Personal Sky Equipment for Inhabitants of Coastal Cities: Envisioning an Evacuation System to Reduce Disaster's Impact During the Climate Change Era

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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 author. The program is focused on adaptive built environments and envision 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
The increasing impact of natural disasters over recent decades has been well documented. This constitutes a serious threat to global security. The global climate change has already had observable effects on human life and its environment. 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 presented 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. **Natural disasters and hazards - climate action**

Natural disasters are defined as complex events “concentrated in time and space, in which 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].

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.

Global climate change may not be responsible for the past skyrocketing cost of natural disasters, but it is very likely that it will impact future catastrophes. According to Munich Re data, the frequency of weather-related catastrophes such as windstorms and floods has increased six-fold since the 1950s, while the frequency of other types of disasters has risen only slightly. Until recently, scientists and insurance experts had tended to disagree on the reasons for the rise in weather-related disasters, but there is now growing consensus that changing patterns of extreme events are a leading culprit. Climate models provide a glimpse of the future. Cities emit significant and growing amounts of greenhouse gases (GHGs) - accounting for 37-49 of total global GHG emissions [5]. An increase of greenhouse gases in the atmosphere will probably boost temperatures over most land surfaces, though the exact change will vary regionally. The Special Report IPCC (Intergovernmental Panel on Climate Change) emphasizes aspects hydrometeorological and oceanographic events; a subset of a broader spectrum of physical events that may acquire the characteristic of a hazard if conditions of exposure and vulnerability convert them into a threat. These include earthquakes, volcanoes, and tsunamis, among others [5]. In the Munich Re opinion even if the global community follows the path of decarbonisation (abandoning fossil fuels), the risks from weather-related natural hazards will, in all probability, continue to increase. This is because CO₂ has a mean residence time in the atmosphere of approximately 100 years and contributes to global warming throughout this period. The frequency and intensity of severely damaging weather events – torrential rainfall and heatwaves in particular – have already increased in many regions over the past few decades [5]. 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 2015 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) [6].

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. 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 [6].

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.

3. **Climate change oriented design - envisioning personal flying equipments**

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 [7]. An intention of this kind of design is to eliminate negative environmental impact through skillful, sensitive
design. This requires a view broader than ever, with a heavy emphasis on various interdisciplinary aspects [8]. 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 Januszkiwicz (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 design tools, 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 away of thinking and material systems.

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.

3.1. Personal flying apparatus and floating urbanism in the past - case study
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 Firmas (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 (figure 1a-b).

Figure 1. Flying models provided by nature before Leonardo da Vinci a) Ikarus' wings, b) Abbas Ibn Firmas' winged apparatus, c) Eilmer of Malmesbury's winged apparatus
Figure 2. Floating urbanism a) floating island city, named Laputa by Jonathan Swift, b) floating cities of the future by Hugo Grensback, c) Hawkmen's floating metropolis Sky City

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" [9] (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 [10] (figure2c). 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.

Figure 3. Lilienthal's early experiment

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 classic of aeronautical literature. Lilienthal was the first man to actually launch himself into the air and fly [11].
Figure 4. "Letalin" personal flying apparatus by Vladimir Tatlin

Vladimir Tatlin’s Letatlin personal flying apparatus was built between 1929 and 1931 (figure 4a-b-c). 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”[12]. 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 did not 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. built environment.

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. 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 [13] (figure 5a-b-c).
Nowadays, the engineering aspects of flight are the purview of aerospace engineering, the study of vehicles that travel through space. For example, Chinese researchers from Northwestern Polytechnical University (NPU) in Xi'an claim they've confirmed the theory behind this "impossible" space drive, and are proceeding to build a demonstration version. This could transform the economics of satellites, open up new possibilities for space exploration, and rapid evacuation to reduce disaster's impact during the climate change era.

4. Research
The research program undertaken in 2017 at West Pomeranian University of Technology in Szczecin attempted to solve the problem of human security in high-urbanized areas during natural disasters through envision a fast, personal evacuation system. Every individual in the area of direct and immediate danger should be equipped with a life saving device such as a personal flying apparatus.

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 intention of this design was not only to minimise but to completely eliminate any negative and dangerous effects of tsunami strike.

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, lifesaving 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, of tsunami strike.

The human-friendly survival environment design was inspired by Nature and Buckminster Fuller works. The design team likes Fuller looked to Nature to find the essential dynamics of her design on the micro, macro and medio scale - “Nature's design is fluid, ephemeral, beautifully patterned. Nature's technology is dynamic, lightweight, and driven by a functional imperative - optimum efficiency” [14]. Nota bene, Fuller conceived low-cost mass-produced emergency shelters and the concept of a dome as a multi-use building for homeless people. He also believed in a passionate and
committed form of architecture that would help citizens of Earth survive and prosper. His seminal works inspired designers around the world.

Figure 6. Formation of initial concept life saving capsule. Learning from Nature (Snowberry tree) and Buckminster Fuller work (the Fly's Eye Dome).

One of the important issues identified in the initial design stage was engineering the personal sky equipment concept (figure 6).

Geometric patterns found in natural world can easy be explained by understanding what mean the 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" [15]. Fuller thus introduced a discussion of the interplay of tension and compression forces in structural engineering. 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 [16]. 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. For example, a cytoskeleton is a dynamic three-dimensional structure that fills the cytoplasm. This structure acts as both muscle and skeleton, for movement and stability. The cytoskeleton can be mathematically modelled if rules of tensegrity model are used to express its shape.

Looking through the 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 processed by a personalized
Results and discussions
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, lifesaving capsule (figure 6). 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. But that is not a final stage of solution. The destinations are artificial intelligent skyscrapers. They catch nearest capsules and attach them to gates. Then a victim is transported under ground level, where essential infrastructure is provided. It contains health care,
providing 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 [17].

**EVACUATION SYSTEM** As the data above shows, 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, called New Hope. This project assumes the creation of individual rescue capsules, allowing for rapid evacuation of vulnerable areas.

The first objective of the project is developing an efficient early warning system. In order to give as much time as possible to escape we assume constant monitoring of the oceans to detect underwater earthquakes. This system would be directly connected to an alarm center that would inform each capsule holder and arms it. After hearing the message, the person is looking for the nearest exit. As soon as the user is in the open space, he or she can activate the capsule. Then the capsule surrounds the man, giving him or her the right conditions to survive the journey. The system is controlled by a GPS, so it is able to reach itself to a safe place. The destination is a docking station, located in the nearest safe area. This station provides safe shelter for the time of the disaster. The main assumption is to reach the evacuation time of less than 5 minutes, from the alarm announcement to the start of the capsule. Tsunami strike can happen very close to the coast, so it is crucial to reduce evacuation time as much as possible.

Presented vision opens a research for new solutions through implementation of advanced technologies and materials of the tomorrow especially during the climate change era.

5. Conclusions
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.

Acknowledgments
The author would like to thank WPUT Szczecin students (Master Program): Anna Biernat, Bartosz Garstka, Michał Świitoń and PhD student Karol G. Kowalski for his contributions to this work as well as for their efforts and enthusiasm throughout the WPUT Szczecin workshop.

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