FROM WATER TO STRUCTURE

Local aquatic bio-based materials for circular floating Architecture

RESEARCH PLAN

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CHOICE OF THE STUDIO

I have a strong technical fascination with passive and circular techniques to meet the urgent needs concerning climate change and sustainability. The Architectural Engineering Graduation Studio is the most advanced and up-to-date in terms of circularity and innovative construction materials. It is also a technical studio which I believe is very relevant in the path of becoming an architect.

KEYWORDS

Aquatic ecosystems, Bio-based materials, Local materials, Blue biomass, Floating Architecture, Circular building, Port regeneration, Renaturation

Figure 1: Wetland in the Netherlands

KEYWORDS DEFINITIONS

Aquatic ecosystems: Ecosystems that exist within or around a body of water. They can be either freshwater ecosystem like estuaries, rivers, lakes, wetlands (Figure 1) and ponds or (saltwater) marine ecosystems like seas and oceans (Gray, 2021). They refer to the habitats provided by surface waters to interdependent communities of living organisms like plants and animals (Zhuang, 2024).

Bio-based materials: “Materials made from renewable biological resources such as plants, wood and organic waste.” (Garcia Saravia, 2022)

Local materials: “Materials that are sourced from within the immediate vicinity of a construction site.” (Construo, 2024)

Blue biomass: Biomass coming from aquatic environments, such as water plants and algae (AgroTechnology Atlas, n.d.).

Floating Architecture: A building system standing on water to offer a usable space for people. Based on Archimedes’ law, buoyant knowledge guarantees that the structure floats (Bayoumi, 2024). Floating architecture is moored to a permanent location and is not designed or intended for navigation. It has a local service system for electricity and water connected to the land or autonomous (Moon, 2014).

Circular building: A building that optimizes the use of resources and minimizes waste throughout its whole life cycle while avoiding pollution and damage on natural resources and ecoystems (van Eijk, 2021).

Port regeneration: Replacing of the industrial port with a post-industrial waterfront including new urban uses such as offices and residential functions. Usually happening in the context of port activity expansion or relocation, it is an opportunity for sustainable urban development (Le Den, 2019).

Renaturation: “A process of returning natural ecosystems or habitats to their original structure and species composition.” (European environment agency, n.d.)

1- GENERAL PROBLEM STATEMENT

1.1 Port regeneration context

A growing number of large European port cities have seen a transformation of their industrial area in recent decades (Marshall, 2001) and more of them are planned to undergo such changes with a goal of densification (Le Den, 2020). In these former port areas, various problems are found in terms of context. Polluting industries in the ports have had a major environmental footprint on the landscape and biodiversity. There will be crucial needs in the future to heal the places from their polluting past. The chosen context is located in the industrial port area of Amsterdam West. Some transformation objectives have been fixed for this area by the city of Amsterdam for the period of 2020-2040. The creation of a new housing district called Haven-Stad is planned to densify the docklands with the construction of 70 000 new homes and the creation of 58 000 jobs (City of Amsterdam, 2020). The potential project of Amsterdam's municipality remains until now at the state of urbanism studies.

1.2 Public program needs

In terms of the program, an increased population density in former industrial areas within a port city will need to be complemented with more public functions. The fundamental opportunity relies on the possibility of reimagining new circular neighbourhoods within cities' brownfields in opposition to unsustainable urban sprawl in natural areas. There is a major responsibility to include from the start public spaces and buildings with public functions in this new kind of neighbourhood to prevent them from becoming mono-functional housing districts like it has been done in the past, especially in the post war period (Scopacasa, 2022).

1.3 Unsustainable floating buildings

The technical thematic focus will be on the necessary innovation in the floating building typology in terms of material use in Western Europe. Most of the existing examples currently rely on polluting materials like concrete and steel for major structural elements. These two materials alone account for 21% of the world's global CO2 emissions (Global Alliance for Building and Construction, 2018). For instance, the 'Floating Office' in Rotterdam is recognised as a state-of-the-art sustainable architecture but a large part of its structure is still made of reinforced concrete used for its barge (Powerhouse Company, 2022). There is therefore a need for bio-based materials for the entirety of the building and also for the floating platform especially crucial for preserving the environment where it sits. The technical focus is to not only do a 'half' circularity but to design entirely in a circular way including the 'submerged part of the iceberg'. Going further, the exploration of technical solutions related to fast-growing bio-based materials is already on its way to offering a viable alternative to timber construction (Göswein, 2022). Pragmatically, a combination of these two types of bio-based materials might be the best formula for today's construction industry. In addition, research on new types of concrete equivalents are conducted based on weeds and crayfish shells (Springwise, 2021) or on shell waste (Chandrasiri, 2019). As they can have a potential in reducing the environmental footprint of traditional concrete according to Chandrasiri, they are still in beginning phases and not yet standardised.

1.4 Knowledge gap

The knowledge gap consists of a lack of information on aquatic locally sourced bio-based materials suitable for building floating structures on the water. Despite a few small-scale experimental projects like the Reef Circular project in Denmark made with 3D printed shell waste (Larsen, 2024), no larger building-scale applications use this type of material yet.

2- THEORETICAL FRAMEWORK

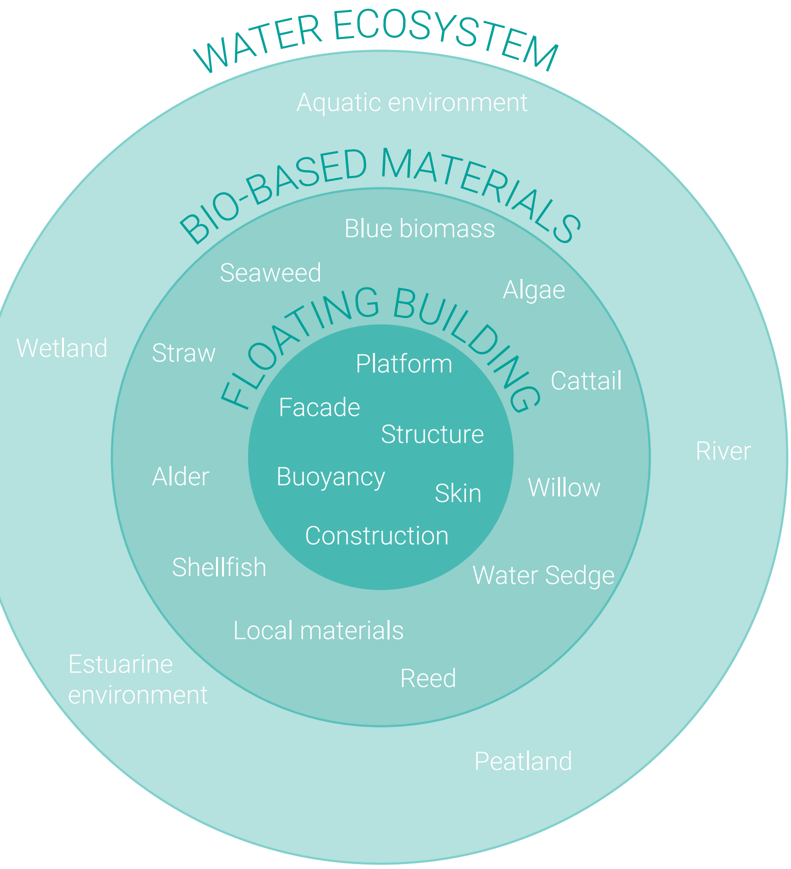

Figure 2: Theoretical Framework Diagram

In reaction to the problem statement, a necessary change in paradigm includes going from a linear to a circular economy. In that objective, the focus shifts from extraction to regeneration according to Ellen MacArthur (2022). This theory was already used by Gunter Pauli (2010) for defining the concept of the Blue economy as a philosophy of ecosystem regeneration through the production system. Material Cultures (2022) built up on this new approach in their book Material Reform: Building for a Post-Carbon Future:

"Instead, a regenerative approach to construction starts at a regional level, with a study of the quantity and character of materials that can be harvested from regeneratively managed land, [...]. Adopting an approach to construction grounded in regenerative resources requires a wholesale re-interrogation of the material palette that we use to make buildings."
(Material Cultures, 2022, p.20)

Indeed, the research and the design will both be defined by a landscape-based and ecosystemic approach. The focus is made on the potential harvest of bio-based materials from the local environment. As seen in the diagram above (Figure 2), the approach is not based on the scale of the building at first but on the systems surrounding it. It is thus a radically different perspective compared to designing from the building specific requirements regardless of the site's resources. In this regard, the ecosystem holds the potential materials for building.

Firstly, the chosen landscape of the Amsterdam port and its ecosystem can be characterised as riverine environment transitioning into an estuarine environment with freshwater and tidal influences (EcoShape, 2020). Secondly, the materials sourced from these kind of environments are multiple. They range from fast-growing grass to wood as well as algae. Thirdly, the building represents the scope and constraints for the use of such materials. Its design and construction language will be the result of the wider material and ecosystem analysis.

3- OVERALL DESIGN OBJECTIVE

The graduation project will propose clear application potentials for aquatic bio-based materials in a floating building typology. The process will lead to the design of a circular bio-based floating building acting as a green island for biodiversity enhancement as well as a catalyst for the social and cultural life of the future Haven Stad. The project will aim to create an overall approach to designing building typologies with local blue biomass.

An opportunity for the design's implementation lies in the availability of large spaces on the artificially excavated water bodies where ships used to be anchored (Figure 3). According to the work of Kuijper (2019) on the Haven Stad, the water surface could be activated with water hubs. The function of these hubs however should be thoroughly defined according to the real needs of the communities. In addition, several urban studies have been conducted to create master-plan propositions for the future city district of Haven Stad. It is the case for example of the research project City of the future made by the urbanism office BURA (2019). Yet, most of the works done on the area remain at an urbanistic scale.

Answering the need for new public functions, the scope of the public building is a medium-size cultural and community centre of approximately 50 meters wide and two or three storeys high hosting various programs. Potential spaces include a representation room, publicly accessible gathering halls, diverse classrooms for music, art and sports, and food or drinks venue. The program will be included in the requirements of the floating building influencing the use of materials.

Figure 3: Aerial photo of Mercurius Haven, Amsterdam

In combination with the beneficial impact of a public building on the neighbourhood and communities, a depolluting role for the port promoting and bringing back biodiversity in the water environment is an expected outcome of the design project. A similar goal has been explored in Amsterdam with the neighbourhood De Ceuvel opened in 2014 on a former polluted shipyard (Space&Matter, 2014). That project aimed to depollute the area of land where it sits. That being said, it did not focus on depolluting the neighbouring waterway. Therefore, the design objective is to additionally have a healing impact on the water environment.

The water context impacts the design objective as it is a starting point for local material sourcing. It will therefore influence the choice and use of construction materials. The site will be considered as having the potential for implementing paludiculture (Islam, 2023) on floating structures and on the river banks. The landscape would then evolve and become similar to a wetland or peatland environment according to Islam's definition. Indeed, if the area or the port is urbanised today, it is located in the middle of a peat soil area (Van Dam, 2021), ideal for peatlands cultivation. The design goal expressed in the diagram below (Figure 4) will be validated or not depending on the findings of the research and on the possibility to grow on the site most of the materials required for the building.

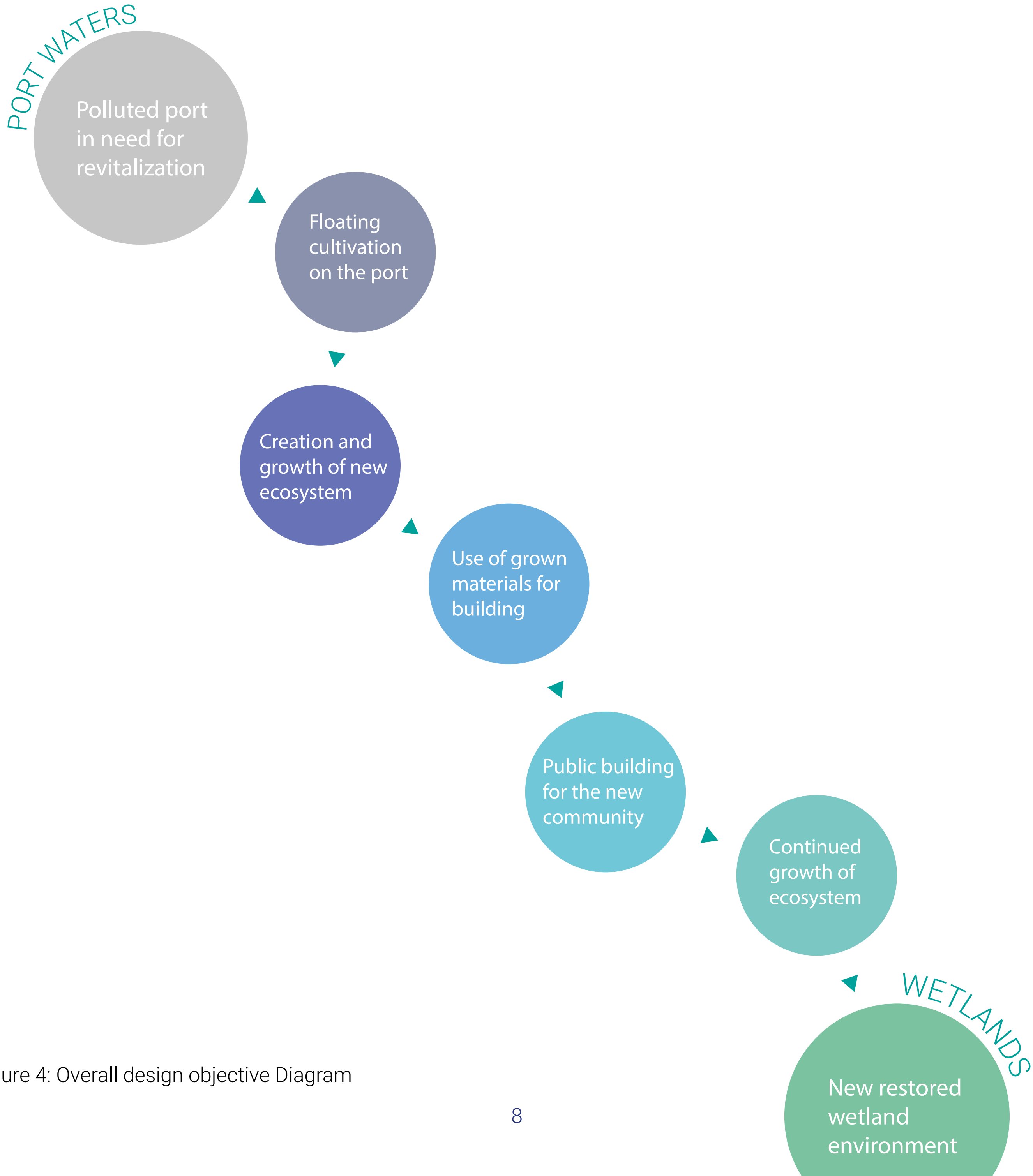

Figure 4: Overall design objective Diagram

4- OVERALL DESIGN QUESTION

4.1 Overall design question

How can bio-based materials sourced from local aquatic ecosystems be integrated in the design of a mixed-use floating building that positively impacts the environment and the inhabitants of Amsterdam's Haven Stad?

4.2 Design Hypothesis

The design hypothesis is that the major part of the floating building can be built using local bio-based materials grown in the context of Amsterdam port, from the floating structure to the skin of the building. The resulted design through its process and characteristics can contribute to a renaturation and depollution of the area in addition to its primary use for the community (Figure 5).

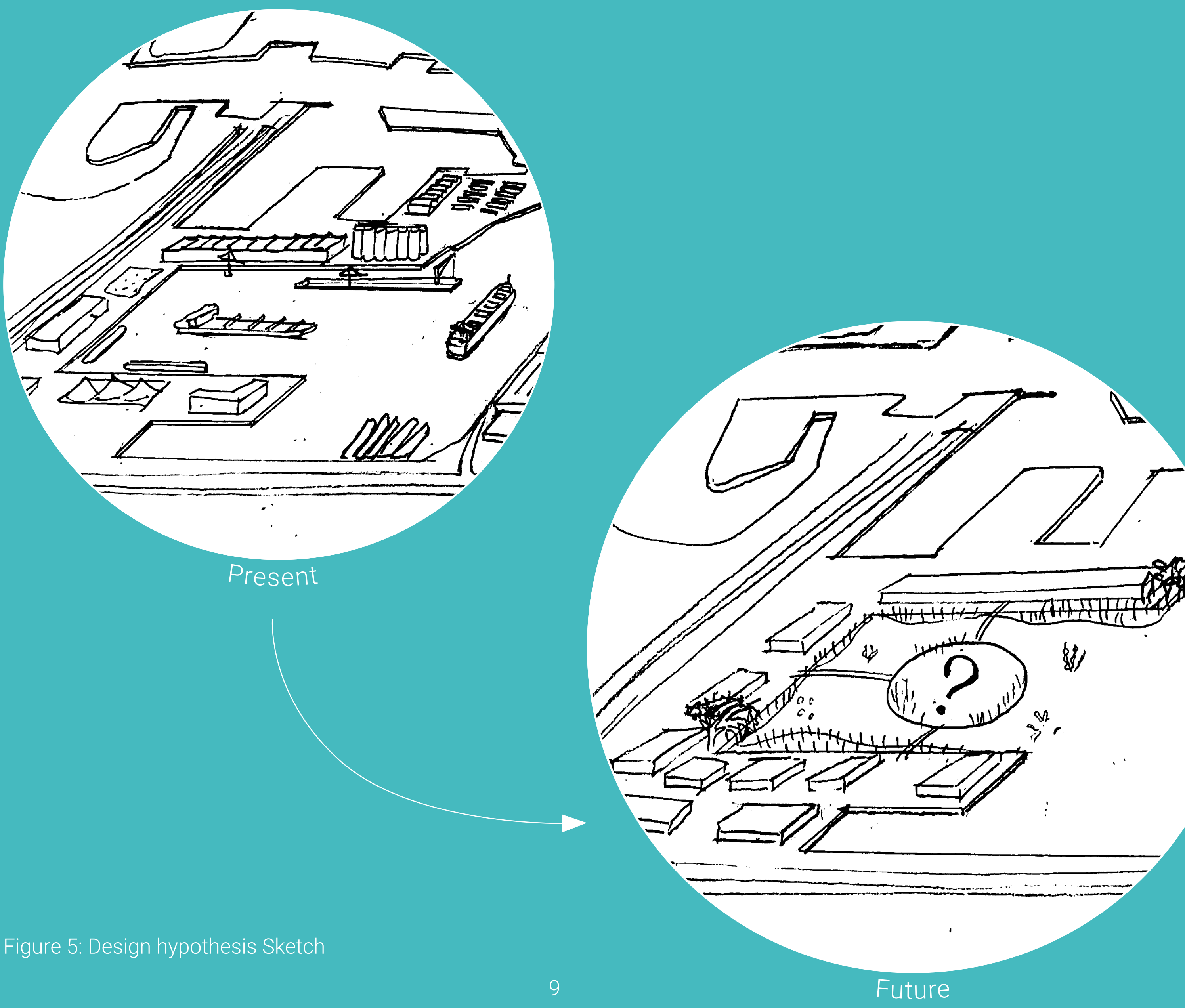

Figure 5: Design hypothesis Sketch

5- THEMATIC RESEARCH OBJECTIVE

The main objective of the thematic research is to fill a current research gap in alternative circular materials to traditional and polluting construction materials used for floating buildings. The research will intend to investigate various aspects of different types of bio-based materials sourced from water ecosystems. The potential for sustainable sourcing of construction material in wetlands has been demonstrated in the work of Islam (2023) on the Berlin region. On a similar topic, the research program Bouwtuin investigated the potential of regional peatland-sourced bio-based materials for housing design (Smit, 2022). The research focused on building in the wetland environment and specifically for housing development. However, the floating constraints still need to be studied in relation to bio-based materials. Additionally, some research has been done on the topic of algae exploitation for greener constructions (Elmeligy, 2019) but through a strictly technical approach and without the specificity of building on water.

The chosen research theme is related to the general problem statement of finding local and bio-based solutions for building on water. Three steps will structure the research: (1) investigating the specific requirements of a floating building (2) studying water ecosystems and bio-based materials to be sourced from them, and (3) researching the possible uses of the available materials (Figure 6).

6- OVERALL RESEARCH QUESTIONS

6.1 Overall research question

How can bio-based materials sourced from local aquatic environments be used to build a circular floating building?

6.2 Sub-questions

1) What are the technical and physical requirements of a floating building for construction materials?

2) Which bio-based materials can be sourced from riverine ecosystems?

3) How have bio-based materials sourced from aquatic environments been used in floating construction in the past?

4) What are the life-cycle performances and considerations for aquatic bio-based materials in a floating building?

5) What technical innovations are emerging in the use of new kinds of water-sourced bio-based materials?

6) How can bio-based materials sourced from aquatic environments be used for a floating building?

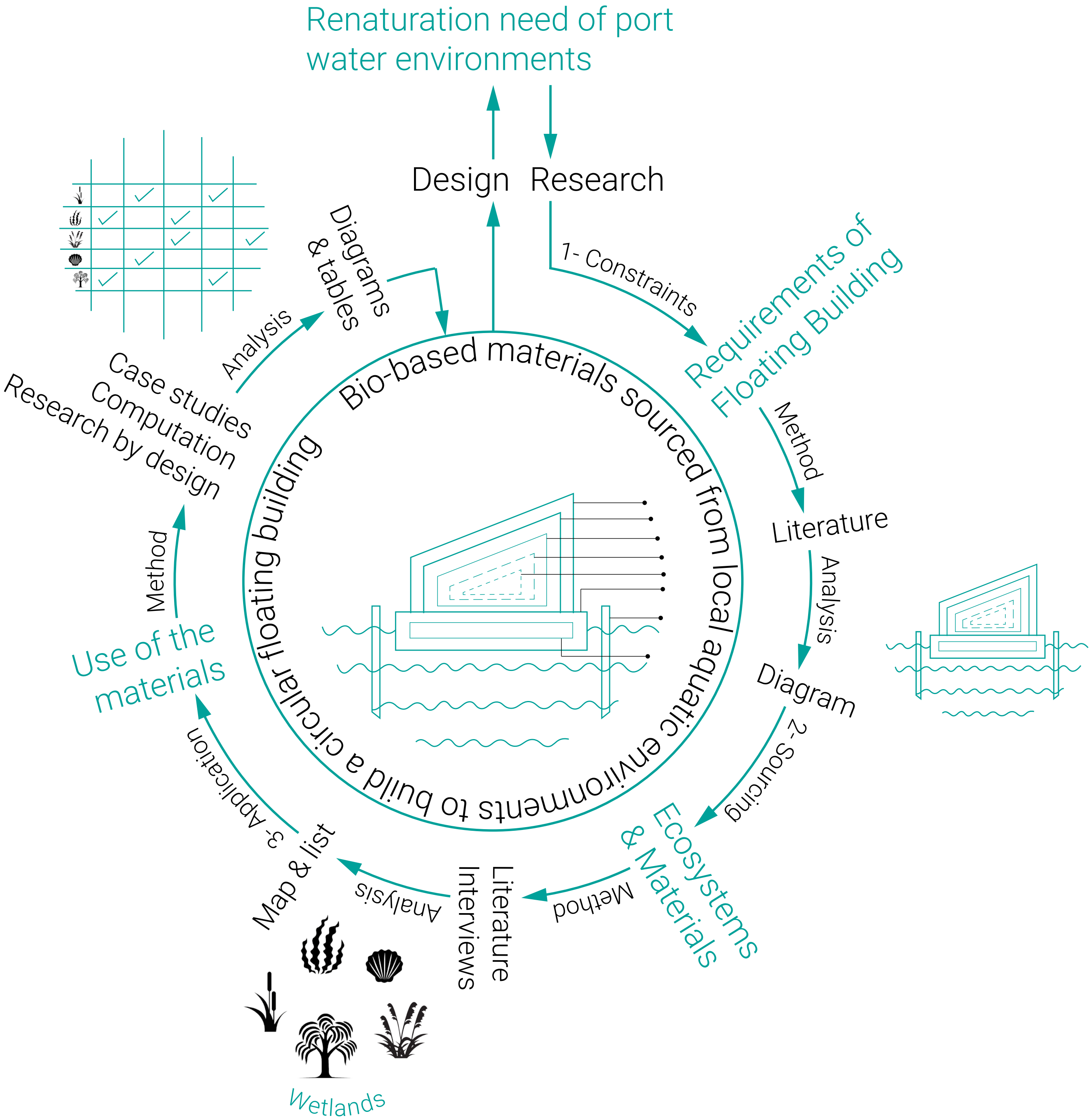

Figure 6: Research Plan Diagram

7- RESEARCH METHODOLOGY

The problem will be addressed by exploring the existing research works and solutions in terms of blue biomass material use innovation and their applications. In terms of methodology, the shearing layers concept and diagram by Stewart Brand (1994) is used as a guiding base for the research, especially for research by design and case studies analysis. It is reinterpreted through the lens of a floating building with additional specificities (Figure 7). The methods used for answering the main research question and the sub-questions are listed in the following table (Figure 8). Possible ethical issues are a risk of over exploitation of aquatic ecosystems in a non sustainable way. The research methodology remains exploratory in its approach and is based on a responsible harvesting of materials.

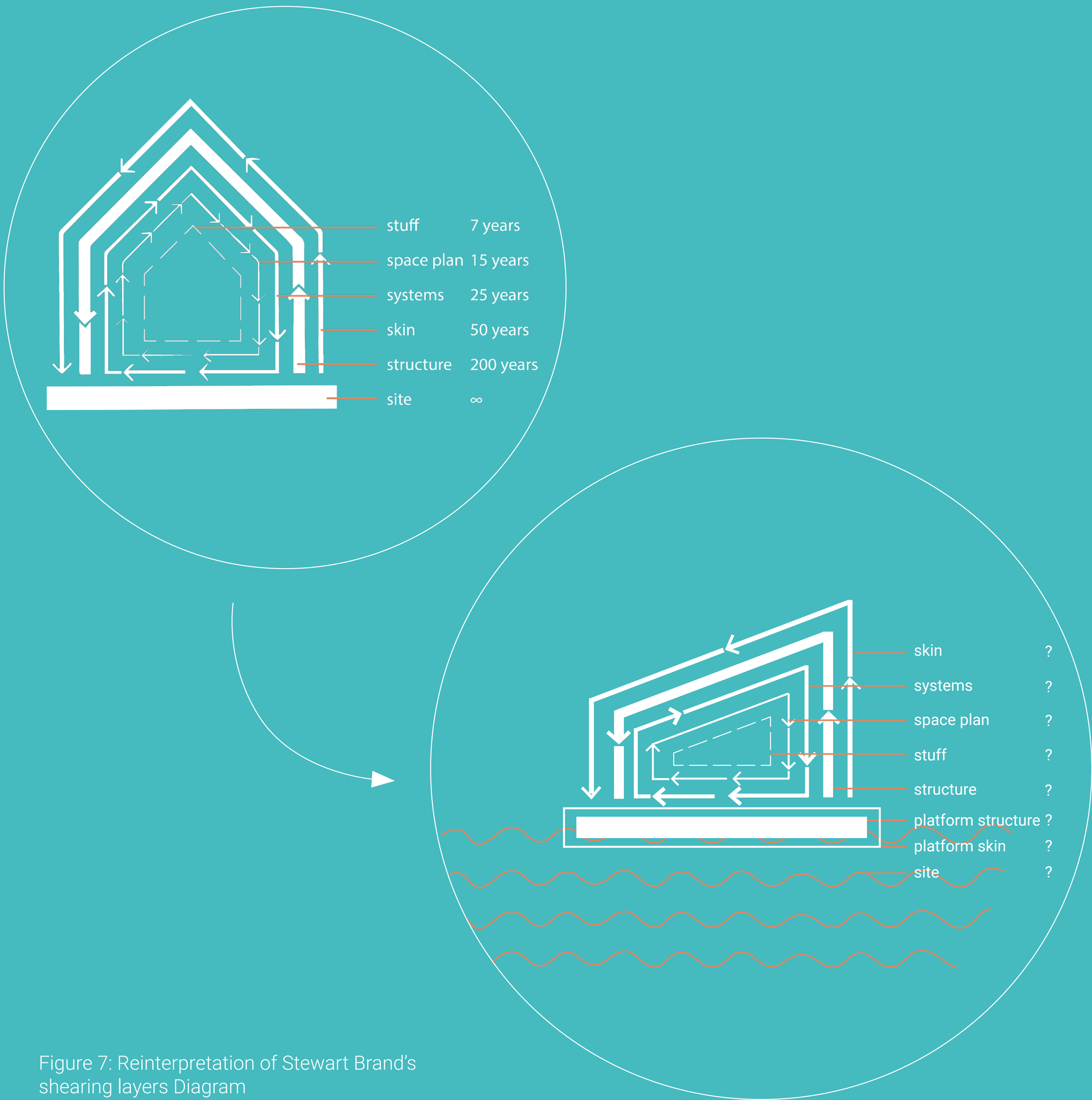

Figure 7: Reinterpretation of Stewart Brand's shearing layers Diagram

Sub research questions	What data do you need?	How can this data be collected?	How will this data be analysed?	What will be the expected results?
What are the technical and physical requirements of a floating building for construction materials?	- Qualitative and quantitative data	- Literature study - Interview of floating buildings experts	- Categorised in different types of constraints and their influence on the construction materials	- Diagram summarizing the different constraints of a floating building
Which bio-based materials can be sourced from riverine ecosystems?	- Quantitative data on material's production potential, volume and availability	- Literature study - Interview of actors of the supply chain of materials from water environments	- Insights on the growing potential of bio-based construction materials in the riverine ecosystem	- List of all potential bio-based material sourced from the aquatic ecosystem and their growing and harvesting needs
How have bio-based materials sourced from aquatic environments been used in floating construction in the past?	- Qualitative data on bio-based solutions for floating buildings and use of aquatic bio-based materials in construction	- Case study analysis	- Extraction of material informations on a systemic approach from the case studies	- Catalogue of different construction methods and characteristics
What are the life-cycle performances and considerations for aquatic bio-based materials in a floating building?	- Quantitative data on material behaviours	- Computational analysis	- Parametric simulations on life-cycle aspects combining material production and use	- Table with material characteristics but also construction and maintenance requirements
What technical innovations are emerging in the use of new kinds of water-sourced bio-based materials?	- Qualitative data on the potential of aquatic bio-based materials for floating architecture	- Interview of researchers on new blue-biomass innovations and experts in marine biology and environmental engineering	- Study of the potentiality of translating the innovations into architectural elements for floating building	- Summary of the different innovations and their potential use for floating building
How can bio-based materials sourced from aquatic environments be used for a floating building?	- Qualitative data on architecture integration of the materials	- Research by design	- Design sketches of possible material use	- Diagrammatic section summarizing all findings on potential material use

Figure 8: Table of methods

8- EXPECTED RESULTS

An expected outcome of the thematic research is a clear choice of material to use. The expected deliverables are sketches of possible ways of integration of the different chosen materials into the floating structure, comparison charts of potential materials (harvesting, specificities, construction method, etc.). The result of the research will be used as a base to start the design project. The expected output (Diagrammatic section drawing compiling the results) is a practical guide for designing a floating building with local blue-biomass.

9- REFLECTION ON THE RELEVANCE

9.1 Relevance of the design objective

From a societal point of view, the design objective will reach an extra step towards designing truly circular buildings resilient to future impacts of climate change such as biodiversity loss, land scarcity, rise of water levels and flooding. From a user point of view, the design will enhance the cultural and social life of the neighbourhood and will bring back nature into a former industrial site risking to become an industrial wasteland.

The project focuses on the ecosystem and context of the Amsterdam port but it can be interpreted and repeated for other similar contexts, making it relatively generic. The advantage of a floating building is its adaptability to any site with water, except with the use of local materials which is the more specific part of the project. The design and the research will benefit future architects, clients and real estate developers wanting to build on water in a non-standard and non-polluting way in the Netherlands and abroad.

9.2 Relevance of the thematic research

The relevance of the thematic research objective lies in its exploratory methodology in the topic of floating structures for buildings. In addition, the topic of blue biomass for construction is emerging as a new focus for the building industry. Recently, a new international network called “Building with Blue Biomass” was created between experts from Denmark, Australia and the UK to collaborate on researches about opportunities for building with renewable marine bio-mass like algae, sea-grass and shellfish (Nicholas, 2024). On the same topic the paper on Marine Bio-based Building Materials from the Nordic Innovation (Nordic Blue Building Alliance, 2024) already investigates existing companies and products in the construction sector using blue biomass. Through these works, it can be said that this field of research is being pushed more and more as a possible additional solution to the climate and ecological crisis.

10- PLANNING

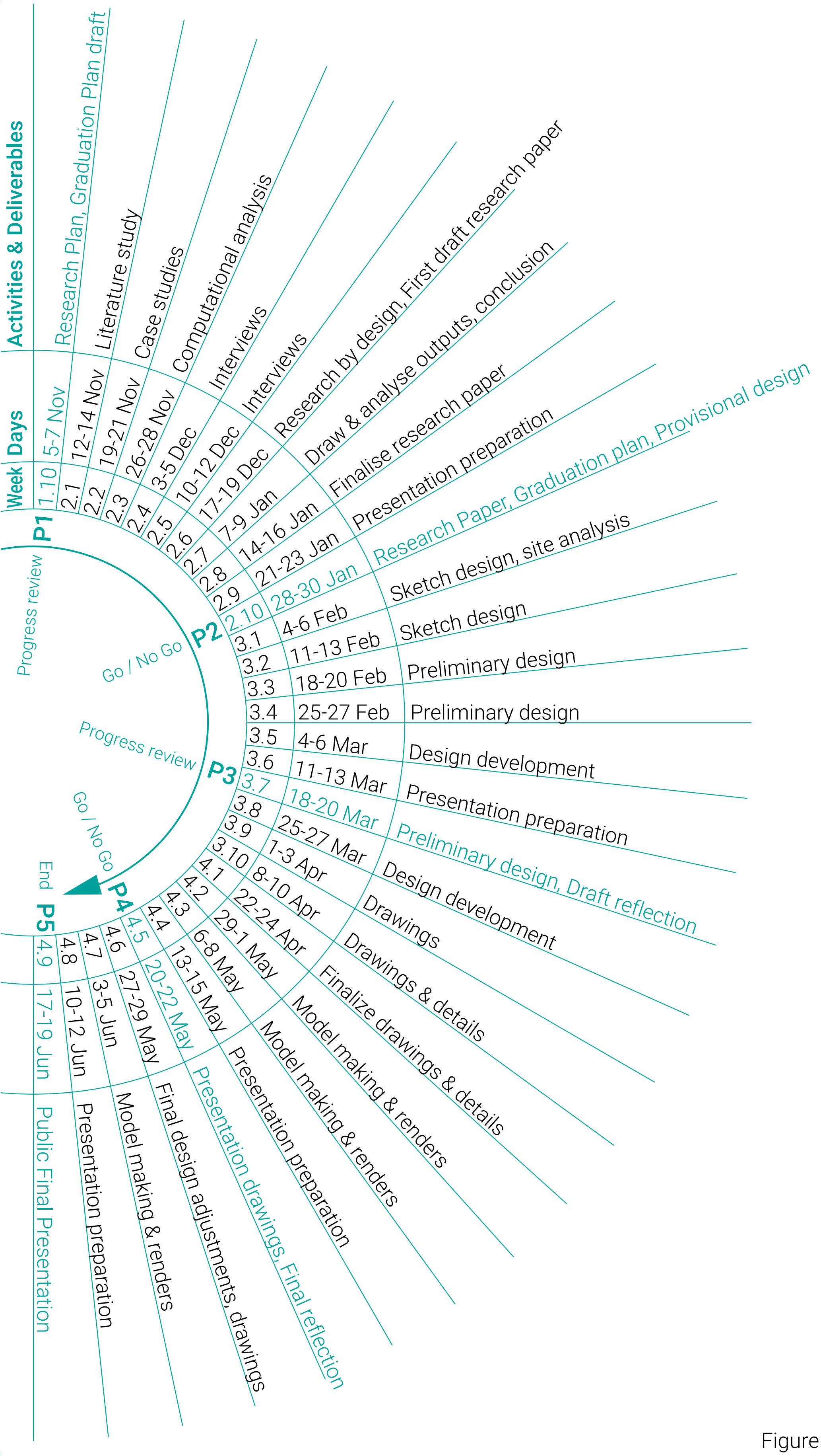

Figure 9: Research & design planning Diagram

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