Designing Large Scale Off-Grid Floating structure: A Modular and Adaptable Approach

Rising Above the Tides

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by creating large scale infrastructure on water?

June (Jae Won) Choi
Research Tutor Jos de Krieger
Design Tutor Stephan Verkuijlen

name June (Jae Won) Choi
number 5927986

Faculty of Architecture and the Built Environment
Delft University of Technology

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WATER - PAST, PRESENT AND FUTURE

WHY A “FLOATING CITY” HAS NOT YET BEEN BUILD?

Climate warming raises an important issue: how can infrastructure adapt with increasing sea levels?

Floating facilities can be removed if they become obsolete, towed, and sunk as artificial reefs, or expanded and grouped with other floating structures as needed (C.M. Wang, 2015)

Research Introduction

As global cities face increasing pressures from climate change, rapid urbanization, and rising sea levels, the need for adaptable, sustainable infrastructure solutions is more urgent than ever. This research explores the potential of large-scale modular floating structures as a response to these challenges, focusing on how such systems can provide critical infrastructure while maintaining resilience against environmental changes.

By examining scientific, engineering, architectural, and societal dimensions, this study aims to establish a comprehensive framework for the design and implementation of floating infrastructure. Key aspects of the research include energy and water self-sufficiency, environmental impact, and urban integration, with a focus on the relocation of airports to floating platforms as a model for addressing land scarcity in densely populated areas.

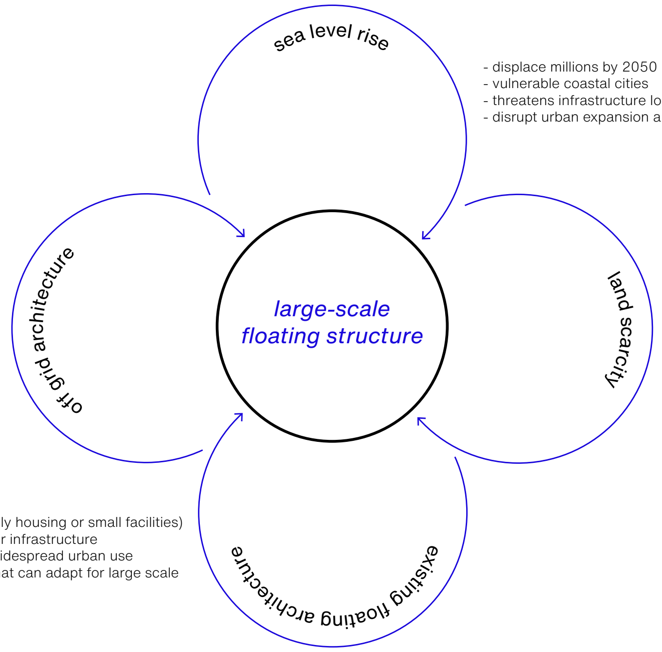
Through comparative studies between land-based and floating structures, analysis of existing energy and water supply systems, and case studies of airport terminals, this research will provide a grounded approach to envisioning how modular floating structures can serve future urban needs. The adaptability of these platforms—offering the potential for re-purposing or disassembly—ensures their relevance in the long term, contributing to a resilient and sustainable urban future.

Keywords

Floating infrastructure, Modularity, Off-Grid systems, Large-scale, Airport terminal, Buoyancy, Self-Sufficiency, Sea level rise, Closed-Loop systems, Resilient design

01

General Problem Statement



- displace millions by 2050 in low-lying areas
- vulnerable coastal cities
- threatens infrastructure longevity
- disrupt urban expansion and land reclamation

- need for independent energy and water systems
- integration of renewable energy remains limited
- underutilized water systems for larger applications
- high costs and technical barriers limiting expansion

- limited land availability in urban centers
- driving up real estate prices
- transportation and environmental issues
- existing infrastructure struggling to meet demands

- limited in scale (primarily housing or small facilities)
- technical challenges for infrastructure
- lack the flexibility for widespread urban use
- few floating systems that can adapt for large scale

Challenges of Large-Scale Floating Architecture

While smaller floating structures like housing and offices have achieved some success, the construction of large-scale floating infrastructures, such as airport terminals, remains largely unexplored. The engineering needed to maintain stability and functionality in varying water conditions is complex and lacks proven examples. High construction and maintenance costs, along with uncertainties surrounding permits and community support, add layers of difficulty to potential projects. Environmental impacts, including effects on marine ecosystems and water quality, must also be carefully assessed. The absence of substantial large-scale floating projects creates a gap in knowledge, complicating future developments in this area. Moreover, the lack of real-world evidence from large projects limits the understanding of their viability and adaptability, highlighting the need for research that examines the different aspects of floating infrastructure.

Melting Ice and Sea Level Continue to Rise

The melting of ice in polar regions due to climate change is causing sea levels to rise, which threatens coastal cities and areas. This increase poses risks of flooding and damage from storms, leading to the loss of land and putting communities at risk. As water levels continue to rise, coastal regions face significant challenges, including potential relocation of populations and infrastructure. The economic burden on local communities can worsen existing vulnerabilities, especially in low-lying regions that may lack adequate defenses against these changes. Additionally, the ongoing rise in sea levels complicates urban planning, making it necessary to consider designs that can accommodate shifting environmental conditions. Addressing these issues requires a comprehensive understanding of both the physical effects of rising waters and their broader implications for urban development and community resilience.

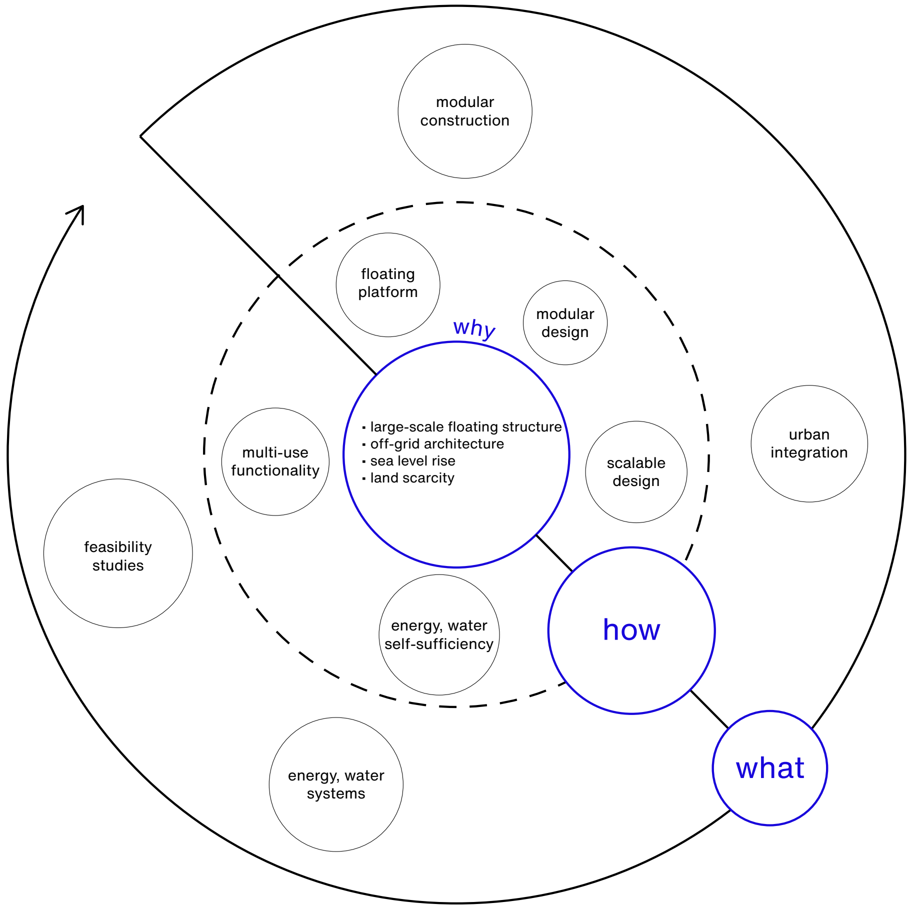
Energy and Resource Sustainability

As global demands for energy and water continue to rise, the sustainability of floating structures becomes increasingly important. These infrastructures must utilize renewable energy sources and effective water management systems to remain viable. However, adapting these technologies to meet the needs of large projects presents challenges related to both cost and efficiency. For example, while floating solar panels offer benefits, they often come with higher installation costs compared to land-based alternatives. Ensuring a steady supply of energy and water under varying weather conditions complicates the design and operational aspects of these systems. Additionally, competition for resources in urban settings raises critical questions about how floating structures can be designed to minimize environmental impacts while maximizing efficiency. Understanding these factors is essential for developing floating infrastructure that is both sustainable and capable of adapting to a changing world.

Increasing Population and Overcrowded City

As the global population continues to increase, cities are struggling to accommodate the growing number of residents. This surge leads to a scarcity of land, resulting in crowded living conditions, rising property prices, and a loss of essential green spaces. Many urban areas find themselves at a critical point where available land is insufficient for new developments. In this context, building on water presents a viable alternative to traditional land-based construction, allowing for the expansion of urban environments. However, the transition to water-based infrastructure requires careful consideration of design, functionality, and the impact on local ecosystems. As cities seek to address land shortages, exploring floating architecture becomes increasingly relevant to ensure sustainable urban growth.

02 Overall Design Objective



1. The Need for Water-Based Infrastructure

As land becomes increasingly scarce due to urban expansion and environmental changes, turning to water as a foundation for infrastructure offers a practical solution. Urban areas are growing at an unprecedented rate, creating pressure on available land for both living spaces and industrial purposes. By building on water, we can alleviate this pressure, allowing cities to expand without further compromising the land. Floating infrastructure provides a new layer of flexibility, creating opportunities to harness underused bodies of water and balance urban growth more sustainably. This shift in thinking opens the door to developing structures that not only address space limitations but also contribute to resource management.

2. Aviation Challenges and Responsibility

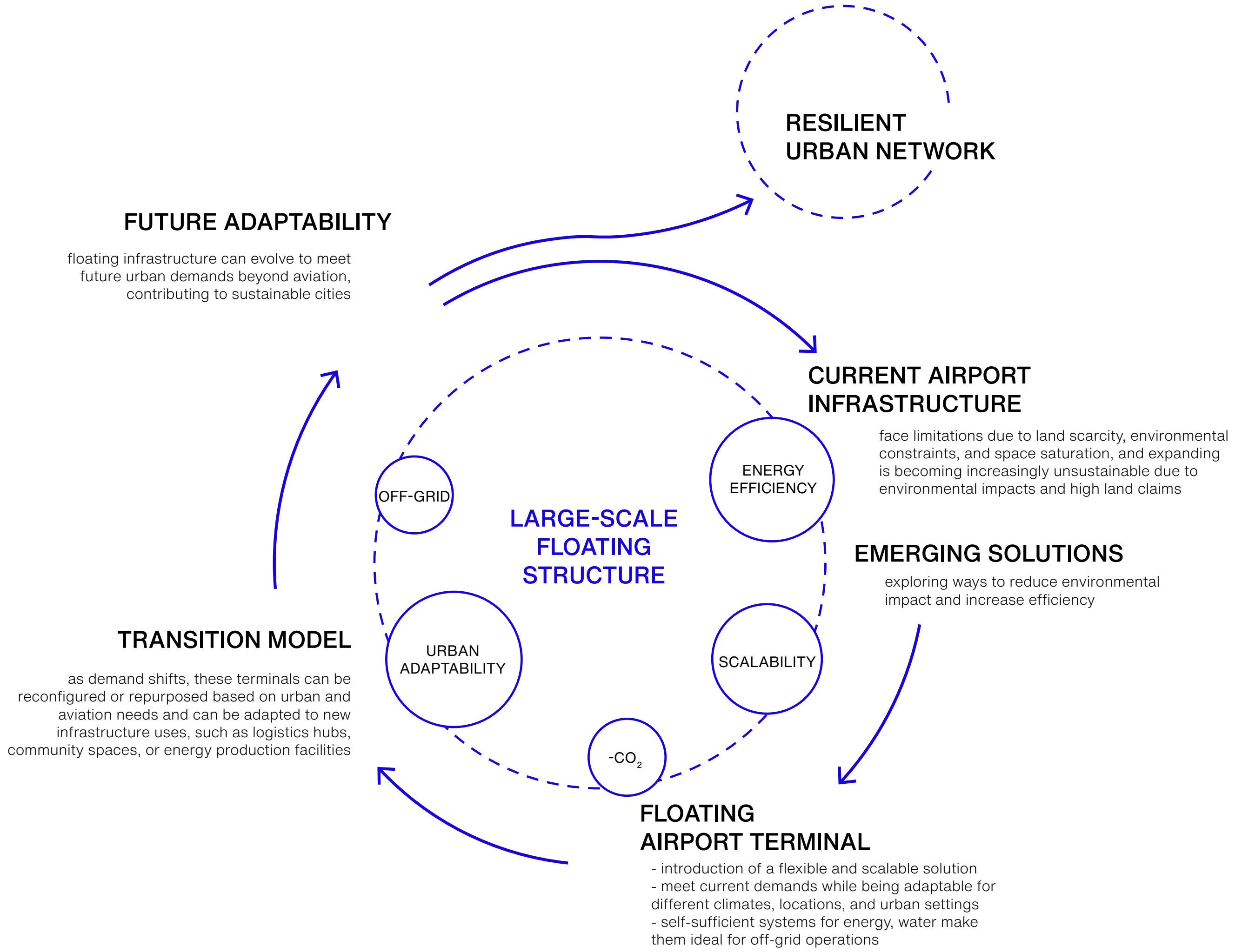
As countries and industries look for ways to reduce their environmental impact, the aviation sector remains under scrutiny for its carbon emissions. While alternatives such as high-speed trains and electric vehicles are emerging, airports remain essential to global connectivity and commerce. Even with efforts to make aviation greener, the demand for air travel is likely to continue, meaning that airports must evolve alongside other transport solutions. Floating airports can offer a transitional solution that adapts to both short- and long-term changes in travel and freight needs. By focusing on modular designs that incorporate renewable energy and water self-sufficiency, we can reduce the environmental impact of these terminals and ensure they operate independently of traditional infrastructure.

3. Airports as Flexible, Transitional Infrastructure

Floating airport terminals allow us to rethink the way infrastructure serves its purpose. They can be designed to be flexible, meeting immediate demand while also being adaptable for future repurposing. Rather than locking up land for long-term airport use, these floating terminals can transition into new forms—whether for public spaces, research platforms, or other community functions—when air travel becomes less central. This reduces waste and the environmental footprint of infrastructure projects, as the terminals can be disassembled or shifted to different uses when no longer needed. Self-sufficient energy and water systems allow these terminals to remain operational in changing cities or countries, extending their usefulness beyond their initial purpose.

4. Sustainable Design for the Future

The key to the future of floating terminals lies in their ability to be self-sustaining. These structures will rely on renewable energy sources like solar, wind, and heat exchange to function off-grid, reducing their dependency on traditional energy networks. Additionally, integrating advanced water recycling and management systems will enable them to operate independently of municipal utilities, addressing one of the biggest challenges for floating infrastructure. As sea levels rise and coastal cities face increasing threats, floating terminals provide a resilient, mobile solution that can adapt to changing environmental conditions. Their modular, scalable design makes them applicable to various geographic and climatic contexts, ensuring they remain viable as our cities and economies evolve.



1. Current Infrastructure Limitations

Traditional airport infrastructure faces increasing pressure from several directions. Due problems such as noise and high land price, making the expansion or development of new facilities are becoming increasingly difficult and costly. Airports are often constrained by their fixed locations, surrounded by built environments and political boundaries, limiting their ability to meet future demand. Environmental issues such as rising carbon emissions, noise pollution, and threats to biodiversity further these challenges. Additionally, as air travel and air cargo continues to grow, airports increasingly contribute to congestion and unsustainable energy usage, putting even greater strain on overburdened systems.

2. Modular Floating Structures

Modular floating structures provide a practical, adaptable alternative to the limitations of traditional, land-based infrastructure. These floating platforms can be expanded, reduced, or reconfigured based on changing demands. They also offer the potential for transformation into different space programs, such as converting the floating terminal into residential, cultural, or industrial spaces if the initial function is no longer required. This flexibility not only ensures that the infrastructure remains useful over time, but also increases its cost-effectiveness and sustainability. Floating structures avoid permanent land use, allowing them to meet the infrastructure needs of cities while preserving ecosystems and mitigating land scarcity issues.

3. Future Adaptability and Integration

The flexibility of large-scale floating infrastructure aligns with future urban planning goals aimed at enhancing climate resilience and minimizing environmental damage. These floating platforms not only provide immediate solutions to current land and infrastructure challenges but also offer the potential for long-term adaptation. In the future, these structures can integrate advanced systems for renewable energy generation, water management, and climate mitigation, all while reducing the strain on land-based infrastructure. Whether they need to be scaled up or transformed for new functions, floating structures remain flexible, capable of adjusting to changing societal demands and reducing the environmental impact of cities over time.

4. Bridging Current and Future Infrastructure

The design focuses on developing a transition model that bridges the gap between current airport infrastructure and future floating scenarios. The proposed model envisions a floating terminal, while the runway remains on land, as there is no existing floating runway yet. This approach allows for a gradual adaptation to floating infrastructure without compromising the stability and safety of key airport functions. Japan previously explored the possibility of a floating runway but abandoned the idea due to concerns about structural stability. By focusing on a hybrid system, this design aims to provide a feasible and scalable solution for future airport infrastructure, addressing both current limitations and future adaptability.

03 Design Question and Relevance

How can large-scale modular floating structures support society's infrastructure demands while ensuring adaptability for future expansion, re-purposing, or disassembly in response to changing urban and environmental needs?

Design Relevance

The design objective of this project holds importance from both societal and user perspectives. This design is intended to adapt to the changing demands of urban landscapes and environmental conditions, offering a flexible approach to addressing community needs.

By targeting the infrastructure gap in coastal and urban areas, this project benefits a diverse range of stakeholders, including local governments, urban planners, and residents. The adaptability of these floating structures allows for re-purposing or disassembly as circumstances evolve, ensuring they remain relevant and useful over time. The flexibility of floating infrastructure provides new opportunities for development in a range of settings, especially those where traditional land-based solutions face environmental challenges.

This project also holds particular relevance in the context of climate change and rising sea levels, which threaten traditional infrastructure. By exploring floating solutions, it contributes to discussions around sustainable urban development and resilience, emphasizing the need for infrastructure that can withstand environmental changes. The design aims to create spaces that not only meet current needs but are also prepared for future uncertainties, ensuring longevity and sustainability.

Ultimately, while the project focuses on the specific application of modular floating structures, its broader implications provide a framework for future infrastructure solutions that can be tailored to various contexts around the world. The research will enhance understanding of how floating architecture can coexist with existing urban frameworks and contribute positively to the environment and the communities it serves.

Relocating major airports in the Netherlands presents a feasible approach to addressing the challenges associated with increasing urban populations and environmental concerns. One possible location for moving Rotterdam Airport is Maasvlakte, an artificial land at the Port of Rotterdam. This area has plenty of space for a floating airport, thanks to its existing facilities, deep-water access, and strategic location that supports both shipping and air traffic. The industrial and logistical strengths of Maasvlakte make it a fitting choice for incorporating sustainable, modular floating structures, aligning with the Netherlands' aims for climate adaptability and resilience.

On the other hand, Markermeer serves as an ideal site for relocating Schiphol Airport. This large lake, situated between North Holland and Flevoland, is close to major urban areas, making it easy to reach for passengers and cargo. The potential for floating infrastructure at Markermeer is enhanced by its location near Amsterdam and surrounding regions, offering a strategic advantage in easing air traffic congestion at the current Schiphol site. Developing a floating airport here not only seeks to address land shortages but also aligns with efforts to foster more sustainable urban spaces, making use of renewable energy sources that prioritize community needs.

04 Thematic Research Objective

1. Exploring the Scalability and Global Applications

The research begins by examining the scalability of large-scale floating structures, focusing on their capacity to serve as infrastructure in diverse global contexts. These platforms can be designed to scale up for large urban centers or down for smaller coastal communities, adapting to the unique needs of each region. This objective is to explore how modular floating structures can be implemented to alleviate space shortages in densely populated cities, but also how they can expand to meet infrastructural needs in emerging or rapidly growing regions. By investigating multiple case studies and simulation scenarios, the research will determine methods for scaling these platforms while considering local environmental conditions and regulations.

2. Assessing Feasibility and Buoyancy for Diverse Environments

A key focus of the research is on the feasibility and buoyancy of floating structures in various water environments, ranging from sheltered bays to open seas. The investigation will explore the engineering challenges of ensuring long-term stability in water conditions, such as fluctuations in water levels and wave dynamics. By researching buoyancy technologies and materials, the research will assess how these platforms can be safely deployed and maintained in diverse aquatic settings. Feasibility studies will include both environmental impact assessments and economic considerations, ensuring that these platforms can remain viable and cost-effective over time without imposing undue stress on local ecosystems.

3. Energy Independence through Integrated Renewable Systems

To ensure sustainability, the research will investigate the integration of renewable energy systems such as solar panels, wind turbines, tidal energy converters, and heat exchange systems. These technologies will be evaluated not only for their ability to generate sufficient power for the platform's immediate needs but also for how they can contribute to surrounding infrastructure, potentially exporting excess energy to nearby cities or towns. A focus will also be placed on energy storage solutions, ensuring that the platform remains self-sufficient during periods of low renewable energy production. The goal is to create a fully self-sustaining energy loop that can maintain the platform's operations independent of traditional power grids, making it a true off-grid infrastructure solution.

4. Developing Self-Sufficient Water Supply Systems

Water sustainability is equally crucial, and the research will focus on creating a self-sufficient water supply system for large-scale floating structures. This system should incorporate advanced rainwater harvesting, graywater recycling, and wastewater treatment technologies to form a closed-loop water management system. The study will explore how to optimize water usage, ensuring that these platforms can support a variety of programs, from residential to commercial, without relying on external water sources. Special attention will be given to the adaptability of these systems, allowing them to be scaled or modified as the platform grows or its usage changes. By achieving water independence, these floating structures can function in water-scarce regions or isolated locations where traditional water supply infrastructure is impractical.

5. Ensuring Adaptability and Modularity for Future Needs

The research will focus on the adaptability and modularity of large-scale floating platforms, emphasizing their potential to be reconfigured, expanded, or even disassembled based on changing urban needs. This flexibility will be essential as cities evolve and infrastructure demands shift, allowing the platform to serve a wide range of functions over its lifespan. Whether re-purposed for new uses, expanded to accommodate growing populations, or relocated to a different site, these structures will offer a dynamic solution to the challenges of modern urban development. The adaptability of modular components also provides a pathway for integrating new technologies over time, ensuring that the platform remains future-proof and relevant for decades to come.

05 Thematic Research Question

How can large-scale modular floating structures be designed for feasibility and sustainability?

Buoyancy

- How can large-scale floating structures be designed to achieve optimal buoyancy and stability in various water conditions, ensuring their functionality and safety?
- What design principles and materials can be employed to enhance the buoyancy and resilience of modular floating structures against environmental factors?

Adaptability

- What modular design strategies can be utilized to allow for the future expansion or reconfiguration of floating structures in response to changing environmental or community needs?
- How can the design of floating structures incorporate flexible spatial arrangements to accommodate different functions over time, enhancing their adaptability?

Energy Supply

- What renewable energy technologies (such as solar, wind, or tidal) are most suitable for integration into large-scale floating structures to achieve energy self-sufficiency?
- How can energy storage systems be designed to ensure a reliable power supply for floating structures during periods of low energy generation?

Water Supply

- What systems can be implemented for the collection and treatment of rainwater and wastewater to ensure a sustainable water supply for floating structures?
- How can graywater recycling systems be effectively designed to maximize water efficiency in large-scale floating structures?

Societal Relevance

Urban and Climate Challenges

Floating structures offer a practical solution, creating additional infrastructure that adapts to urban growth while addressing environmental challenges. These structures contribute valuable space for cities facing population pressures and mitigate the impacts of rising sea levels, supporting sustainable urban development.

Sustainable and Self-Sufficient

The potential for floating structures to be self-sufficient in terms of energy and water supply offers a sustainable alternative for urban development. These systems would reduce dependency on traditional, land-based resources and provide more resilient infrastructure that can adapt to climate change and resource scarcity.

Long-Term Benefits

In the long run, implementing large-scale floating structures could change how cities expand, providing adaptable and scalable infrastructure that can evolve with urban needs. By reducing the environmental footprint of urbanization, such designs can contribute to healthier, more sustainable cities.

Scientific Relevance

Large-Scale Floating Systems

Researching large-scale floating structures fills a gap in current knowledge, especially regarding the technical challenges related to buoyancy and structural integrity. Understanding how these structures can remain stable over time is crucial for developing viable infrastructure on water.

Renewable Energy and Water Systems

This research will also advance the scientific understanding of integrating renewable energy systems such as wind, solar, and heat exchange within floating structures. By focusing on energy and water self-sufficiency, this work contributes to creating environmentally responsible infrastructure solutions.

Modularity and Adaptability

By studying modularity and adaptability, this research provides new insights into creating infrastructure that can be easily modified, expanded, or re-purposed. The ability to disassemble and reassemble floating structures offers flexibility that is crucial in responding to changing urban or environmental conditions.

Feasibility? Stability?

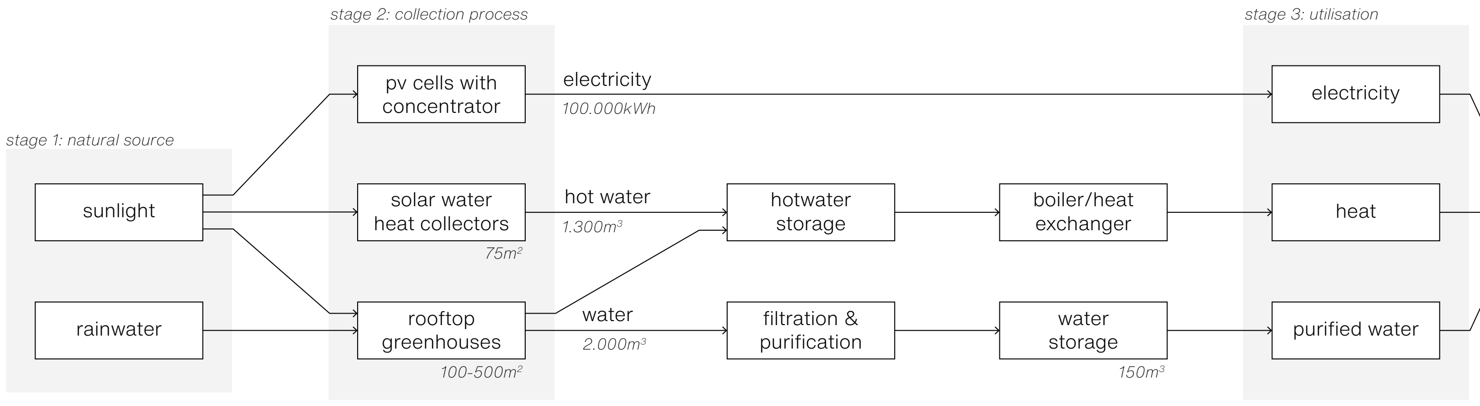
In this research, feasibility centers on the floating pontoon's ability to safely support intended loads and function in aquatic environments. This includes evaluating structural stability through buoyancy testing and load analysis, ensuring the design can withstand expected pressures and conditions like wind, waves, and shifting weights. The feasibility also involves dimensional guidelines—analyzing optimal pontoon size for different applications and evaluating how the structure can accommodate various uses without compromising stability or safety. Additionally, understanding the pontoon’s overall stability requirements aids in designing secure connections to the mooring system, ensuring the structure maintains its intended position and orientation under changing environmental factors. Through feasibility testing, this research will establish a foundational understanding of how modular floating pontoons can reliably meet the unique demands of large-scale infrastructure on water.

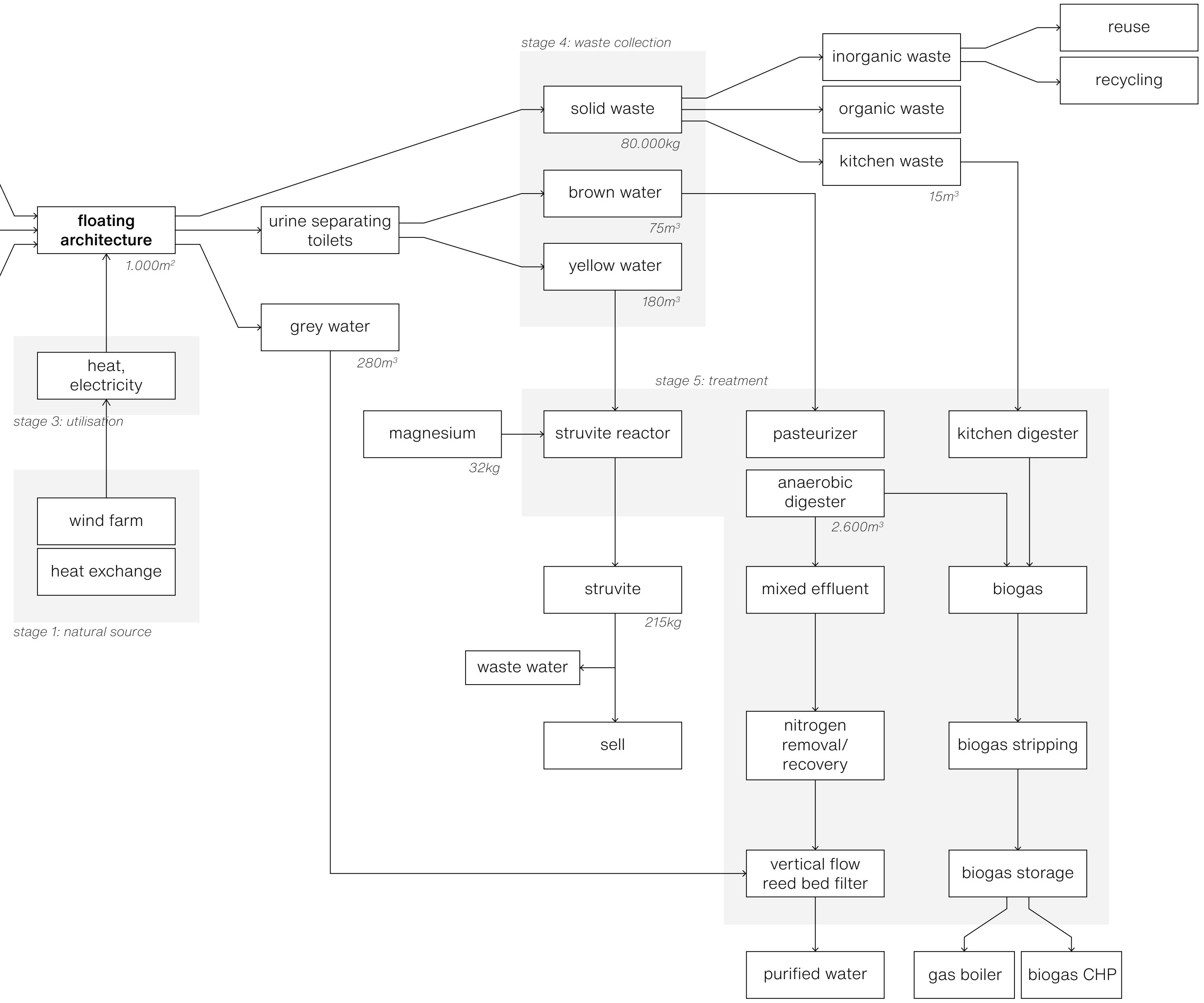
Self-Sustaining? Sustainability? Self-Sufficient?

The terms self-sufficiency and sustainability in this research relate to the pontoon’s capability to operate off-grid, minimizing dependence on external resources. The self-sufficient model integrates renewable energy systems, such as solar panels for electricity generation, to support all necessary on-board functions. Water self-sufficiency will involve methods for rainwater collection, purification, and recycling, with graywater treatment systems in place to support reuse and reduce waste. Heating needs can be addressed through passive solar heating or heat exchange systems, allowing the structure to maintain comfortable conditions without extensive energy inputs. These off-grid elements of self-sufficiency contribute to the broader goal of sustainability, aiming to minimize the environmental impact of large-scale floating infrastructure and provide resilience and adaptability in a variety of urban and coastal contexts. This approach not only supports the pontoon’s primary functions but also reduces operational costs and enhances its long-term viability in response to evolving environmental and urban needs.

Energy and Water Loop

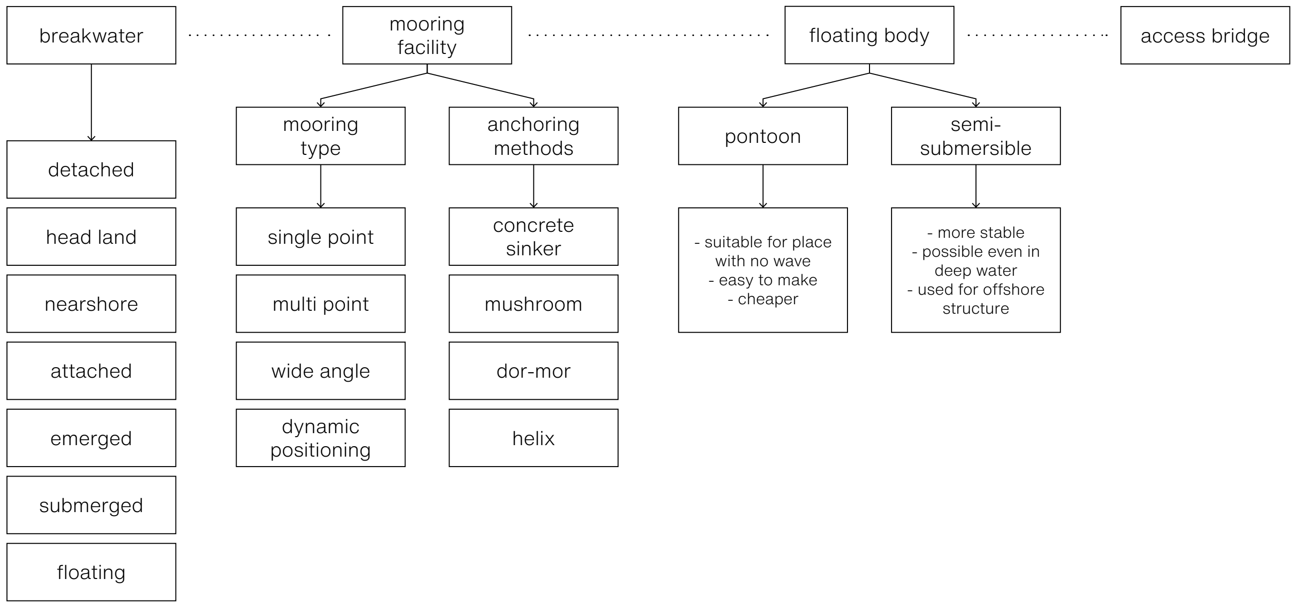
The diagram represents a circular system for energy, water, and waste management. The systems were designed by DELVA Landscape Architects, Metabolic (sustainability solutions), with research support from the University of Ghent. The research assess the supply and treatment process for energy and water in the floating structure. Identify which systems should be embedded in the structure itself and which can be part of the architectural design. The research aims to analyze proportional energy and water requirements in relation to the floating structure and develop a comprehensive guideline.

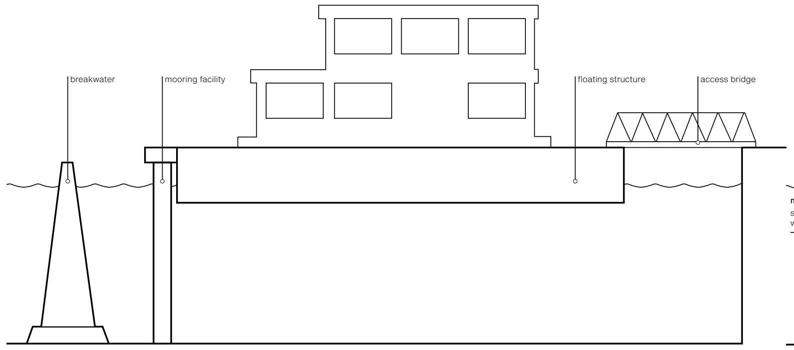


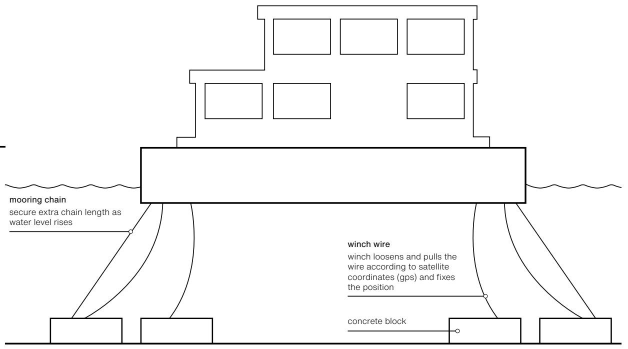


Existing Floating Structure

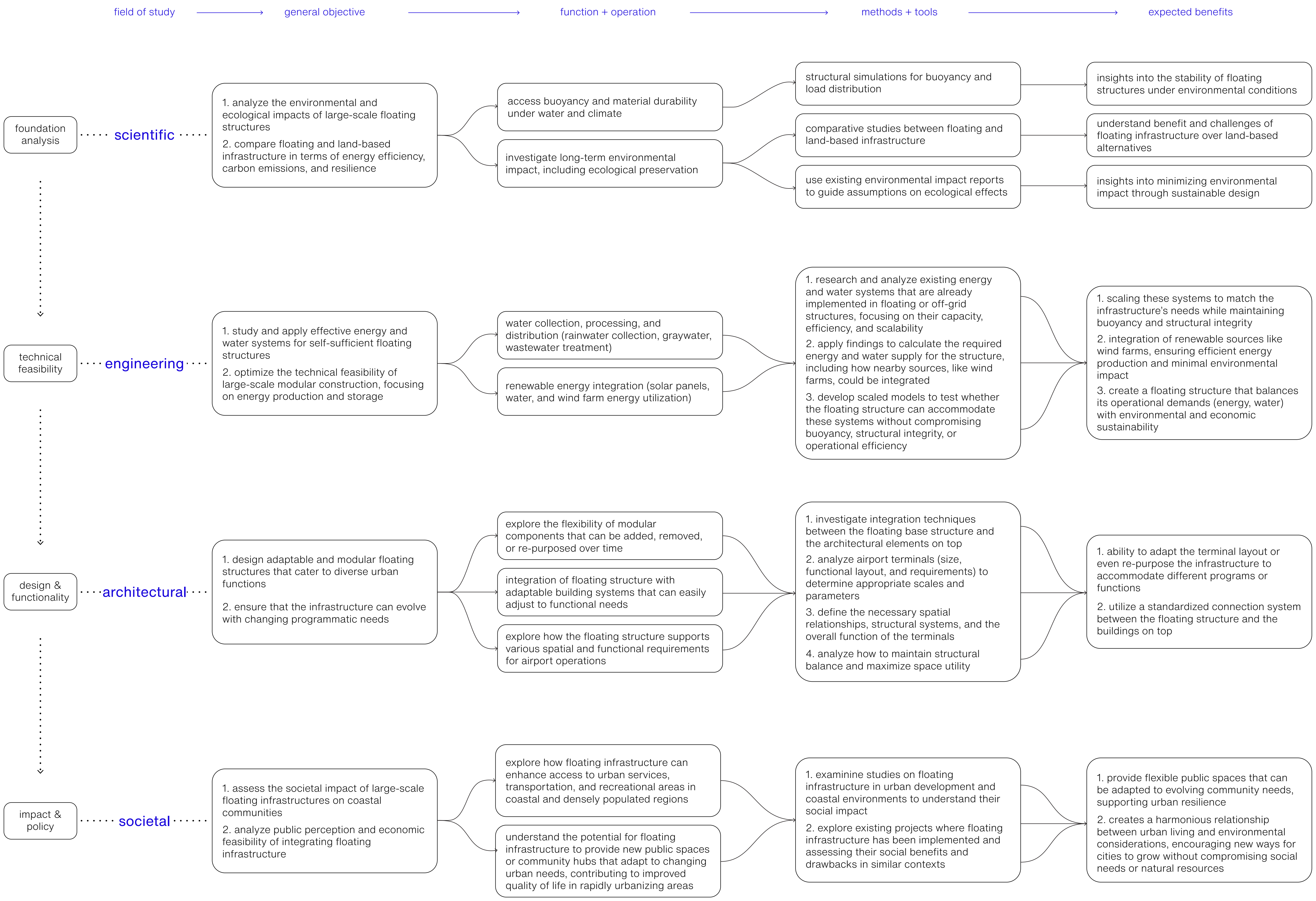
Analyze the advantages and disadvantages of existing floating structures. Then, propose a new structure based on the insights specifically designed for large-scale floating infrastructure. The model will be evaluated for its feasibility in terms of stability and buoyancy.



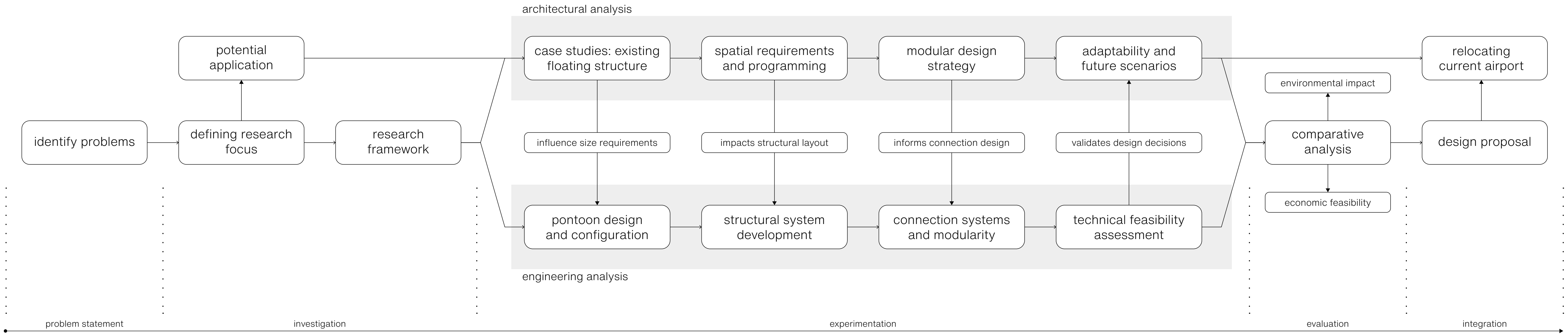




06 Thematic Research Methodology



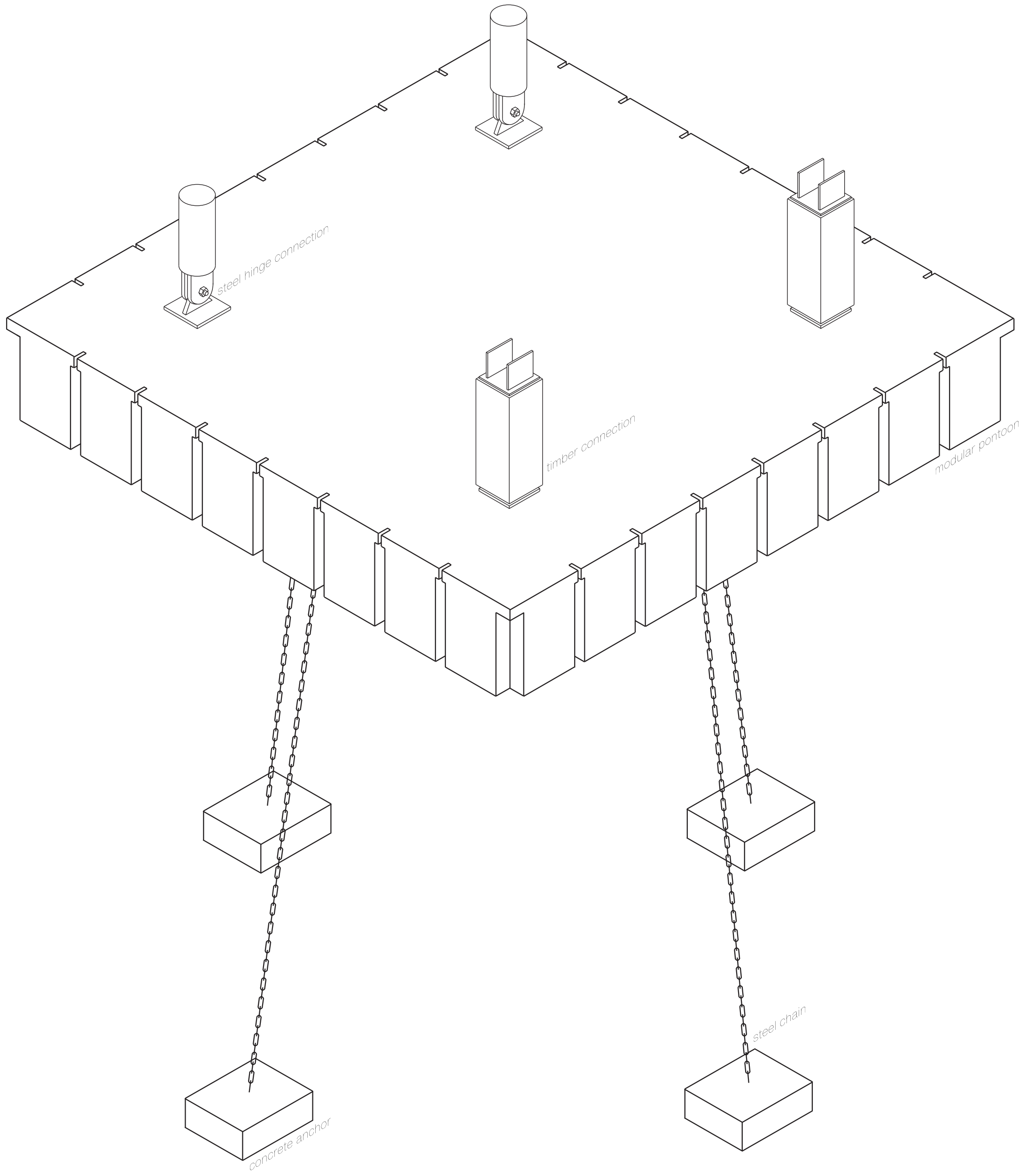
field of study	general objective	function + operation	methods + tools	expected benefits
foundation analysis · scientific	1. analyze the environmental and ecological impacts of large-scale floating structures 2. compare floating and land-based infrastructure in terms of energy efficiency, carbon emissions, and resilience	access buoyancy and material durability under water and climate investigate long-term environmental impact, including ecological preservation	structural simulations for buoyancy and load distribution comparative studies between floating and land-based infrastructure use existing environmental impact reports to guide assumptions on ecological effects	insights into the stability of floating structures under environmental conditions understand benefit and challenges of floating infrastructure over land-based alternatives insights into minimizing environmental impact through sustainable design
technical feasibility · engineering	1. study and apply effective energy and water systems for self-sufficient floating structures 2. optimize the technical feasibility of large-scale modular construction, focusing on energy production and storage	water collection, processing, and distribution (rainwater collection, graywater, wastewater treatment) renewable energy integration (solar panels, water, and wind farm energy utilization)	1. research and analyze existing energy and water systems that are already implemented in floating or off-grid structures, focusing on their capacity, efficiency, and scalability 2. apply findings to calculate the required energy and water supply for the structure, including how nearby sources, like wind farms, could be integrated 3. develop scaled models to test whether the floating structure can accommodate these systems without compromising buoyancy, structural integrity, or operational efficiency	1. scaling these systems to match the infrastructure's needs while maintaining buoyancy and structural integrity 2. integration of renewable sources like wind farms, ensuring efficient energy production and minimal environmental impact 3. create a floating structure that balances its operational demands (energy, water) with environmental and economic sustainability
design & functionality · architectural	1. design adaptable and modular floating structures that cater to diverse urban functions 2. ensure that the infrastructure can evolve with changing programmatic needs	explore the flexibility of modular components that can be added, removed, or re-purposed over time integration of floating structure with adaptable building systems that can easily adjust to functional needs explore how the floating structure supports various spatial and functional requirements for airport operations	1. investigate integration techniques between the floating base structure and the architectural elements on top 2. analyze airport terminals (size, functional layout, and requirements) to determine appropriate scales and parameters 3. define the necessary spatial relationships, structural systems, and the overall function of the terminals 4. analyze how to maintain structural balance and maximize space utility	1. ability to adapt the terminal layout or even re-purpose the infrastructure to accommodate different programs or functions 2. utilize a standardized connection system between the floating structure and the buildings on top
impact & policy · societal	1. assess the societal impact of large-scale floating infrastructures on coastal communities 2. analyze public perception and economic feasibility of integrating floating infrastructure	explore how floating infrastructure can enhance access to urban services, transportation, and recreational areas in coastal and densely populated regions understand the potential for floating infrastructure to provide new public spaces or community hubs that adapt to changing urban needs, contributing to improved quality of life in rapidly urbanizing areas	1. examinine studies on floating infrastructure in urban development and coastal environments to understand their social impact 2. explore existing projects where floating infrastructure has been implemented and assessing their social benefits and drawbacks in similar contexts	1. provide flexible public spaces that can be adapted to evolving community needs, supporting urban resilience 2. creates a harmonious relationship between urban living and environmental considerations, encouraging new ways for cities to grow without compromising social needs or natural resources



1. review existing buoyant structures
   - identify various buoyant systems currently in use, such as pontoons or floating platforms
   - categorize the structures by function, size, mooring system
   - gather data on structural materials, load-bearing capacities, and stability
   - document their success in real-world environments (offshore, nearshore, etc.)
2. analysis of structural design and performance
   - analyze the structural specs, including weight capacity and dimensions
   - evaluate the performance of these structures under different weather and sea conditions
   - identify the materials used and their environmental resistance (corrosion, biofouling)
   - compare energy efficiency, durability, and maintenance needs across various designs
3. identification of design constraints and gaps
   - highlight size, scalability, and load distribution challenges in existing modules
   - note limitations in adaptability to different environments or functions
   - investigate the environmental impact of current designs (CO2 emissions and footprint)
   - identify where designs fail to meet the needs for larger, multifunctional infrastructure
4. develop key strategies for large-scale modules
   - design strategies to increase buoyancy while maintaining structural integrity
   - consider modularity for ease of assembly and flexibility in application
   - develop strategies for integrating renewable energy and self-sufficiency
   - optimize the design for future expansion or reconfiguration as operational needs change
5. investigation of structural forces and stability
   - investigate how various forces (buoyancy, compression, and torsion) affect stability
   - conduct structural load analysis for weather or sea-level rise scenarios
   - analyze potential issues such as material fatigue and joint stability
   - explore stability in dynamic environments with moving loads and shifting water conditions
6. simulation and testing of structural integrity
   - use software to simulate buoyancy and stability under different loading conditions
   - test how environmental stressors, like waves and wind, affect long-term durability
   - simulate energy systems integration, like solar and wind, to see impact on buoyancy
   - perform iterative adjustments based on testing feedback to refine the structural design
7. functional integration of systems
   - assess the feasibility of integrating water collection, treatment, and energy systems
   - map out space for system installations, ensuring they do not hinder stability
   - evaluate how much energy can be supplied by renewable sources
   - ensure that the design allows for waste treatment and energy recovery processes
8. application to large-scale design and infrastructure
   - scale the design to meet large infrastructure demands
   - ensure compliance with engineering and safety regulations for large-scale projects
   - evaluate long-term maintenance needs and sustainability over decades of use
   - integrate the structure into existing urban frameworks or future development plans

engineering research process

Engineering and architectural analyses run in parallel throughout the research, each influencing the other to ensure a functional floating structure. Insights from airport terminal case studies shape the pontoon's load-bearing capacities, while spatial requirements set engineering boundaries on structural integrity. Once designed, the structure undergoes a feasibility test to confirm its buoyancy and stability.

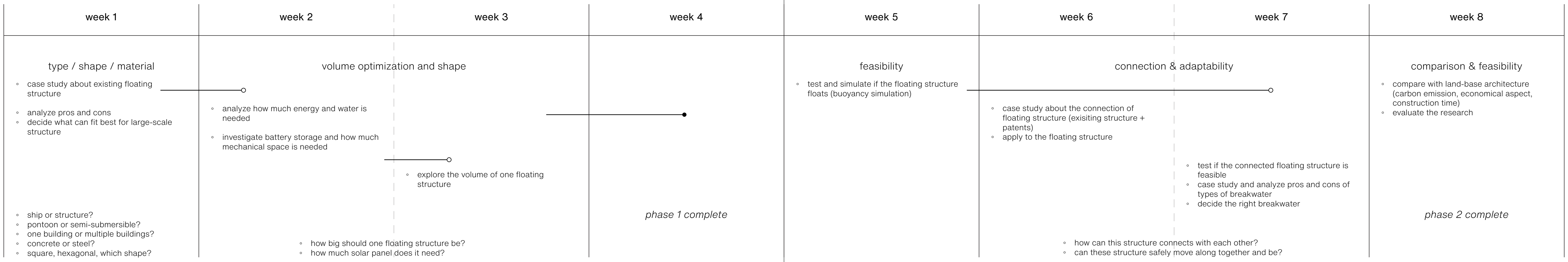


expected prototype

The research will establish the optimal materials, volume, and dimensions of the floating structure. A mooring system, likely employing concrete anchors connected by steel chains, will secure the pontoon in place. Potentially integrating satellite coordinates that could loosen and pull the winch wire, adapting to changing water levels. Due to movement from tides, the architecture on the pontoon may use a hinge connection, allowing flexible alignment with environmental conditions.

07

Research & Design Timeline



type / shape / material

- case study about existing floating structure
- analyze pros and cons
- decide what can fit best for large-scale structure

- ship or structure?
- pontoon or semi-submersible?
- one building or multiple buildings?
- concrete or steel?
- square, hexagonal, which shape?

volume optimization and shape

- analyze how much energy and water is needed
- investigate battery storage and how much mechanical space is needed
- explore the volume of one floating structure

- how big should one floating structure be?
- how much solar panel does it need?

phase 1 complete

feasibility

- test and simulate if the floating structure floats (buoyancy simulation)

connection & adaptability

- case study about the connection of floating structure (exisiting structure + patents)
- apply to the floating structure
- test if the connected floating structure is feasible
- case study and analyze pros and cons of types of breakwater
- decide the right breakwater

- how can this structure connects with each other?
- can these structure safely move along together and be?

comparison & feasibility

- compare with land-base architecture (carbon emission, economical aspect, construction time)
- evaluate the research

phase 2 complete

Phase 1 focuses on the shape, materials, and volume of the pontoon. Data is collected and analyzed through case studies of existing floating architecture to identify advantages and disadvantages. Subsequently, suitable elements are applied to large-scale pontoon. Then, identify the energy and water required per unit area of the building to create guidelines that reflect changes in pontoon size according to the scale of the building. This allows for application not just to this research, but also to other architectural types and environments.
Phase 2 verifies whether the designed pontoon can float and if there is any imbalance. If there are severe waves in open water, a breakwater should be added. For imbalance, consider ideas from ship ballasts and apply to the design. Then study the connection methods for modular pontoons. Explore case studies of existing pontoon connection for application. Finally, compare the designed pontoon with land-based architecture. Results are derived by comparing carbon emissions, economic impact, construction time.

phase 1

data collection methods	*data analysis*
literature review and case study ◦ gather insights on existing floating architecture ◦ provide foundational knowledge and highlight both successes and challenges encountered in similar projects	comparative analysis ◦ analyze and compare materials, shapes, and construction techniques for their performance ◦ compare best balance between durability, cost, and its impact
energy & water requirements estimation ◦ calculate baseline energy and water needs for floating structures ◦ inform the scale and type of energy and water systems required	quantitative calculations ◦ draft a guideline detailing size and volume specifications for the floating structure, ensuring it can support self-sufficiency
simulation testing ◦ model shapes, volumes, and materials for stability, load-bearing capacity, and buoyancy ◦ identify optimal design parameters before physical prototyping	scenario evaluation ◦ simulate various environmental scenarios, such as sea level rise or wave conditions, to evaluate feasibility and resilience

phase 2

data collection methods	*data analysis*
connection mechanism testing ◦ case study different fasteners, hinges, and connectors ◦ test various modular connection methods to determine their durability, ease of assembly	quantitative evaluation of stability and adaptability ◦ analyze test results from the connection mechanisms and adaptability ◦ identify necessary reinforcements or modifications if needed
adaptability & environmental impact assessment ◦ study adaptability features that allow the structure to be reused or repurposed ◦ evaluate the structure's life-cycle emissions, ecological footprint	environmental & lifecycle feasibility assessment ◦ assess the long-term sustainability of the floating structure ◦ examine resource consumption, carbon footprint, and end-of-life disposal or recycling options
comparison studies ◦ assess differences in environmental impact, maintenance needs, and economic feasibility (with land-based architecture) ◦ analyze advantages and disadvantages of floating architecture	synthesis for final design refinement ◦ refine the prototype design to optimize for structural stability, adaptability, and environmental compatibility ◦ align both engineering constraints and architectural aspirations

Floating Office Rotterdam, Netherlands
- world's largest floating office building
- designed to be entirely self-sufficient
- solar panels and use water from the harbor for climate control

Urban Rigger, Denmark
- student housing built from repurposed shipping containers
- solar panels, heat pump, wastewater, rainwater harvesting
- showcasing affordable, eco-friendly living spaces

Floating Pavilion, Netherlands
- serves as a demonstration project for sustainable architecture
- adaptable, relocatable, and uses renewable energy sources
- smaller scale prototype emphasizing modularity, resilience

IBA Dock, Germany
- floating office and exhibition building
- concrete pontoon, buildings made of steel modular construction
- fastened onto dolphins, moves with the tide

Floating Farm, Netherlands
- dairy farm, designed to produce food sustainably
- water recycling systems, solar panels, waste management
- reduce transportation emissions by producing food locally

Sebitseom Floating Islands, South Korea
- three artificial floating islands for cultural and recreational use
- anchored to the riverbed, accommodate varying water levels
- solar panels and energy-efficient systems

Waterbuurt Floating Neighborhood, Netherlands
- addresses land scarcity and flood risks
- built on floating platforms and connected to land-based utilities
- illustrates floating structure function at a neighborhood scale

Lake Huron Floating House, Canada
- private floating residence on steel pontoon system
- designed to be completely self-sufficient
- solar panels, rainwater collection systems, composting toilets

Schoonschip Floating Neighborhood, Netherlands
- one of the most sustainable residential community in Europe
- entirely self-sufficient (solar panels, battery storage)
- decentralized wastewater treatment and rainwater collection

Makoko Floating School, Nigeria
- prototype for challenges of flooding and rapid urbanization
- concept of modular floating structures in low-resource areas
- example of modular and adaptable structures for societal needs

floating architecture case study

Rotterdam the Hague Airport, Netherlands
- single terminal (100m x 30m)
- handles 2.1 million passengers annually
- 2,200 meter runway

Kristiansand Airport, Norway
- single terminal (100m x 40m)
- handles 2.1 million passengers annually
- 2,035 meter runway

George Best Belfast City Airport, Northern Ireland
- single terminal (127m x 45m)
- handles 2-3 million passengers annually
- 1,800 meter runway

Bremen Airport, Germany
- single terminal (245m x 70m)
- handles 2.1 million passengers annually
- 2,634 meter runway

Tampere–Pirkkala Airport, Finland
- single terminal (110m x 18m)
- handles 2.1 million passengers annually
- 2,700 meter runway

Malmö Airport, Sweden
- single terminal (110m x 60m)
- handles 2.1 million passengers annually
- 2,800 meter runway

potential design application considering the scale

08 Research Framework Draft

1. Abstract (120 words)

- summary, outline

2. Introduction (400 words)

- set context, present problems, outline research focus
    - sustainable infrastructure demands
    - state research's aim
    - research question

3. Literature Review (800 words)

- review existing case studies, address research gap
    - overview floating architecture and modularity
    - learning from case studies (referenced in appendix)
- emphasize need for large-scale floating design

4. Methodology (600 words)

- research approach, data collection, analysis methods
    - architectural and engineering analysis
    - case study reviews, data from structure, design specification
    - data analysis: buoyancy, structure stability, environmental impact assessments

5. Design and Prototype Development (1100 words)

- summarize material choice, shape, stability
- modular components: flexible mooring system
- technical integration: energy and water systems
- environmental consideration: outline measures to mitigate coastal impact

6. Results and Discussion (700 words)

- present and interpret key findings
    - structural feasibility: load-bearing and stability results
    - design adaptability: how well design meets multi-purpose criteria
    - environmental impact: assess potential ecological effects
- comparison with traditional land-based infrastructure
- comparison with land reclamation

09 Glossary of Key Terms

1. Floating Airport Terminal

A concept where only the terminal building is located on a floating platform, while the runway remains on land. This hybrid model addresses current limitations while preparing for future adaptability.

2. Mooring Systems

Anchoring mechanisms that secure floating platforms in place. These systems are essential for maintaining the stability and position of floating structures in varying water conditions.

3. Buoyancy

The ability of a floating structure to remain stable and afloat by displacing water equal to its weight. Buoyancy is a key factor in ensuring the stability and safety of large-scale floating platforms.

4. Scalability

The potential for a floating structure to be expanded or reduced in size depending on future needs. Scalability ensures that the infrastructure can adapt to growing urban populations or changing environmental conditions.

5. Renewable Energy Systems

Technologies that generate energy from renewable sources such as solar panels, wind turbines, and heat exchange. These systems are crucial for maintaining energy independence in floating structures.

6. Climate Resilience

The ability of infrastructure to withstand or adapt to the impacts of climate change, such as rising sea levels or increased storm intensity. Floating structures are designed with climate resilience in mind to ensure long-term viability.

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