 million people moved due to climate-related disasters. Slow-onset disasters appear to affect far greater number of people than sudden events, for instance: earthquakes 134 million; droughts 1.6 billion; floods 2.8 billion; volcanoes 4.2 million; storms 718 million [5]. When disaster strikes, the impact on people and places can be devastating - increasingly so, as urbanization continues to make gradual progress globally. But disaster like earthquakes and flooding also create space to renew, rebuild and rethink urban environments we inhabit.

Half of the 37 “million cities” in Africa are either within or have parts that are within the low elevation coastal zone. Banjul, Lagos and Alexandria are among the cities most at risk, but many other are also susceptible to increased risks of flooding- however, due to lack of local analysis, the scale of this risk has yet to be documented. In 365 CE, Alexandria suffered in a result of the impact of more than 10 meters tsunami caused by an earthquake near Crete. This tsunami devastated many large cities in what is now Libya and Tunisia, as well as Alexandria. The anniversary of the disaster was still commemorated annually at the end of the 6th century in Alexandria as a “day of horror”[6]. Many Asian cities are also at risk zone. There are one of the world’s largest cities near coastal areas. Eastern part of the continent is also one of the most seismically active regions in the world. The 2004 Indian Ocean earthquake, which had a moment magnitude of 9.1-9.3, triggered a series of lethal tsunamis on 26 December 2004, that killed approximately 230,210 people, making it the deadliest tsunami as well a one of the deadliest natural disasters in recorded history. The first wave was measured at a height of approximately 33 meters high, making it the largest earthquake-generated tsunami in recorded history. The sudden displacement of the ocean bottom (especially vertical) over a large area causes the water layer to rise (or decrease) as a source of very long waves (150-250km) running through the ocean at speed of 500-850 km/h. The deeper the water, the faster the waves. For example, in the ocean at depths of 2, 4 and 6 km, tsunami wave velocities are approximately 140, 200 and 240 m/s [7].

Action that addresses the interlinked challenges of disaster risk, sustainable development and climate change is a core priority given that 90% of recorded major disasters caused by natural hazards from 1995 to 2014 were linked to climate and weather including floods, storms, heatwaves and droughts. The five countries hit by the highest number of disasters were the United States (472), China (441), India (288), Philippines (274), and Indonesia, (163) [8].

3. Climate change oriented design

However, climate change does not directly affect the movement of people but creates an environment too difficult for them to survive. Disaster type may serve as a deciding factor that influences peoples’ decision to move, whether temporarily or permanently. Sometimes perceptions of an upcoming hazard may prompt people to leave; other times people must leave when a hazard suddenly hits. Then one way to react is rapid evacuation people to a safe place.

Climate change oriented design can be defined as an adjustment of conditions compatible with changeable climate characteristics and ecology. In architecture the term redefines an architectural design process not as the shape of material object alone, but as the multitude of effects, the milieu of
conditions, modulation and microclimates that emanate from the exchange of object with its specific environment - as a dynamic relationship that is both perceived by and interacted with a subject [9]. An intention of this kind of design is to eliminate negative environmental impact through skilful, sensitive design. This requires a view broader than ever, with a heavy emphasis on various interdisciplinary aspects [10]. The main mission of climate change oriented design is to build the designers own interpretation and implementation of environmental systems thinking. Therefore involving climate oriented design principles into architectural and construction phase of design contributes to reach more sustainable and climate-friendly built environment.

A few years ago this issues were undertaken by Krystyna Januszkiewicz (Leader of Digitally Designed Architecture Lab) and faculty member at the WPUT (West Pomeranian University of Technology) in Szczecin. The research program (Climate Change Adapted Architecture and Building Structure) is focused on design adaptive built environment for modern societies and envision new solutions based on advanced digital technology. There are developed new strategies to anticipate exterior environmental variations as well as interior interaction with inhabitants to response to all weather phenomena during the global climate change era. With the use of parametric designtools, and multidisciplinary knowledge design ideas are programmed and represented visually in the form of diagrams, drawings, digital abstract or physical models and computer-generated images. This type of concept representation can be not appropriate for a precise, and unique material reality and further states that even the most convincing techniques of representation do not correspond fully to the experience of the built reality. Therefore, a representation is usually a description of way of thinking and material systems.

4. Research

In last year the research program goes on to attempt to solve the problem of disaster security in high-urbanized areas through envision a fast, personal evacuation system. Every citizen in area of immediate danger should be equipped with a life saving device.

The first part of research project included defining of main positive and negative factors affecting physical security in urbanized environment. The impact of climate change related disasters and interrelated hazards were discussed. The second part of the research program attempted to solve this clearly defined problem through architectural concepts applying the latest technology and design methods.

The second part of the research program attempted to solve this clearly defined problem through architectural concepts applying the latest technology and design methods. This was made possible by using intelligent and sensitive design conceptualization. The proposed personal, life saving capsule system called New Hope would be responsible for the successful evacuation to especially prepared infrastructure of safe landing sites. Every citizen in area of immediate danger should be equipped with this life saving flying device [11].

The intention of this design was not only to minimise but to completely eliminate any negative and dangerous effects of tsunami strike. This was made possible by using intelligent and sensitive design conceptualization. The proposed personal, life-saving capsule system called New Hope would be responsible for the successful evacuation to especially prepared infrastructure of safe landing sites. Every citizen in area of immediate danger should be equipped with this life saving device.

4.1. Floating urbanism and personal flying apparatus in the past

Humans have managed to construct air vehicles or apparatus that raise off the ground and fly, due to their buoyancy in air. The flying models provided by nature (birds and animals) have been an inspiration for constructing personal flying devices since time immemorial. Daedalus, talented and remarkable Athenian craftsman and engineer of King Minos, fashioned two pairs of wings out of wax and feathers for himself and his son (Figure 1a). Literary interpretation has found in the myth the structure and consequence of personal over-ambition. Some attempts at human-powered flight were more successful than others.
In 9th century Spain, a Muslim inventor named Abbas Ibn Firnas (810-887) was said to have successfully floated through the air using a winged apparatus that would later inspire a Renaissance polymath named Leonardo da Vinci. A little later on, an English monk in the 11th century named Eilmer of Malmesbury (born about 980) similarly strapped feathers to his arms and leaped from the top tower of Malmesbury Abbey in 1010[12] (figure 1a-b).

The early concept of incorporating flying directly into the city was presented to a wider public yet in 1726 in the satirical novel titled “Gulliver’s Travels”. Then Jonathan Swift (1667-1745), one of the foremost prose satirist, envisioned an island city, named Laputa, that floated in the sky. The island was suggested to levitate above the Earth by use of the force of magnetism. In the 1920s, Hugo Grensback (1884-1967), writer and editor the first science fiction magazine, speculated about floating cities of the future. He suggested that 10,000 years hence "the city the size of New York will float several miles above the surface of the earth, where the air is cleaner and purer and free from disease carrying bacteria." To stay in the air, "four gigantic generators will shoot earthward electric rays which by reaction with the earth produce the force to keep the city aloft” [13] (Figure 2a-b).

In science fiction, floating cities are settlements that strictly use buoyancy to remain in the atmosphere of a planet. However the term generally refers to any city that is flying, hovering, or otherwise suspended in the atmosphere, as the Hawkmen’s floating metropolis Sky City depicted in 1980 science fiction film “Flash Gordon” based on 1934 comic strip created by Alex Raymond [13] (Figure 2c).

The reality of airborne environments, suspended loftily above, amid clouds, has always inhabited human being dreams but always exceeded the scope of present technologies, until the twentieth century.

Flight is the process by which an object moves, through an atmosphere and the engineering aspects of flight are the purview of aerospace engineering. For this reason, Leonardo da Vinci (1452-1519) also unsuccessfully tested a flying machine in January of 1496 (Figure 3a-b).
When in 1896 Otto Lilienthal (1848-1896) tested biplane versions he found them remarkably stable but more difficult to navigate. Just as Daedalus he was fascinated with the flight patterns of birds and insects (Figure 3c). Lilienthal believed that man might learn to fly in fixed-wing gliders. He conducted whirling-arm experiments to gather data on various wing shapes, then published his research in "Bird Flight as the Basis for Aviation" (1889), one of the classics of aeronautical literature. Lilienthal was the first man to actually launch himself into the air and fly [14].

Vladimir Tatlin’s Letatlin personal flying apparatus was built between 1929 and 1931 (Figure 4). The structure itself was a full-sized model of a human glider/flying apparatus that Tatlin revised into several other manifests of the original glider. He believed that art should live outside of an enclosed frame or space and should be built from simple, organic materials. “The engineers made hard forms. Evil. With angles. They are easily broken. The world is round and soft.”[15]. Tatlin (1885-1953) was ecologically aware of the harmful fumes and by-products made by airplanes and other aspects of the urban environment, which led him to make the glider what he called an “air bike”, since it would be manually pedalled by the user and contain no motor to further contaminate the air. The Letatlin was used as a symbol to remind humanity that seemingly complex, industrialized objects can be made with simple, organic, and unprocessed materials, also meaning that pollution caused by urbanization didn’t have to be the only option. The Letatlin models were great examples of Russian Constructivist approach to art, with all of the models being made of natural, simple, organic materials that were constructed to make a practical and functional work that could not only be viewed by people but serve them as well. century.
At the same time Nikola Tesla (1856-1943) was into the incredible secrets of flight and antigravity which led him to register a patent in 1928, number 1,655,144 for a flying machine that resembled both a helicopter and an airplane. He called it “Space Drive” or the anti-electromagnetic field production system. Interestingly, according to William R. Lyne in “Occult Ether Physics”, in a conference that Tesla had prepared for the Migrant Welfare Institute on May 12, 1938, he spoke about the Dynamic Theory of Gravity. What Tesla was talking about here was unlimited energy, free energy that came directly from the environment (Fig. 5). Mysteriously, all of these incredible discoveries that have to do with Free Energy have been property of the Government, which apparently has made sure for the documents to remain far from the public and the media. Tesla was actually speaking about the conversion of energy into something much greater - “electropulsion”, used to control a weaker gravity force accomplishing more work in the same amount of time but producing more [16].

Nowadays, the engineering aspects of flight are the purview of aerospace engineering, the study of vehicles that travel through space.

4.2. Envisioning the human-friendly survival environment and the personal sky equipment

The presented proposal of "New Hope" Evacuation System for urbanized areas at the time of tsunami strike prepared by the Digitally Designed Architecture Lab (2017) at WPUT in Szczecin shows the possibilities of how to use biological forms found in nature and the latest pneumatic technology and conceptualized them into the human-friendly survival environment (Figure 6). The common snowberry shrub (Symphoricarpos albus) and the pneumatic portable bubble-house presented on the exhibition of the United Kingdom at the 15th Venice Architecture Biennale (2015) and air bubbles used in the new sports discipline called bubble soccer and Buckminster Fuller's works were chosen as a direct sources of inspiration.
The design team examined snowberry shrubs to find the essential dynamics of their design on the micro, micro, macro and medio scale. They did it in a belief, like Buckminster Fuller, that "nature's design is fluid, ephemeral, beautifully patterned and nature's technology is dynamic, lightweight, and driven by a functional imperative - optimum efficiency" [17]. Geometric patterns found in natural world can easy be explained by understanding the meaning of two words: tension and integrity. "Tensegrity describes a structural-relationship principle in which structural shape is guaranteed by the... continuous, tensional behaviours of the system and not by the discontinuous exclusively local compressional member behaviours" [18]. Fuller thus introduced discussion of the interplay of tension and compression forces in structural engineering.

One of the important issues identified in the initial design stage was engineering the personal sky equipment concept (Fig.6). Humans have managed to construct lighter than air vehicles that raise off the ground and fly, due to their buoyancy in air. The flying models provided by Nature have been an inspiration for building personal flying devices since time immemorial. life saving device.

A variety of actuators have been proposed for the personal flying equipment, including electromagnetic, piezoelectric, shape memory alloy, electroactive polymer, electrorheological fluid, magnetorheological fluid, microhydraulic, ultrasonic, and pneumatic methods [19]. Pneumatic power is particularly attractive for tactile displays since it facilitates design of compact, mechanically simple, and portable tactor arrays. Pneumatic actuation can be achieved with a variety of inflatable structures, fabricated from lightweight elastomeric materials. A compressed gas source and control apparatus can be connected by a run of narrow tubing to a thin pad containing the tactor array at the user's fingertips, leaving the user's upper body unencumbered by the bulkier components of the display [20].
Biological structures such as muscles, bones, fascia, ligaments and tendons or rigid and elastic cell membranes, are made strong by the balance between tensioned and compressed parts. Human body is a great example - the muscular-skeletal system is a synergy of muscle and bone. The muscles and connective tissues provide constant pull and the bones presents the discontinuous compression. Tension-compression interactions can minimalize material needed, add structural resiliency and constitute the most efficient possible use of space. The concept of tensegrity has also been developed in molecular biology by Donald E. Ingber, a pioneer in the field of biologically inspired engineering [21]. Recent work provides strong evidence to support the use of tensegrity by cells, and mathematical formulations of the model predict many aspects of cell behaviour [21]. For example, cytoskeleton can be mathematically modelled if rules of tensegrity model are used to express its shape.

Using analogies we can imagine, that the personal sky equipment would be work as a biological structures incorporating or interacting with the human body. With the use of parametric and multi-criteria optimization digital tools, a model of the personal sky equipment can be designed to respond to various requirements. Each of environmental factors could be processed by a personalized system.

5. Results
The final project design New Hope Evacuation System envisions a new concept of a personal protective equipment during tsunami strike. Each individual in the danger zone carries a backpack containing a personal, life saving capsule (Figure 8).

Figure 8. Michał Świtoń, Anna Biernat and Bartosz Garstka, New Hope Evacuation System for urbanized areas at the time of tsunami strike, West Pomeranian University of Technology in Szczecin, 2017.

When a tsunami warning system (TWS) detects tsunami in advance and issues warnings the capsule inside „life-backpack” unfolds itself and surrounds a person with protective sphere. The
individual is transported away from danger zone to safe destinations of artificial and intelligent skyscrapers that detect and pickup nearest capsules. Then the capsule carrying individual is transported to underground level, where essential infrastructure is provided: health care, food, housing and places for prayer. The skyscraper is self-sufficient with various systems, such as fresh water storage acquired from underground sources. Main objective of this place is to create essential base for future district inhabited by survivors. In conclusion, this design task can only be tackled by means of an integrated approach to design, i.e. interdisciplinary collaboration between architects, structure and environmental engineers.

The time to escape from a flood-risk area plays a key role in reducing negative impacts on people’s lives. Modern building science, computer engineering and possibility of using artificial intelligence gave us inspirations and opportunity to create an architectural concept of design New Hope Evacuation System (Figure 7). The project assumes the creation of individual rescue capsules, allowing for rapid evacuation of vulnerable areas. The first objective of the project is development of an efficient early tsunami warning system (TSW). Each individual carrying a life-backpack would be directly connected to the system. After receiving the warning message, each occupant inside the buildings must use the nearest emergency exit. The „life-backpack” can be activated in the open space. The capsule let off the backpack surrounds the user with protective sphere providing the right conditions to survive the evacuation journey. The system controlled by a GPS in order to reach the docking station located in the nearest safe area providing safe shelter for the time of the natural disaster. The destination is a docking station, located in the nearest safe area that provides safe shelter for the time of the disaster.

Our assumption is to reach the evacuation time of less than 5 minutes, from the alarm announcement to the start of the capsule. Earthquakes can happen very close to the coast, so it is crucial to reduce evacuation time as much as possible.

6. Conclusion
Urban institutional, policy, legislative and regulatory frameworks need to be reviewed to address the challenges posed by rapid urbanization, population growth, climate change and disaster risks. Climate change policy is often presented as a choice between mitigation and adaptation, where “mitigation” refers to efforts toward reducing the accumulation of greenhouse gases in the atmosphere and “adaptation” refers to adjusting to the impacts of a warming world. This dichotomy should be revised. Ensuring engagement of all relevant stakeholders is necessary to engender broad-based support for risk resilience and climate action. This should take place within the broader context of sustainable urban development. Security, health and wellbeing of populations must remain as a guiding principle in disaster risk reduction plans and programmes for the urban planning and architectural design.

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