Study on the Architectural Projects of the Floating Structures for Housing and Leisure, along the Danube

Iulia Claudia Danilescu[1]

Abstract: Floating structures for housing and leisure, give people opportunities to live, work, and play on the surface of the water. If someone is fond of a relaxing atmosphere, romanticism, and living on the water, there are plenty of reasons to live on a floating home. Such projects aim at bringing people closer to the natural aquatic lifestyle, without any negative impact of the water body. Another main advantage is safety during floods being a necessity in some of the areas. Also, such houses can be integrated with beautiful landscapes and comfort conditions with minimum energy bills and a small carbon footprint. There are also disadvantages of living on the water, one of them being limited space for storage, the cost and inconvenience of heating in the wintertime, and maintenance and repair if required. Nevertheless, architects are constantly developing solutions to minimise recurring electricity and water costs, which can be reduced by using unconventional energy sources. The large level fluctuations of the Danube waters, which are sometimes up to 8 meters, brought an additional challenge to the architects. To solve it, they designed appropriate structures, to which the floating houses are attached one by one.

Keywords: floating structures; floating and amphibious houses; leisure; sustainability

Introduction

Floating architecture can be considered a developed discipline regarding its extended history and the increasing number of contemporary projects. Nonetheless, its progressive advance over the last two decades is connected to the consequences of climate change and the overcrowding of metropolises. Also, the technological advances created the opportunity to design sustainable buoyant structures, with new, more economical construction methods and lighter, more durable materials.

The various types of waterfront constructions vary in function, size, and application, depending on their context and location. Considering our planet's water surface in comparison to land, and the increasing sea and ocean levels, it is inevitable to expand urban planning farther from shores and riverbanks. The notable benefits of such constructions are the resilience towards natural hazards, the modernisation of vulnerable floating communities, the furtherance of ecotourism, and the reconnection to the natural environment.

The Danube, as the second-largest river and a major axis of Europe, has invariably had a significant role in the economy, culture, and geopolitics of the continent. Additional to

[1] Interior Architect, Faculty of Interior Architecture, Ion Mincu University of Architecture and Urbanism, Romania, Address: 18-20 Academy Street, Bucharest 010014, Romania, Corresponding author: iulia.danilescu@outlook.com.

navigation and river transportation on the Danube, its riverbanks in municipalities offer the possibility of increasing the number of floating structures and modernising the existing ones. Moreover, the riverside vulnerable cities could benefit from the construction of floating and amphibious houses. There is also a notable potential for building floating, sustainable structures for leisure and accommodation in the particularly biodiverse Danube Delta, and elevate tourism by creating floating resorts.

Types of Aquatic Structures and Architecture

The terms of floating structures and amphibious architecture have multiple meanings in the literature, as a result of their extensive history and multi-disciplinarity. Albeit 'amphibious' indicates the quality of existing both on the land and in water, in practice, it can suggest either aquatecture - the architecture shaped in the water context or a building capable of floating on floodwaters. Aquatic architecture is frequently classified into three categories: flood resilient buildings (static or amphibious), waterfront buildings (buoyant or built on stilts), and moored watercraft, often without a navigation system. Nonetheless, researchers propose a less ambiguous typology of aquatic structures, where the terms are based on three criteria: the design approach, the level of mobility, and the position in relation to water (Piatek, 2016):

- over-water buildings: elevated, static and non-buoyant buildings supported by ground-based structures (piles, stilts) built over permanent or temporary water levels;

- waterside buildings: waterfront, submerged or partially submerged in the water basin, non-buoyant, erected on waterproof foundations;

- amphibious buildings: kinetic, buoyant buildings, constructed on land and supported by elevating structural systems of flood-proof foundations;

- floating structures: buoyant, movable, partly submerged structures, kept in place by a variety of systems such as mooring or stopping piles, anchors, and mooring lines; they include structures of different functions, applications, and sizes, comprising a singular unit or multiple interconnected floating units; depending on the number of units and their dimensions, they can form very large floating structures (VLFS) - artificial floating islands: floating breakwaters, bridges, airports, storage or military facilities, wind and solar power plants, parks, mobile offshore structures or floating cities and living complexes. (Wang & Tay, 2011);

- residential vessels: cruising, transient and buoyant watercraft designed especially for living on board, not as a means of transportation: houseboat, mega yachts, cruise ships;

- facility vessels: navigating, transient and buoyant watercraft designed to combine water mobility with the function of the land facility that needs to be substituted offshore (aircraft carrier, hospital ship, prison ship, or power plant ship).

Floating and Amphibious Houses

A floating house is a structure that incorporates a floatation system, intended for use or being used or occupied for residential purposes, containing one dwelling unit only, not primarily intended for, or usable in navigation and does not include a watercraft designed or intended for navigation. (British Columbia Float Home Standard, 2003).

Floating houses have been, for a while, a viable solution for coastal cities with issues related to flooding from the river and sea-level rise, land scarcity, and more recently, overpopulation. The earliest residents of houseboats were fishermen and merchants, then living on water became an economical alternative to a larger number of individuals during economic recessions. Recent years indicate an increasing interest in floating houses due to the technological advances and the benefits they offer to both vulnerable and affluent waterside areas.

Conventionally, floating houses are built on pontoon-type structures, with a flexible connection to the docks, due to the fluctuating to the water levels (Roy, Wagle, Vaghasiya, & Wadekar, 2019) The floating compartment is a waterproof platform made of fiberglass, steel, or concrete, filled with light-weight materials, such as foam, and the floatation system must be designed within the marine engineering and naval architectural standards.

A significant aspect of these constructions is their resilience potential (Moon C. , 2015). Buoyancy makes them resilient to natural hazards, and the potential use of renewable energy sources and nearly self-sufficient energy systems makes them resilient to energy shortage. Regarding the environmental damage, they are resilient through their mobility, long-term usage, water cycle system, and their prefabricated modules. Also, their resilience to social issues is given by their placid ambiance in direct connection with the natural environment, combined with the social unity and security within the floating communities.

The differences between floating and amphibious houses are given by their location and structure. While floating houses are built with a floatation system and they are located in a water basin, the amphibious houses are built on land and their structure elevates at the occurrence of floods.

Along the Danube, there have been proposed and built a reduced number of floating houses, in comparison to coastal areas. The selected projects follow design principles similar to contemporary floating or over-water houses located elsewhere: minimal-planned units with vast openings, terraces faced towards the aquatic environment with fixed or retractable sun-blinds, the use of wood in the facade cladding and other lightweight materials, in neutral tones that integrate with the scenery. The more recent proposals include systems for energy self-sufficiency, sustainable sewage treatment, and modularity of prefabricated units.

The conceptual project designed by Oszkar Vagi and Csinszka Cserhati aims at bringing inhabitants closer to Danube's panorama and its ecosystem, in Budapest, Hungary. Each house is connected to the bank via a pontoon bridge that overcomes the fluctuating levels of the river. The residential units include two bedrooms overlooking the Danube. The designers also considered the possibility of building units with underwater bedrooms. The floating houses are equipped with all basic facilities and they are designed to be energetically independent by utilising the water's thermal energy and solar energy for electricity (Contemporary floating houses in Budapest sit on Danube River, 2015).

Figure 1. Floating house project (Uszohaz), Hungary, 2015

Figure 2. DOC Floating House, Romania, 2016

The DOC floating house in Calarasi, Romania is designed by Lime Studio. The 60sqm construction was built on an existing abandoned pontoon, adapted by the architects. DOC is situated on the distributary channel Borcea and it was designed to be used as a temporary housing unit and a meeting point for water sports enthusiasts. The house is compact, with a minimal, rectangular plan. The open space with wide windows and a patio integrates with the aquatic environment (DOC Floating House, 2016).

The Egreta Complex is the first floating village of Romania, in Berzasca, Caras-Severin county, on the Danube Gorge. Each of the 15 over-water houses can host a family of three or four. On the first floor, a 16 sqm terrace extends from the living room and the bedroom area is on the second floor. The complete project included two identical islands, which included two swimming pools, a restaurant, a promenade, a marina, and a bicycle trail (The Danube River's floating houses in Berzasca, 2019).

Limitations of Floating Houses

Floating homes offer their residents a fitting solution of housing, however, there are a few limitations. Municipalities with a high number of such constructions expressed concerns regarding their safety provisions and location. Albeit the authorities developed a set of regulations regarding the design, construction, safety, and ease of access for ambulances and firefighters, they also must have jurisdiction over the area in which the floating houses or residential complexes are moored (Roy, Wagle, Vaghasiya, & Wadekar, 2019).

Further limitations are correlated with water quality and wind. Researchers found that the blockage of sunlight and shadow can affect the temperature of the upper layer of the water body and reduce the production of oxygen by photosynthesis which results in the development of a low dissolved oxygen zone below the floating houses and allows the development of sessile organisms. Moreover, the presence of floating houses can influence the wind pattern, depending on the distance between two adjacent houses. Fortuitously, studies revealed that the fluctuation of the oxygen level and wind levels are limited and temporary. Nonetheless, water quality parameters and the influence of floating houses on the surrounding environment require further monitoring, considering their increasing large-scale application (van de Giesen, et al., 2015).

Figure 3. Egreta Complex, Romania, 2016

Floating Structures for Leisure

Waterside cities tend to extend their urban tissue by building floating structures with multiple functions. These areas become a hybrid between land-based constructions and watercraft, as a transition towards the natural aquatic environment, and creating novel experiences for their users. The floating structures for leisure are often multipurpose, offering their communities a range of activities to choose from. These constructions also expand tourism, leading to the economic growth of the areas.

Floating swimming pools offer an appealing activity. In Vienna, Badeschiff (Swim ship) floats on the Danube Canal which meets the river Wien in the city centre. The 17 km long Canal is a recreational area for the Viennese. During the summer there are music festivals and flea markets. The swimming pool comprises two converted push barges, which were formerly used on the Rhine-Main-Danube canal system. The smaller barge is used only for swimming. It is 33 m long, 8 m wide and 1,6 m deep. The longer barge has three levels: the central level hosts the restaurant with a capacity of 750 people, the upper deck is a terrace with deck chairs and a barbecue, and the lower deck is a club equipped with bowling lanes (Floating swimming pool in the centre of Vienna, 2018).

Figure 4. Badeschiff, Austria, 2006

On the Danube riverbank, there are also various floating structures for accommodation and dining. Among the earlier ones, there are moored watercraft transformed into floating hotels and restaurants. For example, Anastasia 1 and 2 floating hotels are moored in the Danube Delta, in Uzilina. The watercraft have a maximum capacity of 34 passengers, in 8 (Anastasia 1) and 9 (Anastasia 2) fully equipped double rooms. Both hotels have a restaurant and bar situated at the upper level (Floating Hotel in Danube Delta, 2001).

The floating hotels or boatels follow the principles of floating houses, on a larger scale and many of them are built more recently. A relevant example is Boatel Charlie, moored beside Friendship Park, in Belgrade, Serbia. The floating hostel was built on a pontoon. It has four double rooms, two triple rooms, and two four-bedded rooms. The boatel also provides a shared kitchen and a large living room on the first floor. The cantilevered second floor creates a peripheral deck area that integrates with the natural environment. (Boatel Charlie, 2014).

Figure 5. Anastasia 1 & 2, Romania, 2001

Figure 6. Boatel Charlie, Serbia, 2014

Future Approaches to Floating Structures on the Danube River

Floating structures have been researched and built in numerous regions, either by the oceans, seas, or rivers. There is also a rapid development of amphibious architecture in areas that are constantly affected by natural hazards, such as floods, tsunamis, and hurricanes. The Danube riverbanks and waterfront areas allow the construction of amphibious and floating house projects implemented elsewhere, with preliminary research and potential adaptation of the projects to the river's context and parameters.

An important aspect is the vertical flexibility of the houses, as the water level of the Danube can rise to eight meters and various projects were designed for smaller fluctuations.Several European countries such as the Netherlands, Germany, and Austria produce prefabricated floating and amphibious houses of various configurations. Nonetheless, studies in the Netherlands show that the population is generally hesitant towards living in amphibious or floating prefabricated houses, due to the higher cost of acquisition and the insecurity on the interpretation of regulations by municipalities (Amphibious housing in Maasbommel, the Netherlands, 2015).

Recent conceptual projects and prototypes portray a promising future towards the design and sustainability of floating houses. Projects of modular dwellings seek to incorporate more efficiently manufactured standardized components and maximize the use of durable and non-corroding materials, with environmental efficiency with the potential to achieve near-zero energy use. They also prioritize the experience of inhabitants and promote a strong sense of community through shared spatial resources, such as floating gardens and terraces (Dada envisions modular floating dwelling units for coastal communities over the world, 2020).

An innovative project is the Floating 3D-printed house, Protozoon. Created by a team of architects and designers in collaboration with various consultants, the house is inspired by protozoa. The 3D printed house can be finalized in 32 hours and the 17 tons of concrete harden in approximatively a month.

The prototype, to be displayed in Prague on Vatava river, has an organic shape and a sculptural facade. The Protozoon passed the mechanical and sustainable resistance test and after further research, it could be a viable solution for the construction of floating houses (Czech Republic builds its first 3D-printed floating house in 32 hours, 2020).

Figure 7. 3D-Printed House, Protozoon, Czeh Republic, 2020

Other ingenious projects focus on accommodation in assembled floating units or pods, such as the houseboat designed by the Russian architect Max Zhivov and the “Athenea” pod. Zhivov’s design encourages eco-tourism and comprises an over-water house and a houseboat with a navigation system. Tourists can enjoy navigating autonomously and they can either be accommodated in the houseboat or in the over-water unit (Max Zhivov designs the 'tiny eco hotel' to travel across water, 2019). The “Athenea”pod is also autonomous and its spherical shape is ideal for resisting to extreme conditions on the water. The pod is made in France, designed by the naval architect Jean-Michel Ducancelle and it has an innovating sand screw anchoring that does not damage the underwater ecosystem. Furthermore, it is self-sufficient and every part of the pod is recyclable (The 'Anthenea' pod is a floating, eco-hotel suite running on 100% electric energy, 2020).

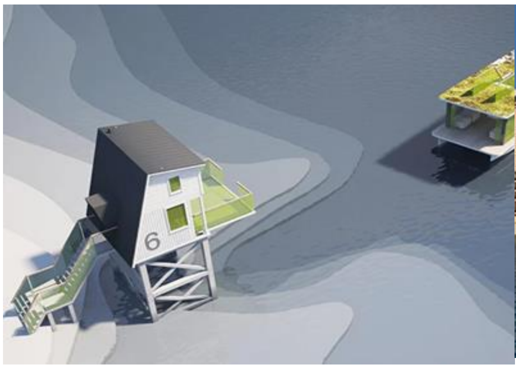

Figure 8. Tiny Eco Hotel, Russia, 2019

Figure 9. The "Athenea"Pod, France, 202

The latest projects designed for other sites can be a starting point for researching the construction of similar floating structures for leisure on the Danube River. For example, NLÉ Architects recently designed the fourth prototype of the Mokoko floating system, an energy-sufficient buoyant system of three wooden-framed triangular prisms, clustered around a central platform. The four prototypes have various functions from school to multipurpose centre and floating music hub. They were also placed on different locations, from Nigeria to Italy, Belgium, China, and Cape Verde (NLÉ and Kunlé Adeyemi are building a floating music hub in cape verde, 2020).

However, further approaches to building floating structures for leisure, on the Danube River, will probably have a limited size, due to the river's reduced width compared to other waterside areas. The floating structures should be sustainable and adapted to the specific conditions of the river. Also, future research should include the study of large-scale application of these floating structures, their resilience to natural hazards, and their potential impact on water quality, ecology, and riverside communities.

Figure 10. Floating music hub, Cape Verde, 2020

References

Amphibious Housing in Maasbommel, the Netherlands. (2015). *The European Climate Adaptation Platform Climate-ADAPT*. https://climate-adapt.eea.europa.eu/metadata/case-studies/amphibious-housing-in-maasbommel-the-netherlands.

*** (20 January, 2016). *Baca Architects completes buoyant house on the River Thames*. https://www.dezeen.com/2016/01/20/baca-architects-bouyant-amphibious-house-river-thames-buckinghamshire-floating-architecture.

Boatel, Charlie (2014). http://www.boatelcharlie.com.

*** (2003). *British Columbia Float Home Standard*. https://www2.gov.bc.ca/assets/gov/farming-natural-resources-and-industry/construction-industry/building-codes-and-standards/guides/2003_float_home_standard.pdf.

*** (21 September, 2015,). *Contemporary floating houses in Budapest sit on Danube River*. https://www.homecrux.com/contemporary-floating-houses-in-budapest-sit-on-danube-river/35235/.

*** (6 July, 2020). *Czech Republic builds its first 3D-printed floating house in 32 hours*. https://www.stirworld.com/see-features-czech-republic-builds-its-first-3d-printed-floating-house-in-32-hours.

*** (22 June, 2020). *Dada envisions modular floating dwelling units for coastal communities over the world.* https://www.designboom.com/architecture/dada-envisions-modular-floating-dwelling-units-coastal-communities-world-06-22-2020/.

Dal Bo Zanon, B.; Roeffen, B.; Czapiewska, K. & de Graaf-van Dinther, R. (2019). Potential of Floating Urban Development for Coastal Cities: Analysis of Flood Risk and Population Growth. *WCFS2019 Proceedings of the World Conference of Floating Solutions, Lecture Notes in Civil Engineering*. 41, pp. 299-308. Singapore: Springer.

*** (2000). *Danube Space Study Report.* https://ec.europa.eu/regional_policy/sources/docgener/studies/pdf/danube/part1/1-tds.pdf.

DOC Floating House. (2016, June). https://limestudio.ro/portfolio-item/doc-floating-house.

Endangish, T. & Ikaputra (2018). Floating Houses Technology as Alternative Living on The Water. IOP Conference Series. *Materials Science and Engineering*, ICMID. 797. Kendari: IOP Publishing Ltd.

English, E.; Klink, N. & Turner, S. (2016). Thriving with water: Developments in amphibious architecture in North America. FLOODrisk 2016. *3rd European Conference on Flood Risk Management*. Lyon.

*** (2020). *Floating and Moving Houses: A Need of Tomorrow*. https://www.mgsarchitecture.in/architecture-design/projects/380-floating-and-moving-houses-a-need-of-tomorrow.html.

*** (2007). *Floating Buildings.* https://www.hpw.qld.gov.au/__data/assets/pdf_file/0011/4313/mp-3-1-floating-buildings.pdf.

***(2020). *Floating Homes*. https://www.floatinghomes.de/en/house-types.html.

*** (2001). *Floating Hotel in Danube Delta*. Wild Danube: https://www.wilddanube.ro/en/.

*** (28 October, 2015). *Floating House/ Friday SA.* https://www.archdaily.com/776059/floating-house-friday-sa.

*** (6 June, 2020). *Floating House waterlilliHaus/ SysHaus*. https://www.archdaily.com/940995/floating-house-waterlillihaus-syshaus.

*** (2017, May 25). Floating Pools. https://www.architecturaldigest.com/gallery/floating-pools-to-seek-out-this-summer.

*** (2016). *Floating Structures design and analysis*. https://www.modlar.com/news/156/floating-structures-design-and-analysis/.

*** (April, 2018). *Floating Swimming Pool in the centre of Vienna*. https: www.itinari.com/floating-swimming-pool-in-the-centre-of-vienna-jit6.

*** (1 January, 2020). *Grimshaw and concrete valley develop innovative system of modular water dwellings.* https://www.designboom.com/architecture/grimshaw-concrete-valley-modular-water-dwellings-01-01-2020/.

Habibi, S. (2015). Floating Building Opportunities for Future Sustainable Development and Energy Efficiency Gains. *Journal of Architectural Engineering Technology*.

Leow, B. T. & Tan, H. K. (2019). Technology-Driven Sustainable Aquaculture for Eco-tourism. *WCFS2019 Proceedings of the World Conference of Floating Solutions, Lecture Notes in Civil Engineering*, 41, pp. 209-218. Singapore: Springer.

*** (24 May, 2019). *Max Zhivov designs the 'tiny eco hotel' to travel across water*. https://www.designboom.com/design/max-zhivov-tiny-eco-hotel-houseboat-05-24-2019/.

Mohamad, M. I.; Nekooie, M. A. & Ismail, Z. B. (2012). Amphibious House, a Novel Practice as a Flood Mitigation Strategy in South-East Asia. *Public Policy and Administration Research,* 2.

Moon, C. (2012). A Study on the Sustainable Features of Realized and Planned Floating Buildings. *Journal of Navigation and Port Research*, 36(2), pp. 113-121.

Moon, C. (2015). A study on the Floating House for New Resilient Living. *Journal of the Korean Housing Association*, 26, pp. 97-104.

Mutia, I. (2013). Old Tradition with New Approach: Water-based Dwellings in the Netherlands. *LANTING Journal of Architecture*, 2, pp. 51-61.

Nakajima, T. & Umeyama, M. (2019). An Integrated Floating Community Based upon a Hybrid Water System: Toward a Super-Sustainable Water City. *WCFS2019 Proceedings of the World Conference of Floating Solutions, Lecture Notes in Civil Engineering*, 41, pg. 309-328. Singapore: Springer.

Narasimalu, S. (2019). Floating Clean Multi-energy Systems Towards Driving Blue Economic Growth. *WCFS2019 Proceedings of the World Conference of Floating Solutions, Lecture Notes in Civil Engineering,* 41, pp. 329-357. Singapore: Springer.

*** (13 July, 2020). NLÉ and Kunlé Adeyemi are building a floating music hub in cape verde. https://www.designboom.com/architecture/nle-kunle-adeyemi-floating-music-hub-cape-verde-07-13-2020/.

Piatek, L. (2016). *Displacing Architecture? From Floating Houses to Ocean Habitats: Expanding the Building Typology.* Architecture for the Society of Knowledge, 1, pp. 273-280.

*** (4 February, 2020). *Powerhouse Company reveals floating off-grid office in Rotterdam* https://www.dezeen.com/2020/02/04/powerhouse-company-sustainable-floating-office-rotterdam.

*** (19 October, 2015). *Prefabricated floating house can be transported to lakes and waterways worldwide*. https://www.dezeen.com/2015/10/19/floatwing-prefabricated-floating-house-shipped-worldwide-university-of-coimbra-portugal/.

Ronzatti, G. & Lovric, P. (2019). Floating Infrastructure Large Scale Public Spaces on Water. *WCFS2019 Proceedings of the World Conference of Floating Solutions, Lecture Notes in Civil Engineering*. 41, pg. 49-66. Singapore: Springer.

Roy, A.; Wagle, R.; Vaghasiya, R. & Wadekar, P. (2019). Floating Construction. *Viva-Tech International Journal for Research and Innovation*, pp. 1-6.

*** (7 November, 2019). *Seine design floats 19th-century inspired glass restaurant over famed parisian river*. https://www.designboom.com/architecture/seine-design-floating-restaurant-rosa-bonheur-sur-seine-paris-france-11-06-2019/.

Simovic, M. & Stankovic, D. (2019). Activation of a Waterfront through Implementation of Floating Architecture. *Architecture Construction Education Journal*.

Simovic, M.; Krasic, S. & Nikolic, M. (2019). Floating Solutions: The New Meaning of Mobility. *WCFS2019 Proceedings of the World Conference of Floating Solutions, Lecture Notes in Civil Engineering*, 41, pp. 411-437. Singapore: Springer.

*** (17 July, 2020). *The 'Anthenea' pod is a floating, eco-hotel suite running on 100% electric energy*. https://www.designboom.com/architecture/anthenea-pod-floating-eco-hotel-electric-energy-07-17-2020/.

*** (2019). *The Danube River's floating houses in Berzasca*. https://www.itinari.com/the-danube-river-s-floating-houses-in-berzasca-2t5v.

van de Giesen, N.; Lima, R., de Graaf, R.; Boogaard, F. C.; Rutten, M. & Foka, E. (2015). *The effect of floating houses on water quality*. Amsterdam International Water Week Conference. Amsterdam.

Wang, C. & Tay, Z. (2011). Very Large Floating Structures: Applications, Research and. *Procedia Engineering*, pp. 62-72. Singapore: Elsevier.