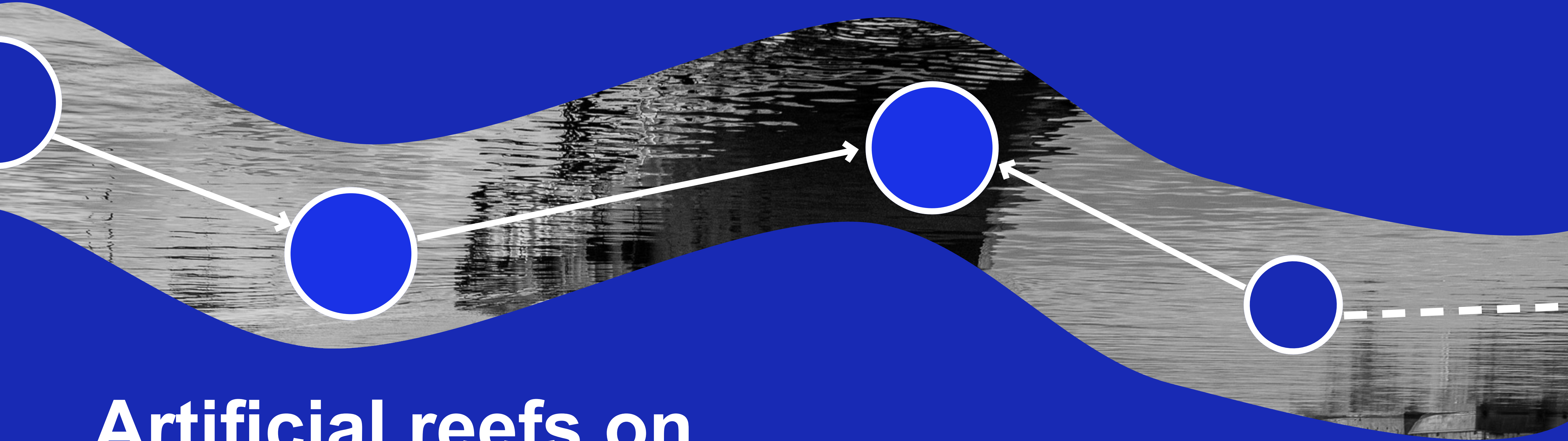

Artificial reefs on surfaces for biodiversity in Oslo harbor:

how system oriented design and a digital service brings us one step closer

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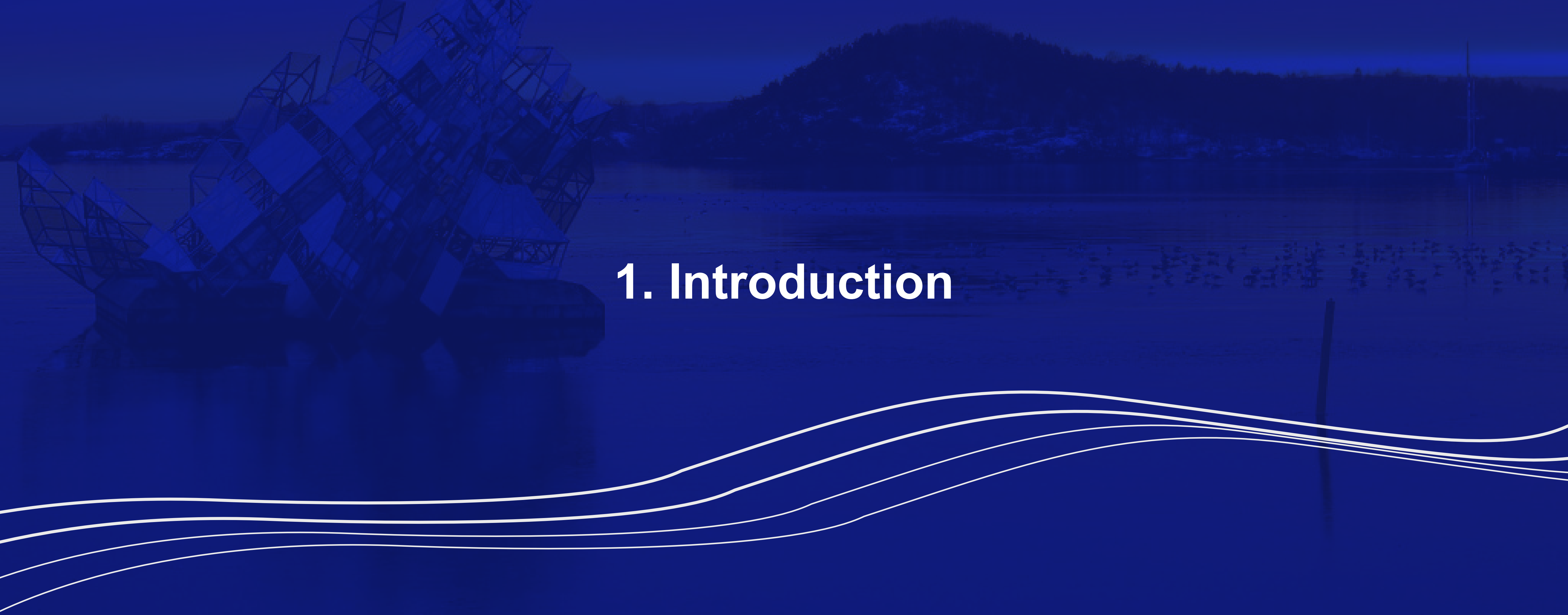
Foreword

I grew up along the coast of Norway. On the southern tip of the Oslofjord. Screams of seagulls were the anthem every summer. We always had long stays at one of the many local beaches. We could choose between sandy ones, grassy ones and rocky ones. I remember being shocked when I realized that not everyone had access to the ocean. Swimming was the best getaway from heat, because swimming with friends was exciting.

Recently I learned that the same Oslofjord is in a state of dire straits. It was calling to me. I had to take on this last truly value driven challenge as a student.

Throughout this project I have thrived on the support from my girlfriend Ingrid, my tutors Nenad, Tore, Kristin, my fellow students, and my friends. I also want to thank my garden.

I had no previous knowledge of working with marine life restoration. As a consequence, the project has seen changes along the way. The end goal stayed the same - to increase biodiversity in the fjord, and to help highlight issues along the marine coast.



1. Introduction

The purpose of this project is to find design opportunities and a designed proposal for habitat restoration and more specifically 'artificial reefs' on surfaces in Oslo harbor. This is also known as 'diversification of surfaces'. Through the project, I share 5 valid intervention points, several key insights from the process, concepts, and a proposed solution with discussion. This is a system oriented design project. The project is informed by literature review, interviews and evaluation sessions with stakeholders. The data has been worked using GIGA-map (Sevaldson, 2011) and analyzed using zip analysis (Sevaldson, ZIP-analysis, 2012). Concepts were tried and tested using evaluation sessions with stakeholders. Many concepts failed. A final prototype was analyzed using context of experience (Gulden & Moestue, 2011), and testing for usefulness principle (Nordbø, 2017) with stakeholder.

In this chapter, I will quickly present the Oslofjord. Then, the inner workings of artificial reefs (Man-made structures for attracting life). From there, we move on to the problem statement and the design related content.

1.1: The inner Oslofjord and Oslo harbor

For many, the Oslofjord needs to introduction - but I will make one either way.

The inner Oslofjord is a marine area used by millions of people every year. The Inner Oslofjord stretches from Drøbak on its most southern point, to Oslo in the north. Around the port city of Oslo, we find the harbor (Askheim, 2021). The harbor area is a developed and varied cultural landscape. If we stroll down along the harbor area, we see tourists and locals eager to explore the islands (Hovedøya for example). We also see cruise ships with passengers, and cargo ships with necessary goods. Down Aker Brygge, we find piers with shops and restaurants. The sea is at our disposal. One can even argue that the sea is a large part of Oslo's identity.

The story of the inner Oslofjord is a story of change. The fjord has changed from a busy fishing hub with tuna, whale, Atlantic cod, to a more barren and ecologically challenged place (Solvang, 2021), (Ringnes, Iversen, Kristiansen, & Drageset, 2021). This ecological situation has gradually developed at a time when the citizens of Oslo are welcomed into the harbor with open arms. Citizens of Oslo now have more access to the sea than in decades. Examples of this access is for example the moving of the highway which used to run right on the seafront.

1.2: Oslofjord in crisis

During a rather serious conference called 'Status Oslofjorden', the main speaker stressed that the threat in the Oslofjord can be summed up by 4 main trends: Plants are under pressure. Fish are under pressure (Borchgrevink, 2021). Nutrients runs off into the Oslofjord from various sources (these nutrients creates great conditions for unwanted plants). Last trend was environmental poisons entering the fjord (Borchgrevink, 2021). Most likely, the two first trends are symptoms of the two last ones.

Unfortunately, the pressure on plants and fish are produced by more than nutrients and environmental poisons. These factors also play a big role: development and construction, fishing, and plastic pollution, rising temperatures (Ringnes, Iversen, Kristiansen, & Drageset, 2021) (NIVA, 2019). The effect of these problems are hard to measure, but it is clear that destruction and misuse of habitats is a reality in the fjord. We replace natural ecosystem with cultural ones.

Figure 1: Highway over Bjørvika, *2004, by Bjørvika Utvikling, https://www.bjorvikautvikling.no/portfolio-item/bjorvikas-historie/.*

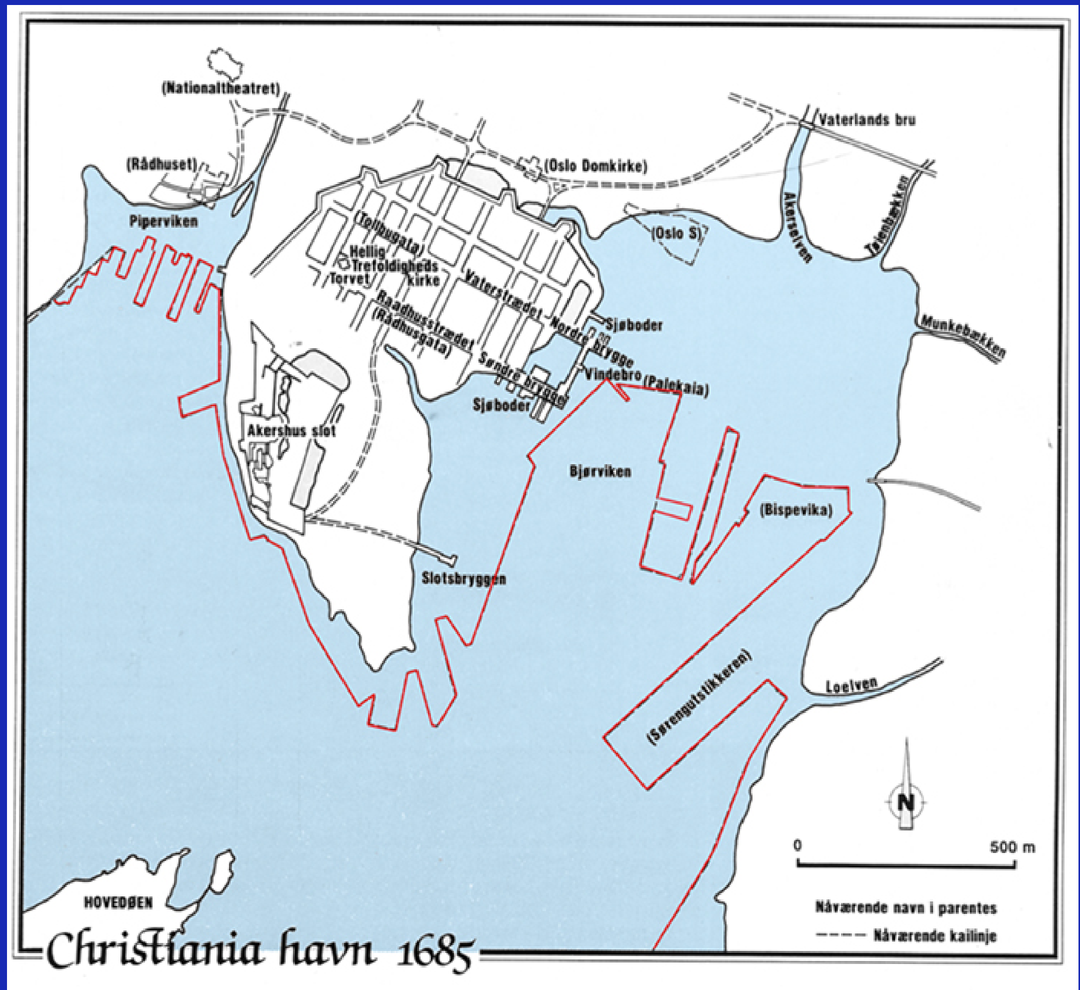


Figure 2: Christiania Harbor (Oslo harbor), by Bjørvika utvikling, https://www.bjorvikautvikling.no/portfolio-item/bjorvikas-historie/.

1685 then and now. Red line signifies current design of the harbor. Black line signifies the 1685 state. In 2022 this area is completely cultural.

Figure 3: Harbor front in Oslo harbor, by the author, 2022.

“Figure 3” captures a current philosophy with construction along the water. This picture is from a central area in Oslo, which has been developed quite recently. Notice the oxidized steel which is attached to the pier? The details stop almost as soon as the water begins. Under water is an afterthought. A group of officials at Oslo Havn FK emphasised that much of regulation ends under the water’s edge (Myklebust, Johansen, Pehrson, Nielson, & Winsvold, 2022).

1.3: Artificial reefs

Artificial reefs are central to this thesis. Contrary to what the name suggests, they are not necessarily structures that replicate coral reefs. Artificial reefs are man-made structures that are placed on the seafloor (Jayanthi, et al., 2020). Goal of artificial reefs is to boost biodiversity (Jayanthi, et al., 2020)(Jahren, 2016). The manifestations of artificial reefs span the globe and exist in many examples. Have you for instance heard of shipwrecks that attracted bunches of life? Perhaps you have seen how different organisms grow on rocks, cliffs and even concrete in the beach near you? Did you ever notice how schools of fish hide and congregate around wooden beams on old piers when you swim there? All of these are examples of unintentional artificial reefs.

Anything man-made under-water is an artificial reef in some respect. In more systematic practice though, Artificial reefs can be used as a tool on the surfaces in a harbor and it can be free-standing structures on the seafloor. Using artificial reefs on the harbor's infrastructure will be the main topic and primary concern of this thesis. This was just a warm-up. More on artificial reefs will come.

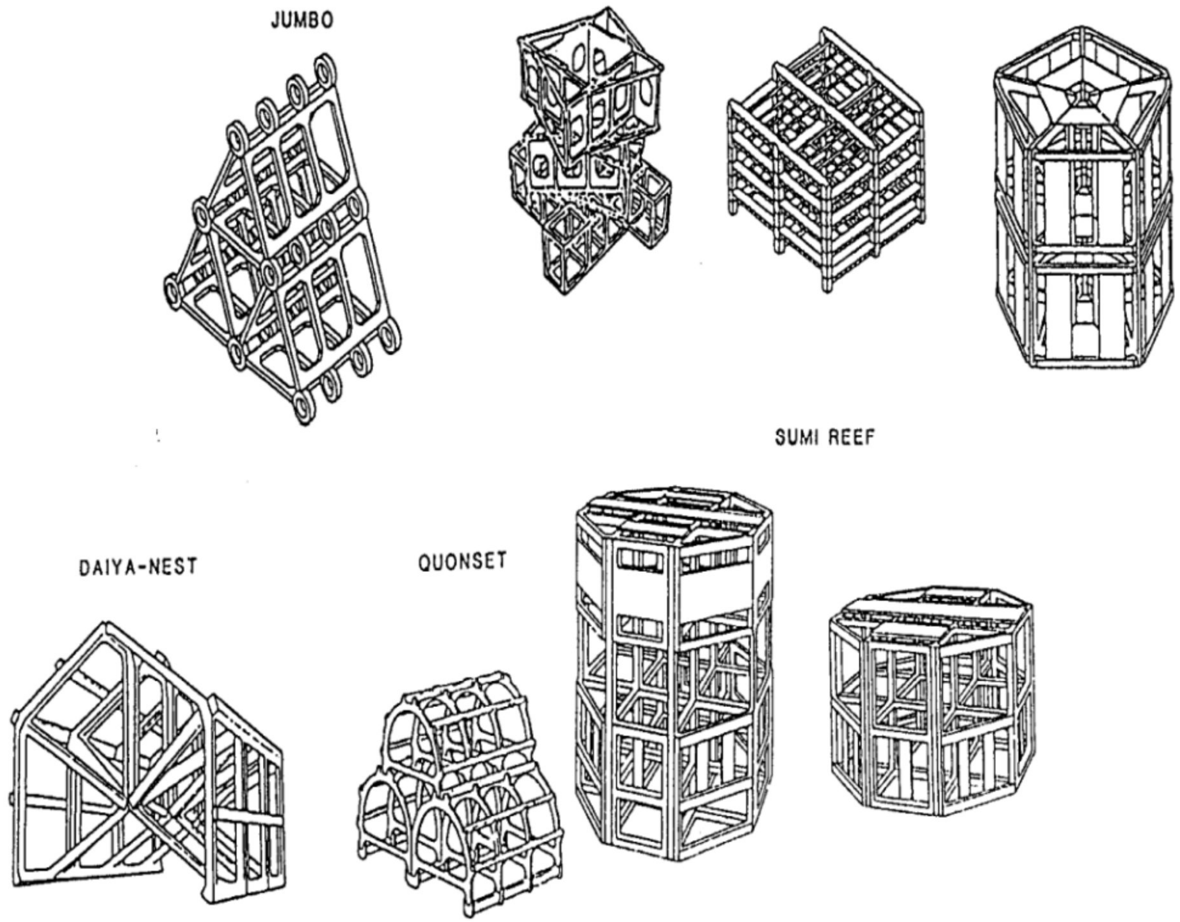


Figure 4: From Considerations in design of AFR, 2020. Examples of Japanese designed reefs for deep waters (Jahren, 2019)

1.4: System design and the end of pipe

I have to disclose the role of artificial reefs in a system. An artificial reef intervention will always be put in place to fix problems caused by human actions. Artificial reefs does not address the actual cause of these problems. Solutions that mitigate the problem, rather than solve the root problem are called ‘end of pipe’ solutions. ‘End of pipe’ solutions are not incompatible with system design, as long as we acknowledge the need for other solutions as well to create a holistic strategy.

How to increase the accessibility of artificial reefs on surfaces in Oslo harbor, through system oriented design practice?

Problem statement

2. Methods

2.1: Method overview

Thematic Literature review (Muratovski, 2015):

Key articles and books on the topic of artificial reef research were identified and read. These provided view of the state of the art on the field.

Service blueprint (Young, Mannheimer, Rossman, Swedman, & Shanks, 2019) (Service Design Tools, 2022):

This method was used to map out all the steps of working with artificial reefs, from planning to implementation. This information was collected during the interviews. The actors involved were also mapped. This method is also similar to user journey. It's all about mapping sequence of action over time.

Interviews (Muratovski, 2015):

Interviews were in a format of 90 minutes. The interviews were semi-structured. They were used to get data I could not find online. Over the course of this project, 9 interviews were carried out.

Actor map

My actor map is inspired by conventional actor analysis (Aakre & Scharning, 2016), actor network theory (Latour, 2005) and system thinking (Meadows, 2008). I will come back to this later.

Giga-map (Sevaldson, 2011):

Giga-map is used to visualize and completely immerse myself in all the data throughout the project. The giga-map will evolve as the project evolves and it will also try to capture some of the complexity of the project. Data comes from different sources and therefore we can use this technique to assess them simultaneously although the way of viewing data is different.

Interconnections (Meadows, 2008):

Not a method, but a way of viewing data. Central to system thinking. It describes the relationship between elements in a system. Most times in this thesis, they will be identified as text on arrows between two elements in an illustration.

ZIP Analysis (Sevaldson, 2012):

Zip analysis is an approach that comes naturally when mapping out - one assesses the problems in a system. Also, one will dive deeper where there is more to learn or more to explore. This is a fairly opportunistic way of working, as we will try to uncover potential interventions.

Intervention and intervention-points:

Not a method, but a term I use frequently. I use the term 'intervention' when referring to the implementation of a solution into a system. I use the term 'intervention-point' to describe the context in the system where a designed solution may be put in place. I use these term because it reminds me that all solution exists within a context - they never float in space.

Back-casting (Robèrt, et al., 2019):

Back casting is the opposite of forecasting. In forecasting we use today's situation and forecast towards a plausible future. I used a set of values as inspiration for the future.

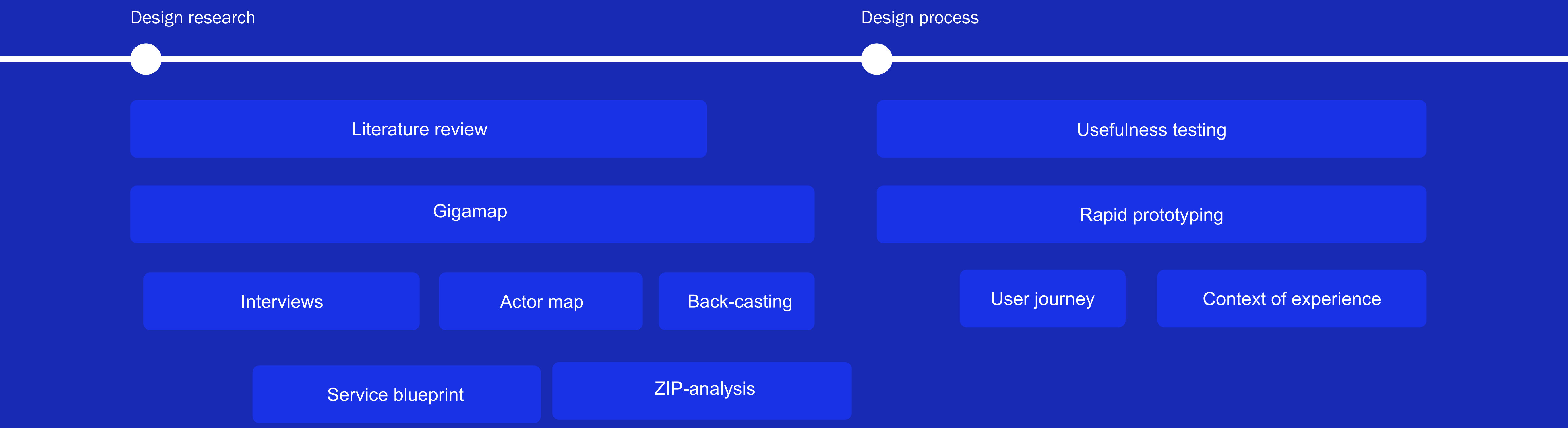
Intervention and intervention-points:

Context of Experience is a strategic tool to boost experience of products by looking at important contexts of product interaction.

Usefulness testing (Nordbø, 2017):

Usefulness testing was done with participants as part of product evaluation. The source here does not refer to the testing itself, but to the principle of usefulness.

2.2 Method Map



3: Design research

In this chapter you will learn sufficiently about artificial reefs to survive this thesis. I will show you the good things and the bad things. You will learn about the process of working with them in Norway and you will understand the context that surrounds them. I will also highlight the relevance of working with reefs right now and the reasoning behind choosing Oslo harbor as a location for design intervention. All these points steered the project in the direction of a handful of intervention-points, which I will present in the next chapter.

Data reviewed in this chapter are gathered from: literature review, service blueprint and several interviews.

3.1: Researching for a design project on the Oslofjord

Researching for this project, I tried to get on top of several societal aspects. I wanted to cover aspects following a steep (Social, technological, economical, ecological, political) format. The reason for this is that a project in marine area in a heavily regulated Norway will touch all of those aspects.

Design research was an iterative process. I worked myself inward from a vague starting point. Later I got track of methods for intervening in broken marine ecosystems. This lead me to restoration and reparation, which again lead me to artificial reefs on surfaces in Oslo harbor. It was like bouncing back and fourth inside the first diamond of the double diamond, until I had what I needed to move on.

3.2: Working with restorative measures in Oslo Harbor 2022

In a unique report from 2019, NIVA (Norwegian institute for water-research) observe the Oslo harbor (NIVA, 2019). The purpose of this report is to look at possible solutions for restoration work (NIVA, 2019). The goal of restoration work is to re-establish weakened ecosystems and boost biodiversity. The report was ordered by Bymiljøetaten (Oslo Kommune). Miljødirektoratet also support restoration efforts in the Oslo harbor area (Miljødirektoratet, 2022). This report comes at a time when Miljødirektoratet releases an action-plan for restoring the Oslofjord to its former glory (Miljødirektoratet, 2019), and the time UN declares a decade of “ecosystem restoration” (Miljødirektoratet, 2019 p. 118).

Figure 5 : Oslo harbor, by Bahnfrend, 2019, https://commons.wikimedia.org/wiki/File:Skyline_of_Oslo,_2019_(01).jpg

3.3: Artificial reefs

Artificial reefs are manmade structures that are placed on the seafloor (Jayanthi, et al., 2020). Some say that artificial reefs encompass anything man-made dropped into the sea (Burt, 2021). Well designed artificial reefs will provide hiding places for fish or lobster (Jahren, 2019), and rough surfaces (NIVA, 2019) for plants to attach to, which in turn attracts more life. All of these things promote ecosystems and biomass growth. Those properties are missing in plenty of areas where humans have intervened.

Artificial reefs can be implemented for commercial benefit too. In Japan, there's a thriving culture for artificial reefs (Jahren, Conversation about Artificial Reefs, 2022). In China, kids learn about artificial reefs in educational videos (海底小縱隊, 2020). In the children's show, we see a train cart attracting various life-forms over time.

In the US there are examples too. In 'Rigs-to-reefs', oil rigs are systematically cleaned, transformed and optimized for colonization of animals (Bureau of Safety and Environmental Enforcement, u.d.). These ironic projects, where a polluter is transformed into a hub for life, save oil companies time and money. The bureau of safety and environmental enforcement explains the effects of the 'Rigs to reefs' program for different actors: "for the environment.. it saves fuel emissions", "for oil companies, it saves money", "for states, it attracts commercial and recreational fishing", "for divers and fishers, artificial reefs create a rich diversity of life", "for marine species, it provides habitat, shelter, food" (Bureau of Safety and Environmental Enforcement, u.d.).

In Norway, one of the most prominent examples of artificial reefs are in Hammerfest. In Hammerfest, 24 artificial reef structures were dropped at circa 10 meters and 20 meters depth (Hammerfest Kommune, 2010). The goal was to bring back extensive areas of kelp that had been eaten away by sea urchins. After one year, kelp and other forms of life had established on the artificial reefs. After six years, the cycle had played on repeat and the urchins had again ravaged the entire forest (Hammerfest Kommune, 2010). This is an example of the chaotic and unpredictable behavior of ecosystems.

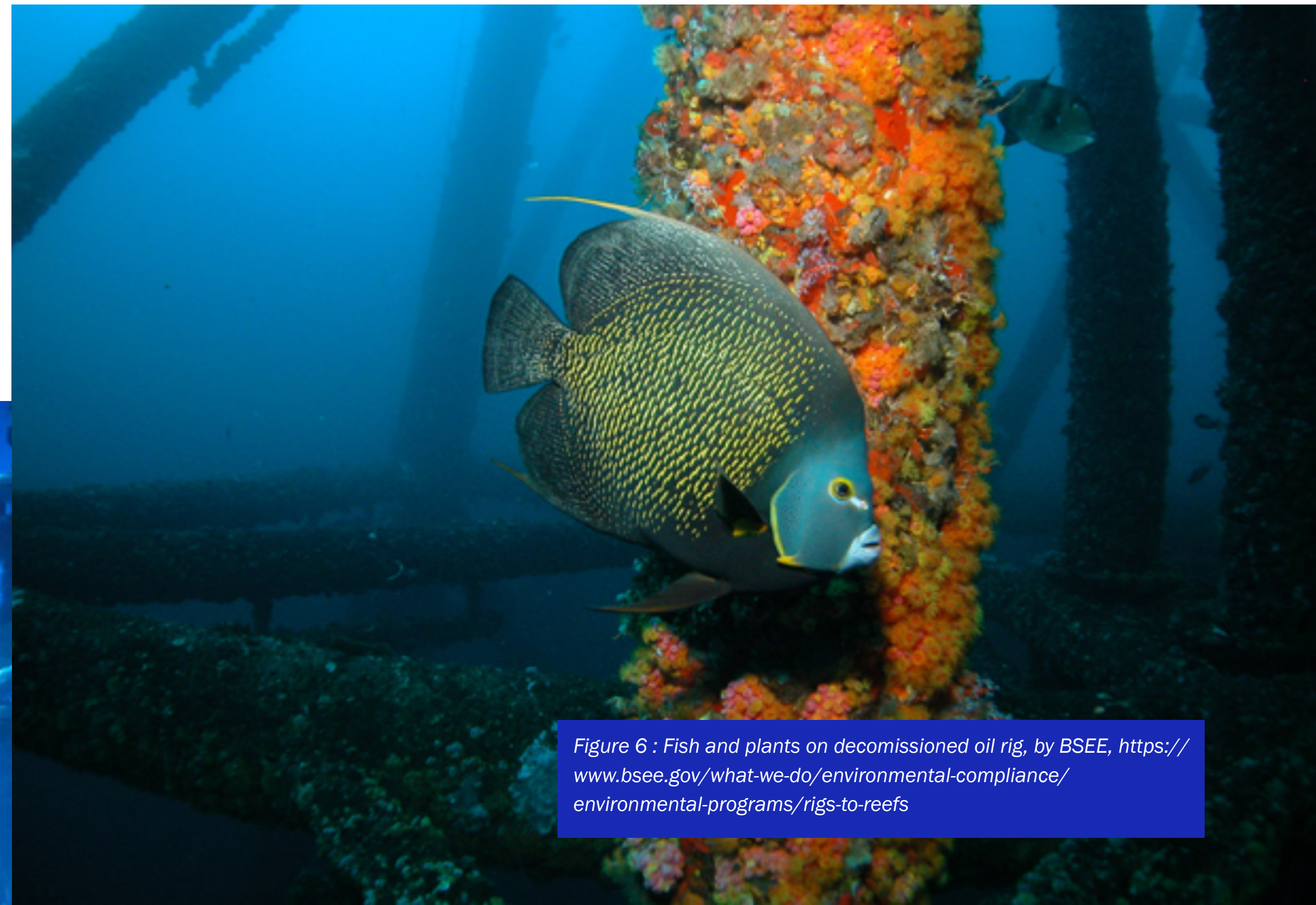


Figure 6 : Fish and plants on decomissioned oil rig, by BSEE, https://www.bsee.gov/what-we-do/environmental-compliance/environmental-programs/rigs-to-reefs

3.4: Restoration

Ocean conservation efforts and human well-being go hand in hand (Blumberg & Bruno, 2018). Habitat protection and restoration is stated as one of the four primary strategies for reversing the decline of marine life. The other strategies are “regulation of hunting”, “Management of fisheries”, “Water quality improvement” (Blumberg & Bruno, 2018).

Marine restoration is interesting, because we see that marine life is incredibly resilient. When pressure is lifted from it, the life will bounce back naturally (Blumberg & Bruno, 2018). These incredible recoveries was observed in the adriatic sea after the collapse of the Soviet Union. The Soviet Union’s extensive use of fertilizer was one of the reasons for why the fish stocks declined so rapidly (Blumberg & Bruno, 2018).

But the type of pressure put on marine life varies. In the case of the Oslo harbor, there is for example: lack of light, lack of oxygen, and more importantly for this project, a lack of correct areas for organisms to grow and hide (NIVA, 2019) - also known as habitat. This brings us to the next paragraph.

3.5: Diversification of existing structures

Oslo harbor has man-made surfaces that are represented well throughout the capital’s coastline. 22.2km of Oslo coast was assessed by NIVA in their report (NIVA, 2019). In that same report, they shed light on a strategy called “diversification of existing structures” (NIVA, 2019). That process revolves around making existing surfaces more suitable for life (NIVA, 2019). Most of the 22.2km of existing surfaces are monotonous and slippery. They were never intended to suit the needs of the life that surrounds them. Keep this strategy in mind, as it is the kind of artificial reef strategy I focus on here.

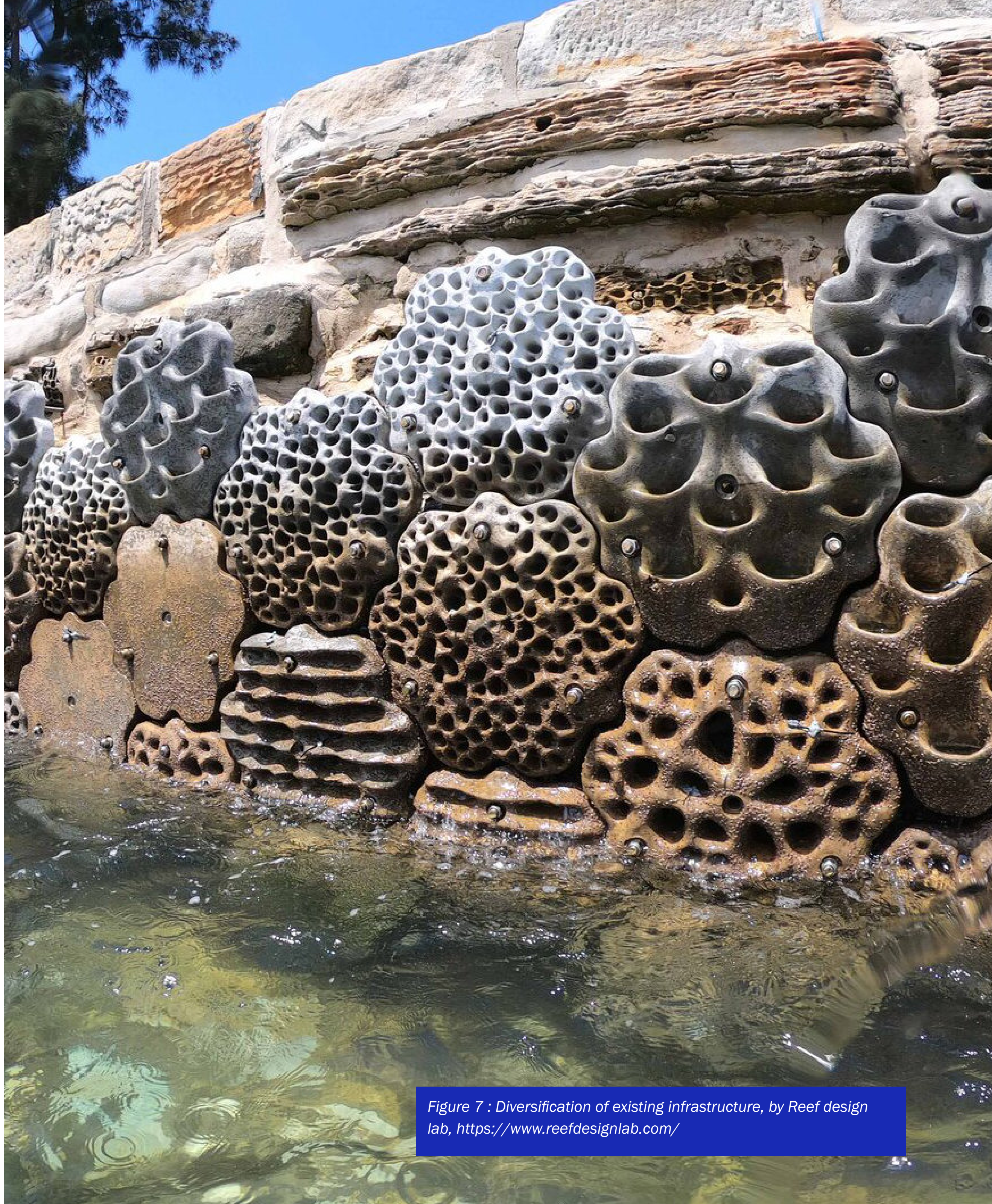


Figure 7 : Diversification of existing infrastructure, by Reef design lab, https://www.reefdesignlab.com/

Figure 8: Artificial reefs in Futo, Japan, by capsellanaut, 2021 https://commons.wikimedia.org/wiki/File:Artificial_fish_reef_in_Futo,_Japan.jpg. Creative commons.

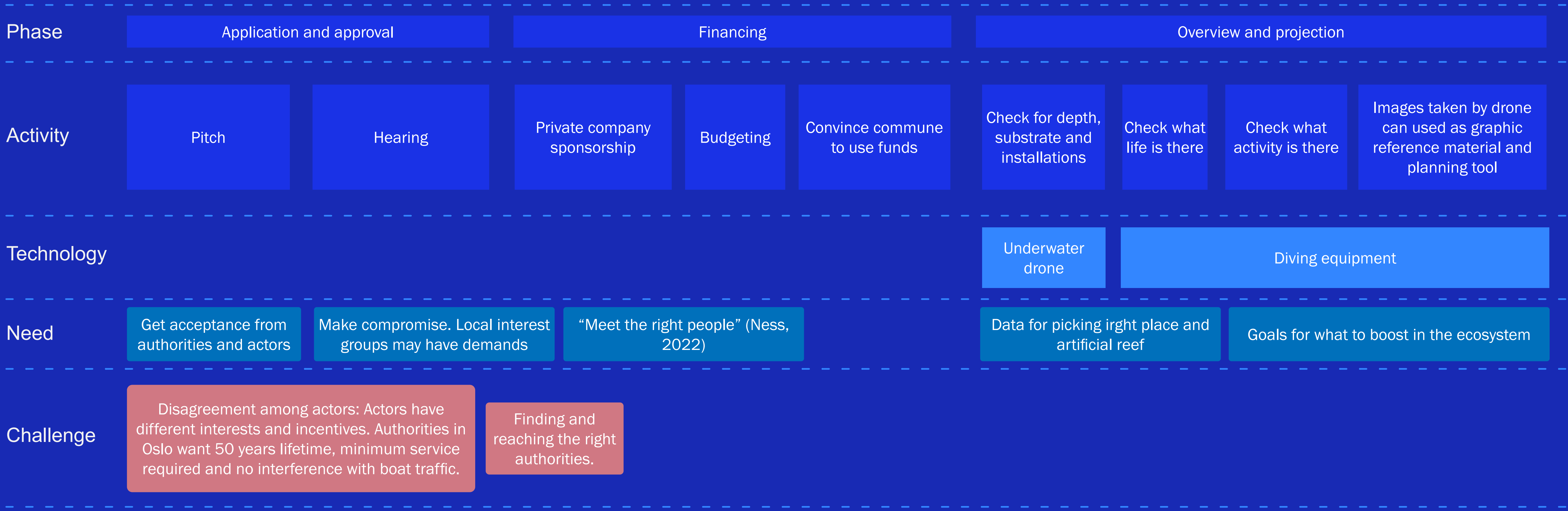
3.6: Critical look at artificial reefs

Artificial reefs has a darker side too, if not done right. In the 1970s, 2 million used tires were dumped into the coast of Florida with ambitions of creating habitats for wildlife (NPR, 2007). The tires had almost no positive effect at all. A group of fishermen organized the campaign - it was approved by local authorities too. Fishermen failed to take into account the extreme weather events. The tires shifted around as a result (NPR, 2007).

According to public broadcaster PTS, in Taiwan, over 30 years, more than 200,000 structures of different kinds have been implemented in more than 80 waters (PTS Ocean, u.d.). This has been done by a public body similar to the Norwegian fiskeridirektoratet. Some ecosystems have suffered from these structures being dropped there (PTS Ocean, u.d.). Implementing hard surfaces on soft sea bottom changes the properties (Miljødirektoratet, 2022) and may invite alien species in (NIVA, 2019).

3.7: Topics missing from reviewing literature

When looking through literature, I did not find sufficient material on political and social perspectives of marine restoration. Especially lacking were information on the urban perspective and the Norwegian perspective. Also, I did not find satisfactory approaches on how to introduce restoration into systems that exist, such as harbors or fishing estuaries. Research usually focused on the ecological perspective (Alam, Yamamoto, Umino, Nakahara, & Hiraoka, 2019) (Jayanthi, et al., 2020), where counting biomass and reef type was central. To solve this, I try to get smart on those missing topics by conducting my own research.



3.8: Artificial Reef Projects in Norway

Artificial reefs are products, but surrounding these products are value chains. These value chains demands attention in order for achieving the desired effect. The whole process from start to finish of working with real life artificial reef projects is scarcely documented. In Norwegian waters I will dare say that there is no complete documentation currently in existence. I talked to two individuals with artificial reef experience in Norway (Ness, 2022)(Miljøorganisasjon, Artificial Reefs in Oslofjord, 2022). Together with them, we built a complete service blueprint (Service Design Tools, 2022). This service blueprint method has been used to understand a service rather than to design it. The blueprint shown above is a simplified version of the original blueprint for communicative purposes.

Some phases in this service blueprint are interchangeable. This adds complexity, but also flexibility. One can for instance collect financing before the authorities have approved the project. I will go through the blueprint phase by phase.

Application and approval: Let’s imagine that we will try to implement artificial reefs somewhere in Norway. Our goal is to restore a broken ecosystem. Up to this day, these projects starts with a person like us - a person who’s motivated for these type of restoration measures. One of my informants had access to plans for artificial reefs designed by a company that makes those. For them, the next step was to pitch the project to the local authorities. If we get the project accepted by the local authorities, then we will still need funding. Keep in mind that the application and approval process can be complicated, but that is not the topic of this exercise.

Phase	Cleanup	Production			Transport and implementation			Follow up and documentation	
Activity	Manual cleanup work	Inhouse production for smaller parts that can be placed on Europall	Outsource bigger structures	Leftover materials from industry if possible	Transport from production site to buffer zone storage	Transport from buffer zone storage to implementation site	Implementation	Observation	Cleanup
Technology					Truck, boat, et cetera	Large storage areas	Crane, gps, boats, crew	Divers	
Need	Clear the site for intervention	Right design according to place, ecosystem and goal		Material with no harmful effects on environment			Correct coordinates	Control areas. Compare.	
Challenge	Expensive							Asessment of the quality of reefs may well determine the future of use in Norway.	

Funding: It's difficult to get funding for an artificial reef project. It generates no direct revenue or income, and it has little documented effect in Norwegian waters. Authorities have come together before with the funding. A project in Hammerfest was almost entirely sponsored by Norwegian energy company Equinor (Hammerfest Kommune, 2010). One of the informants wisely said that "People who have money want something in return" (Jahren, Conversation about Artificial Reefs, 2022), and this applies to those who invest in artificial reefs too. Energy companies for instance, can invest in a restoration project to generate PR. This acts as a diversion from other activities that they do. In Oslo it's different and funding needs to be incentivized by other means.

Gaining an overview: This part is about surveying the site(s) that one wants to intervene in. This step involves someone with the understanding of marine ecosystems. This phase is often time consuming and quite cost heavy. The reason for this is that processes of surveying water is manual labor in many situations. While gaining an overview, we can look for: water depth, type of sea bottom, expected sea life (Jahren, 2019), local natural diversity and surface deisgn (NIVA, 2019), amongst other things. This phase can be skipped, although skipping this phase is much like taking the highway with your eyes closed - it's possible, but the outcomes may vary. In good projects, this phase is obligatory and used to ensure quality of the outcomes.

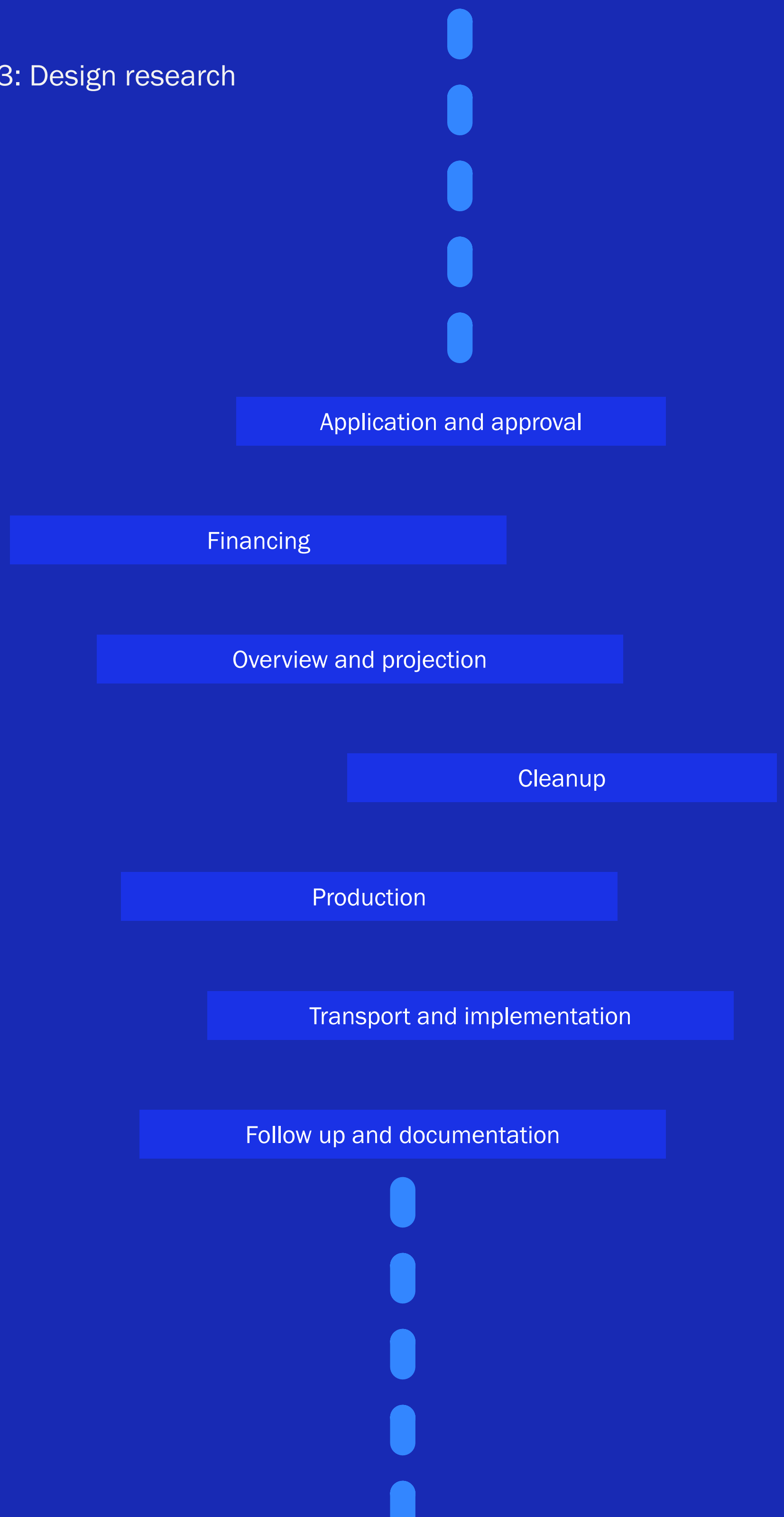
Cleanup and preparation: This phase comes when a decision has been made on exactly which sites to intervene in. Clean-up work should be done to make sure that the site is clear and ready for artificial reefs there. This is especially true for more population dense areas, where litter is a bigger issue.

Production: Status quo is that artificial reef structures are created on demand. There are no off the shelf options. One of my informants had to use a concrete factory in Sweden (Ness, 2022). With the reefs themselves, it's possible to consider leftover materials. NIVA raises the point of using materials that are local, because they will have a more positive effect on the ecosystem too (NIVA, 2019). The discussion of reef properties and material properties is a whole field and I will not dig further into it.

Transport and implementation: Reefs are transported from production to the site of implementation. If the reefs are big, a buffer site may be needed until the date of implementation. Size matters here of course. Boats and cranes will be chosen based on the size of the reefs. Precision is a factor, but the level of precision needed was different depending on whom you ask. One informant stressed that one would use gps on the crane itself, to make sure that the coordinates are completely correct (Miljøorganisasjon, Artificial Reefs in Oslofjord, 2022). Another informant said that the crane operators knew what they were doing and that the reefs ended up in the right spots (Ness, 2022).

Follow up and documentation: After the implementation, it's time to document and understand the effects of the intervention. In science, control areas are used to understand the quality of the artificial reef (Jahren, 2019). NIVA communicates that problems unforeseen in the planning phase may occur. Proper monitoring may help fix these problems (NIVA, 2019). In a perfect world, one can use results from monitoring to iterate on the artificial reefs. Any errors can be corrected in future artificial reef projects too. Communicating the effect of restoration in this phase will help share the narrative with people too (Miljøorganisasjon, Artificial Reefs in Oslofjord, 2022).This phase may be crucial for the future of artificial reef projects, seeing that authorities in Oslo (Oslo Havn FK) are very result driven.

Figure 9: From utsetting av kunstige rev I Hammerfest Kommune, by Tom E. Ness, 2006.



3.9: The missing steps in a blueprint

There are weaknesses in a service blueprint. It does not highlight the connections between the different phases or actors. Also, it does not explain well what happens before the first phase and after the last phase. Something missing from this service blueprint is how we implement the reefs into society and how citizens may benefit from it in years to come. But now that we have most processes of working with artificial reefs in Norway on paper, we can identify areas to intervene into. The next challenge is to transfer these contexts to Oslo and to understand the benefits for society.

3.10: Finding the right authorities

For an informant, it was like a riddle finding out whom could authorize the use of artificial reefs (Ness, 2022). In the case of one of the informants, the authority was Hammerfest harbor and Forsvarsbygg. These authorities demanded the acceptance of locals as well, so a hearing was set in place for the authorizing process. These processes vary depending on area. In Oslo harbor for instance, the company Oslo havn FK has authority to run pilot projects in harbor areas (Neilson, 2022).

Another frame to work within are the laws. When a marine area is protected, there are additional boundaries. These paragraphs are to be found in the law “Lov om forvaltning av naturens mangfold”, or “naturmangfoldloven” for short (Lovdata, 2021). One informant explained that there is too much regulation on the use of structures in the sea (Miljøorganisasjon, Artificial Reefs in Oslofjord, 2022). This regulation hinders exploration and efforts to understand the effects of these structures. According to the same informant, it is not much different than placing “bird-houses in the forest” (Miljøorganisasjon, Artificial Reefs in Oslofjord, 2022).

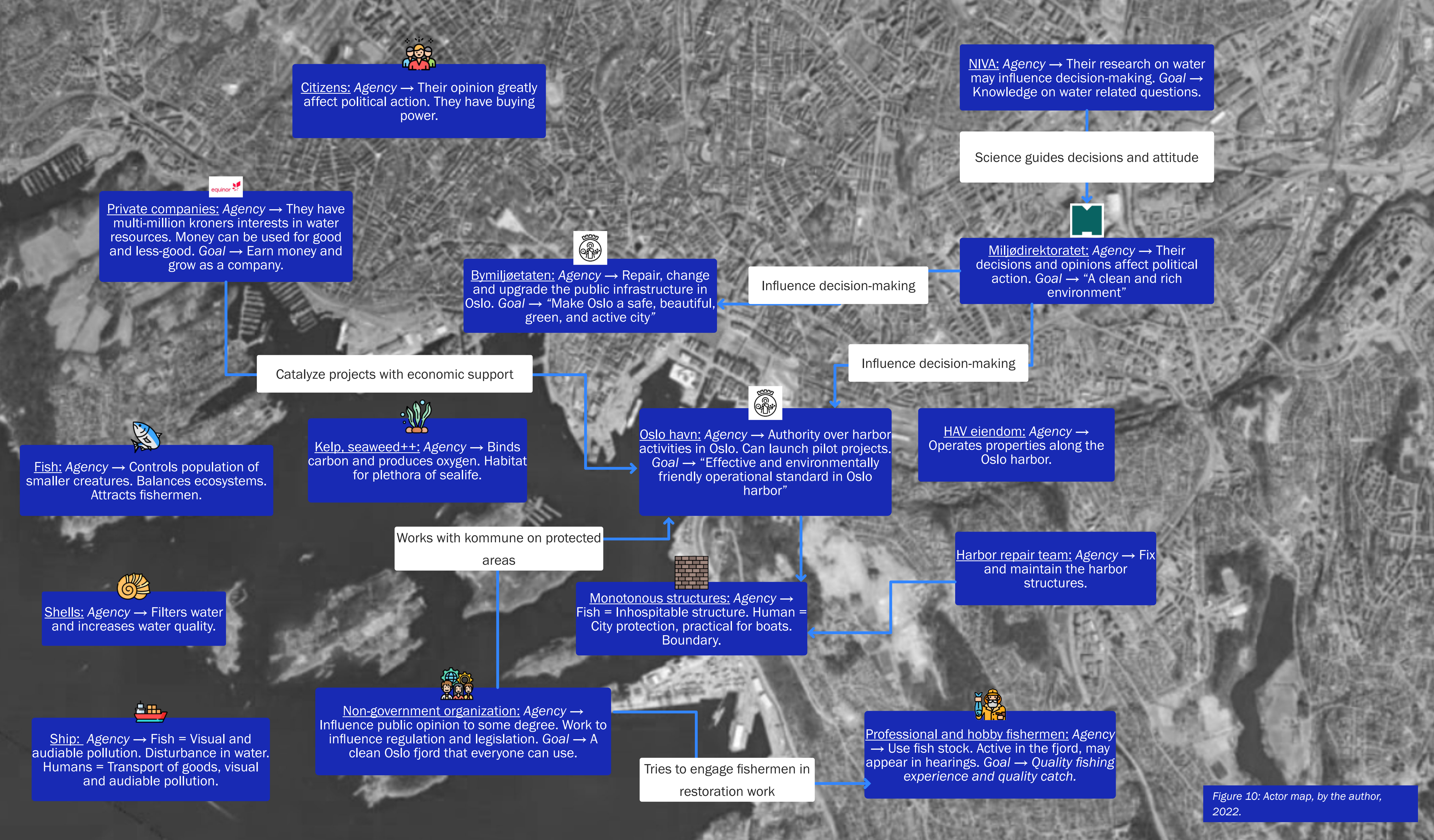


Figure 10: Actor map, by the author, 2022.

3.11: Actors in the harbor "Figure 10"

This method is inspired by different theories. On a fundamental level, this can be some variant of a stakeholder analysis (Aakre & Scharning, 2016). But I diverge from the standard stakeholder analysis because I chose to highlight the interconnections (Meadows, 2008) between the actors. The agency is described too. Agency is their power to influence (Latour, 2005) in a system. This actor map is an overlay over an image of the harbor. Let's go through the most important actors.

Oslo havn KF: Operates most of the harbor area in Oslo. Except for Sørenga and Operastranda. Oslo havn has the power to try new interventions in the harbor. In their eyes, artificial reef projects should "Not hinder boat activity", and it should be "easy to maintain". This topic is "important for harbors around the globe" (Neilson, 2022).

Bymiljøetaten: Operates a significant amount of the public infrastructure in Oslo. They have authority over Sørenga and Operastranda.

Non-government organizations: These are the people who notice the decline of sea-life in the inner Oslofjord. These organizations are also present when developing new protected areas. Non-government organizations try to motivate and engage the public as well. They are active in using the fjord and active in engagements to protect the fjord. The organization I talked to in this project truly believed in artificial reefs and even wanted more legal room to experiment with structures in the sea.

Fishermen: Fishermen may also notice the decline of biomass in the fjord. Field research tells me that they are sometimes hard to engage. They are active users of the sea.

Miljødirektoratet: They are non-political, but they influence political action. My paradoxical impression is that they are somewhat ideological, but at the same time it's difficult to test their stance on new things. They are slightly positive to artificial reef strategies in areas that are destroyed (Miljødirektoratet, 2022). Especially if few other solutions exist. It's also important to them that the interventions are away from the sea floor (Miljødirektoratet, 2022).

Civilians: Civilians use the harbor area for different purposes everyday and they are looking for different things. They spend money and time there around the sea. They influence political action. One informant stresses that conveying the narrative of marine restoration to civilians is of utmost importance (Miljøorganisasjon, Artificial Reefs in Oslofjord, 2022).

3.12: What does biodiversity mean for the different actors?

The kommune is split into different operators and communal companies. Some relevant once are Bymiljøetaten and Oslo harbor. For bymiljøetaten, the goal is to make Oslo a "safe, beautiful, green and active city" (Bymiljøetaten, 2022). For Oslo harbor, the vision is to be the world's most "area-effective and environmentally friendly urban harbor" (Oslo Havn FK, 2022). Miljødirektoratet, which reports directly to the climate and environmental department, aims for a "clean and rich environment" (Miljødirektoratet, 2022).

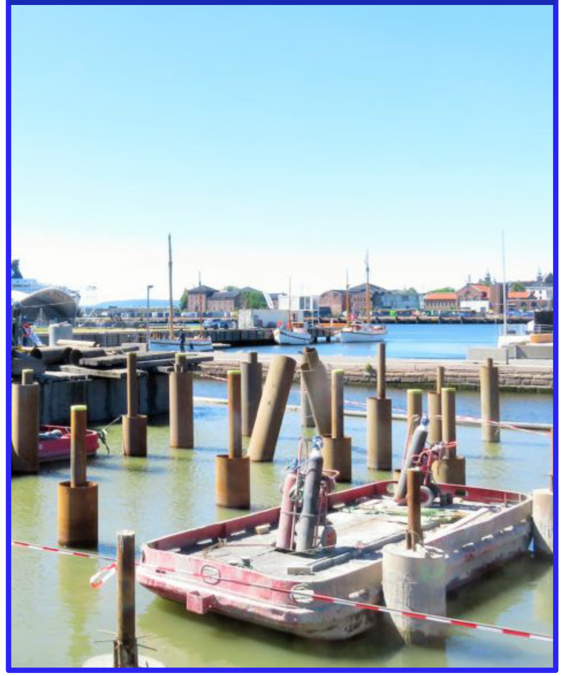
Then there are environmental organizations. Organizations want different things, but quite often they propose fishing, diving, education, recreation, and a clean environment. It's difficult to generalize the opinion of civilians, but recreational activities are popular in Oslo. Swimming is a big hit every summer. Therefore I assume in this project that they want clean water and a healthy fjord as well. At last, there are private companies which have nothing financially to earn from projects that boost biodiversity. They can still invest in these projects for the promotional value, such as Equinor did in Hammerfest.

The harbor

NIVA asks for more nature centered approach when developing in the sea (NIVA, 2019). Miljødirektoratet is more positive to human intervention for restoring ecosystems in harbor areas than more wild areas (Miljødirektoratet, 2022). Organizations wants more action for biodiversity and citizens needs clean water for recreational activities.

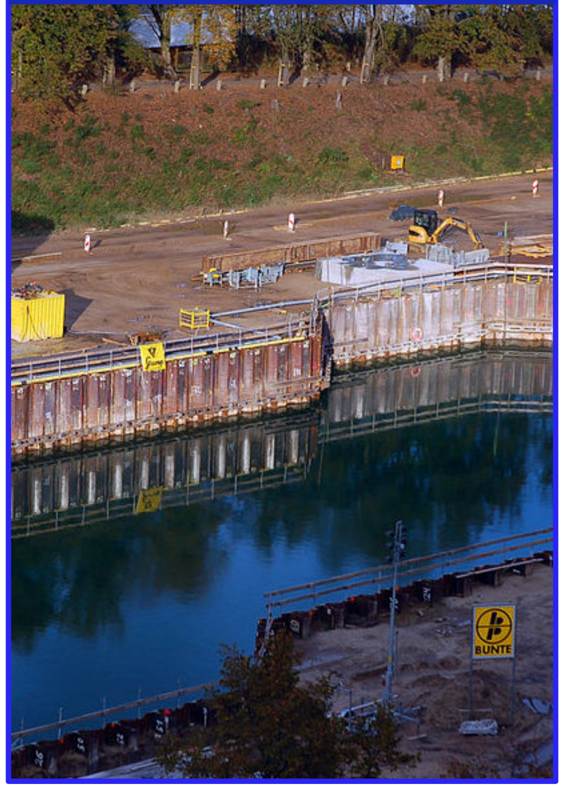
3.13: Architectural solutions in the Oslo harbor.

Figure 11: Steel pillars in Oslo harbor, by Veidekke, 2016, https://munch.veidekke.no/2016/06/20/kompetent-fundamentprodusent/.



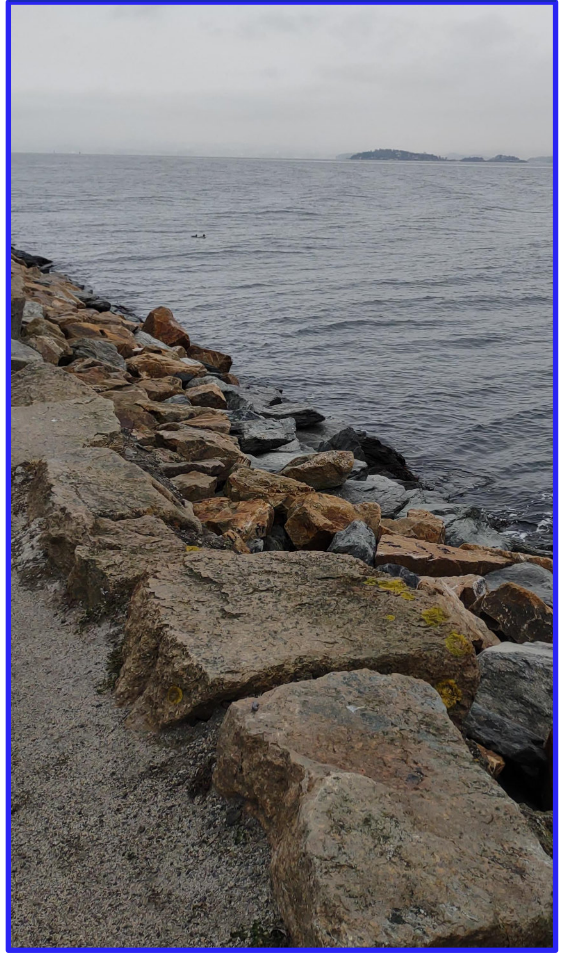
Steel pillars (stålpeler) are used under piers and harbor structures to bear weight.

Figure 12: Sheet piling, by Ralf Roletschek, 2009, https://commons.wikimedia.org/wiki/File:2009-10-19-schiffshebewerk-niederfinow-neubau-by-RalfR-27.jpg. Creative commons



Sheet piling (spuntvegg) Is a structure used to determine or shut-off areas on land or at sea. This is used to create a foundation for piers in the harbor.

Figure 13: Rock filling, by the author, 2022.



Rock filling: Rocks and blocks used as wave-breakers along the coast. These structures provide more complexity than any other construction so far.

Figure 14: Pier, by the author, 2022.

Other walls: Walls of different materials, such as concrete, granite and treated wood may be found along the Oslo harbor. Some older walls are protected too and cannot be changed.

Figure 15: Fishing vessel, by Anestiev, 2018, https://pixabay.com/photos/fishing-vessel-fisherman-fishing-3855153/. Creative commons.

3.14: Key insights

First of all, It's useful to emphasize that these key insights are gathered from different sources. All sources are mentioned in this chapter. Some are gathered from a single interview. Therefore the absolute truth of some key insights are up for debate. Also, the importance of these insights are based on the problem statement.

Right time and place to work on marine restoration: Makes this project feasible. UN makes 2021-2030 the decade of restoration (Miljødirektoratet, 2019). Miljødirektoratet and NIVA agrees on using interventions along the surfaces of the harbor to re-establish ecosystems (Miljødirektoratet, 2022) (NIVA, 2019). Environmental organizations are challenging regulation with small-scale artificial reefs (Miljøorganisasjon, Artificial Reefs in Oslofjord, 2022). Oslo Havn FK says that this is "important for harbors around the globe" (Neilson, 2022).

Complexity on the long-term effect of artificial reefs: The complexity of ecosystems makes the exact long-term effect difficult to forecast. In Hammerfest, the urchins ate up all the kelp after six years again (Ness, 2022) and dead shells from artificial reefs at Tjuvholmen fell to the seafloor and contaminated it (NIVA, 2019).

Hard to finance and difficult investment: It's near impossible for businesses to make profit off of the effects of artificial reefs, since ownership of the life produced by reefs is hard to claim ownership of. This means that the goal of artificial reefs in Norway should be restoration and conservation for example.

High focus on ecological and biological perspectives in research: Reports and articles focus less on the social, aesthetic, functional and operational perspectives. Questions such as: 'How do we implement artificial reefs into society', or 'how do we start working systematically with them in harbors?', are hardly asked.

Placing artificial reefs on the soft soil may cause problems: placing reefs on the soft soil may change composition and increase the chance of non-native species (NIVA, 2019)(Miljødirektoratet, 2022).

Oslo Havn FK needs solutions: To them, there are uncertainties to artificial reef projects - where to intervene, who to include in the process, what to measure and maintenance (Neilson, 2022).

Harbors have many submerged surfaces that have not been made usable for sea-life: These structures and surfaces may be rethought and redesigned for the purpose of boosting biodiversity (NIVA, 2019).

Oslo Havn FK wants data on the effect of Artificial Reefs: They don't have enough proof on the effect of artificial reefs in Norway. There's a trust problem, although the willingness is there.

There are benefits of communicating the narrative of ecological restoration to the public: People shape political action and they use the harbor areas. With their acceptance and understanding, the artificial reef projects may reach further.

People pay no attention to the things under water: It's out of sight - out of mind (Miljøorganisasjon, Artificial Reefs in Oslofjord, 2022).

Little room for small scale experimentation with artificial reefs in Norway: Bunches of red tape needs to be overcome if you are to experiment with restoration efforts as an organization or person today. Small scale experiments would provide free valuable insight.

4: Design process

This is where I start making hypotheses and conceptual extrapolations from the data I dumped on you in the previous chapter. As mentioned before, this project has seen its share of failures. This is the chapter where I will tell you about the most important failures that brought me to the proposed solution.

More concretely, I will present intervention points that came out of the key insights. After, I will convey how analyses and concepts were used. Then I will share with you how iterations were made, and how expert evaluation was used as a learning tool in a complex topic. The methods used in this chapter are GIGA-map, ZIP analysis, Cause & effect mapping, and usefulness testing.

4.1: Intervention points

We start this chapter off with intervention-points. Again, I use ‘intervention-point’ to describe the context in the system where a designed solution may be put in place. Intervention-points here are based on the key insights from the previous chapter. Many of them are difficult for a designer to intervene in (without tight partnership and competence from biologists for instance). I have felt that level of difficulty often in this project. As a result, this chapter has been heavily influenced by searching for the right intervention-point for a designer without the need for an entirely new research phase.

I spend time with ideas in intervention point 2, 3 and 4. Intervention point 2 provides designed tools early in the process of restoration projects, and therefore compels me to believe that the effect is substantial as well. Intervention point 3 is also looked at, as design solutions are very possible here.

Intervention point 4 is a natural addition to all other interventions as well, and I will always try to consider information to the public in any proposed solutions. Keep in mind that interventions often are under water and therefore hard to spot for citizens of Oslo.

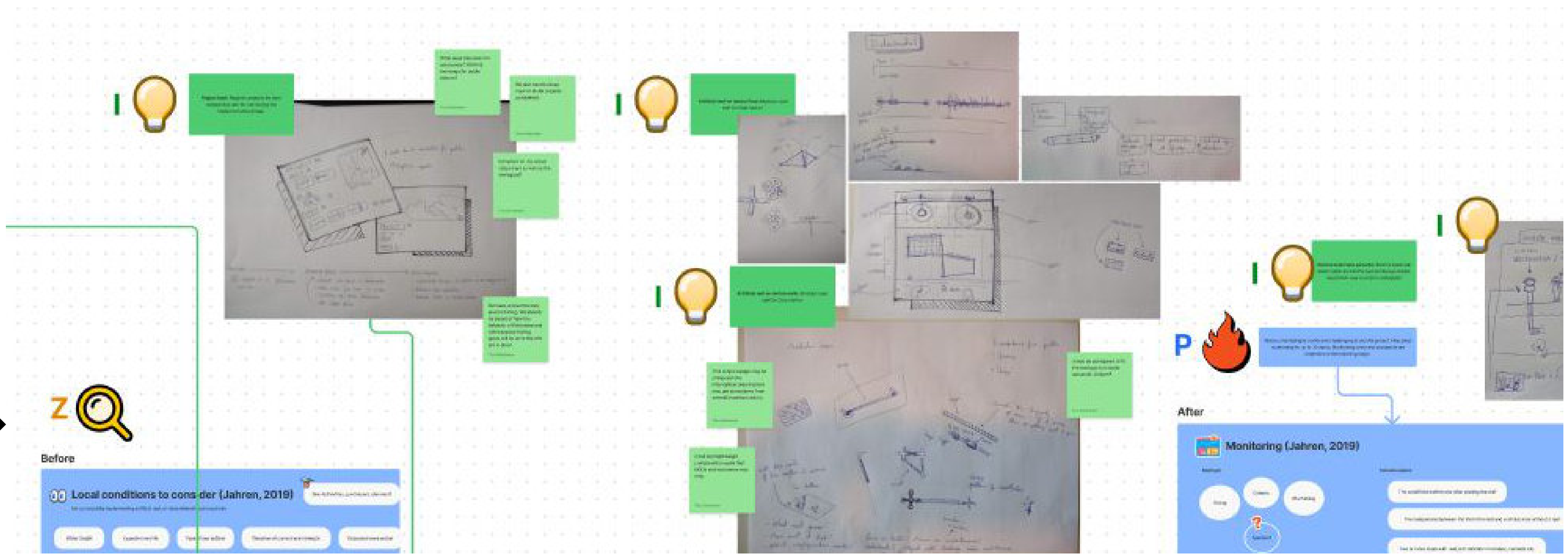
1. Design incentives, regulation or even legislation that aims at making developers include artificial reefs, free-standing or in their architecture. This goes for architecture that touches water.
2. Design the tools for decision-makers, land-owners, planners, developers, architects, or authorities. Tools that makes it easier for them to safely bring restoration ideas into new projects and existing infrastructure.
3. Design solutions that focuses on the follow up of restoration efforts. This can be operation, cleanup work, monitoring, maintanence, or iteration. Designed intervention can cut cost, communicate well to citizens, or engage.
4. Inform the public about the importance of restoration efforts in urban marine environments. There’s no reason why this can’t be done through other interventions too.
5. Design the artificial reefs that fits the Oslo harbor.

4.2: Working creatively with the GIGA-map

I used the GIGA-map (Sevaldson, GIGA-Mapping: Visualization for complexity and systems thinking in design, 2011) throughout the project. It kept - in a visual way, all the information from interviews, literature review, mappings, and so on. Connections were made between different pieces of data too - it helped me see the continuity and interconnections between things. Once pieces of the data puzzle came together, I could finally synthesize hypotheses and ideas on a systematic level (although I have to admit that I start doing that sporadically from the beginning). I synthesized all my data using a ZIP analysis (Sevaldson, ZIP-analysis, 2012). The 'Z' stands for Zoom, the 'I' for Idea, and the 'P' for Problem. Zooming means to zoom in further on something interesting in your data.

Carefully looking through my GIGA-map, I start finding ideas everywhere. Big I's and P's start popping up everywhere on my map. Z's arrive later, as they take more time. I try to develop and extrapolate on all of them while working quickly. One idea turns into another - 'zoom' brings along a new idea. Problems can be turned around into ideas as well.

Figure 16: Part of GIGA-map with ZIP-points, by the author, 2022.



Suddenly I'm showered with ideas. Like how to communicate artificial reefs to citizens. We can do it by letting them design the constellations of artificial reefs that go on the surfaces in Oslo harbor. They can help us make it look great. Further, we can work on the problem of "out of sight, out of mind", by inviting citizens into the water. They can dive, they can see the live video footage while enjoying their ice cream on Aker brygge.

Or maybe it isn't with the citizens at all? What if we design a platform that helps Oslo Havn FK plan for restoration in the harbor, by using all the insight that exist out there? They can set the restoration goal, they can input all the measurements they need. They can get an overview over all their restoration projects. It can be shared publicly too. That way we may see a positive feedback loop: more knowledge and sharing = more projects = more knowledge and sharing - you get the drill.

It also came up to build a platform that acted as a guide for architects, developers, and planners. This platform could provide over-arching arguments for working with artificial reefs, but also concrete case studies, research, and market examples. The world of artificial reefs in Norway is limited, but on a global level, we have seen some great initiatives. What if sharing that was enough to inspire action?

What about monitoring? It's difficult to budget that in - because it takes years and it's not the most exciting part. In the harbor, they have a service team that checks all surfaces regularly - what if they snap photos of how the reefs are doing too? That could be sent to marine-biologists and then we can contribute to research. But how do we document things under-water? Either by drone, or by having reefs that can lifted easily out of the water. By taking pictures of one artificial reef, we can assume a lot of things about other artificial reefs around.

If monitoring is too difficult, we can always try to intervene in the information gap found at Oslo Havn FK. What do they need to go from idea to action? What about information about water quality, so that they can easily understand where in the harbor it's best to intervene?

And then there's the artificial reefs themselves. There are so many challenges there, such as low cost, easy to maintain, longevity, aesthetics, easy to transport, and so on. So what about a modular reef made of ropes? The configuration could be designed by citizens and it can fit almost everywhere. We can also learn from nature here. Because what are natural reefs? In Norway, kelp are the "natural reefs" (Miljøorganisasjon, Concept evaluation, 2022). What if we can in fact design the whole service to bring kelp back into Oslo harbor, assuming that the lack of habitat is the reason that kelp is no longer there? This could bring on a whole new industry in the Oslofjord, with education about kelp and ecosystems, kelp farming and harvest.

4.3: Diversification of structures

This cause and effect map shows potential outcomes of using diversification of existing surfaces as a strategy in Oslo harbor. If we do the right intervention, then we will attract life. However, life also means fishing and people. People means littering and less life. When we reach the point of less life and plastic pollution, we are at a cross-roads, where we either clean up, or do nothing. If we do nothing, then this may be the last artificial reef project, due to the bad press that it will attract. However, if we clean it up, or increase measures to reduce pollution and fishing, then we may see a positive feedback loop, where more projects are encouraged. Clean up without any other long-term measures will create an endless loop of more life, less life, more pollution, less pollution. This hypothesis shows us that product intervention is not enough, we need other type of change as well, such as regulation or communication, to make it fit into society.

Figure 17: Cause effect of diversifying structures, by the author, 2022.

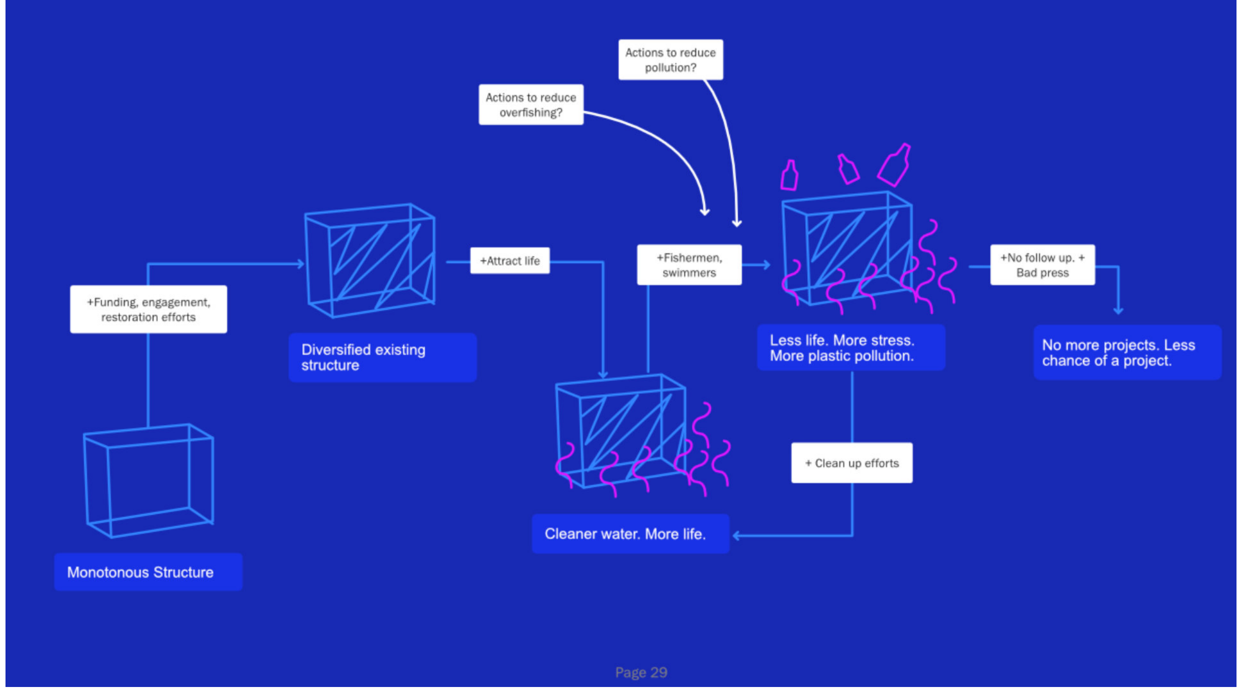
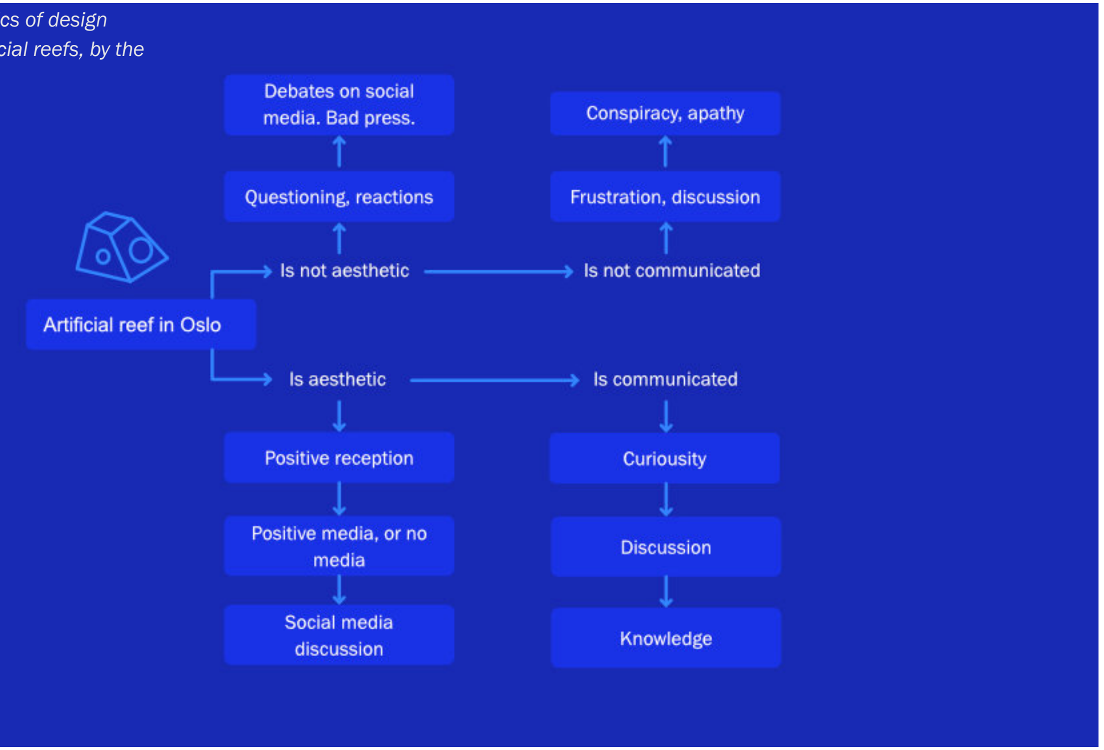


Figure 18: Dynamics of design principles on artificial reefs, by the author, 2022



4.4: Effect of design principles on artificial reefs

Zooming in on the GIGA-map using ZIP analysis (Sevaldson, ZIP-analysis, 2012), I argue that artificial reefs may use design principles to make people care more, or to evoke emotions. These design principles were communication and aesthetics (keep in mind that I do not enter into the hairy debate of what aesthetics is). I used these design principles in a system oriented way. I tried to hypothesize the effects associated with using these principles on artificial reef in the urban harbor context. In this hypothesis, I argue that bad communication will lead to frustration and apathy, as citizen will fail to understand the project (nobody knows what artificial reefs are). Perhaps it is even possible to sacrifice aesthetics for communication if the message is clear and inspiring enough.

4.5: Back-casting: mapping out needed solutions to solve artificial reefs on surfaces in the harbor.

In this part of the design project, I used methods to squeeze out all the potential ideas and concepts I could get from my current knowledge of the theme. We have already covered ZIP analysis and the ideas that came out of it. As a final quest to get just a few more good ideas from these intervention points, I set up a back-casting method (Robèrt, et al., 2019). As mentioned earlier, back-casting is the opposite of forecasting. In forecasting we use today's situation and forecast towards a plausible future. In back-casting, you set the desired future and work your way towards it (Robèrt, et al., 2019).

In my back casting, I foresaw the future using a set of principles. Principles were: biodiversity in harbor, closeness to water, animal-centered architecture. I set up the back casting using several actors and I tried to guess what they would do to reach the principles. As usual, I took in interconnections between the actors as well, to see how they would influence each others.

Already in the first steps of this method, I see ideas come up. Because once the authorities have been convinced by science that they need great solutions for artificial reefs along their harbor, they quickly realize that they do not have the competence needed to move on. Also, they start setting demands to developers and architects, which means that developers needs the competence as well. Thus, marine biologists get peppered with questions on these type of artificial reef solutions. Someone comes in here and creates technological tools that makes it possible for developers and harbors to go without biologists when creating artificial reef structures.

In this narrative, the citizens also starts building their own reefs, as government push for changing monotonous architecture along the coast. This creates so much ownership that citizens wants to monitor the artificial reefs to and products are needed for that.

The developers are trying to keep the cost down, as they do not want their projects to come across as expensive when they enter into competitions for new projects. This allows for new cheap artificial reef solutions that can be implemented easily in new projects and on old infrastructure.

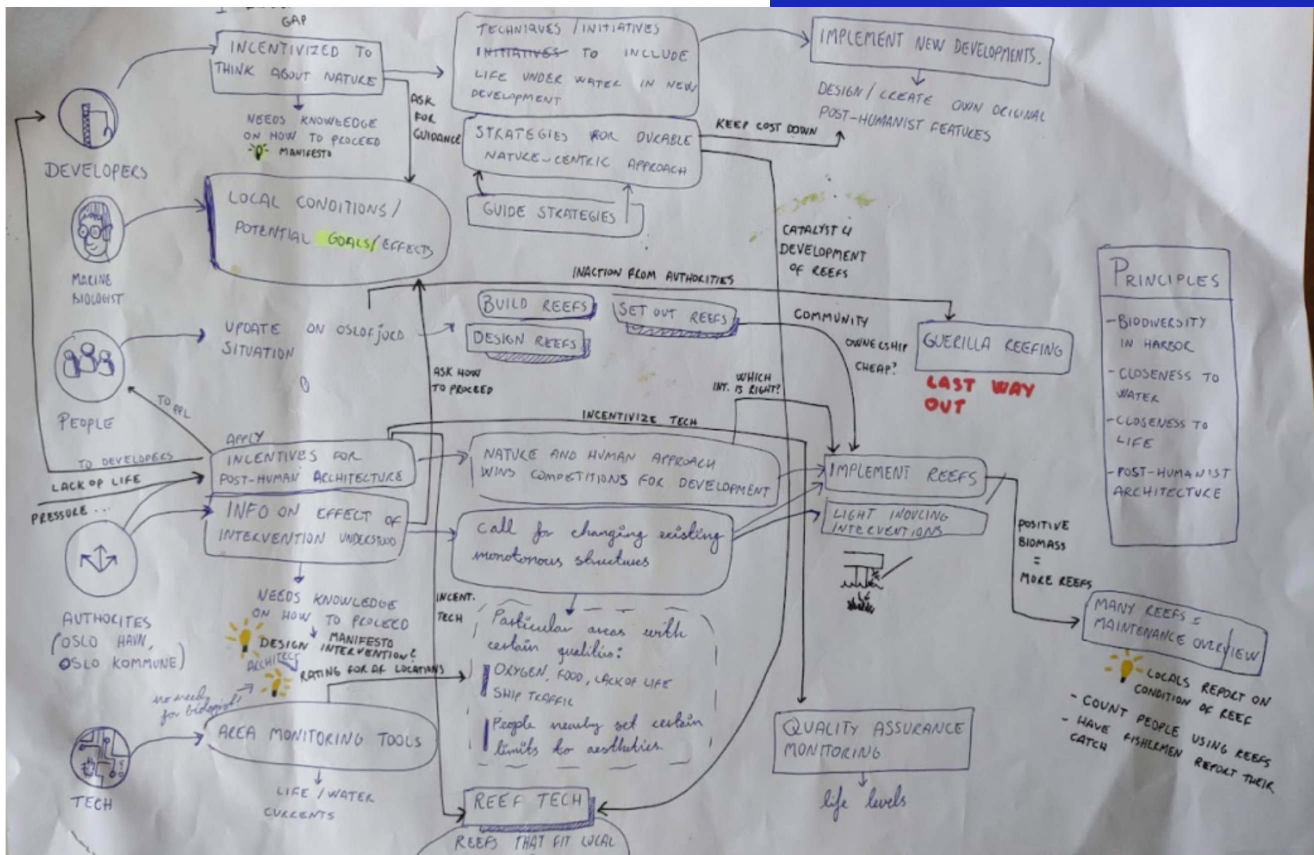


Figure 19: Back-casting (this figure is for illustrative purposes), by the author, 2022.

4.6: Evaluation of concepts with usefulness testing

I will describe an evaluation session with a person that knows marine restoration and marine issues well (Miljøorganisasjon, Concept evaluation, 2022). I approached the informant with three concepts. All three had drawings and explanations. The goal was to evaluate the usefulness of concepts through conversation and perspectives. The format was very flexible and the informant was free to deliver feedback on things that were most interesting to them.

The first concept was kelp as structures for marine restoration. The second concept centered on a digital platform for know-how for using artificial reefs in restoration work. The third concept consisted of a software that would translate raw data about water quality into key insight for authorities to use in restoration projects.

I planned to meet up with my informant in a simple building in the inner oslofjord. After a boat ride and a short walk, I was there. Despite the appearance of the place, we had a view of the sea that could contest with any location in the capital city. The informant is the face of an organization that works fiercely to rebuild life in the Oslofjord. We poured ourselves some licorice tea, and the meeting started.

The informant describes kelp as a natural reef (Miljøorganisasjon, Concept evaluation, 2022). Introducing kelp into the harbor "needs to be tested first". One also needs to "find the right areas to work with kelp". From there, the informant explains that kelp needs certain conditions as well. "Kelp is more complicated than for instance artificial reefs... Kelp needs sunlight". A fear of poisons in the water around the harbor also came up here. With poisons being consumed by kelp, it is unclear whether or not we can use the kelp for anything. The reason why we need to use the kelp for something is because the kelp will eventual fall off over time. To top things off, a concession of aquaculture is needed from the fiskeridirektoratet to be able to start using kelp on any basis in Norway. Finally, the informant recommended me to stay away from a very complicated area of kelp. The informant thought in systems, and identified along with the other things, three main challenges: Finding the right conditions, finding the right use, solving the operational challenges (Miljøorganisasjon, Concept evaluation, 2022).

Now to the second concept. Knowledge and inspiration for developers and architects. The interviewee did not doubt the value of knowledge sharing about the topic of artificial reefs and restoration. But the quality of our current knowledge is questionable, and the informant moves on to argue that "we do not have the right solutions yet". As for the architects and developers, the informant interestingly claims that they should be a part of a journey (Miljøorganisasjon, Concept evaluation, 2022). With the journey, I think the informant wants a cross disciplinary

Figure 20: Oslofjord boat ride, by the author, 2022.

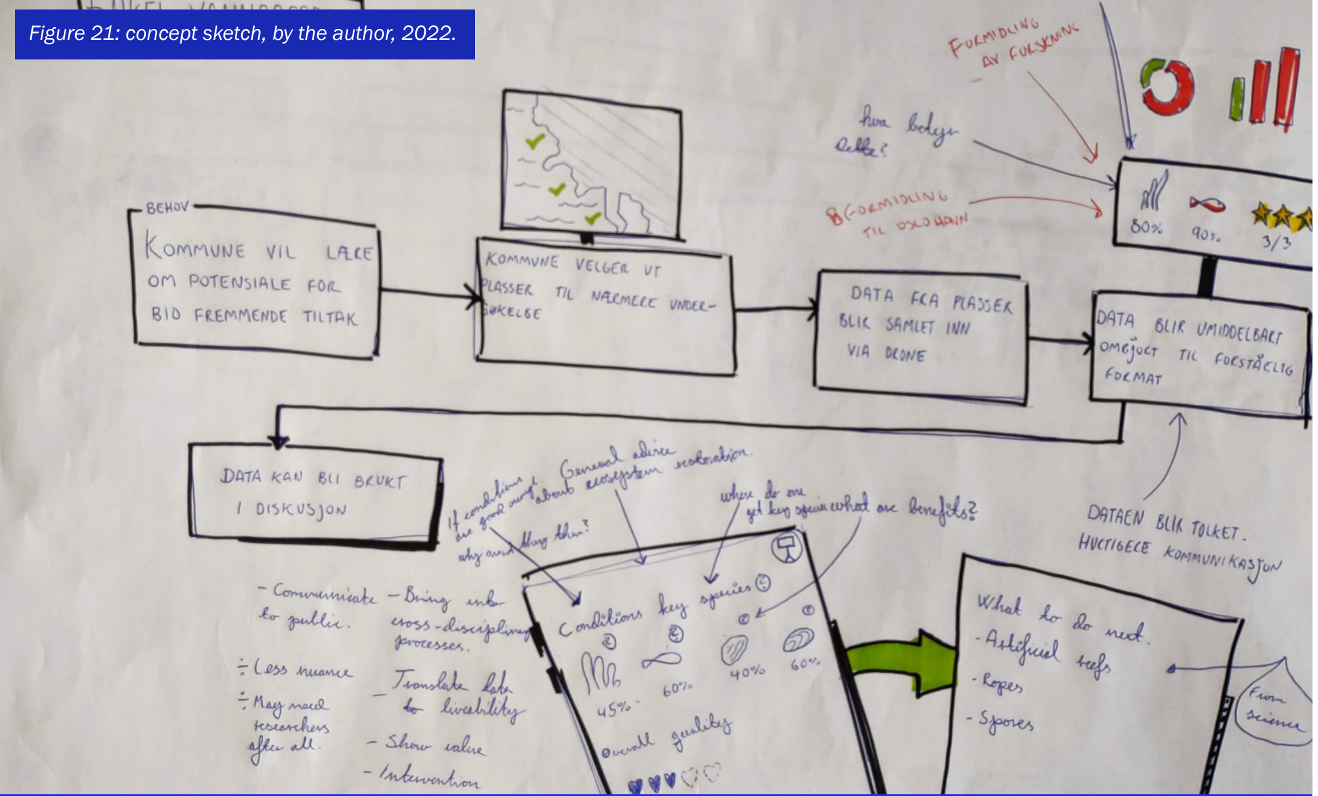


Figure 21: concept sketch, by the author, 2022.

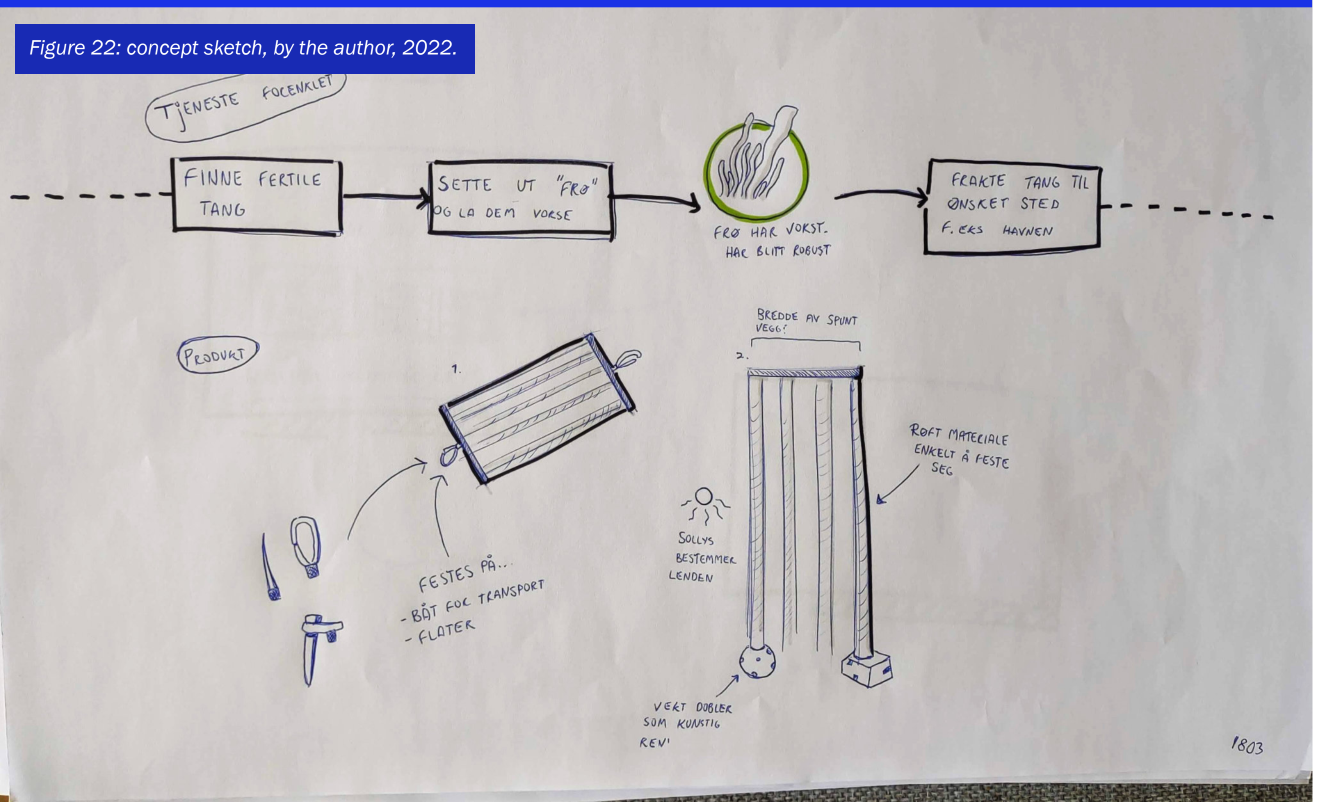


Figure 22: concept sketch, by the author, 2022.

approach, where the actors work together with a goal to create the right architecture to a higher degree than today.

With the concept that translates raw data about water quality into communicative key insight, the informant intuitively reacted to the "growing importance of communication". The informant also claims that communicative data is something a biologist easily manages to do if asked to do it. "The need for a standalone service is not there". It was more interesting for the informant to either work with communication of the effect of artificial reef projects to the people, or to collect all existing data in one place (Miljøorganisasjon, Concept evaluation, 2022).

Information flow is one of the leverage points (Meadows, 2008). Communication to the public plays around that leverage point. However, I do think we need power to act on that information too. How will citizens be able to act on the information about quality of restoration intervention? Is that the most valuable intervention?

The interview did not run according to plan. The informant at times felt confused about my intentions. Why was I showing these different concepts? It was clear that they were received as way too detached from reality and perhaps even a bit 'out there'. This experience works as a reminder of my responsibility as a designer to properly emphasize the goals of the exercises I run. The approach and mindset can be emphasized too. Figure 18 and 19 shows a few of the sketches I presented to the person. I am almost certain that they were too complicated for the evaluation format. Therefore, I partly blame the misunderstandings on my sketches and I will improve on the communicative values of them in the future.

I needed to iterate, or look to other concepts. It seemed like little value could be contributed to this field that felt at the time more like a mine-field. Therefore, my goal was from there to concentrate on interventions that was more design-friendly and needed less help from experts around every corner. Communication solutions and monitoring solutions became more tempting.

4.7: Evaluation of monitoring service

Here, i try to evaluate a concept related to monitoring the effect of artificial reef measures in the Oslo harbor. This sketch assumes that artificial reefs are already in place on the surfaces in the harbor.

This system acknowledges that dis-satisfactory and satisfactory results may occur whether we monitor or not. Monitoring makes it possible to act on the results, change things and possibly communicate the effect to the grand public. This whole process of monitoring takes time, as the reefs may take years to mature (Jahren, 2019). In this sketch, we intervene into the monitoring phase with a digital tool where pictures and observations are collected by the public. Scientists can go in and assess the results from the application as well. By doing this, we engage the public in the restoration effort, while monitoring at a reduced price.

The forecast good effect of this intervention is: citizen engagement and understanding. More knowledge about restoration efforts and marine life. Opportunity to iterate on artificial reef.

Problems arise though of course. Restoration work happens under water. This means that taking photos will be difficult, and that counting may only be done by divers with the right equipment.

We could of course also rely on AI-image recognition of key species in artificial reef areas, and directly report to a database accessible by scientists and the public.

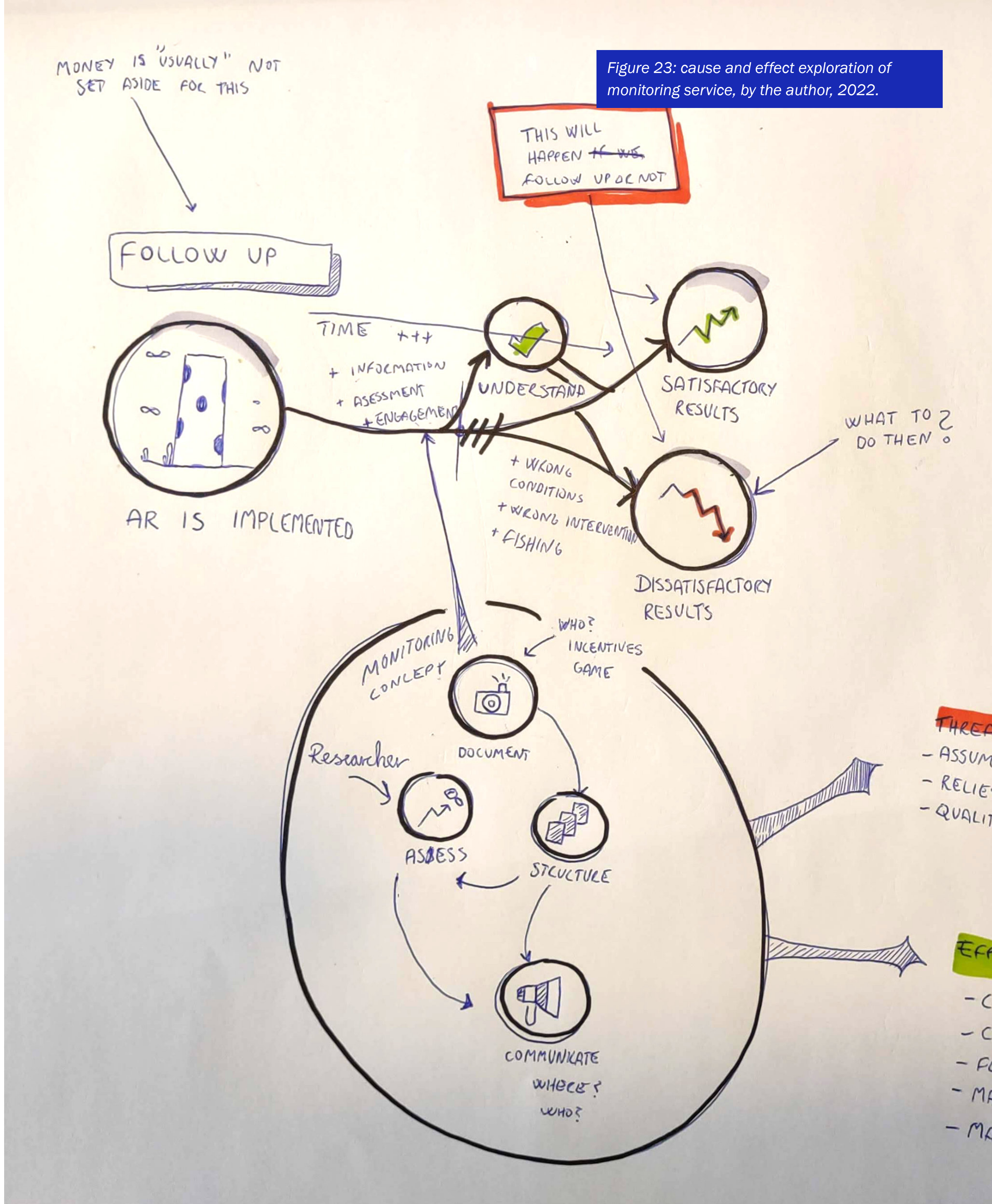


Figure 23: cause and effect exploration of monitoring service, by the author, 2022.

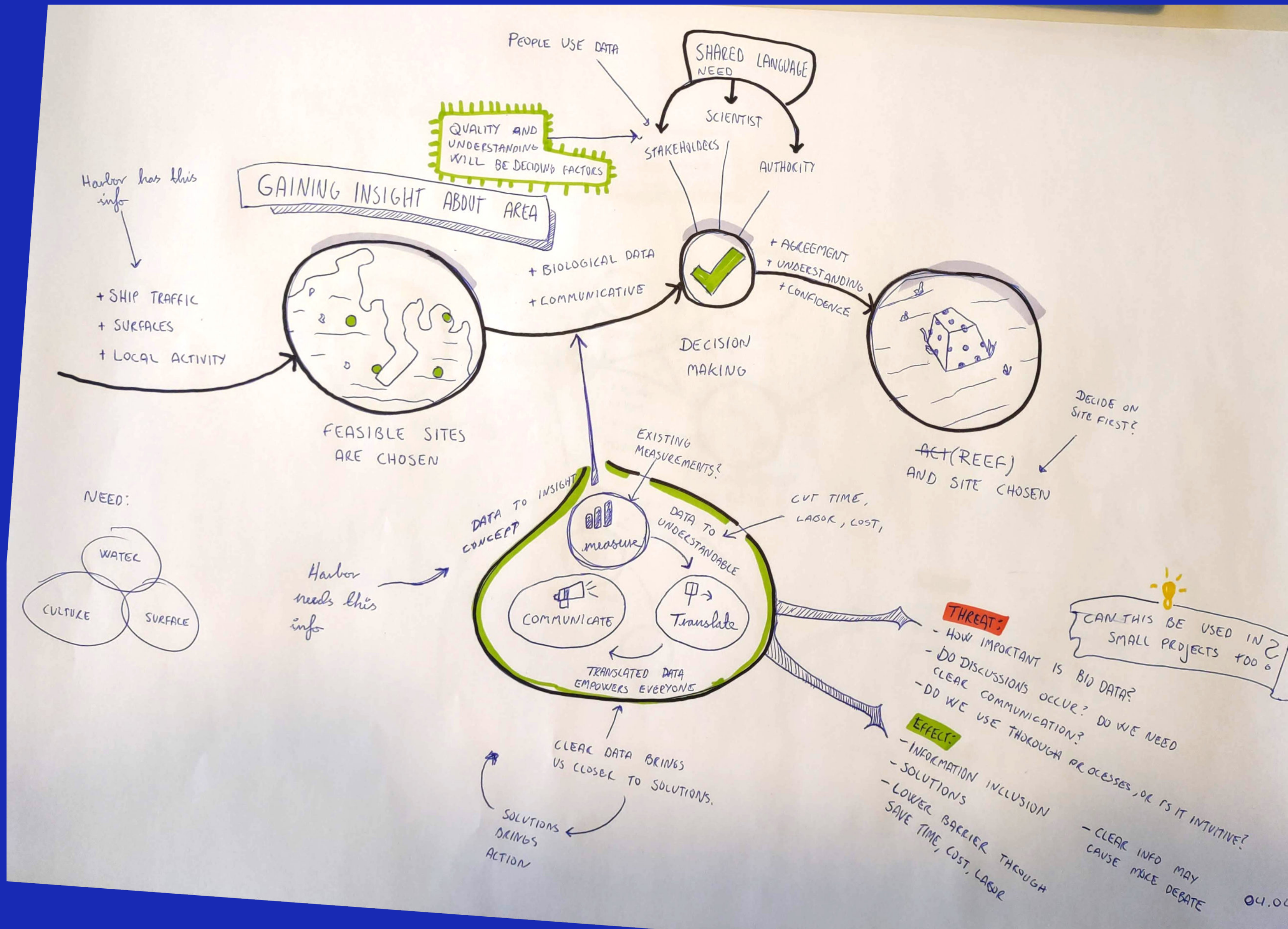


Figure 24: cause and effect exploration of insight service with effects and threats, by the author, 2022.

4.8: Evaluation of data to insight service

This system starts out with the status quo of the relevant authorities. They have an interest in restoration efforts in the harbor. Also, they sit on some data about the harbor. This data is mostly about ship traffic, public use of the harbor, and the architectural properties that interact with the sea (Neilson, 2022). They are trying to introduce eelgrass into the harbor this year and that's an example of their willingness to restore.

Let's look at the map. First up, we see that the authorities have chosen feasible sites for working with artificial reefs and restoration. These sites are chosen based on their existing data and knowledge on architectural situation, boat traffic, public use, and more. The next thing on a list in a decision making process is the status of the ecological situation. What's the life situation like in the water where we intervene? This data is either unavailable for specific sites, or presented in a format that only scientists understand. This is where the concept comes in. The concept translates water quality into tangible information about the needs of life there. It matches the properties of water with the needs of the marine life. This information may then be easily processed at meetings and can inspire concrete measures.

Hopefully a well communicated ecological status will help simplify and rationalize decision making by inspiring concrete measures, cutting costs and including more stakeholders. However, this service assumes that the authorities will be data-driven and that they look for right conditions before choosing intervention, not the other way around. This tool could of course be used to find the right sites for premeditated interventions, but that would not be recommended.

I go on to hypothesize that confidence will actually help create action. With clearly communicated data I believe that the pendulum will swing with confidence and that one will boost the chance of these restoration efforts going through. This hypothesis is based on the Oslo harbor's need for information on 'what to do' in relation to restoration.

This data will help make the choice of site much easier. Further on, the harbor will need advice on the type of artificial reef to use, which is a whole different challenge in itself. However, the information about key species to target in the area will certainly help inspire which artificial reef to use. Reef design and goal go hand in hand.

Further, the communicative data may be used for the public as well. This data may be shared through the harbor's website, or more suitable, on the piers or shore in the area in which the measurements have been made.

4.9: Evaluation with Oslo havn and HAV eiendom

I met up with several individuals from Oslo harbor and from HAV eiendom. These two companies together operate significant portions of the Oslo harbor. Among the people: a harbor engineer, chief of plan and development at Oslo harbor, and a chief of sustainability at HAV eiendom (Myklebust, Johansen, Pehrson, Neilson, & Winsvold, 2022).

In the session, I presented the project and a concept. We discussed the topic, but also the concept at the end. Their engagement and openness was admirable. The concept was the 'data to insight service'.

In this session, my hypothesis that few or no incentives were in place for developers in terms of bio-centered infrastructure was confirmed. One person in the room said that responsibility for the developers "stops at the water's edge". This leads to practices where architects, developers and harbor alike does very little to accommodate for our friends under the sea (Myklebust, Johansen, Pehrson, Neilson, & Winsvold, 2022).

Oslo harbor has no lack of documentation. Annually, Oslo harbor documents the docks by taking pictures. These images are used to understand the state of the surfaces. These images are currently of surfaces over water level. Oslo harbor owns the gear needed to document state under water as well, but this is not a part of the routine. These types of documentations can be used for various designs.

Now, to the concept, it was clear that accurate data points for local area water quality would be a challenge. One of the participants confidently stated that water shifts around quickly. It's a moving thing, and therefore one can not create local readings in a simple way (Myklebust, Johansen, Pehrson, Neilson, & Winsvold, 2022).

Figure 24: Oslo Havn FK offices, by Google street view, 2020.

When I asked them if this would fit in with the way they work, they answered that "consultants would use something like this" (Myklebust, Johansen, Pehrson, Neilson, & Winsvold, 2022). It's a concept for the early stages of development. I later learned that consultants often create the applications for development in the sea on mission from Oslo harbor. Could these insights be used in those processes?

It seems like the concept could inspire new thinking in engineers. Engineers get "tunnel vision" when working on their projects (Myklebust, Johansen, Pehrson, Neilson, & Winsvold, 2022). Their concern is primarily with durability. The topic of how piers interact with life under water was never relevant.

Further, the informants lightly conversed around how water quality data is communicated today. They said that they always look for the colors. It's good "as long as it's not red", they said, followed by a laugh. A color scheme has been introduced in Norwegian regulation of water quality. My take-away is that a color scheme fails to deal with understanding. Instead of understanding water data, the data has been reduced to good and bad colors. It's unclear whether or not "good" or "bad" guides correct action at all. My guess, based on their response, is that "bad" guides desperate action, whilst everything else is good enough.

More nature friendly architecture is still in the future, but it is discussed now. Participants of this evaluation session were interested in the topic. Most of them had some prior knowledge (Myklebust, Johansen, Pehrson, Neilson, & Winsvold, 2022).

One great challenge brought into light during this evaluation is that the technology cannot easily be adapted into any existing processes, since processes are not currently focusing on life under water. Oslo harbor does not take life under water into account when developing new piers (to any meaningful extent) and developers have no responsibility to do this work either (Which brings us back to incentives intervention-point mentioned earlier).

Also, the harbor has a fear of instilling too many demands as well when it comes to artificial reefs. As it will bring more work back to them. They are afraid that monitoring and maintainance of the structures will be their responsibility (Myklebust, Johansen, Pehrson, Neilson, & Winsvold, 2022).

Between the Oslo harbor and HAV eiendom people (who share an office space), they seem critical to solutions that have no proven effect. This means that they are critical to trying things that have no proven data to back it up. Therefore it is crucial that any solution, even if going into pilot stage, has scientific data as a foundation.

This evaluation session inspired me to use design to make engineers, harbor officials, and developers think about nature friendly architecture using principles from science. I also was compelled to use their extensive library of harbor-front documentation somehow. I would still intervene into the same intervention-point, but I would be considering the surfaces and their properties, rather than water and its properties. The more things that were already in place - the better.

5: Proposed Solution

In this chapter, I will dive directly into a proposed solution. The solution attacks the intervention point “Design the tools for decision-makers, land-owners, planners, developers, architects, or authorities.” First, I will describe and show the product. Then, I will explain a strategy for developing good experiences with the users, using context of experience. After, I will discuss potential effects and challenges of the solutions, according to a harbor engineer. Finally, I go through business models and further research.

5.1: What is the proposed solution?

The solution is two part. First of all, the solution builds on technical parameters for more 'nature friendly' development on harbor fronts and in harbor areas. These parameters aim to make restoration efforts in troubled ecosystems, such as the ones in Oslo harbor more accessible. The parameters have been developed with help from scientific literature - namely (NIVA, 2019) and (Jahren, 2016). The literature is rather limited though, and none of them are peer reviewed, but it proves as a decent starting point.

Secondly, the solution is a digital product. This digital product is a platform where assessments of harbor infrastructure can be viewed and used. I will discuss the value propositions in detail later.

5.2: Wire-frames

The front-page (Figure 25-28 next pages) of the digital solution is there to acquaint the reader with the concept. Here I expose the reader to the idea of infrastructure that plays along with nature. It also introduces everyone to the parameters that are being used to measure how well infrastructure plays along with nature. I call the concept of playing along with nature *bio-inclusive* from now on. There are several call to actions on this first page too. These call to action buttons invite the user to do things. They can for example check out what efforts are being made in *bio-inclusive* architecture in their city, or they can become a member.

The webpage uses the principles of designing for the most common jobs (Nordbø, 2017). At an early stage, I believed those to be: A person trying to see what efforts are being made in *bio-inclusive* architecture in their city for different purposes. A harbor official or engineer seeing what level of *bio-inclusive* properties their current architecture has . A harbor official or engineer entering their measurements into the platform.

Color and graphic choice is a mix between activism (bright, spicy colors and crisp text) and professionalism (great photos and pitch-like narratives). This solution balances on a fine edge between the disruptive goal of changing our harbors infrastructure and the pragmatic reality of convincing the people that have the power to make this real. The graphics need to reflect that.

It is my wish that the website should be understood by everyone who may have an interest in work being done in cities to combat decline of life. One of the reasons why I'm including everyone in this concept is due to the feedback I have been getting throughout the entire project. No matter who I spoke to: engineers, leaders, biologists, or climate organizations, they all had a shared vision of spreading the effects and efforts from these projects to people. Mostly because without the interest of people, these projects become increasingly difficult.

5.3: Why the digital solution?

The parameters and the index are the main elements, but they do not work in a vacuum. The digital solution is required to store data on harbor's scores and infrastructure. It will also provide the necessary information on how to get started with parameters and measuring. The map will also compel more harbors to join, in the spirit of the social proof principle.

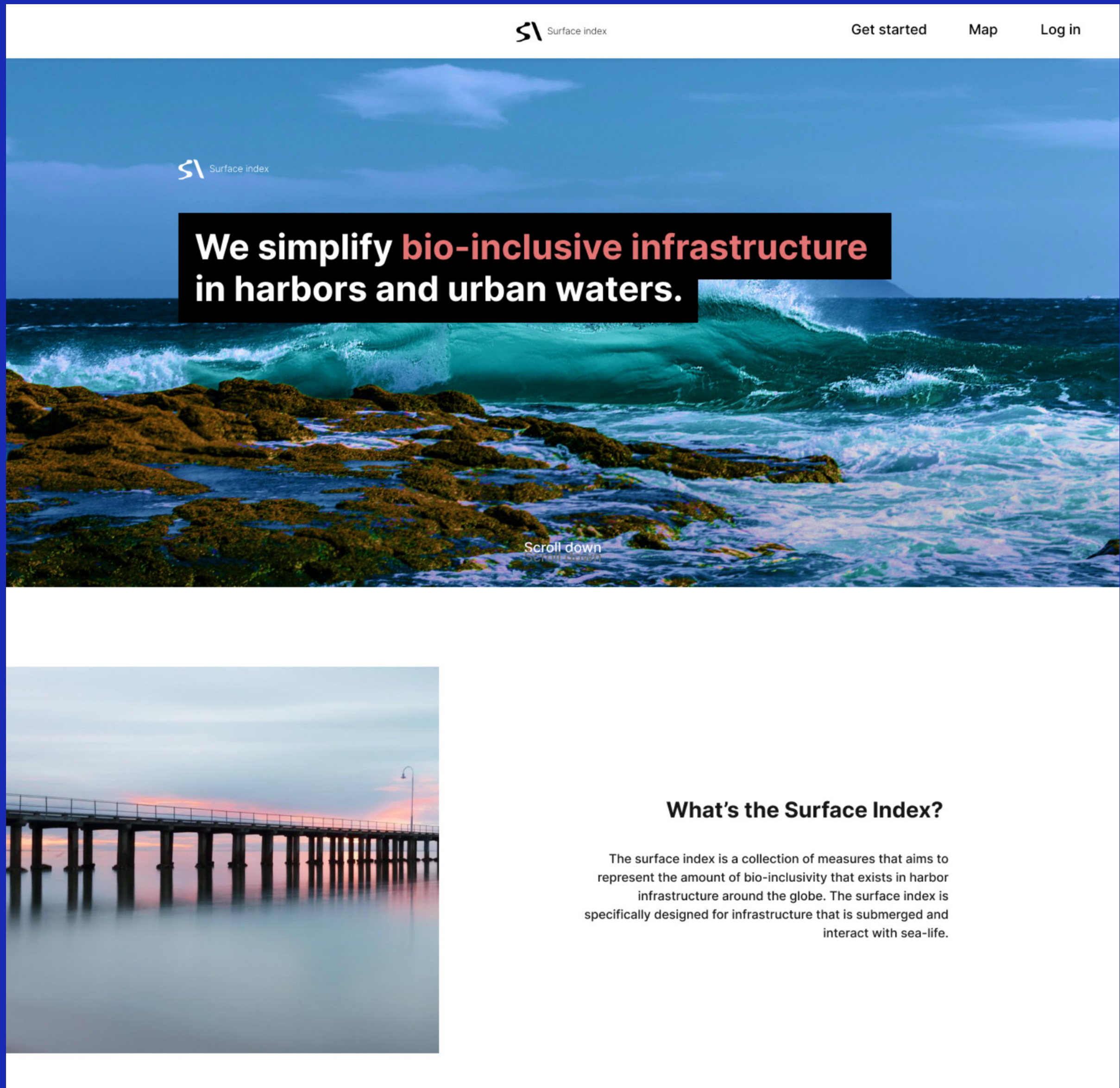


Figure 25: Front page 1, by the author, 2022.

Figure 26: Front page 2, by the author, 2022.

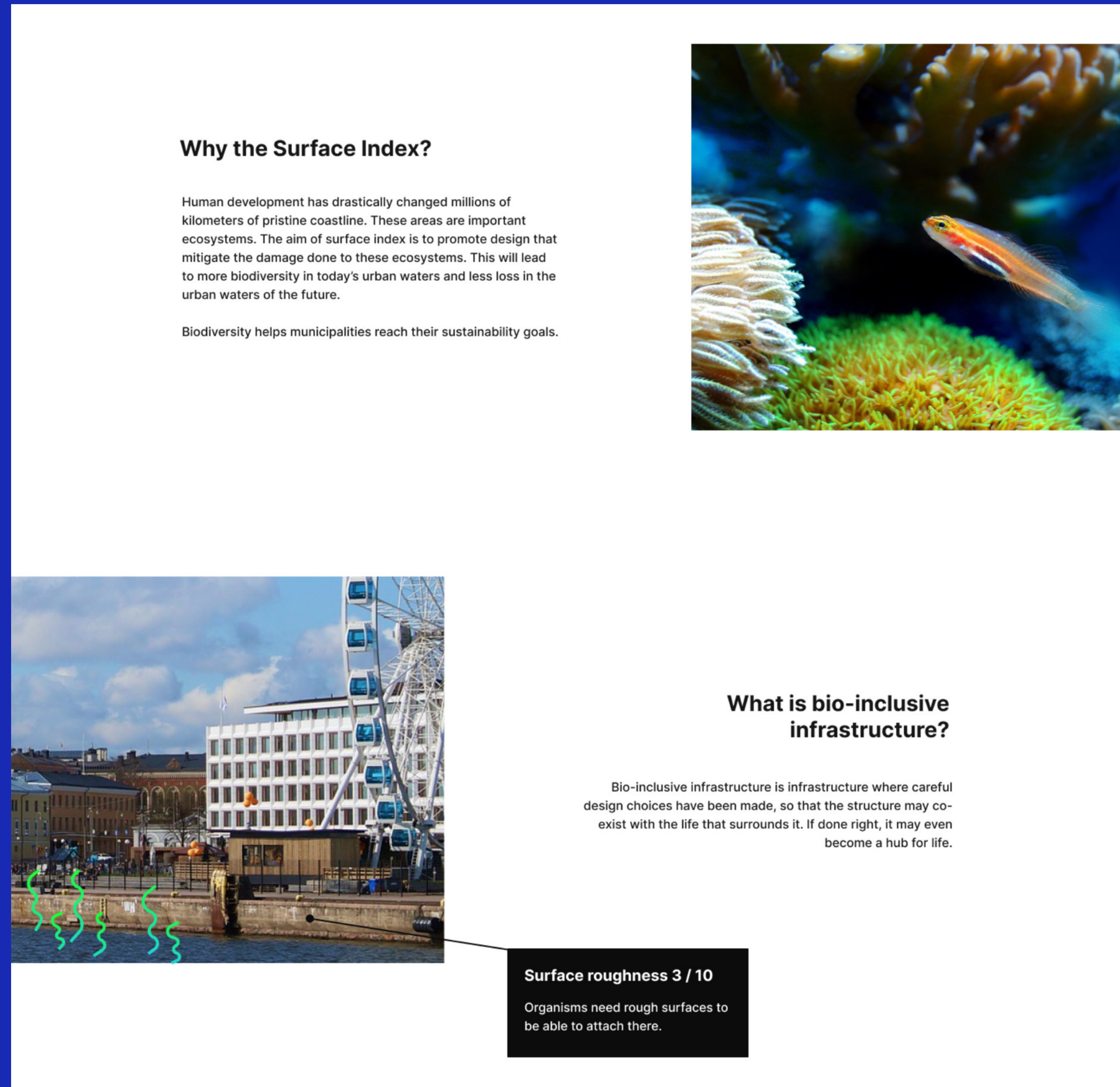
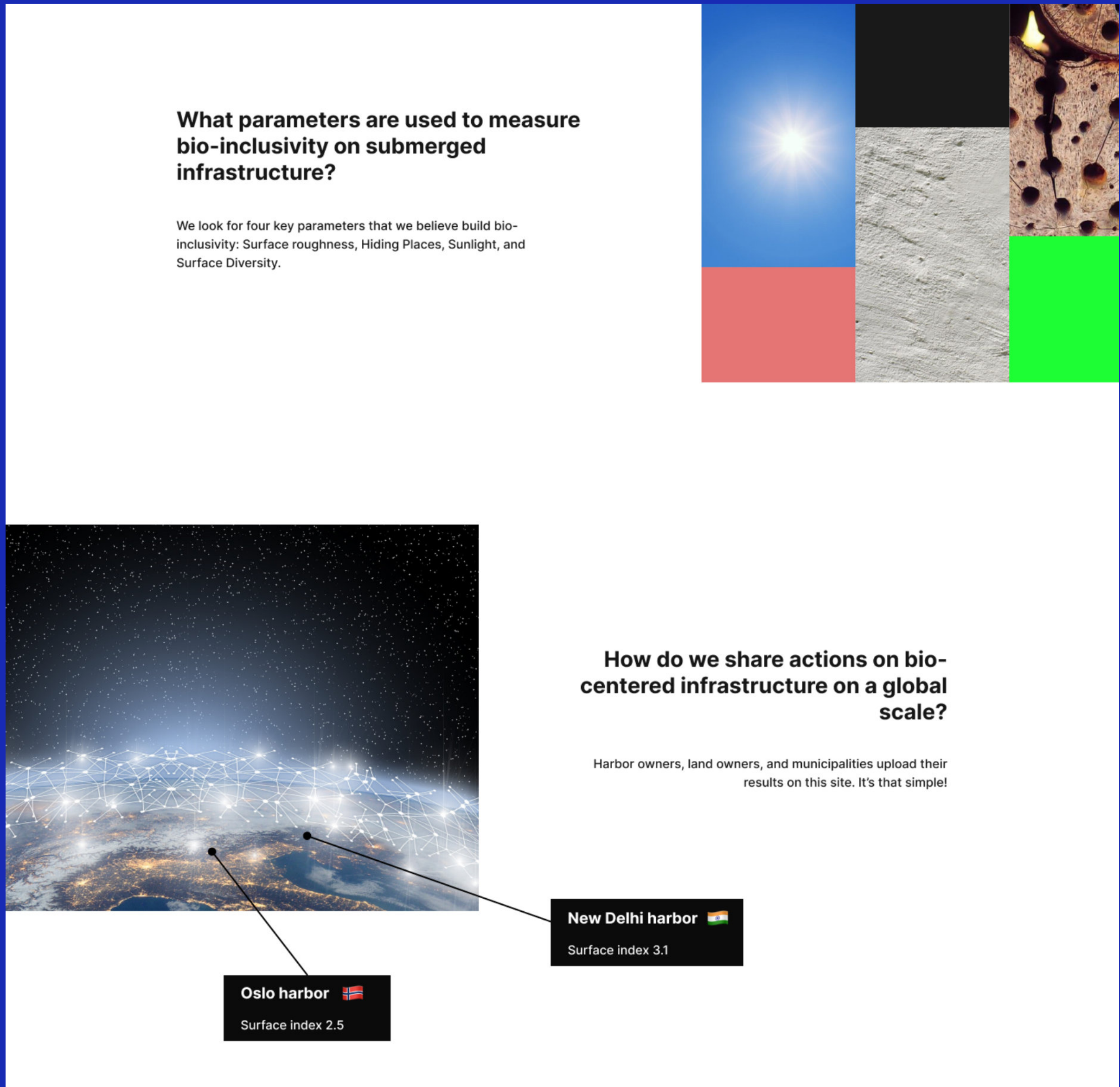


Figure 27: Front page 3, by the author, 2022.



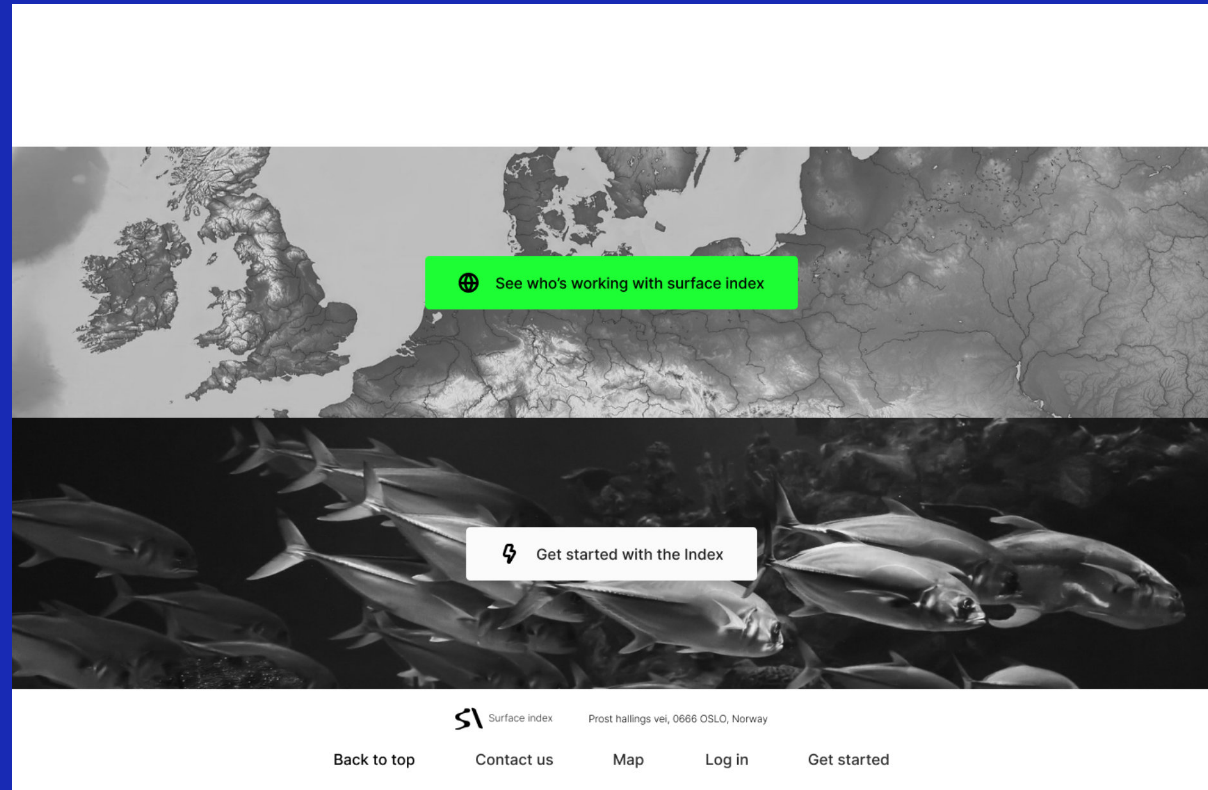
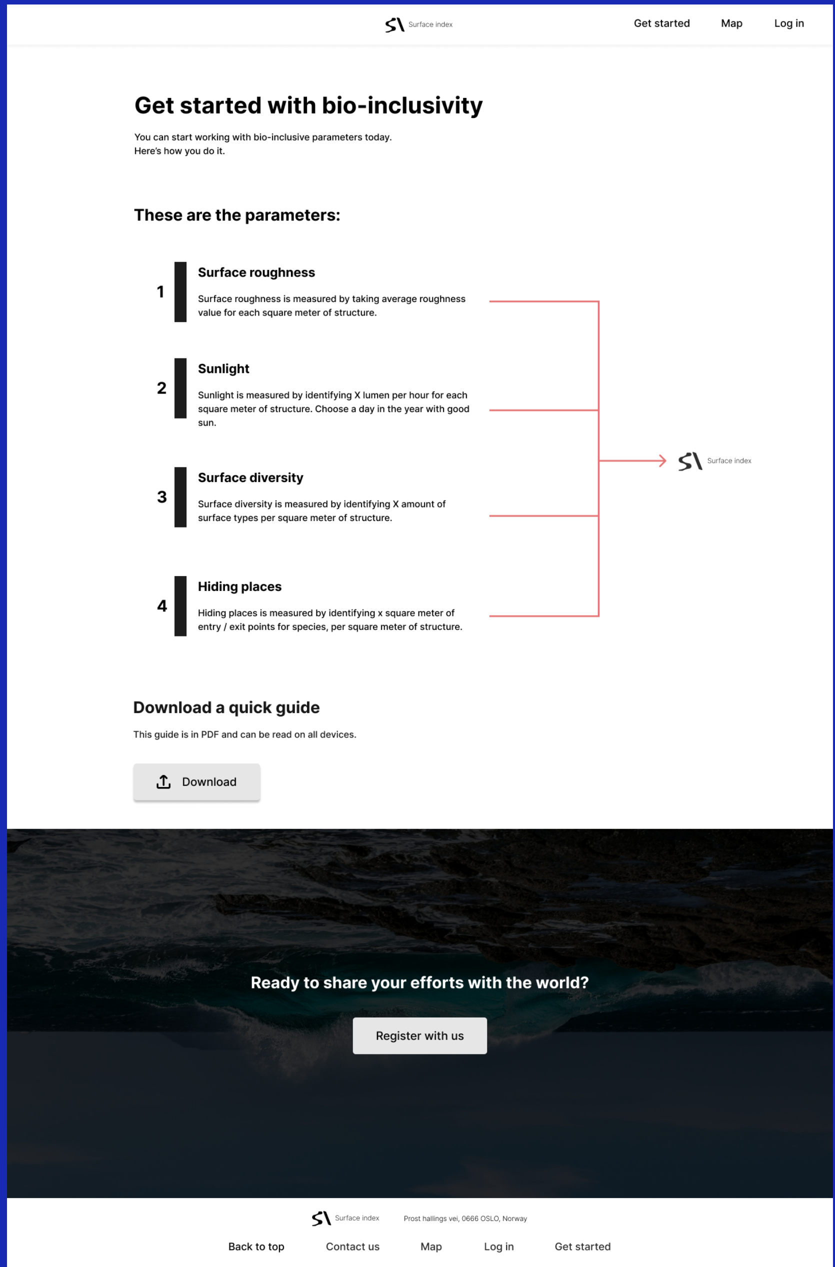


Figure 28: Front page 4, by the author, 2022.

Figure 29: “Get started with bio-inclusivity”, by the author, 2022.

Get started with bio-inclusivity. This page holds information about the parameters, how to use them and so on.



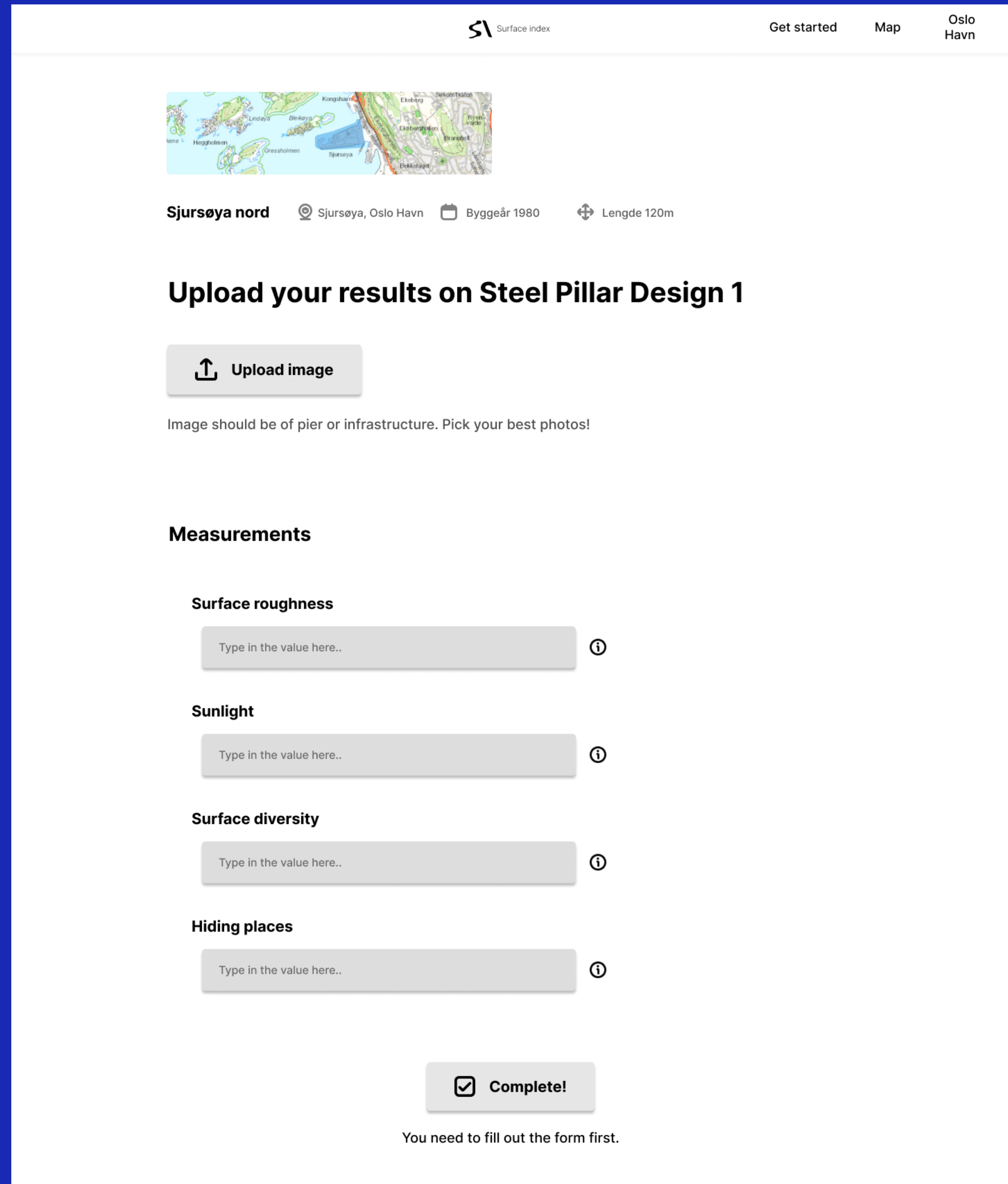


Figure 30: Upload design, by the author, 2022.

This page is where harbor architecture is uploaded to the platfom.

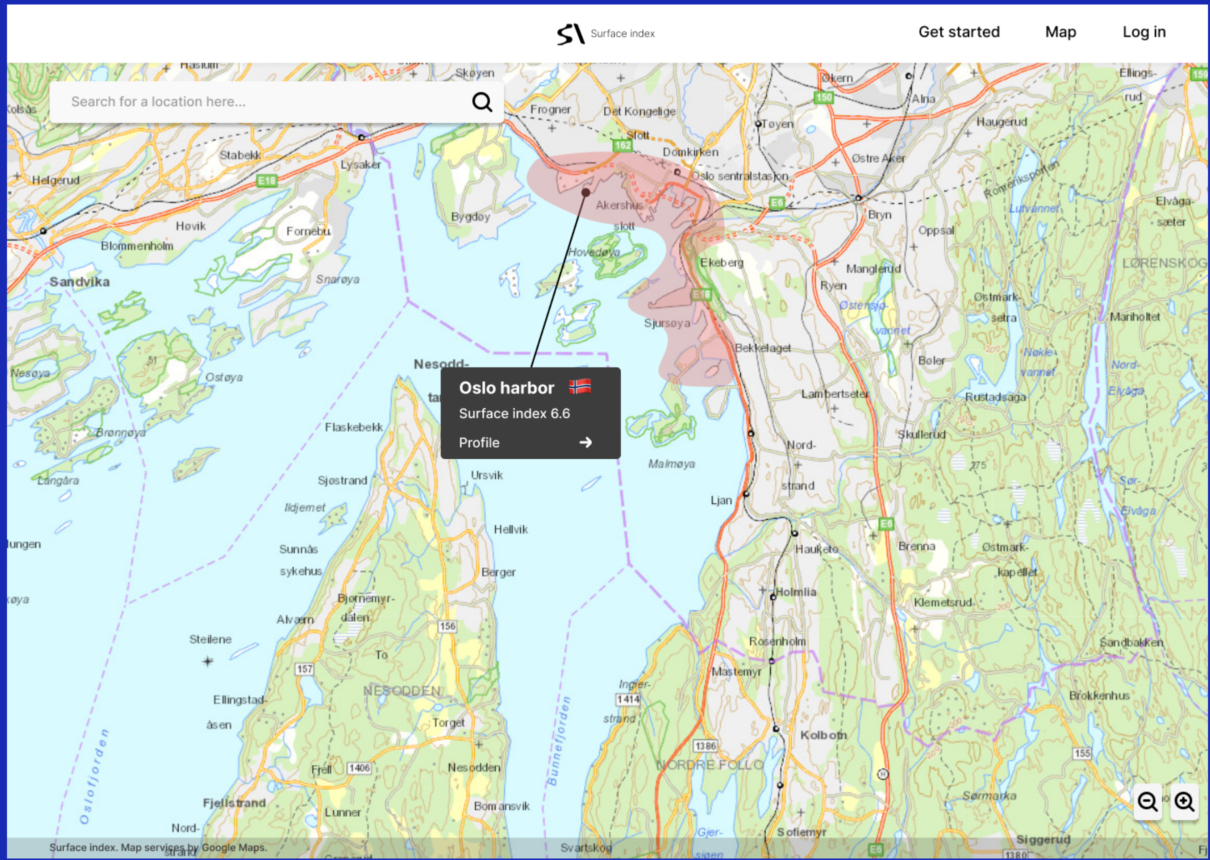
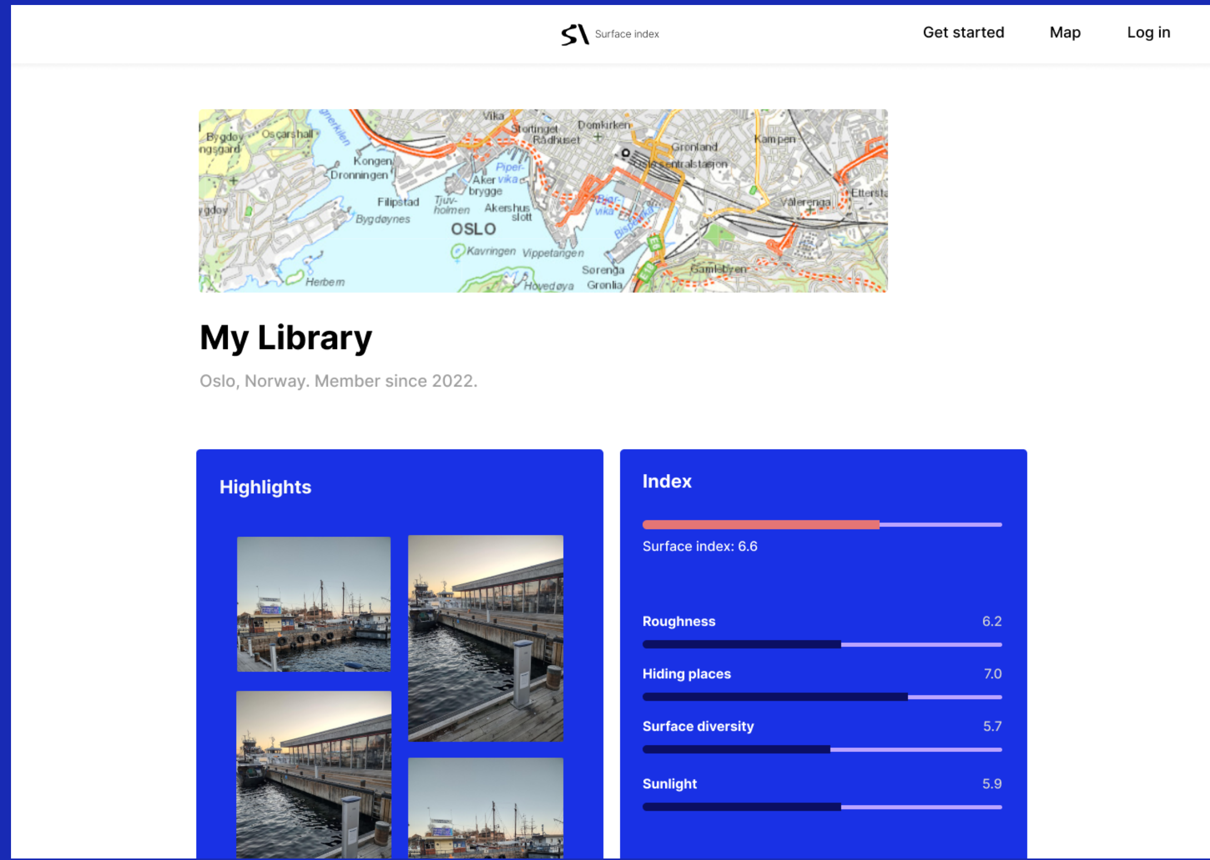


Figure 31: Map, by the author, 2022.

This is where anyone can check out the progress made by harbors world wide.

Figure 32: My Library, by the author 2022.

This page will show detailed information on all the surfaces and their ratings.



5.4: Two use cases

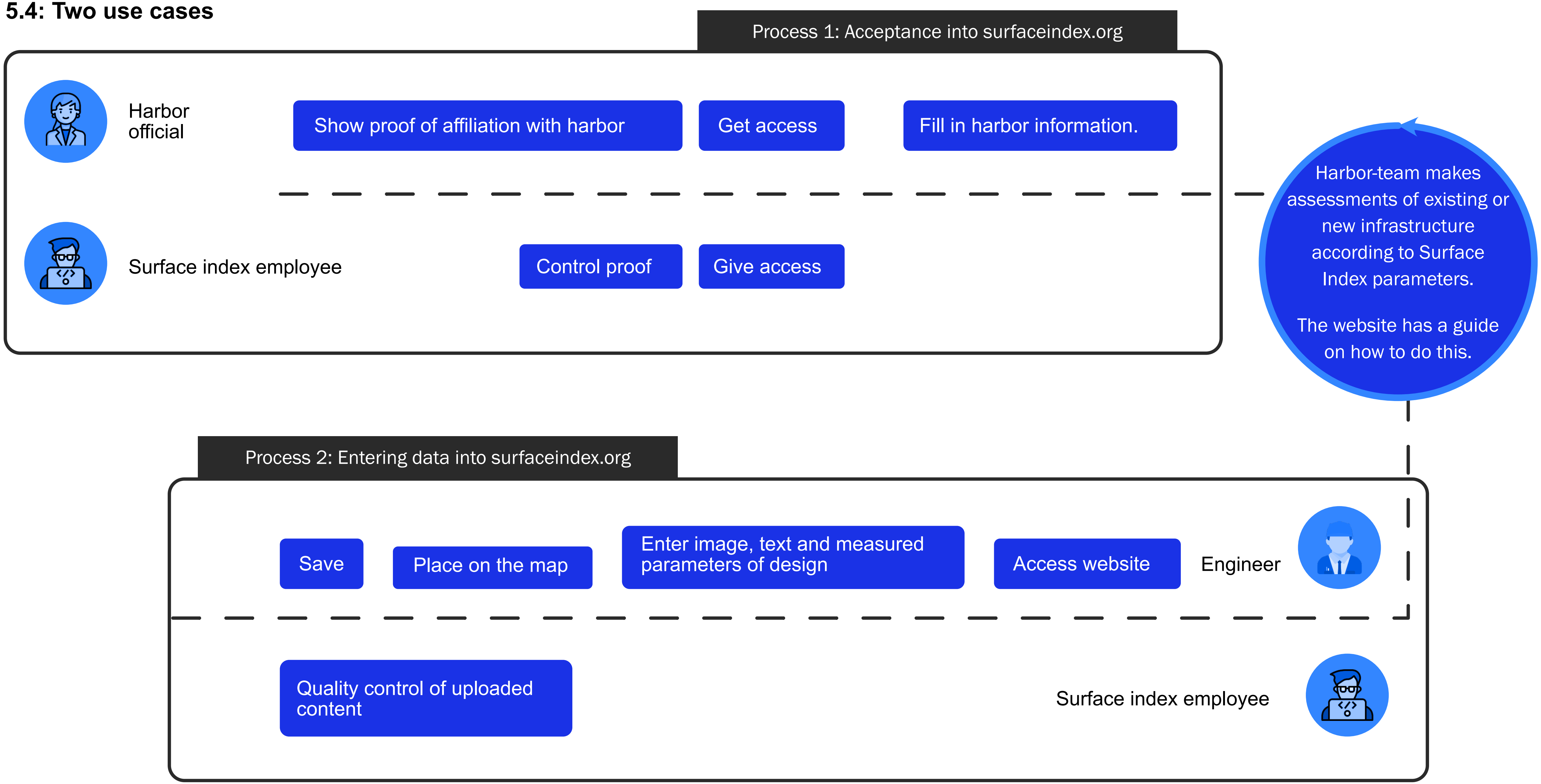


Figure 33: Use cases, by the author, 2022.

Pre-purchase

1. Reports and rankings are shared publicly and online.

2. An interactive map may be checked out by everyone.

3. The website will contain a library of bio-inclusive architecture and solutions.

4. (Idea) Limited spots for the website in the beginning - triggering scarcity principle and competition.

Point of purchase

1. Gamified acceptance period for harbors around the globe.

2. Everyone gets a chance to test the parameters themselves and make the index manually. For those who are sitting on the fence.

Product

1. Competition with other harbors.

2. Store information about bio-inclusive measures in the harbor.

3. Show the amount of Co2 stored and the amount of bio mass stored vs. a reference index.

4. All the help you need to get started with bio-inclusive infrastructure.

Use

1. Upload images, descriptions and assessments every time new projects are done or announced.

2. Check what is being done elsewhere for inspiration (on harbor design).

3. Social proof (Cialdini, 2014) in map function .

Social proof is doing as others do. The actions of others influence our actions.

Late use

1. Reports.

2. Evaluate quality scientifically.

3. Use for existing infrastructure as well.

5.5: Context of experience

I used context of experience (Gulden & Moestue, 2011) as both a creative and a strategic tool. As a creative tool, it helped me see new functions and interactions, as every context has new constraints. As a strategic tool, context of experience tool was used to focus on crucial contexts in order to increase quality of experience and maybe even longevity of product.

Measures are described in the figure, but I will explain the philosophy behind the contexts for the proposed solution. Pre-purchase signifies reaching out to the users - be that harbors officials, engineers, activists, journalists, scientists. This is done through the measures described in the figure. Point of purchase is all about making adoption of the product as enjoyable as possible. Therefore, I focus on user friendly and engaging sign-up periods and test schemes that allows anyone to try. In the product context, we have gamified elements (Fullerton, 2008), around the core functionality. In this product phase, standard UX principles apply for evaluating quality. One of the main indicators for quality in this project is usefulness - What do the users get out of the product (Nordbø, 2017). Use refers to repeated functionality and regular actions. This phase also depends on usefulness, but user-friendliness and ease of use also comes into play for the user to continue to engage with the product over time. Late use focuses on the long term. For Surface index, this will depend on expanding the community of users and making sure that results are shared and new techniques tried.

5.6: Effects and challenges of solution

Most of this discussion is gathered from an evaluation with an engineer from Oslo Havn FK (Myklebust, Solution evaluation, 2022).

First and foremost, the solution will most likely raise awareness of the topic to people and harbor workers (Myklebust, Solution evaluation, 2022). It's also possible that Oslo harbor FK may get incentives to act on these parameters to reach climate goals set by the commune (Myklebust, Solution evaluation, 2022).

First challenge is on measuring of the parameters. Who will do the measuring? At Oslo harbor, they do not have the resources to do a complete assessment of their harbor (Myklebust, Solution evaluation, 2022) as "[They] have enough with today's tasks and work". Once the measurements are up and running though, the Harbor may be able to spare the resources to perform measurements on new projects (Myklebust, Solution evaluation, 2022).

Measurements is about more than money and time. It's about trust. Who does the measuring, how accurate and what are the incentives? If harbors measure their own infrastructure, then there's plenty of room for user errors (Myklebust, Solution evaluation, 2022). This tarnishes the trust. Mitigation of user-error could be done by inserting a third-party to do the measuring. It can also be done by making a complete guide on measuring the surface index. Both should be considered. Finally for trust, the parameters need to be proven by science. Parameters I currently use are suggested in (NIVA, 2019) and (Jahren, 2016). Also, it's possibly to consider authority principle. Cialdini states that authority works as an influencing factor (Cialdini, 2014). Surface index can set a strategy for piloting in 'hard hitters' in early stages, to tailor to the authority principle and eventually influencing others into using the index.

Next up is pilot testing. Pilot tests are used by in the Oslo harbor (Neilson, 2022). The pilot will give quick results to both the company behind the service and the early adopters. Early adopters are those that start using a product in the very early stages. During the pilot phase, we could choose a site in a harbor and do a complete assessment of it and upload it to the platform. According to the engineer, the tool has no value before the measurements have been uploaded to the platform (Myklebust, Solution evaluation, 2022). It is on "the platform we may see the different surfaces and why they are performing like they do" (Myklebust, Solution evaluation, 2022).

Competition is a game element and can be used as a tool to increase engagement (Fullerton, 2008). It's a planned feature in the solution. With the harbors, there's a worry that competition may cause lower scoring harbors to feel left out. Also, some harbors have an advantage for geographical or economical reasons (Myklebust, Solution evaluation, 2022).

This may suggest a milder form of competition, or simply a more nuanced form of competition, where these weaknesses are addressed and the rankings adapted to that.

there are two languages in terms of harbor front infrastructure: Building new infrastructure and maintaining old infrastructure. So how does the surface index fit in here? If Oslo harbor has surface index information on all their fronts, then they can use that insight to guide new projects. It seems that the surface index information is useless in the context of maintaining old infrastructure, as this process is all about fixing, with the goal of returning the infrastructure to its original state. Can the surface index inspire a new language? The language of changing existing infrastructure?

Development along the harbor is dazzling in its complexity. I will not provide detailed information on it here. However, the engineer gave me a simple introduction. When Oslo Havn develops fresh infrastructure in the harbor, they first use consultants with the right competence to create an application to the *statsforvalter*. Further down the line, Oslo Havn discuss projects and concepts with developers, architects, or both (depending on the frames of the project). Oslo Havn has the power to set demands to architects and developers in these phases. When the effects of surface index are proven, they may apply that as an argument and we may see bio-inclusive architecture in the future. They may set climate demands already today, so if proven and accessible, the surface index can be another layer of climate considerations to make in a projection phase.

For the future iterations, the profile would most likely be replaced with a ‘library’ type functionality, where harbor engineers and planners can see the independent types of architecture and how they score on this index. From the evaluation, this type of precision is necessary to use this index for improvement and understanding. For the future, the site needs more proof as well. Statements from scientists and proof from scientific articles should be there for rhetoric and trust.

5.7: Business model

First iteration will depend on an *open model*. Everyone has access and all harbors who wants, can create a user and start using. This model will rely on funding from governments, stipends, EU, or investments from private investors. It depends on goodwill in the beginning, but it provides opportunity to develop parameters and product in tandem with harbors, since it is free. It’s always possible to change to a “closed model” when the product is ready.

The *closed model* will to a larger degree be closed off to the public and to harbors. Harbors who pay, will gain access to assessment of their harbor and a library of their and others’ infrastructure. This insight can be used to provide their harbor with surfaces that help them reach climate goals. This closed model is only possible if the product is scientifically proven and thus convincing.The closed model will for example be very relevant if it turns out that the regulation moves in favor of the surface index.

There’s a third option too. A *fluid* model, where the company starts out with the open model and moves towards a closed one when the company is more mature and confident. The open model will attract more customers, but will earn the company less money. It’s about striking the balance between those two poles.

6: Conclusion

In the conclusion, I will recap the entire project. After, I will discuss the approaches used. Finally, I will go through the underlying vision that I have kept for the project, and further research.

6.1: Wrap up

This project has used methods from system oriented design as an approach in research, analysis, and design in a complex theme. Throughout the thesis, we have been introduced to artificial reefs - their uses, their effects. We have also covered in detail how we can work with artificial reefs in Norway. From there, we investigated diversification of surfaces and using it as a strategy in Oslo harbor. We also discovered that restoration work in Oslo harbor is relevant right now, as several institutions, such as NIVA and Miljødirektoratet see the potential. Frames to work within, such as actors and regulations have also been raised.

Further on, five intervention points were condensed from the research. These intervention-points were:

1. Design incentives, regulation or even legislation…

2. Design the tools for decision-makers, land-owners, planners, developers, architects, or authorities…

3. Design solutions that focuses on the follow up of restoration efforts…

4. Inform the public about the importance of restoration efforts in urban marine environments…

5. Design the artificial reefs that fits the Oslo harbor.

We looked at intervention point 2, 3 and 4. In an iterative way, the project relied on evaluation tools such as cause and effect maps and usefulness testing. Through evaluation, the project iterated its way to the final proposed solution.

The final proposed solution relies on intervention point 2, but also includes information to the public (intervention-point 4). The proposed solution is a library of harbor infrastructure. In this library, harbor officials and engineers can control to which degree their architecture is bio-inclusive. They can check how bio-inclusive it is by using the “Surface index”, which is a collection of parameters from science that aims to create better living spaces for marine life.

This platform has a goal of injecting bio-inclusive thinking into everyday life of planners, harbor officials and engineers. The platform will guide decision-making for future projects and inspire to change existing infrastructure. Bits of this information will be available to everyone - meaning that the message and knowledge may spread beyond the harbor niche. The last wanted effect of this service is for the demand of artificial reef designs to peak - inspiring a new industry to emerge.

6.2: Further Research

For further research and design, I recommend further study on the intervention points in this thesis. If we progress on incentives and regulation, artificial reef design (for Norwegian conditions), and monitoring solutions, we move closer to an urban landscape that provides symbiosis (to the extent which it is possible) between people and animals.

Authorities in Oslo harbor still want more proof of the effect of artificial reefs in Norway. Further, they are still curious about the maintenance needed for keeping artificial reefs going. Therefore, I would recommend any further research to take those points into consideration too.

For further iterations on the proposed solution, focus should be on credibility of the surface index, pilot strategies, usability testing, assessment procedures, business models.

In credibility of the surface index, I am referring to several things. First of all, this thesis believes that credibility i s about the scientific foundation for the parameters that go into the index - the parameters should have a proven effect. Further, I extracted from an engineer that credibility is higher when there is little room for error in measuring procedure. Therefore, the process of measuring needs to be worked on. Finally, I hypothesize, using authority principle from Cialdini (Cialdini, 2014), that bringing hard hitters on the platform will boost credibility.

Usability testing of the platform has not been done. It was beyond the scope of this project. Simple wire-frames were made for this project, but was not tested for usability. Usability testing refers to concrete user interface and user experience design of the service. The service should be centered around the main jobs to be done and tailored to central users.

Pilot strategies encompasses the activities related to launching first iterative rounds of testing with a real harbor environment. For further work, the service needs concrete strategies on doing that. However, I do suppose that pilots will be created in dialogue. Therefore, this strategy may not be set in stone, but rather developed AD-HOC.

Business models *open, and closed* should be further developed.

6.3: Designer's thoughts

Oftentimes in this project, I found myself stuck. The unanswered questions were so technical, or so complex that I needed evaluation from an expert. At first, I relied heavily on response from marine-biologists and experts. Further down the road I reflected that it was my responsibility to find concepts that can be developed without excessive hand-holding. That's one of the reasons why I scrapped ideas such as "Kelp as the structure" and the idea about water data - they were just too complicated from a biology perspective.

Therefore, I tried to build concepts in the same intervention-points that did not require the expert heavy knowledge. This was paramount for the progression of my project.

Often I experienced a discrepancy between practice and theory in this project. I collected data from people and literature into a GIGA-map. In many cases, I believed this GIGA-map to be pretty much the truth. It turned out that my map was anything but the truth in some cases. It's unclear where the data and findings go from the words of experts to hypotheses that are incorrect. Therefore, I will try to include stakeholders into the GIGA-mapping process in future projects. This way I can try to not only develop it together, but also confirm and discuss the contents within. This will most likely provide valuable insight, while also sparing the designer from diverging too far from truth. I don't think the GIGA-map has any real value before you shared it with others.

6.4: System oriented design and user-centered design

I have worked with core concepts in system oriented design, such as interconnections, cause & effect, GIGA-map and zip analysis. I have tried to see the connections between things everywhere. This lead me down a path where I diverged from the much used 'user centered' format. I gained much from using the system oriented approach, such as 5 very varied intervention-points that could arguably change the system in a positive way. However, by diverging from the 'user centered approach', I observed that I had less insight about specific processes within for example Oslo Havn FK, and the individual needs of people within the organizations and bodies that will impact my topic the most. It felt as if I had an over-arching understanding, but lacked the specific know-how to help the individuals.

Therefore, in further work, I would advice to put on a more user centered approach in order to make sure that the service can cater to the specific needs of harbor officials, engineers and curious civilians.

6.5: The vision

This project was driven forward by a vision - a vision to create harbor-fronts that could serve as livable areas for life under water in all urban coasts. So can we do that? Requirements and regulation for infrastructure under water are scarce. They “stop at the water’s edge” (Myklebust, Johansen, Pehrson, Neilson, & Winsvold, 2022), remember? If our needs stop at the water’s edge, then the water’s edge should mark a boundary where needs of the marine life begins.

Appendix

Don't worry. There's not much here. The only thing I have provided here is a link to the GIGA-map. The GIGA-map is not meant to communicate well with others, but I welcome you to take a look.

Link: https://www.figma.com/file/yP8GNPcWkxWlNzwI4ZVZ7Q/Work-environment?node-id=0%3A1

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