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EMBRACING FLOATING ARCHITECTURE AND GREEN INFRASTRUCTURE: COASTAL INNOVATION FOR RESILIENT WATERFRONT COMMUNITIES IN BATAM CITY

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ABSTRAK
Untuk menanggapi masalah degradasi lingkungan akibat urbanisasi yang tidak terkendali, sehingga mengakibatkan emisi gas rumah kaca yang mengkhawatirkan serta kenaikan permukaan laut yang disebabkan oleh hilangnya es pada kutub dalam jumlah yang besar, artikel ini mengeksplorasi solusi untuk daerah pesisir yang rentan terhadap banjir yang memerlukan evaluasi ulang untuk mengakomodasi populasi yang terus bertambah. Artikel ini mengusulkan arsitektur terapung sebagai solusi untuk masalah ini. Arsitektur terapung dapat menyatu dengan badan air, sehingga dapat mengatasi kebanjiran. Pergeseran paradigma ini bertujuan untuk mengatasi keterbatasan ketersediaan lahan, tekanan urbanisasi, dan kenaikan permukaan laut dengan beradaptasi dengan tingkat air. Arsitektur terapung memungkinkan kota untuk berkembang ke perairan ketika lahan semakin langka. Arsitektur terapung juga berfungsi sebagai atraksi yang menciptakan pengalaman unik dan meningkatkan komunitas sekitarnya. Studi ini menggunakan metodologi kualitatif yang diikuti dengan pendekatan deskriptif untuk menganalisis proyek-proyek yang telah selesai dan yang prospektif guna mendapatkan wawasan tentang struktur terapung dan pertimbangan desain. Hasil menunjukkan bahwa mengintegrasikan desain berkelanjutan dengan arsitektur terapung jauh lebih hemat biaya, berkelanjutan, efisien, mobilitas, dan fleksibel dibandingkan reklamasi lahan.

Kata Kunci: arsitektur terapung, keterbatasan lahan, perkembangan pesisir, berkelanjutan

ABSTRACT
In response to the pressing issues of environmental degradation due to uncontrolled urbanization, leading to alarming greenhouse gas emissions as well as the consequential rise in sea levels that is caused by the extensive loss of ice, this article explores the solution to coastal areas that are prone to flood which require a re-evaluation to accommodate growing populations. The article proposes floating architecture as the solution to this issue. Floating architecture seamlessly unites with the water bodies. This paradigm shift aims to tackle limited land availability, urbanization pressure, and rising sea levels by adapting to water levels. Floating architecture allows the ability for cities to expand to the waters when the land is scarce. Floating architecture also serves as attractions creating unique experiences and enhancing the communities surrounding. This study uses qualitative methodology followed by a descriptive approach to analyze completed and prospective projects to obtain insight into floating structure and design considerations. Results show that integrating sustainable design with floating architecture is much more cost-effective, sustainable, efficient, mobility, and flexible than land reclamation.

Keyword: *floating architecture, limited land, coastal development, sustainable*

1. Introduction

In this modern world, we experience both incredible technological advancements and environmental shifts. Even though technology development is on the right path, it seems that the more advanced the tech, the more harm it does to the environment. 50 billion tonnes of greenhouse gases are emitted globally each year. Greenhouse gas emissions came from energy uses. Ritchie stated that 73.2% of emissions came from energy uses for industries like electricity, heat, and transport. In addition, population expansion, economic growth, lifestyle, energy, and land usage all contribute to greenhouse gas emissions that potentially to significantly alter the well-being of the environment. One of the greenhouse gas effects is the rising sea level. (Slater et al., 2021) stated that the earth has lost a staggering 28 trillion tonnes of ice between 1994 and 2017 which caused the sea level to rise 3.5 cm and will continue.

Particularly in coastal areas, it is evident that global warming significantly increases the risk of flooding. Many people will probably end up living in places more susceptible to sea level rise and more extreme weather events due to the pressure on available urban space. Despite the potential risks, the economic and social benefits of coastal development still outweigh them. Its strategic location opens up economic opportunities in shipping, trade, transport, recreation, and businesses. This could lead to an extensive build-up of wealth and infrastructure in densely populated coastal flood-prone areas. It is undesirable to introduce such a trend; we should also prevent inefficient urban planning. Urbanization also played a role in decreasing land space.

In urban development, balanced planning is essential to ensure controlled development. Uncontrolled development could lead to a degrading environment, increased urban sprawl, and disarray in land-use patterns. Eventually, this could disturb the idea of building sustainable urban development and resilience of the city. Rapid population growth pressures the urban areas to provide housing and infrastructure to accommodate the population's needs. Batam City's annual growth rate reached 2.11% with a total population of 1.230.097 people and with population density reaching 318/km2. Batam City has faced the problem of urban sprawl build-up in a few areas due to population growth, ineffective governance, and inefficient land use. With this problem growing, Batam City will soon face the problem of insufficient land. Currently, there are several land reclamations are ongoing to increase the coastal horizon. New urban living arrangements must be taken into consideration due to land shortages and the need to turn at least some impermeable urban surfaces into open green spaces. Future cities may benefit substantially from increased urban resilience if open water and urban floodplain use were approached more multifunctionally for residential, recreational, and other adaptive uses in addition to flood water storage (De Graaf, 2009). This problem encouraged broadening the building horizon and implementing an innovative approach that goes beyond the paradigm in how we designed and inhabited coastal environments. It is no longer a smart idea to "sterilize" such water-related areas by forbidding growth due to the risk of flooding. Larger cities usually have space constraints, thus building space on water might help to address the issue and broaden the city range.

Floating architecture refers to a structure that is designed to float and ride the waves gracefully while adapting to fluctuating water levels. Cooperating green infrastructure with the floating structure enhances sustainability and makes the structure itself self-sufficient which only relies on nature's regenerative powers. This paradigm shifts the traditional way of building on land, introducing the unity between technological advancement and architectural innovation that is more aware of the wellness of the environment creating a new coastal development. Hence, this concept not only becomes an effective solution for facing the rising sea level problem, but it also preserves coastal areas, is space-efficient and is much more efficient than land reclamation when facing the land insufficient problem. This study aims to explore the characteristics of floating buildings through projects that have been completed and proposed, as well as to recommend the applicable materials and methods for future building projects on water. Other than that, this study will include an overview of technologies to apply to floating structures and environment-friendly materials to keep in line with the sustainable concept.

2. Literature Review

Building and living on water by no means something new or inventive concept. In reality, there arenumerous examples of floating structures in Asia that were constructed since the 18th century. For instance, floating settlements coexisted in the South of Vietnam along with the inland fishermen tribes in the 18th era (Stopp & Strangfeld, 2021). There's a certain guideline dividing amphibious architecture based on its structure, its mobility, and its position in the water, considering the possibility of constant changes. The following types of amphibious structures have been suggested based on research conducted (Piatek, 2016):

a. Overwater building – non-buoyant building; is raised to the appropriate height to allow water to pass beneath it by using a foundation anchored in the ground.
b. Waterside building – built by or entirely in the water, non-buoyant building, waterproof foundations not intended to float.
c. Amphibious building – capable of floating on the rising floodwaters due to its lightweight and specific structure, such as the floatable foundation or a watertight chamber that forces aside the water and is supported by vertical piles to adjust vertically also to ensure the building stays in its place and prevent it from being carried away by the current. These structures are typically constructed next to a water basin and set on the ground.
d. Floating structure – a portable and buoyant structure that is partially submerged and rests on the water's surface due to its lightweight body and specific buoyant structure and watertight body. It is held in place by a variety of mooring systems.
e. Residential vessels – cruising vessels intended for living on board. Houseboats, megayachts, and cruise ships are examples of residential vessels.
f. Facility vessels – massive, temporary, and inflatable vessels are built to replace land- based facilities that require replacement offshore. Examples include aircraft carriers, jail ships, and power plant ships.

Floating Architecture

As its name suggests, floating structures are made to rest on the water's surface. To achieve such a goal, it requires unique structural components such as an inflatable foundation, a watertight body, and a mooring system to keep the floating structure in place and not being dragged away with the current. The following image can help to clarify the previous explanation:

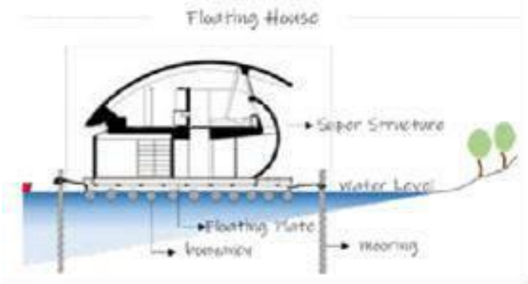

Figure 1. Floating Structure
Source: (Endangsih & Ikaputra, 2020)

The floating structure has several major advantages compared to land reclamation. Reclamation works require 2-5 years for the recovered area to stabilize after reclamation efforts (Rehman, 2020). If the fill material has been pumped from the seabed, the consolidation process will take several more years. In the meantime, a floating structure may be constructed somewhere else and assembled at the desired site due to the constructions are modular (Koekoek, 2010). However, (Wang & Wang, 2014) observed that this structure requires a higher skill set to build and manufacture. Additionally, the floating structure offers the superior advantages of mobility and flexibility. The floating structure can be expanded and grouped with other structures, or it can be taken down, towed, and sunk as an artificial reef, as needed. Not every situation will benefit from the floating concept. However, compared to land reclamation, this method offers greater advantages.

Structure

a. Floating Structure

The structure part where the superstructure is attached, consists of a cover layer, frameplate, and inflates. This part is also called a floating plate or even a pontoon. In Indonesia, floating systems are made from wood logs with a diameter range of around 80-100 cm (Murti et al., 2020) or even bamboo rafts and used drums as the floating system and main structure of wooden houses that are very vulnerable to high winds and water currents, due to limited building materials, particularly wood, other nations, like as New Zealand utilize a combination of structural steel and reinforced concrete, which eventually evolved into hollow concrete blocks (Endangsih & Ikaputra, 2020). Expanded polystyrene or EPS, serves as the foundation for this floating system, whichis then encased in a concrete shell.

b. Mooring System

It is a mechanism to restrict the structure's movement caused by waves, currents, andwind. The mooring system could be divided into permanent mooring and temporary mooring systems. Mooring systems vary between three varieties (Wang & Tay, 2011);

1) One mooring system with truss (attached mooring system/ permanent)
   Tethering a special part of the mooring line to the floating structure. There are two ways to implement this mooring system; truss fixed and the pier/quay wall technique.
2) Mooring system with piles
   It uses piles on both sides to keep the floating structure in position. Given that thepiles must be drilled into the ground, therefore this mooring system is permanent.Two different methods for applying this mooring system; the dolphin-frame guide method and the jacket pile and fenders method.
3) Mooring with cable
   The floating structure will be attached with anchors with fixed heading directions without swivel components. It's a spread-mooring system. There are two types of cable configurations; crossing mooring and spread mooring.

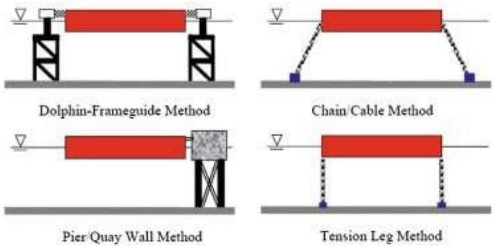

Figure 2. Mooring Systems
Source: (Wang & Tay, 2011)

Types of Floating Architecture

a. VLFS (Very Large Floating Structure)

A floating land parcel on the sea, normally only serves one function (large scale, ex; airports, bridges, ports, and utility plants). It's a giant plate resting on the water's surface. This flexible structure can be removed by being towed and sunk as artificial reefs or expanded and grouped with other floating structures. VLFSs are classified into two types: the semi-submersible and pontoon types. Pontoons mostly are deployed in calmer sea areas or where breakwaters and other wave-protectiveinstallations can be constructed to protect from large waves and swells. Pontoons alsoconsist of a mooring to keep the floating frame remain in place. Meanwhile, semi- submersibles are thicker than pontoons. It is partly raised above sea level using big watertight columns or tubes to withstand larger wavelengths and swells. Floating oil drilling platforms are one of the semi-submersibles. Materials used for floating surfaces are steel or composite materials of concrete or concrete steel and other materials that meet the specifications of floating buildings (Wang & Wang, 2015).

b. MFS (Modular Floating Structure)

A modular floating structure is multiple individual smaller modules that can be assembled and connected creating a larger group. Unlike Very Large Floating Structures (VLFS) that serve on single purpose either as airports, storage facilities, or energy plants, MFS is typically designed to have a modular layout that allows dynamic spatial growth. The advantage of MFS is its flexibility. MFS can be assembled on-site and transported when needed. MFS also promotes dynamic growth due to its ability to customization its function on every platform to correlate the demand. MFS is divided into two main parts, the substructure and the superstructure. Mooring and anchoring systems are also a part of the substructurefunctioning to prevent the structure from drifting away along with the current.

Meanwhile, the superstructure is where the functional building rests. This study uses MFS to create a dynamic space with dimensions of approximately 500 by 600 meters considering the “5 minutes walk” rule or (Perry, 2015) “neighbourhood unit” theory. Based on the (Kizilova, 2019) forms and function, the characteristics of modular floating structures that were emphasized were as follows:

1) “Branching” growth pattern: arranging the cluster on the water’s surface based on the growing branch principle.
2) Functional flexibility: modules’ structure can be changed to accommodate changing population needs.
3) Energy autonomy: modules are equipped with technologies that could produce themodule resource to provide energy. For instance, photovoltaic panels.
4) Continuous greenery: additional areas of green landscape to bring shade andnatural elements to the module.

Sustainability

Sustainability is a multifaceted concept that embodies the principles of ecological balance, social equity, and economic viability. It represents the capacity of human societies to meet the needs of the present generation without compromising the ability offuture generations to meet their own needs (Brundtland, 1985). Sustainability is not only about environmental protection but also about ensuring that people's basic needs are met, and they have access to resources and opportunities to thrive. It is about creating a world where ecosystems, communities, and economies can coexist in harmony to promote long-term well-being.

In architecture, sustainability aims to reduce the adverse effects of buildings on the environment by promoting strategic use of materials, energy, and development space. The structure ought to contribute positively and suitably to the social environment. For example, buildings should balance the ecosystem according to practical requirements, which can improve the well-being of humans and the quality of life (Nguyen, 2021). Therefore, sustainable architecture requires an eco-friendly and energy-efficient approach to designing the built environment. Floating architecture is one of the efforts of sustainable development for coastal development. Floating structures have the potentialto operate as stand-alone units. It is dynamic and adaptive because it works with the flowof water. Hence, the ability to float turns into a benefit with independent technologies such as wastewater treatment, wave energy generation, photovoltaic cells, rainfall collection, and saltwater desalination to provide renewable energy sources and reduce dependencies. Another advantage of buoyant architecture is its mobility. These structures are either temporary or movable; regardless of their size, they may be readily disassembled, rearranged, or even transported without impairing the users' ability to use them. The table below are few realized floating projects with their sustainability system:

Table 1. Realized Floating Architecture Projects

Project	Sustainability Systems
BUSAN OCEANIX - A blueprint created by OCEANIX and BIG for the world's first 10,000-person floating town. The idea behind the city is that it will grow organically over time, vibrant, self-sufficient modular neighborhoods with two hectares of mixed-use area for living, working, and meeting may accommodate up to 300 people. All of the built superstructure is below seven stories evolving from neighborhoods to cities and even beyond.	Net-Zero Energy: clean, inexpensive, and accessible energy produced from the sun, wind, sea, and waves.
	Freshwater autonomy: using the late water harvesting, filtering, recycling, and distillation technologies to supply fresh water.
	Zero waste systems: waste will be converted into electricity, feedstock for agriculture, and repurposed materials through closed-loop processing.
	Habitat regeneration: an innovative ocean technology called biorock, marine construction material that may grow, mend, and get stronger over time.
	Shared mobility: reduced transportation through shared and multimodal mobility as well as active modes.
Global Center on Adaptation (GCA) headquarters - The project, named Floating Office Rotterdam (FOR), is primarily constructed from European wood that has been acquired sustainably. A building's carbon footprint is greatly decreased. GCA's new global headquarters is fully self-sufficient.	Approximately 900 square meters of solar panels are arranged on the south-facing slope of the roof to capture as much sunshine as possible.
	The north side of the roof is covered by a green roof, which has several advantages including noise reduction, rainfall management, and energy efficiency.
Floating Pavilion in the Rijnhaven, Rotterdam - Completed in 2010, is an innovative and sustainable floating project located in the Rijnhaven harbor. Is designed to adapt to rising water levels and serves both as an iconic landmark and a demonstration of resilient urban planning.	Cooling with solar energy: heat is extracted from the auditorium by using solar collectors and absorption material.
	Vegetation wall: plants regulate humidity, improve air quality, and are used as noise isolation.
	Heat from the river: energy for heating and cooling is extracted from the river with heat pumps.
	Wastewater treatment: decentralized water treatment. Reclaimed water is used for toilet flushingand irrigation of plants.
	Microclimate concept: heating and cooling are dynamically regulated according to the use of space.
Makoko Floating School – The floating structure, which is half building and half boat, serves as an educational facility for the Makoko slum. Built on a floating platform composed of barrels is the Makoko Floating School.	Utilizing solar PV modules, adjusting to natural ventilation, recycling organic waste, and gathering rainfall for the toilet are all part of its design. The primary resources for the completed school's structure, support, and finishing are bamboo and wood from the surrounding area. The entire construction rests on a base that is normally used tostore extra rainwater collected in plastic barrels for the catchment system. Rainwater overflowing from the catchment system can be stored in the barrels around the perimeter.

Source: (Author, 2024)

3. Research Methods

The qualitative method, according to (Sugiyono, 2017), is more of an approach that takes its uniqueness from the post-positivist paradigm. It appears as a means of locating, discovering, and comprehending the significance of the occurrences under study which places a strong emphasis on subjective circumstances, researchers. Therefore, it is thought that the qualitative approach is the most effective way to collect data for this study. This method seeks to explore and analyse the data in great depth rather than concentrating on statistical generalizability. The qualitative method tends to use analysis and is descriptive. The research is carried out using a descriptive research approach, in which data is gathered, and analysed, and conclusions are drawn from all the available information. In this research, the focus is mainly on process and meaning. To ensure that the study focus is on relevant information, basic theories are employed as a guide. Furthermore, the theory serves as an outline for a general overview of the research introduction and provides material for case studies.

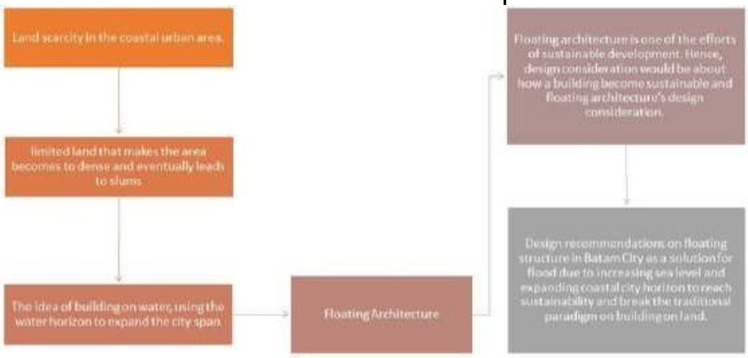

Figure 3. Thinking Process Framework
Source: (Author, 2024)

The article's data primary data are from geographical observation, while the secondary data come from previous studies and fundamental theory through research journals. The data then is processed and analysed in light of the floating structure's design consideration and implementation in Batam City.

4. Results and Discussions

Building a sustainable floating building needs to take a few main keys in its design process into consideration. There is no set standard for designing floating buildings since the materials that are accessible locally will vary from place to place and because each place has unique requirements that must be met while developing the floating structure itself. However, we could come to a consensus that to construct a sustainable floating building there are a few that are commonly found in sustainable architecture and summarized by (Wang & Wang, 2015)'s floating structure design considerations that should be considered when building:

a. Material selection: environmentally friendly and recyclable materials with low embodied energy and minimal environmental impact and preserve the existing sea ecosystem. Selected material also needs to resist corrosion and degradation for a longer life span.
b. Modularity and flexibility: design structures with modular components for easier assembly,disassembly, and maintenance to adapt to the possibilities of sea-level rise, storms, and other climate-related factors. The structure has to be resilient to withstand extremeweather.
c. Energy efficiency: integrate renewable energy sources such as solar panels or wind turbines to power the structure. Implementing energy-efficient systems for lighting, heating, and cooling. These could minimize the structure's reliance on outside resources.
d. Construction technique: implement pre-fabrication and modular construction

techniques to reduce on-site construction time and environmental impact to minimize disturbance to marine ecosystems.

e. Buoyancy and stability: the structure should have sufficient buoyancy to remain afloat andstable under varying conditions.
f. Waste management: develop systems for waste collection, recycling, and disposal to prevent pollution that could harm the marine ecosystem with closed-loop systems to minimize waste.
g. Biodiversity protection: design a support system for marine life, such as artificial reefs or habitat enhancement.
h. Water and energy conservation
i. Local community engagement and regulatory

Site Analysis

Selecting a site is a crucial process because the decision will impact the success of theproject and ensure that the chosen location aligns with the project's goal which is to respond to the resilient waterfront and sustainability. The chosen site is near a waterfront community were dominated by housing, resulting in the project functioning as an iconic multi-functional commercial area. Hence, the area wouldn't be filled with housing. The selected area is in waters where international ferries pass. The only land access is vacant undeveloped land, resulting inthe access to the site is unclear.

The selected site is currently enveloped by expansive undeveloped vacant land, the majority of which is designated for residential purposes in the future. Taking it into consideration, floating architecture emerges as a strategic solution, not only serving as a resilient response to natural disasters like floods but also presenting an innovative means for urban areas along the coast to expand their horizons without compromising land.

Table 2. SWOT Analysis

	Strength	Weakness	Opportunities	Threats
Location	Located in the center of the city. The site is also located near the international ferry terminal and government offices	Unclear road access	The building can be focused on commercial and public functions. This is because the site is surrounded by residential	Unclear road access that will lead to inaccessible sites.
	Unique location, breaking the tradition of building on land is one of the site's strengths that could be used as one of the city's icons			Other than the access, since the building is located on the sea waters, corrosions may happens more often

Neighborhood Context	10 minutes to the ferry terminal 9 min to Mondial School 6 minutes to the immigration office 4 min to One Batam Mall	Surrounded by few vacant land but still undeveloped and uncertain function. Hence, the access to the site is still not public	The first modern floating structure	Land development might disturb access
	There is some vacant land but the future land development is still unclear The site is surrounded by residential			
Size and Zoning	The total size of the area is about 165.000 m^2			
Legal	Permen KP no. 28 tahun 2021 KKPRL			
Natural Physical Features	Calm waters resulting in more stability	No shade	On-site plantscan be shade	Extreme tide
Man- Made Features			Floating commercial uses buildings	Land reclamation
Circulation	Two ways of access: landand water	Uncertainty of the landaccess	Could be a port	Land access may not be available
Utilities			Ways of a floating structure could stand alone with its waste management technologies and its self-sustainable technologies such as photovoltaic and desalination	
Sensory & Climate	This can be seen in figure 4			

Source: (Author, 2024)

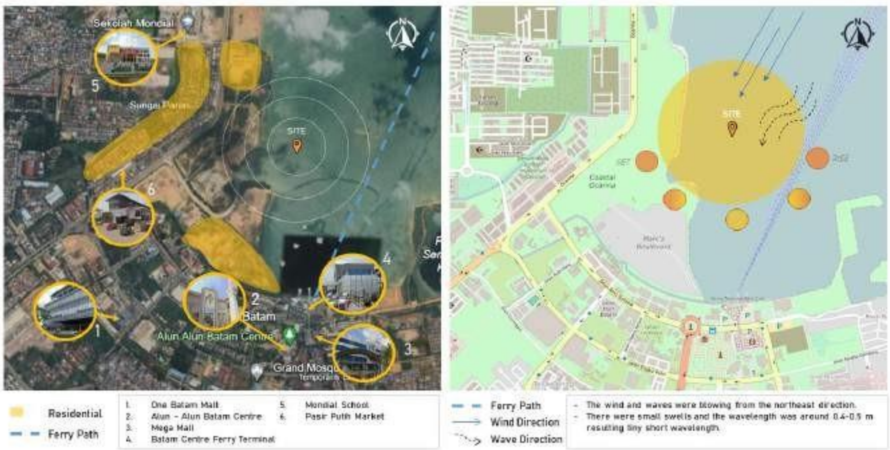

Figure 4. Site Analysis
Source: (Author, 2024)

The site analysis is based on Edward T. White's site data classification which is then combined with the SWOT strategy. Situated in the sea near Kecamatan Bengkong, Kota Batam with an area of 165.000 m^2. Based on (Jefridin, 2023), indicates the area is a prospective land reclamation plan and will be developed further as a sustainable environment (see Figure 5.) This deliberate choice aims to lessen the need for extensive land reclamation in the future.

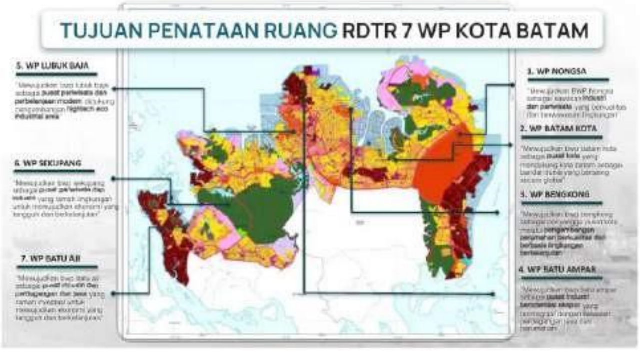

Figure 5. Batam Spatial Planning
Source: (Jefridin, 2023)

Following the completion of the analysis, the data has shown that the site is surroundedby residential/housing. Instead of introducing floating houses, this study will be focused on proposing the concept of creating a small "city" to expand the city horizon without land reclamation. The project will serve as a commercial public space to provide a space where thecommunity can engage and gather for activities. With the needs of the community in mind, combining retail, green spaces, and public facilities, the space becomes more dynamic, fostering a sense of belonging, and connection for the visitors.

Lay Outing

The very essence of this layout design draws inspiration from the principle of cell divisionand fusion. A district where architecture and biology converge in a mesmerizing dance of cellular life itself, influencing every curve and creating organic shapes. It consists of three sizesof modular structure and is placed randomly with organic-shaped floating paths to connect each structure. These floating structures eventually will become a city of its own inside a city, reflecting the growing cells inside cells. These structures function as commercial multi-functioning buildings to provide a new commercial and public space for the growing residents around the area.

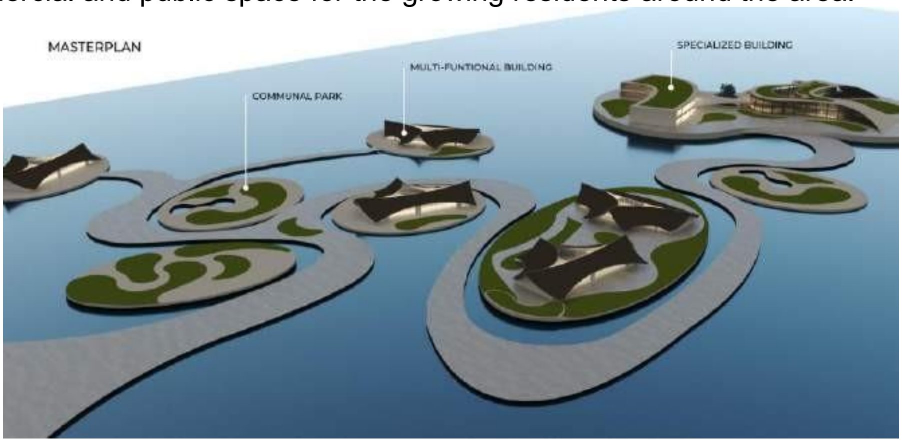

Figure 6. Masterplan
Source: (Author, 2024)

The specialized neighborhood facilities platform consists of two buildings with a bridge connecting each other. The area of the two-story right-wing building is 1549,94 m² per floor. It's a public building where all the public activities take place. Meanwhile, the building on the left wing is a semi-private building. It's the building where the authorized offices take place. The area of the left-wing building is 2404,29 m² per floor. Its expansive interior is strategically designed to host multifaceted events of heightened complexity, such as bustling port activities and art exhibitions. Figure 7 depicts the process of building mass.

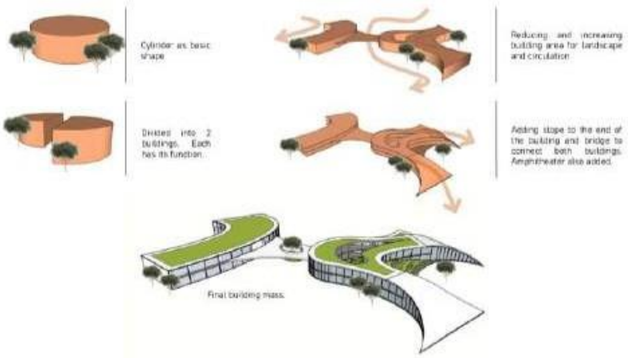

Figure 7. Building Mass Transformation
Source: (Author, 2024)

Figure 8. 3D Visualizations of Specialized Neighborhood Facilities' Building
Source: (Author, 2024)

The second building is a multi-function commercial building. This remarkable building spans an impressive 1058 square meters (about twice the area of a basketball court) and stands at a height of 8 meters. What sets it apart is the innovative arrangement of its roofs. Each roof is gracefully curved to interlock seamlessly, forming a cohesive enclosure. At the center of these roofs, a sizable opening facilitates air circulation, reducing the reliance on air conditioning.

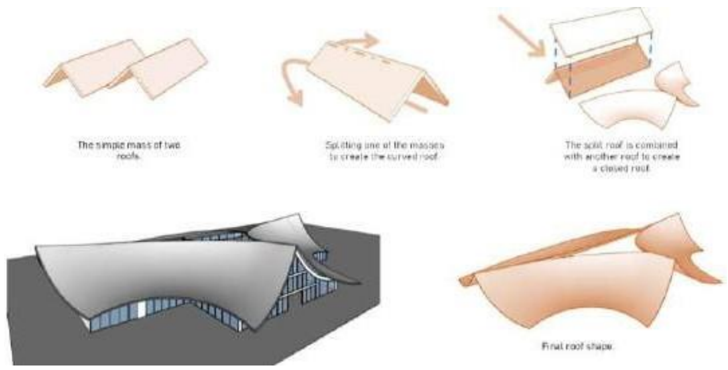

Figure 9. Building Mass Transformation
Source: (Author, 2024)

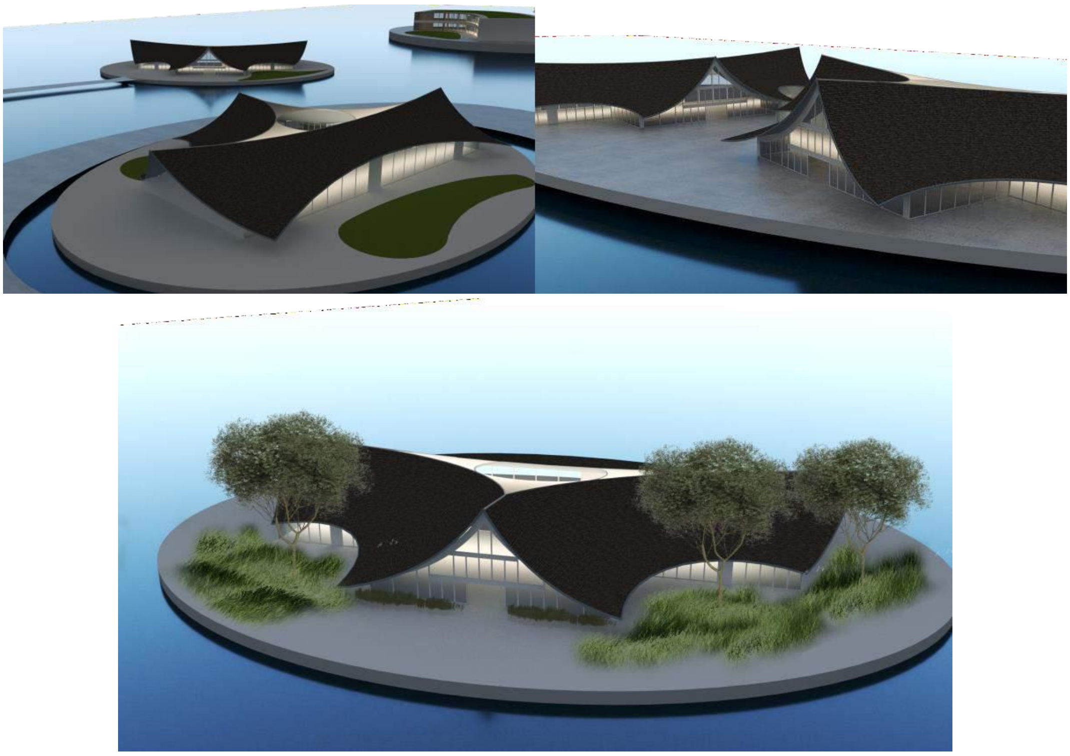

Figure 10. 3D Visualization of Multi-Funtional Building
Source: (Author, 2024)

Technologies

Sustainable floating architecture relies on innovative technologies to address environmental challenges and ensure resilience in the waters. Here are several technologies that are applied to the structures:

a. Photovoltaic systems: integration of solar panels on the roof surface to harness solar energy for electricity generation. In this design, we'll be using photovoltaic panels called "dragon scale" solar skin roofs. Other than their sleek looks, these solar skins could generate enough to power the whole building without concerning inefficient electricity.
b. Wave energy converters: harvesting systems that capture the kinetic energy from ocean waves and convert it into electricity. Even though the waves around the site's area are small, the harvested energy still could be used as backups.
c. Rainwater harvesting system: a rainwater collection system is essential when it comes to sustainable building. It captures and stores rainwater for various uses, such as irrigation, and cooling systems, or can be used for toilet flush.
d. Water treatment: water purification and desalination technologies to ensure a

continuous supply of freshwater.

e. Green roof: incorporating green roofs with vegetation on floating structures not only enhances aesthetics but also provides insulation.
f. Hydrothermal: using temperature differences between water and outdoor air as an energy source to be used for cooling and heating.
g. Waste treatment: implementing closed-loop processing that turns waste into energy. Greywater and wastewater will be processed and reused for watering plants.

Materials

Floating architecture involves designing structures that can float on water surfaces. To achieve the floating, chosen materials must be watertight, lightweight, floatable, and resistant to corrosion. Here are some considerations on floating architecture materials (Endangsih & Ikaputra, 2020):

a. Foundation (buoyant): made of steel, concrete, HDPE floating cube, and Expanded Polystyrene Foam (EPF). The chosen material has to be strong enough to support the above loads.
b. The house: this is the central structure, concrete, wood, and steel are typically used to make building frames. Materials for walls: glass, timber planks, and lightweight concrete.
c. Upper structure: steel or wood could be used for the roof truss.

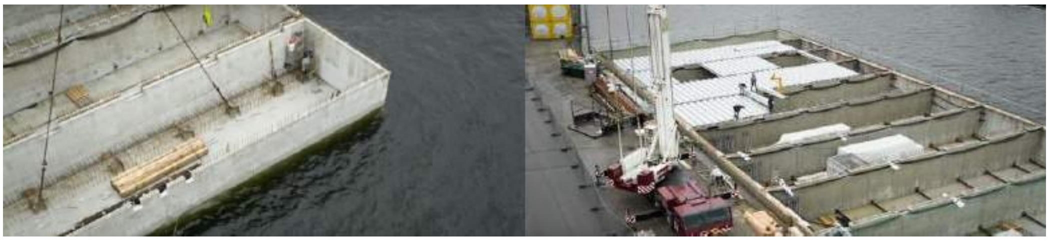

Figure 11. The Foundation of the GCA Office Building
Source: (IJzerman, 2021)

Concrete is a common building material. Its durability and widely used, concrete pontoons which are hollow structures filled with air allow it to be floatable. There's one type of concrete by LITEPANEL which is lightweight concrete. It's like the other concrete but this lightweight concrete could float and it's efficient when it comes to building. Other than concrete, plastic pontoons or High-density polyethylene (HDPE) pontoons are lightweight, durable, and resistant to corrosion. Often used in modular systems due to the ease of assembly. Steel is more suitable for the construction of the framework with a combination of concrete to create stability and resilience. Wood-treated hardwoods can resist water damage. Other than providing a warm aesthetic, wood also lightweight and easily to be found everywhere.

Another type of material is rubber which has been vulcanized and proved to be the most effective material for floating structures. They were simpler to move, lighter, and easier to replace or repair. Wood and canvas were used to create larger constructions that could support large weights. However, they are no longer in use and have grown outdated. Nowadays, steel, concrete, steel-concrete composite, advanced concrete, and plastics are the most often used materials. Either offshore concrete or waterproof concrete should be utilized since the ability of the concrete to withstand water is crucial for preventing or limiting corrosion of the reinforcing. The best use case for high-performance concrete with fly ash and silica fume is in corrosive salt water (Rehman, 2020).

5. Conclusion

Floating architecture represents a promising avenue for challenges like urbanization, land scarcity, and the impacts of climate change. Batam City is an ideal location for floating architecture due to its historical significance as a port city and its robust presence in the shippingindustry. The calm waters further enhance its suitability. Although the impact of rising sea levels may not be immediately apparent, it's noteworthy that Batam City is a coastal area that is prone to flooding. Batam City has a notable history of land reclamation. Recognizing the challenges posed by increasing population and the time-consuming and cost-inefficient land reclamation, floating architecture emerges as a more viable solution for addressing the city's spatial needs. In terms of sustainability, floating architecture has the potential to be a stand-alone structure. Integrating with technologies, floating architecture could produce its resources which makes it more sustainable. For structural, further research is needed.

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