THE CITY CLEANER

A WASTE-COLLECTING SYSTEM FOR URBAN WATERWAYS

A Master Thesis by Anna Belenguer Martí

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"We forget that the water cycle and the life cycle are one."
- Jacques Cousteau

"There's plenty of water in the universe without life,
but nowhere is there life without water."
- Sylvia Earle

Supervisory team

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TUDelft NORIA

PREFACE

This document marks the completion of my master thesis and the final chapter of my studies at the Faculty of Industrial Design Engineering.

Over the past years, I have developed a strong passion for sustainability, systems thinking, and the role of design in shaping a better future. This thesis reflects those values, connecting environmental responsibility with a practical, human-centered solution.

I am sincerely grateful to Noria Sustainable Innovators for giving me the opportunity to work with them. After I reached out with an initial proposal, they welcomed my ideas and allowed me the freedom to reframe the project in a direction I believed in.

I also want to thank the Municipality of Delft for their enthusiastic support of the project and for allowing me to test my prototype (free of charge) in in a central canal of the city.

Alongside this thesis, I was actively involved in communities that have deeply shaped my journey. As a board member of *Librae*, a network for female+ students in STEM, and part of *Hii*, a student-led organization promoting mental well-being in the TU Delft, I found inspiration and purpose.

Finally, I want to express my gratitude to my parents, Lidón and Javier, for always being my biggest support system and believing in me unconditionally. My journey in the Netherlands would not have been possible without them.

I am proud of the work presented here, and thankful to everyone who contributed to it in ways big and small.

Enjoy reading!

Anna Belenguer Martí
09.06.2025

ABSTRACT

This graduation report presents The City Cleaner: a community-engaging waste collector for urban waterways.

Process

This project explores the development of a small-scale waste collection system designed for urban canals.

Conducted in collaboration with Noria Sustainable Innovators and TU Delft, the project responds to the growing challenge of plastic pollution in city canals, where large-scale technical solutions are often unfeasible to deploy due to narrow spaces, infrastructure obstacles, or minimal water current.

Through site analysis, stakeholder interviews, field observations, and iterative prototyping, the project identified a design opportunity that combines physical waste collection with public engagement and awareness-building.

The City Cleaner demonstrator

The City Cleaner demonstrator

Final Design

The final design consists of a floating waste trap that collects captured floating debris through a submerged basket system that can be emptied manually from the canal shore.

The structure is lightweight, easy to install, and tailored for still water locations with 90 degree corners such as canal corners, areas under bridges, or between boats.

Two week-long public tests were conducted in Delft to assess performance, public response, and ergonomic handling.

Unique Selling Points

Unlike other existing solutions, The City Cleaner is not defined by its collection capacity alone. It functions as a visible, approachable installation that raises awareness, encourages civic participation, and creates learning opportunities.

Its human scale, low-tech design and affordability make it an ideal solution for integration in highly populated areas, supporting municipalities that want to combine sustainability efforts with education and community engagement.

In addition to public entities, the product is also relevant to private canal-side property owners, such as cafés, cultural venues, or offices, who may wish to own a unit as a way to show willingness to contribute to water pollution. By involving their employees, clients, or visitors, these stakeholders can demonstrate their commitment to clean waterways and foster a culture of shared responsibility.

Future Development

Looking ahead, the product has the potential to grow into a modular system that can be deployed as a network across urban waterways. Each unit would not only capture waste but also serve as a platform for education, volunteer involvement, and local partnerships.

By integrating visual storytelling, co-branding options, and interactive elements, the system could be tailored to different neighborhoods, events, or audiences.

Further iterations could explore seasonal adaptations, smart sensing for maintenance alerts, or collaborations with schools and community programs.

The long-term ambition is to merge the system into both municipal strategies and private initiatives, making it a recognizable symbol of collective action against urban water pollution.

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0. INTRODUCTION

This chapter serves as an introduction to the report of “The City Cleaner: a Waste-Collecting System for Urban Waterways”, an Integrated Product Design Graduation Project in collaboration with Noria Sustainable Innovators and TU Delft. It presents the the **client company** and its **initial project brief**.

The CirCleaner by Noria Sustainable Innovators

0.1 NORIA SUSTAINABLE INNOVATORS

Client Company
Noria Sustainable Innovators is a scale-up based in Delft, The Netherlands, dedicated to developing practical solutions to tackle the pressing environmental challenges of the plastic pollution in in-land water like rivers and canals.

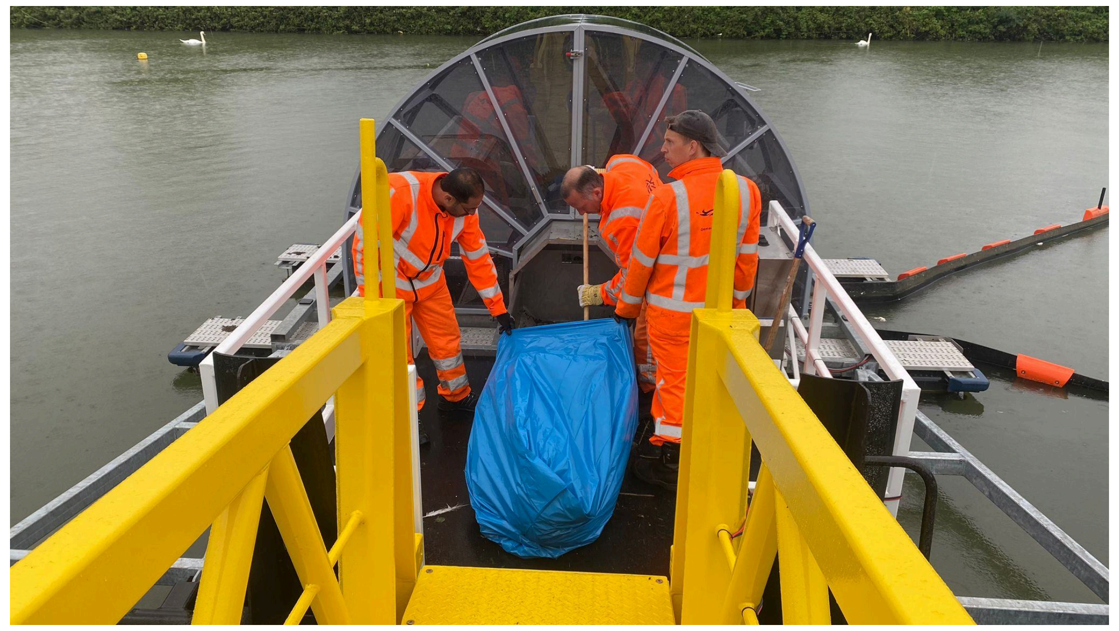
Founded with a mission to create cleaner and healthier aquatic environments, Noria employs a holistic approach known as the **"3R Method"**: Research, Remove, and Reduce to tackle the issue effectively.

The **Research** phase forms the backbone of Noria's operations. Using advanced tools such as geographical analysis (GIS), mathematical modeling, and AI-powered camera monitoring, Noria identifies sources, transport routes, and accumulation hotspots of floating waste. The company also employs GPS trackers to simulate the movement of litter and uses sonar and sampling methods to study the distribution of microplastics in water columns.

In the **Remove** phase, Noria deploys waste-catching systems such as the CirCleaner and CanalCleaner:

- The **CirCleaner** is an active collection system designed for use at pumping stations, canals, and rivers to remove plastic from the water in a sustainable and fish-friendly manner. It is solar powered, and features five mechanic arms that scoop up plastic from the water and collect it in a container located beside the system.

CirCleaner by Noria deployed in Keilehaven, Rotterdam



Collectors emptying the CirCleaner

- The **CanalCleaner** is a passive collection system designed for cities and marinas, particularly in areas with strong winds. It operates without energy and requires very little maintenance.

CanalCleaner by Noria deployed in Amsterdam

Finally, the **Reduce** phase emphasizes prevention, with Noria utilizing findings from its research to support the creation of effective policies and measures that address the root causes of littering.

This graduation **project focuses** on the **Remove and Reduce** domains of Noria's approach by designing a catching system for urban canals that performs functional action and builds awareness.

0.2 ASSIGNMENT

Goal

The goal of this assignment is to **develop** and **test a functional proof-of-concept** for a passive waste trap designed for high-visibility, small-scale urban canal areas. The system should be easy to install and maintain, leverage natural forces for debris guidance, and include potential for educational or ecological add-ons.

At the end of this report, a validated prototype demonstrates the feasibility, viability and desirability of the approach and serves as a **foundation for future development** and up-scaling by Noria.

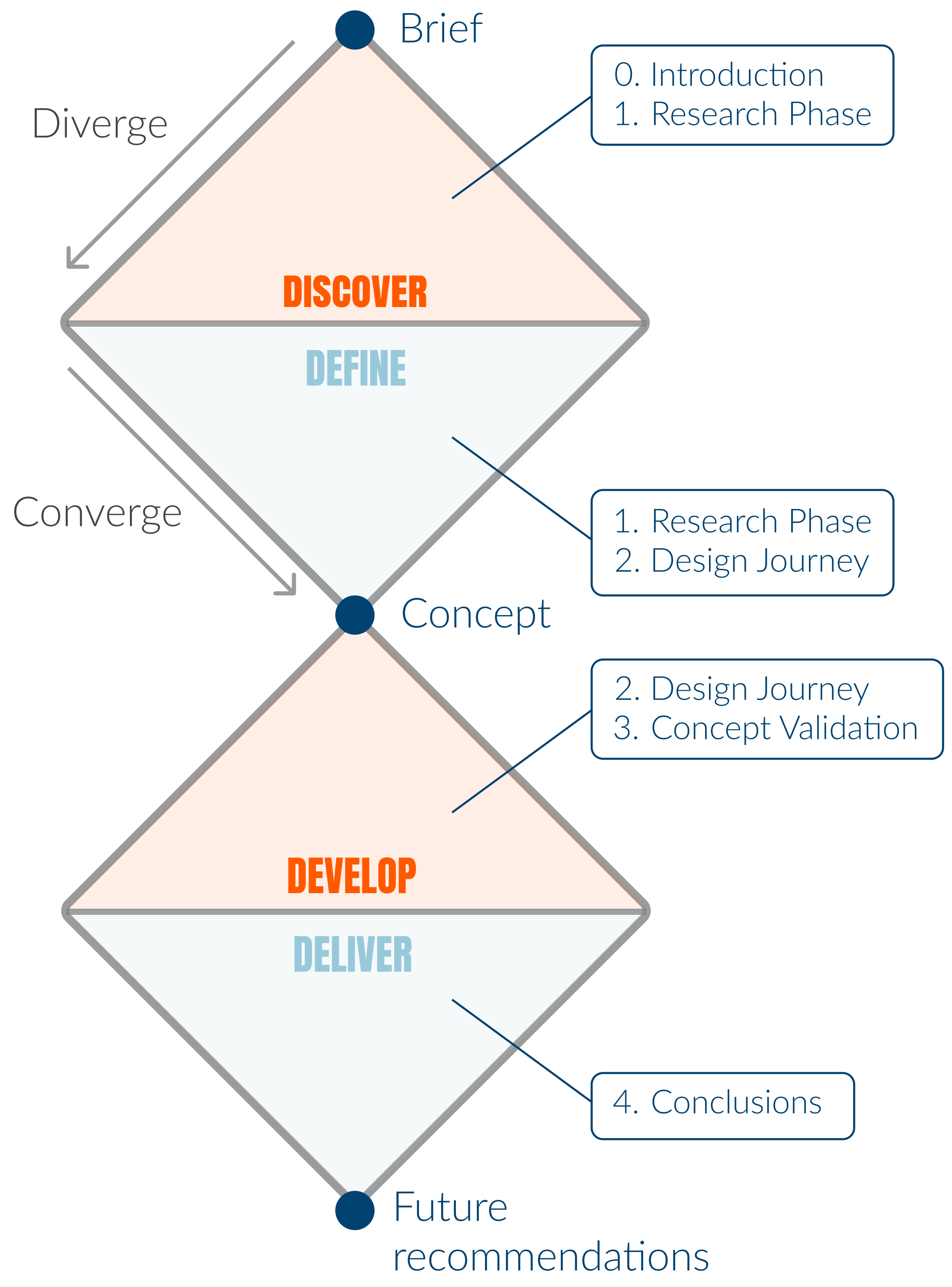
To guide the project, the following **main research questions** were formulated:

- **Where and how does floating waste accumulate in urban canals?**
- **What design strategies can improve ergonomic, efficient, and passive retrieval of this waste?**
- **How can the system also serve as a tool for public engagement around water pollution?**

Methodology

This thesis follows **The Double Diamond Approach**, a widely recognised design framework that has four different phases: Discover, Define, Develop, and Deliver. This methodology blends convergent and divergent thinking, guiding the process from broad exploration to focused concept development.

The Discover phase is dedicated to research, where key insights are gathered; the Define phase is the synthesis stage, where these insights are structured and distilled into clear
drivers and a design goal; the Develop phase focuses on ideation, generating a wide range of potential solutions; the
Deliver phase involves implementation and validation, ensuring the concept's feasibility and effectiveness. Every chapter of this thesis aligns with a phase of the Double Diamond, as visible in Figure X.



The Double Diamond Approach

Scope of the Project

In Scope:

- Collection of floating debris
- Public awareness
- Foster community involvement in canal cleanups
- Slow-moving urban waterways with public visibility
- Marketability

Out of Scope:

- Collection of micro plastics
- Collection of duckweed
- Collection of large-scale industrial waste
- Fast-flowing water bodies like rivers or oceans
- Design for mass production
- Use and integration outside The Netherlands

Disclaimer of AI usage

This thesis made use of AI tools, such as ChatGPT and Grammarly, to help improve language, carry out quick research and ideation. All content and conclusions remain the author's own, and critical analysis was conducted independently.

0.3 INITIAL PROBLEM STATEMENT

In the previous chapter, it was shown the two catching solutions that Noria currently offers: the CanalCleaner and the CirCleaner. However, these systems are often too large for installation in urban areas where canals are narrow and there is ongoing boat traffic that must navigate around them. Because of this, Noria is considering the development of a smaller catching system that would occupy less space than its existing solutions.

Initially, the idea of developing a smaller system started in the city of Groningen, when the organisation *Groningen Schoon Dankzij mij* asked Noria to provide a **catching solution** that would clean **areas of stagnant water around boats and living boats**.

These areas are often characterized by having little to no water current and by containing several obstacles that naturally trap dirt such as ropes, piping systems from the houses, or the boat's shape in relation to the canal wall.

Consequently, an initial design goal was formulated:

> "Design a **compact trapping system** that cleans **stagnant water** in areas such as **around living boats**"

Initial problem statement and showcase of the morphology of house boat infrastructures

Waste interfering nature (Het Parool, 2025)

1 RESEARCH PHASE

This chapter identifies key **knowledge gaps** within the project.

The findings presented in this chapter are derived from **desk research, field observations, and interviews**. The main findings from this section will be utilized in the next stages of the product development process.

1.1 Desk Research

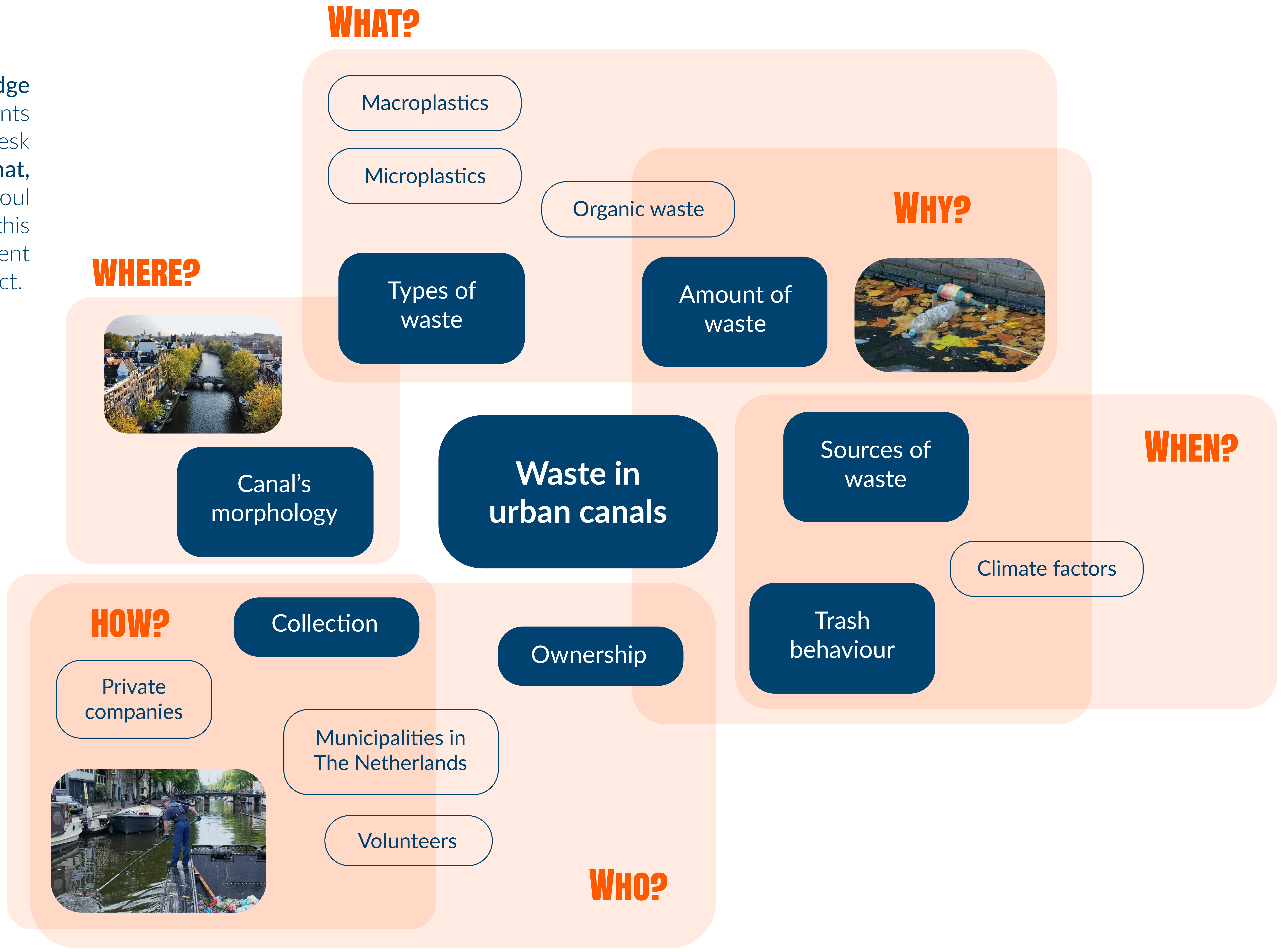
1.2 Field Research

1.3 Water pump experiment

1.4 Conclusions

1.1 DESK RESEARCH

This chapter highlights the key **knowledge gaps** identified in the project and presents data and conclusions derived from desk research using the **method Who, What, Where, When, Why and How** (Tassoul M., 2006). The main findings from this section will be utilized in the development of the design requirements of the project.



WHY?

A Growing Urban Challenge

Pollution in waterways is a rising concern globally, with far-reaching environmental, health, and logistical consequences. In the Netherlands, known for its unique system of rivers and canals, the issue is particularly pressing. Increasing plastic waste not only threatens aquatic ecosystems and public health but also disrupts vital urban infrastructure and cultural heritage.

The Scale of the Problem

The extent of plastic pollution in Dutch waters is alarming. Research shows that less than 1% of Dutch surface waters meet European water quality standards (European Environment Agency, n.d.).

Urban centers are especially affected. In Amsterdam, for instance, approximately 3,500 kilograms of debris are removed daily from canals (Waternet, 2021). This challenge is compounded by high population density and the millions of tourists who visit Dutch cities each year.

Rivers like the Rhine carry an estimated 20 to 31 tonnes of plastic annually into the North Sea (Schouten, 2021).

Meanwhile, busy nightlife districts, social areas, and popular attractions experience significant littering pressure. Within city canals, waste tends to accumulate behind moored boats, at canal corners, and under bridges, where water flow is slow and debris gets trapped.

Since these canals are not only functional infrastructure but also iconic public spaces, pollution becomes an aesthetic and cultural issue.

Sources and Movement of Plastic Waste

Plastic in waterways originates from diverse sources: 40% from industrial activities, 35% from consumer litter, and 19% from deliberate dumping or unknown causes (NL Times, 2023). Improper waste management, wind, and rainfall allow plastic debris to move from streets and landfills into rivers and canals (Schouten, 2021).

Research from P. Tasseron (2023) shows that the weather conditions with the greatest influence on waste transportation are windspeed and rainfall, which can rapidly mobilize litter into waterways.

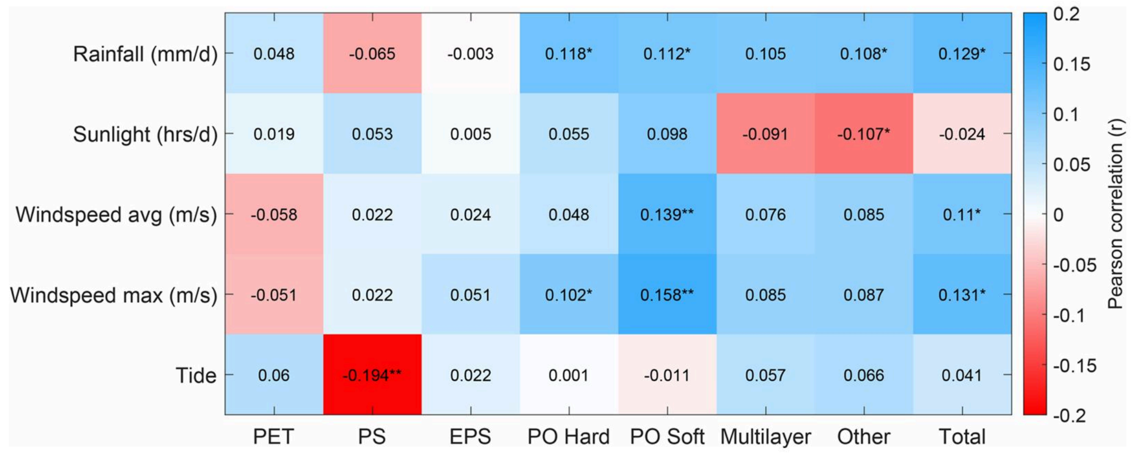
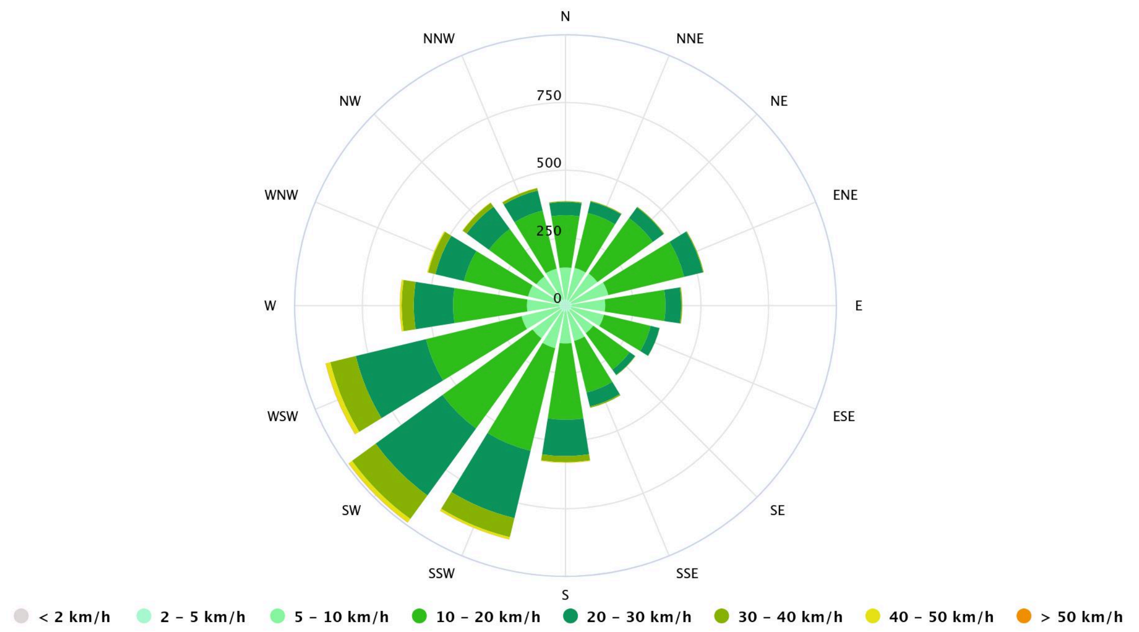


Fig. 5 Pearson correlations between the litter categories used for visual counting and environmental factors. Stars indicate the level of significance: $p \leq 0.05$ (*), $p \leq 0.01$ (**)

Wind sources in Delft yearly (Weatherspark, 2025)

In Delft, meteorological data reveals that for about eight months of the year, the prevailing wind blows from the southwest, with southern and northern winds dominating during the remaining months (WeatherSpark, 2025).

The wind rose for Delft indicates how many hours per year the wind comes from each direction, e.g., SW wind blows from the southwest to the northeast—an important factor in understanding how waste is transported across the city.



Wind direction and speed in Delft yearly (Weatherspark, 2025)

Environmental and Health Impacts

The implications of plastic waste go far beyond mere nuisance. Macroplastics break down into micro- and nanoplastics, releasing toxic additives and persisting in aquatic environments (Van Emmerik & Schwarz, 2020). These particles degrade ecosystems and play a central role in marine plastic pollution (Schmidt et al., 2017).

Microplastics also pose severe health risks to humans. They have been detected in human liver, kidneys, and even placental tissue, raising concerns about chronic exposure. Studies link these particles to developmental disorders, immune dysfunction, neurological effects, and hormonal disruption (Ragusa et al., 2021; Leslie et al., 2022).

WHAT?

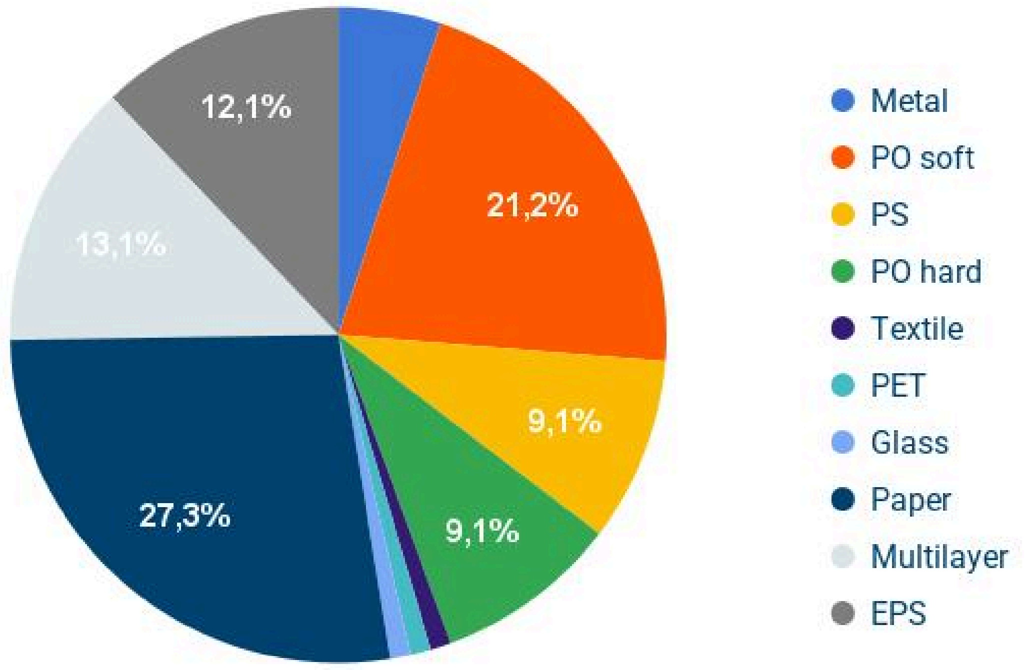
Types of Waste on water

Based on visual counting of floating litter from bridges, it is estimated that **2.7 million** items enter the **IJ river annually**. This emission ranks the Amsterdam water system among **Europe's most polluted rivers** observed to date. (Environmental Science and Pollution Research, 2023).

Inorganic waste found in urban canals in the Netherlands is primarily composed of **plastics**, which account for over **60% of the litter** in these waterways (Schmidt et al., 2017). Common items include bottles, food wrappers, and single-use packaging.

Most common types of plastic in consumer products

Moreover, **metal and glass** debris, such as aluminum cans and bottles, are often found near nightlife districts and busy social areas. Occasionally, larger and unconventional items, including bicycles, shopping carts, and discarded furniture, end up in the canals, usually due to vandalism or improper disposal (Waternet, 2021).



Overview of materials from consumer products found in water. (J. van Wijk, 2022)

Item	Weight	Weight totally filled with water	Size
0,5 L PET bottle	20–30 g	520–530 g	22 cm × 6.5 cm
Plastic cup	3–7 g	253–257 g	10 cm × 7.5 cm
Plastic bag	5–20 g		40 cm × 30 cm
0,33 L glass bottle	200–300 g	450–550 g	19 cm × 5.5 cm
Branches	100–300 g	100–300 g	50 cm × 3 cm
Cardboard	20–50 g	40–100 g	(A4-sized): 30 cm × 21 cm

Most common items found in urban waterways

Seasonal variations

In addition to inorganic debris, **organic waste** accumulates throughout the year, with distinct **seasonal variations** that can create unique challenges.

In the **fall**, falling leaves from overhanging trees create a significant influx of organic debris in urban canals. While leaves are biodegradable, their accumulation can lead to oxygen depletion as they decompose, contributing to poor water quality (Nijssen et al., 2019).

Winter introduces a different challenge, as freezing temperatures can result in ice formation on the canal surface which can also create blockage in waste catching systems.

During the **summer**, the growth of algae, particularly **kroos (duckweed)**, becomes a significant issue. Kroos can rapidly cover large portions of the water's surface, especially in stagnant or slow-moving canals. While it is a natural phenomenon, its excessive presence can block sunlight, disrupting aquatic ecosystems and reducing oxygen levels, which can harm fish and other aquatic life (Van der Molen et al., 2016).
Additionally, it can clog drainage systems and hinder the operation of waste-collection devices.

Duckweed and plastic accumulation in Delft city centre. (Het Parool, 2023).

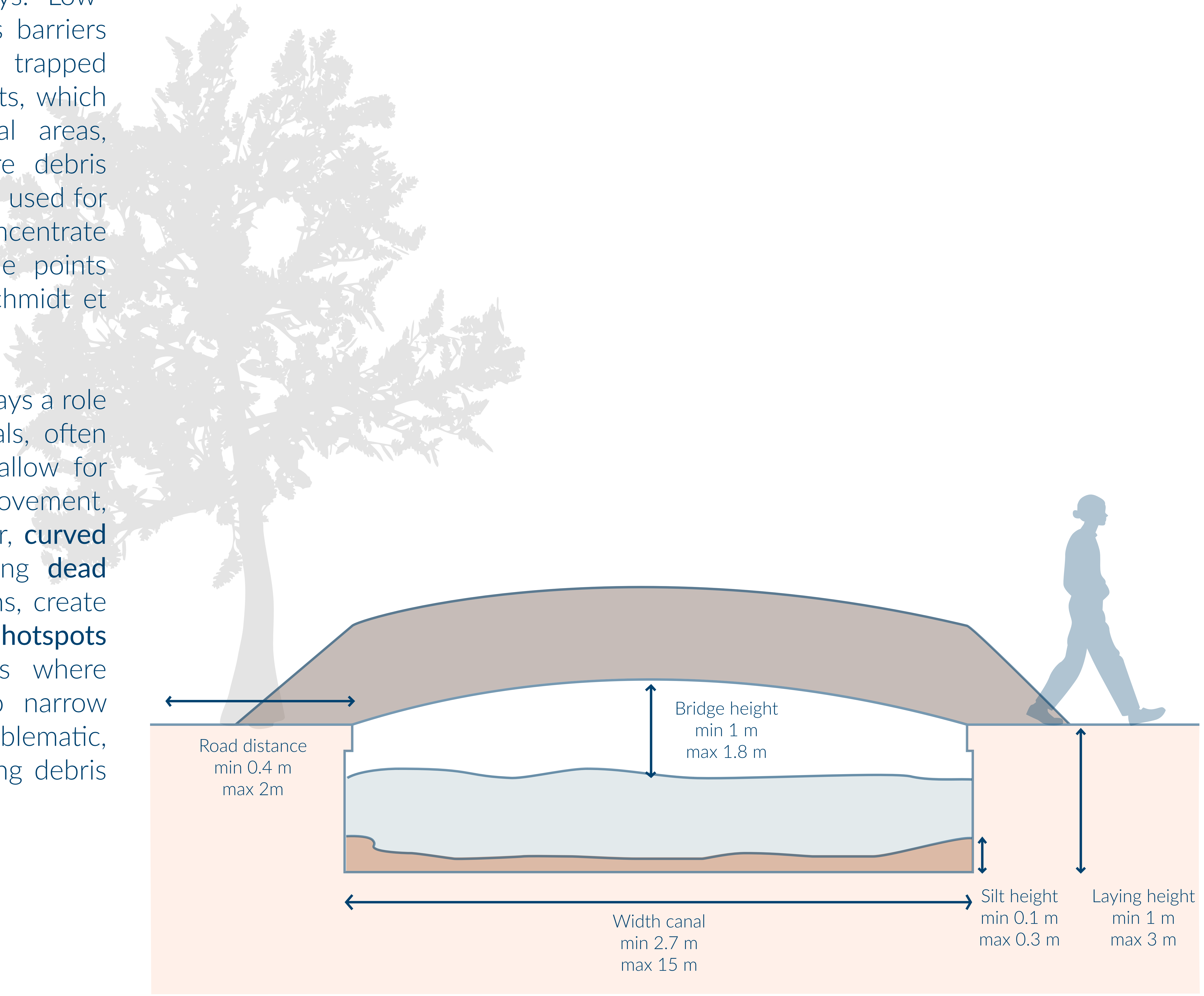
WHERE?

Canal Morphology and Its Role in Waste Accumulation

The structure and layout of urban canals significantly influence the types and quantities of waste they retain. In historic city centers like Amsterdam, Utrecht, and Delft, narrow canals with **widths of less than 6 meters** and **height** of approximately **1,30 meters** are common (Rijkswaterstaat, 2020). These smaller waterways often suffer from stagnation, making them prone to accumulating waste in corners or along the edges. In contrast, wider commercial canals, exceeding 20 meters in width, typically experience better water flow, although litter can still collect in transition zones or at the base of obstacles.

Obstructions such as bridges, houseboats, and locks further shape how waste behaves within these waterways. Low-lying and arched bridges, act as barriers where floating litter often gets trapped (Nijssen et al., 2019). Houseboats, which line many canals in residential areas, create additional pockets where debris gathers. Similarly, locks and dams used for water regulation frequently concentrate floating litter, particularly at the points where water flow is minimal (Schmidt et al., 2017).

The morphology of canals also plays a role in waste behavior. Straight canals, often found in modern urban areas, allow for more consistent water movement, reducing litter build-up. However, **curved canals** and those with branching **dead ends**, typical of older city designs, create zones of still water that become **hotspots for waste accumulation**. Areas where canals transition from wide to narrow sections are particularly problematic, acting as natural traps for floating debris (Van Emmerik & Schwarz, 2020).



Front view of a Dutch canal in ahistoric center, showing average dimensions.

WHO AND HOW?

The collection of waste in urban waterways in The Netherlands involves a **collaboration between public institutions, private companies, and community efforts**.

Municipal Responsibility

In most Dutch cities, municipalities are primarily responsible for **maintaining the cleanliness of public spaces**, including canals. They often coordinate trash collection efforts, either by directly employing cleaning teams or by contracting private companies specializing in waste removal. In addition, many municipalities make use of digital platforms like **BuitenBeter**, a citizen-reporting app that allows residents to easily flag issues in public spaces by sending photos and locations directly to municipal services.

Crane extracting heavy waste in an Amsterdam canal

Role of Water Authorities

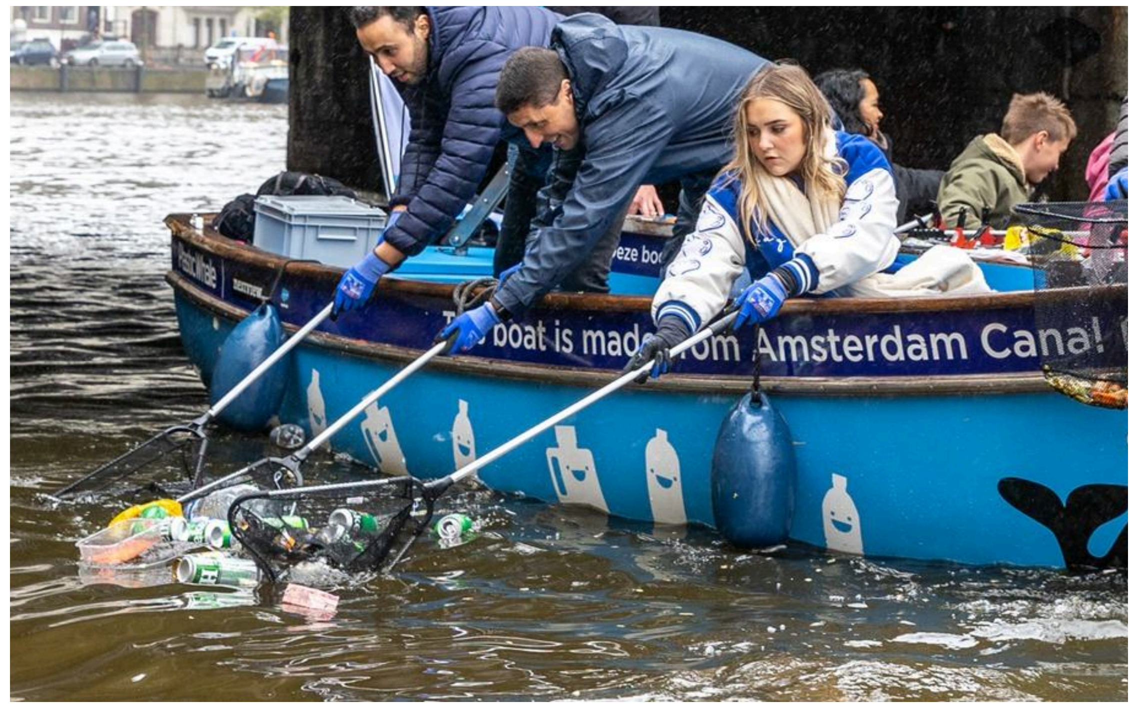
Water management institutes, such as regional water boards (waterschappen), also play an important role, particularly when waste affects **water quality** or impedes **drainage systems**. These boards are tasked with maintaining waterways to prevent flooding and ensuring ecological balance.

Private Companies

Private companies are sometimes contracted to provide specialized services, especially for large-scale waste removal or challenging cleanup operations. For example, firms like **Waternet** in Amsterdam are actively involved in cleaning canals, operating both as a public utility and a contractor for specific projects. These companies use advanced equipment, such as trash skimmers and cranes, to remove waste efficiently, including larger items like bicycles or shopping carts (Waternet, 2021).

Volunteers and Community Initiatives

Volunteer groups and community organizations play a growing role in trash collection, particularly in cities with a strong culture of civic engagement like Groningen. Events like "plastic fishing" or "clean-up days" attract residents, tourists, and local businesses to actively participate in removing waste from canals. Organizations like the **Plastic Whale Foundation**, for instance, organize regular cleanup activities where participants collect litter while navigating canals on boats (Plastic Whale Foundation, n.d.).



Volunteers from the Plastic Whale foundation fishing waste

The Problem with Trash Ownership

One of the significant challenges in managing trash in waterways is the issue of ownership. Waste floating in canals often appears to belong to no one, creating a **lack of clear accountability**.

Unlike household or industrial waste, where responsibility is assigned to individuals, companies, or municipalities, trash in water exists in a **legal and practical gray area**. This ambiguity can lead to neglect, as no single entity feels obligated to address it. Municipalities and water authorities often step in to take charge, but the lack of a defined owner complicates efforts to assign responsibility, recover costs, and prevent littering. This issue highlights the importance of public awareness, stricter enforcement of anti-littering laws, and innovative approaches to monitoring and removing waste.

1.2 FIELD RESEARCH

Next to the desk research, observational research including waste-picking activities and visits to Noria's catching systems on-site, were conducted from September 2024 to May 2025. This research also involved interviews with houseboat owners in houseboat areas and city centers of Delft, Amsterdam, and Rotterdam.

Observational research
Whilst the focus was initially finding design opportunities among house boats, these environments appeared relatively clean and did not exhibit significant waste accumulation.

However, city centers consistently showed **patterns of litter collection**. These findings emphasized the potential for implementing trash-trapping systems in densely populated urban areas, particularly **near transport hubs**, **landmarks**, **tourist attractions**, **social gathering spaces**, or **event locations**; areas where waste is more likely to accumulate due to **high human activity and limited accessibility** for maintenance.

Consequently, locations were identified as **hotspots** where trash naturally collects due to environmental and societal factors. These include:

- Areas where canals transition from wide to narrow.
- Canal corners that create dead spots in collaboration with wind patterns.
- The base of bridges.
- Canal waters beneath public trash containers.

Selected hotspots in the city of Amsterdam

Interviews
A total of eight interviews were conducted with relevant stakeholders to gain insights into urban canal waste issues. These stakeholders included three houseboat owners in Delft, one houseboat owner in Groningen, two employees from the Municipality of Delft, one employee from the Municipality of Rotterdam, volunteers from the Canal Hoppers, and finally, multiple co-workers from Noria.

These conversations provided valuable context to complement the observational research. Notably, the **houseboat owners reported minimal waste accumulation** around their homes, aligning with the findings of field observations. This contrasts with claims made by *Groningen Schoon Dankzij Mij*, suggesting that trash trapping between houseboats may not be as prevalent as previously reported.

"Living on a houseboat, I've never really had to clean up trash around my home. The occasional piece of litter might float by, but it usually moves along with the currents, and it's never been a big enough issue to worry about."

Jacob (32 y/o), **livingboat owner** in Groningen

"Once the **duckweed** takes over in the summer, it's like a green carpet: **trash just gets stuck and can't move anywhere.**"

Ruud, from **Cannal Hoppers Delft**

Waste-picking

As part of the field research, several waste-picking activities were undertaken to better understand the types of waste present in urban canals and the **practical challenges of manual collection**.

These activities included joining a cleanup session by boat with the Canal Hoppers volunteers in Delft, stand-up paddling in Delft to observe waste from a water-level perspective, and participating in land-based waste collection throughout the city of Delft.

Plastic waste, particularly single-use items, was found to be the most prevalent. Additionally, large amounts of organic waste such as leaves, algae, and occasional dead animals were frequently encountered. Beyond the types of waste, this experience also highlighted the **significant physical challenges involved in manual trash collection**.

Volunteers from Canal Hoppers faced difficulties retrieving waste from the water especially when debris were tangled in vegetation or stuck under floating structures. The **repetitive bending and lifting** required during the cleanup present **ergonomic challenges**, therefore the **weight of waterlogged items** is definitely to be taken into account for the development of this project. These observations emphasized the need for systems that reduce the **physical burden of manual waste removal**.

Canal Hopper’s volunteer picking up waste manually, froma boat

Visiting Noria’s systems

Additionally, a visit was conducted to the CirCleaner in Keilehaven to better understand the existing products from Noria.

While the system demonstrated to capture waste effectively, the process of collecting the trapped trash from the container showed opportunities for improvement.

The material and thickness of the retrieval container makes it **heavy** and **challenging to maneuver** with just one person, especially when full of wet waste, and the current setup requires users to bend down to handle heavy loads. Another observation was the **inevitable clogging** of the scoops' **meshes**, which require regular cleaning to maintain their functionality. While this clogging is a natural consequence of operating in open water, it remains an operational challenge to consider for future designs.

Observations from the CirCleaner in Keilehaven

1.3 WATER PUMP EXPERIMENT

To explore the posibility of integrating power into the project, an experiment using an electric water pump was conducted. **Inspired by the Seabin project** CNET. (n.d.). and **swimming pool skimmers**.

The experiment included three small variations to understand the behavior of electric water pumps, the dynamics of floating debris and water flow, and the challenges associated with stabilizing objects in water.

Water pump test set-up

Key Learnings

1. Stabilizing Objects in Water

Achieving a stable and controlled position for objects in water proved to be more difficult than anticipated. The bucket tended to float unless it was intentionally submerged, at which point it filled with water and began to sink. The desired position, with the bucket aligned at water level, required external weighted floaters to maintain stability.

This highlighted the importance of **incorporating buoyant materials** or adjustable floatation devices into the design **to counteract water forces** and maintain the system's orientation.

2. Structural Integrity

The force generated by water movement was stronger than anticipated, causing the wooden mounting system to break. This highlighted the **need for robust, weather-resistant materials** and a design that can withstand continuous water pressure and dynamic forces.

3. Water Pump Performance

The suction power of an electric, non-submergible pump with a flow rate of 3,800 l/h and a power rating of 650 W was not as strong as expected, but still could be a viable option for further testing.

Main Takeaways and Next Steps

While creating a pull in the water using powered systems could increase waste capture efficiency by attracting more debris in less time, the **complexity** of integrating such systems within the project's **time frame** makes this approach **unfeasible**.

Additionally to these testing conclusions, an independent study evaluating the Seabin system found that although it successfully captured floating plastic debris, its **performance was limited compared to manual collection**. The Seabin also unintentionally trapped marine organisms, raising concerns about ecological impact (Parker-Jurd et al., 2022). These findings further support the decision to **shift away from powered solutions**.

Instead, the project will focus on containing waste at its source to prevent it from spreading to larger waterways and causing greater environmental harm.

Although this method may not achieve the same **level of collecting efficiency** as powered solutions, it offers significant other benefits by **intercepting debris early, reducing environmental impact, and raising awareness** about plastic pollution in densely populated areas.

By **embracing natural forces** such as wind patterns, currents, and natural waste accumulation points, the system prioritizes **simplicity and affordability**. This approach also aligns with Noria's goals of keeping development costs low.

More information about the water pump experiment can be found in the Appendix C.

1.4. OVERVIEW OF KEY fiNDINGS

Key findings

Waste

- **Organic waste** is the **biggest bulk**, with clear **differences depending on the season**. Autumn with falling leaves, winter with ice, summer with duckweed.
- **Plastic waste (>60%)** is the most common among inorganic waste.
- **Waste sources**: 40% industrial, 35% consumer, 19% deliberate dumping/wind blown.
- In **Delft**, **southwest winds dominate**, influencing waste movement.
- Macroplastics degrade into micro/nanoplastics, releasing toxins.

Collection

- **Waste collection is primarily manual**, carried out by volunteers using grabbers, either on foot or by boat.
- Municipalities handle **large debris** using **crane-equipped boats**.
- **Safety risks** include falling into the water and handling heavy, waterlogged containers.
- **Cold and wet conditions**, especially in winter, make collection uncomfortable.
- Meshes allow drainage but require frequent cleaning to remain effective.
- There are a lot of parties, public and private, involved in waste collection. **Stakeholder management is crucial**.

Context

- **Narrow canals (<6 m wide) with low height (~1.3 m)**.
- Obstacles like **bridges, houseboats, and locks** create hotspots for **waste accumulation**.
- **Curved canals and dead ends** increase stagnation and waste retention.
- **Wide-to-narrow transitions** act as natural waste traps.
- **High tourism and urban density** increase littering in central canals.

Client

- Current systems are mainly focused on the collection phase, not retrieval, making the **process not ergonomic for the operator**.
- Noria's current systems will stay in catalogue, proposed design should **focus on providing a different value**.
- Exploring the idea of a powered system is currently too costly and misaligned with the client's preferences.

Responsability

- **Municipalities are primarily responsible** for canal cleaning, often contracting private services.
- **Community initiatives** (e.g., Plastic Whale) engage the public through events like plastic fishing.
- **Trash ownership is unclear**, creating legal and practical barriers to responsibility.
- No defined ownership can lead to neglect and **complicate cleanup funding and enforcement**.
- Public awareness and stronger policies are essential to **address accountability gaps**.

2 NEW PROBLEM STATEMENT

This chapter **redefines** the **initial problem statement** proposed by the client company and states a **new design direction** for the project. Continuously, it presents the **design requirements** gathered from the findings of the research phase.

2.1 DESIGN DIRECTION

Refined Design Focus: Urban Canal Corners as Waste Collection Points
While the original brief provided by Noria focused on waste accumulation between houseboats in Groningen, early field analysis and interviews revealed these areas are not major hotspots for floating debris.

In contrast, urban canals in central areas, especially near tourist attractions, nightlife zones, public transport hubs, and bridges, consistently showed higher concentrations of litter. These locations often lack significant water flow, causing debris to settle in corners where two canal walls meet at right angles.

Observing these natural accumulation patterns inspired a shift in the design brief: to **leverage how waste collects naturally** and develop a **solution that retrieves trash from these hotspots** as **effectively** and **ergonomically** as possible, while also utilizing these central areas for **raising public awareness** about the urban plastic soup problem.

Toward a More Impactful Solution
This re-framing of the design brief allowed for a more context-sensitive and strategic approach to the problem of urban water pollution, one that not only considers environmental impact, but also the social dynamics of public space.

Planning
To remain practical within the project's time frame, a standardized prototype, based on potential locations in Delft, will be developed and tested on-site. While this initial iteration may not represent the final market-ready product, it will serve as a **proof of concept**.

By testing the feasibility, viability and desirability of passive trash collection in these urban areas, the system aims to **evaluate whether natural forces alone can adequately address the problem**.

This exploration will also inform if future iterations may require more advanced, powered systems to optimize waste capture and retention.

Consequently, the design goal was reformulated.

Design Goal

"Develop a **waste-catching system** for **narrow urban canals** that harnesses **natural waste accumulation patterns** for effective trash collection while also **fostering public engagement and awareness** around water pollution."

Main Drivers

These are the three **main drivers** for the project, which follow the SMART setting goals method (Specific, Measurable, Acceptable, Realistic, Time bound), (Doran, 1981):

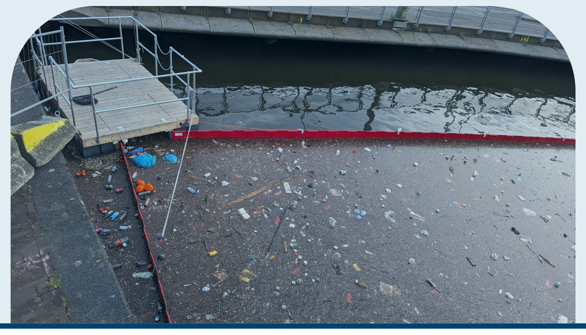
1. Mounted in 90 degrees corners

The system is mounted into any 90 degree corner and must be able to **adapt to the location** size.

2. Cost-effective

The **final development cost** of the system **must not exceed €2,000**. Given the limited funding often allocated by municipalities for such projects, keeping the system affordable is essential.

Moreover, it is critical that this system **does not compete with the existing products in Noria's catalog**. Instead, it aims to complement their portfolio by addressing a different market segment.



X

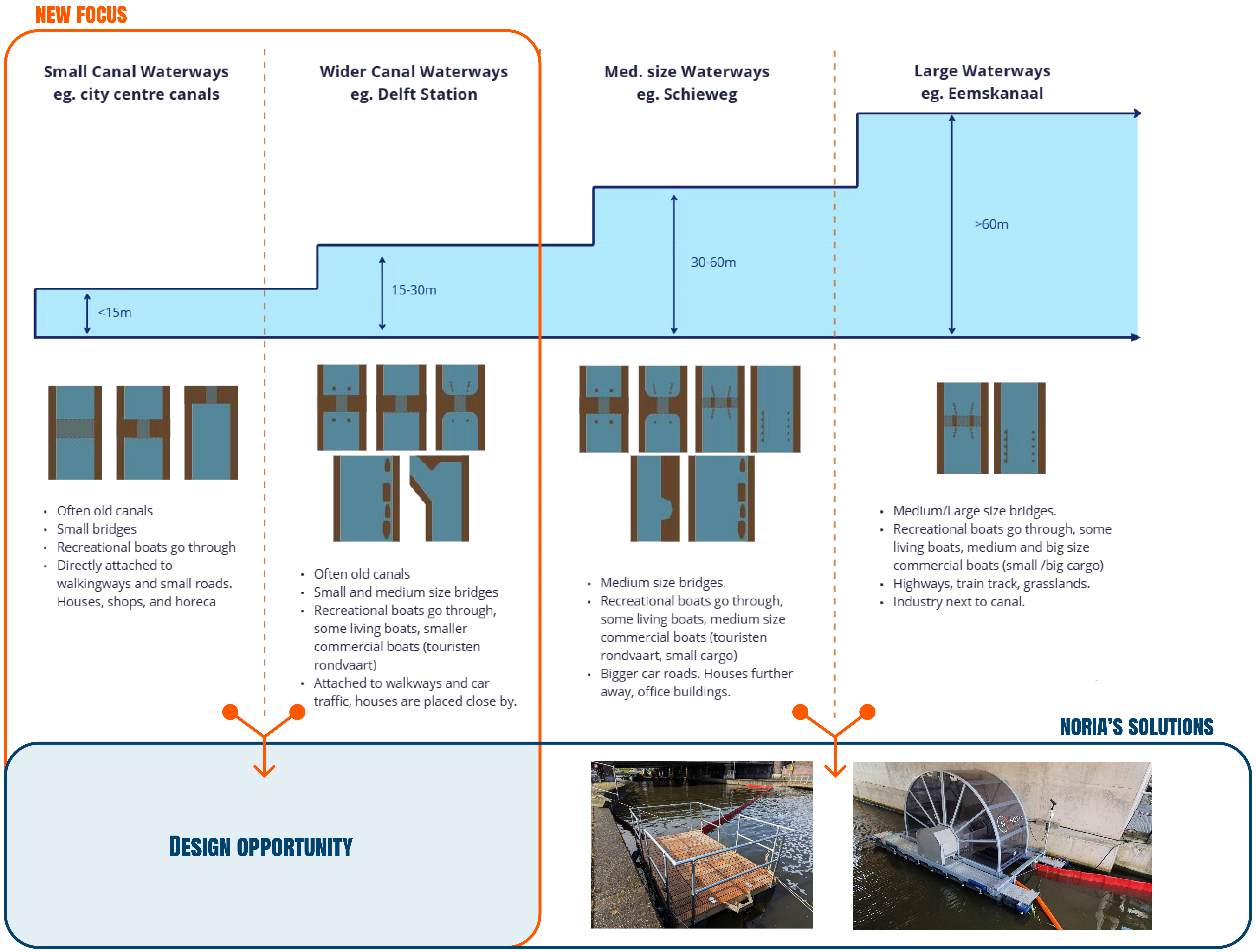
3. Easy and ergonomic emptying

Noria's existing systems primarily focus on how trash is effectively collected. This system focuses on the emptying phase, ensuring that the trash is **easily accessible for collection and disposal without the need for special equipment or multiple operators**.

This new focus highlights a **key design opportunity** in small-scale urban canals with high visibility and social interaction.

Unlike open waterways, these confined spaces benefit most from systems that guide debris passively using natural forces such as wind, boat movement, or water flow, thereby minimizing complexity and energy use. These strategies align closely with Noria's values of modularity, simplicity, affordability, and educational potential.

However, active solutions involving pumps or mechanical elements were not excluded at this stage yet, allowing for a broad and creative ideation phase.



Urban waterway's shapes morphologies VS current Noria's solutions

Potential locations of implementation in Delft

This map highlights four locations in Delft identified as suitable for implementing such a waste-trapping system in 90 degree corners. By focusing exclusively on Delft, the project remains practical and manageable, taking into account my proximity to and familiarity with the city.

These selected locations exhibit high trash accumulation caused by environmental and societal factors, making them strong candidates for further development of the project.

Selected corners in Delft

2.2 DESIGN REQUIREMENTS

The following design requirements were derived from key findings in the research phase and prioritized using the MoScoW prioritization method (Clegg & Barker, 1994):

	Design requirements	Key findings
Must-have	1. The system **collects floating waste**, with a focus on organic and plastic waste. 2. The system **faces** the most common **wind direction** of the selected area, (with it being south-east in Delft). 3. The system must **fit into narrow canals**, (<6 m widths and ~1.3 m heights). 4. The system is **mounted in 90 degree corners**, where waste naturally accumulates by itself. 5. The system is **installed in city central areas**. 6. The system is passive: **it does not use energy** or power. 7. The system is **safe for public interaction**. 8. The system is **easy to access** and generate **low physical effort for retrieval**. 9. It is **durable in outdoor** urban canals for extended use. 10. It **does not obstruct boat traffic or wildlife**. 11. Designed for **low-cost production**. 12. The final development cost of the system must not exceed €2,000	← • Organic waste is the biggest bulk, with clear differences depending on the season. Autumn with falling leaves, winter with ice, summer with duckweed. • Plastic waste (>60%) is the most common among inorganic waste. • Waste sources: 40% industrial, 35% consumer, 19% deliberate dumping/wind blown. • In Delft, southwest winds dominate, influencing waste movement. • Narrow canals (<6 m wide) with low height (~1.3 m). • Obstacles like bridges, houseboats, and locks create hotspots for waste accumulation. • Curved canals and dead ends increase stagnation and waste retention. • Wide-to-narrow transitions act as natural waste traps. • High tourism and urban density increase littering in central canals.
Should-have	13. The system **encourages public curiosity and engagement**. 14. It is **easy to install without special tools**. 15. It **supports community interaction**. 16. **Easy to maintain and clean**. 17. It **adapts** to various **canal shapes**. 18. **Circular design**.	← • Municipalities are primarily responsible for canal cleaning, often contracting private services. • Community initiatives (e.g., Plastic Whale) engage the public through events like plastic fishing. • Trash ownership is unclear, creating legal and practical barriers to responsibility. • No defined ownership can lead to neglect and complicate cleanup funding and enforcement. • Public awareness and stronger policies are essential to address accountability gaps.
Won't-have	19. Microplastics collection 20. Automation or power-dependence. 21. Open water or river/ocean deployment	← • Macroplastics degrade into micro/nanoplastics, releasing toxins.

3 DESIGN JOURNEY

This chapter transforms the design requirements into **tangible concepts**. The first part focuses on **ideation**, where various methods are employed to generate ideas and are merged into the chosen **concept direction**. The second and third parts consist of two rounds of design iterations which shape the chosen concept in a concrete and realistic solution.

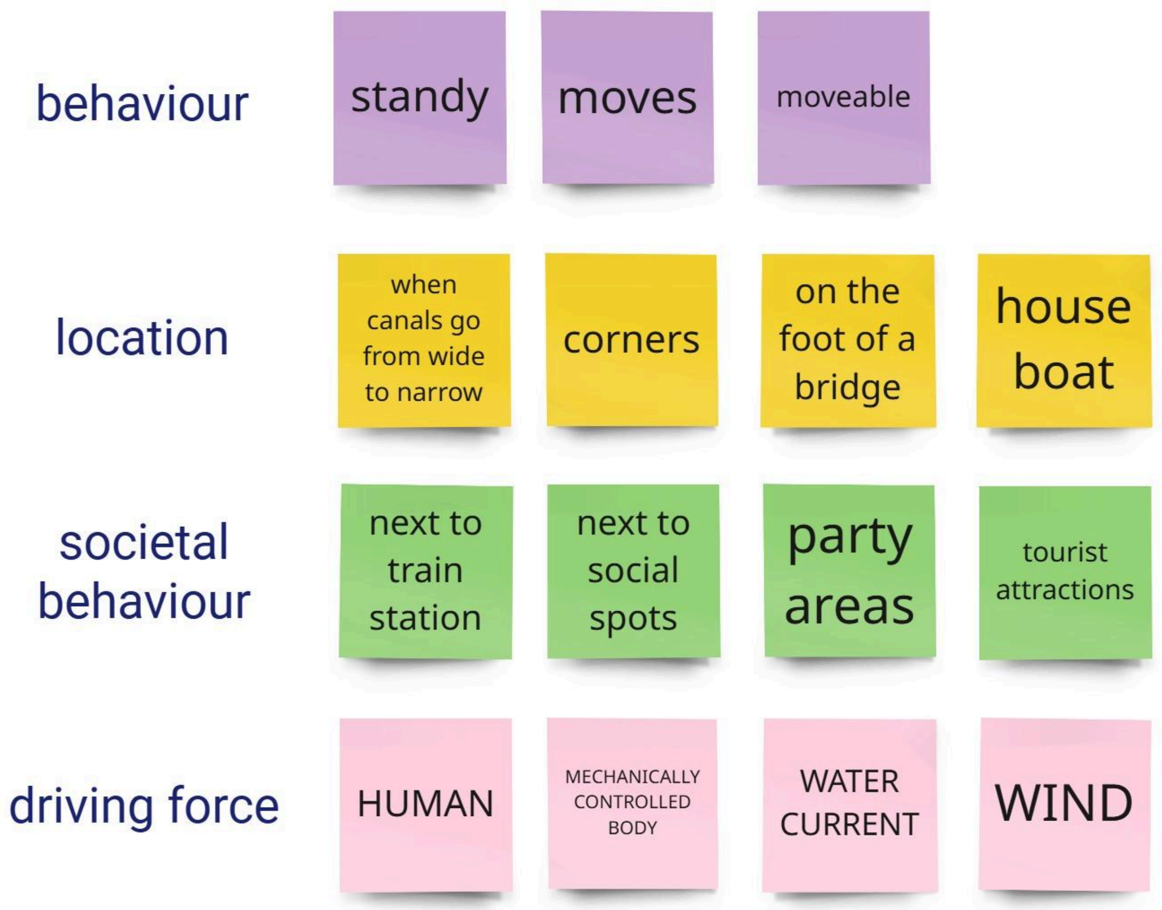
3.1 IDEATION

Before starting the ideation phase, a **market** and **competitor analysis** was conducted to better understand existing products and identify opportunities for differentiation. This exploration is detailed in Appendixes A and B.

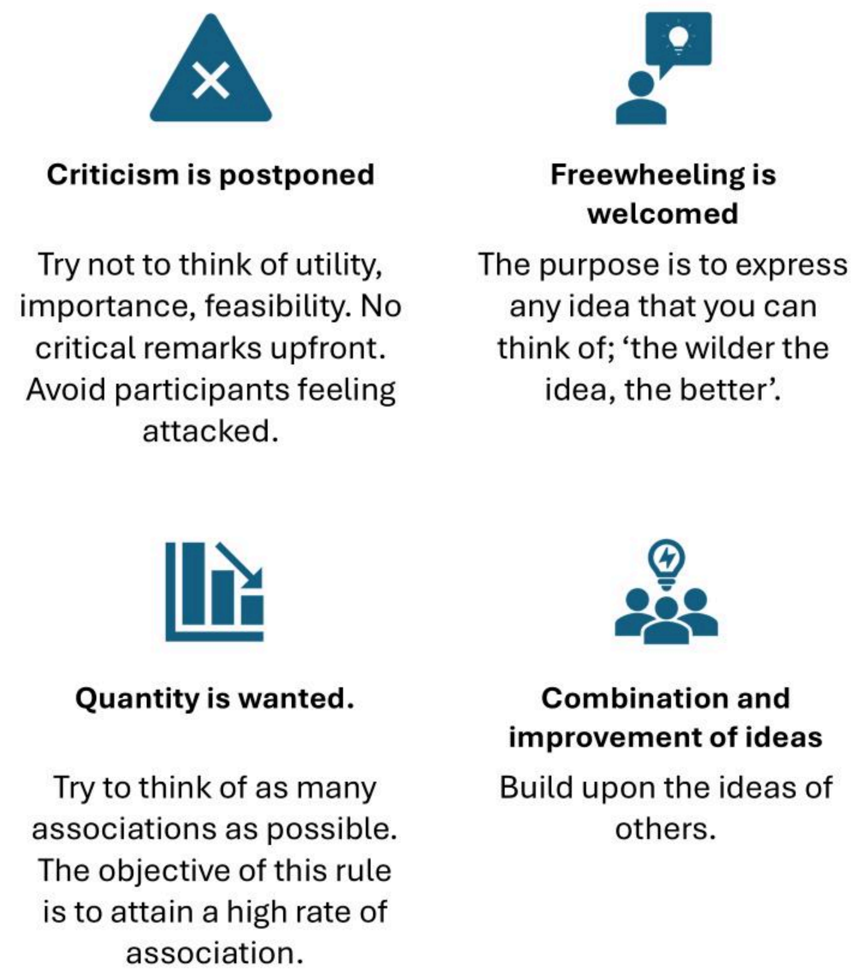
During the ideation phase, several **methods and tools** were applied to generate and refine design directions, including:

- Brainstorming
- Morphological charts
- An ideation session at Noria
- Conceptualisation
- Evaluation of pros and cons
- Sketching
- Vizcom AI visualizing tool (Vizcom, 2024)

The majority of these methods are commonly used in the design field and are described in the Delft Design Guide (Van Boeijen et al., 2014)



Morphological chart made to help generate ideas



Rules for the ideation session

Ideation session

To explore early directions for the design of the waste-catching system, a collaborative brainstorming session was held with two employees from Noria.

The objective was to generate a diverse range of ideas related to the system's form, core functionality, and potential for creating social impact in urban environments.

The session followed key guidelines of creative ideation, including postponing judgment, encouraging quantity over quality, and building on each other's ideas. These ground rules helped foster an open and creative atmosphere where unconventional thinking was encouraged.

The session was structured around three rounds of fast-paced design sprinting, each guided by a provocative question intended to spark fresh perspectives and solutions.

Provocative questions:

1. What elements of a canal's unique environment might actually enhance our design instead of limiting it?

*Think about:
- Canal shape
- Obstacles
- Tight spaces
- Social hubs

2. How could the system capture trash even when there's minimal water movement?

*Think about:
- Power sources: human? machine?
- Does the system consist of multiple elements?

3. If emptying the system was as simple as possible, what would that process feel and look like?

*Think about:
- Who takes care of the emptying?
- Do you need equipment?
- How often?
- How ergonomical is it?

A complete overview of the rest of the session can be found in the appendix X.

Ideation session at Noria

Ideal human-product interaction

During the ideation phase, an ideal interaction journey was envisioned to guide the development of the waste-catching system. During this period, this vision served as a **foundation for evaluating concepts**.

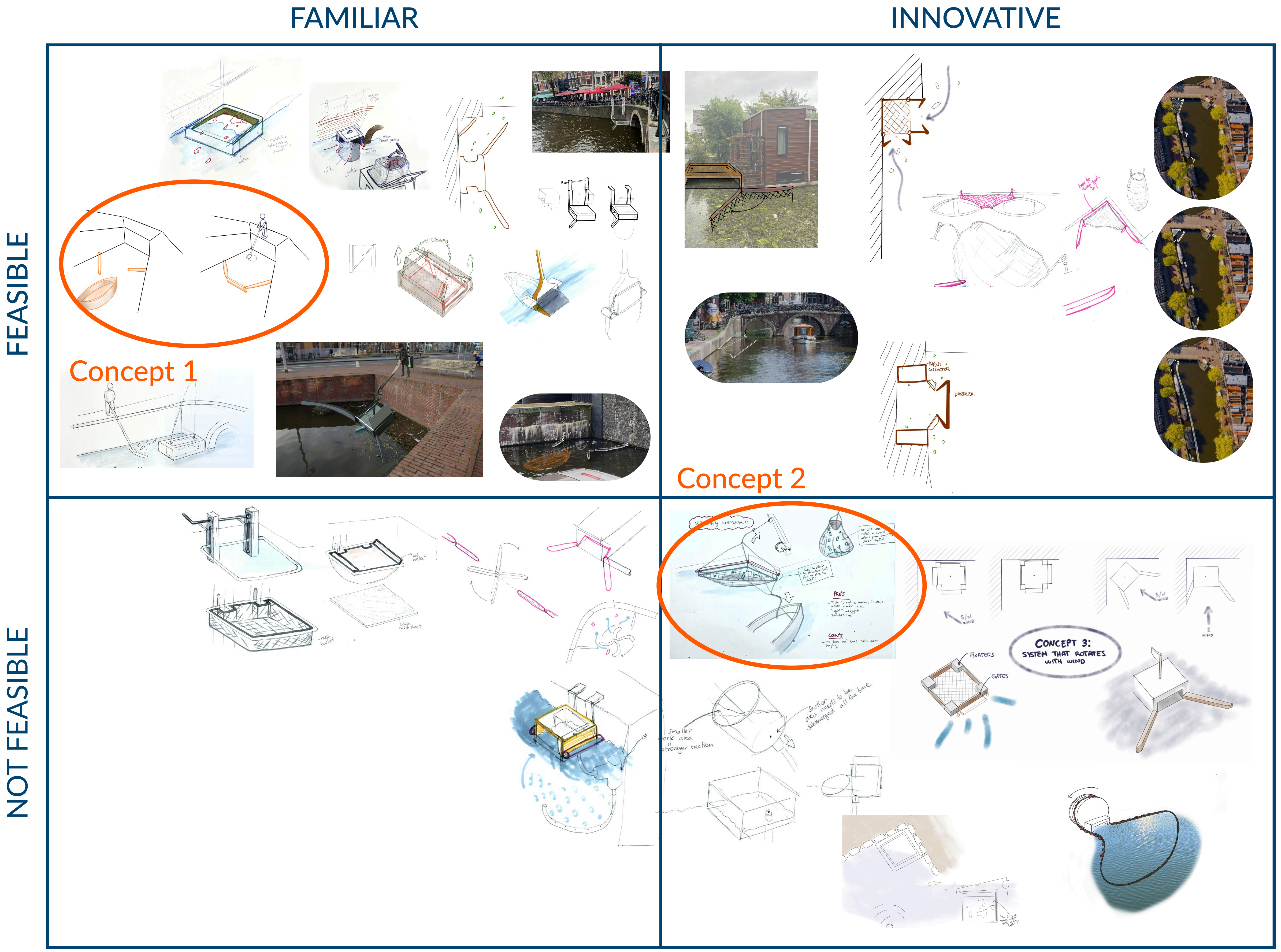
The ideal interaction includes the following steps:

1. **All cleaning supplies are present**: Grabbers, gloves, or trash bags are made available within or near the system.
2. **Accessing the system**: Operators can easily locate and access the system, whether from a boat or the canal shore.
3. **Opening the system**: A secure but simple mechanism allows users to open the collection compartment.
4. **Emptying the system**: Waste is easily removed from the container.
5. **Reinstalling the system**: After emptying, the container is returned to its position with minimal effort, ready for continued use.
6. **Disposing of waste**: Collected debris are disposed in nearby public bins or designated waste stations.

Idea Evaluation

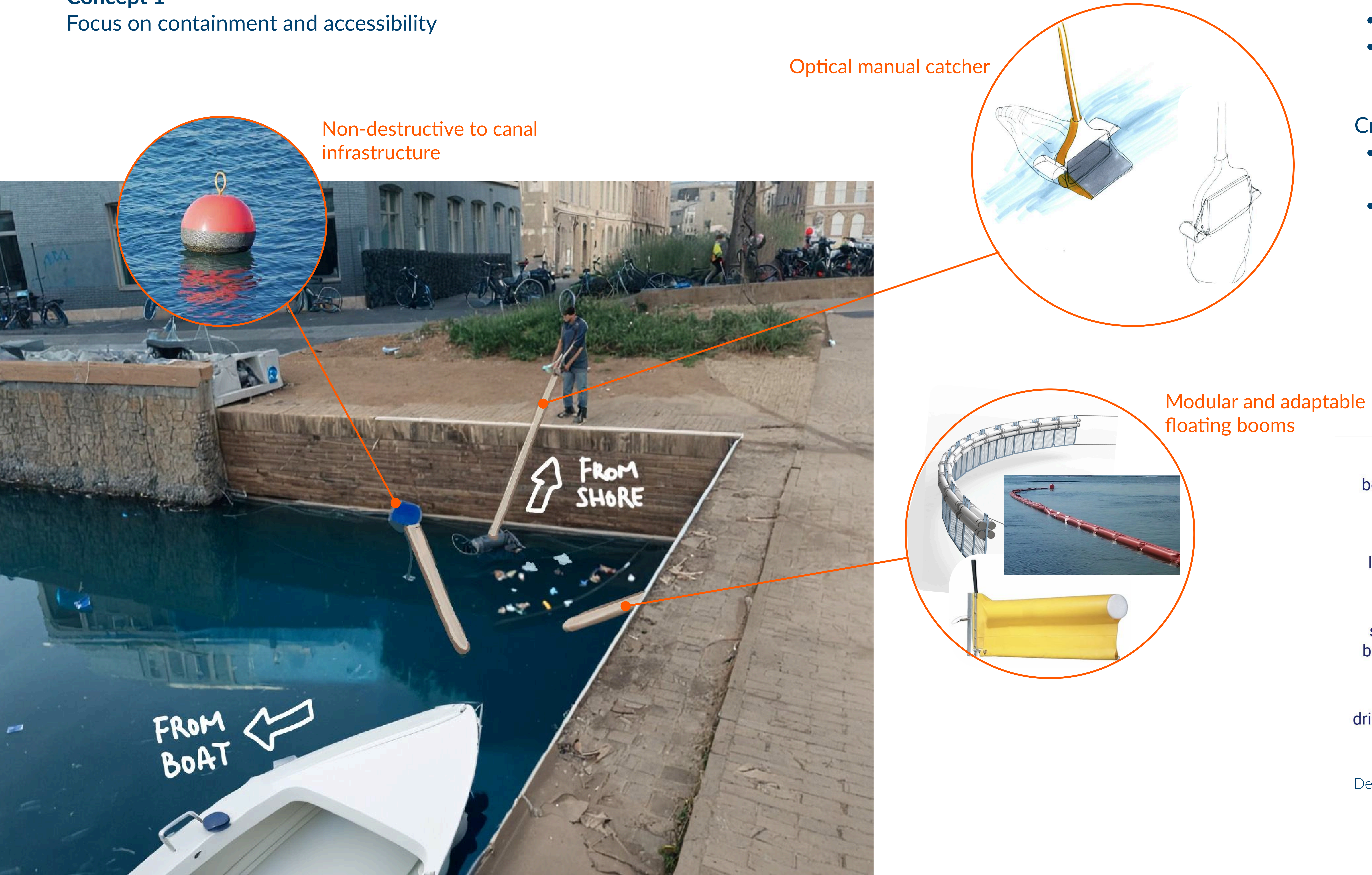
In addition to defining an ideal interaction journey, a C-box (Concept Box) method was used to evaluate the wide range of ideas generated during the ideation phase, assessing each idea based on two main parameters: feasibility and familiarity. Tassoul, M. (2006).

From this evaluation, **two ideas were selected** to be further developed into concpets.



3.2 CONCEPTS AND CONCEPT CHOICE

Concept 1
Focus on containment and accessibility



Design variables

- Personalized funnel configuration
- Mounting solutions
- Connecting solutions within booms
- Depth of booms

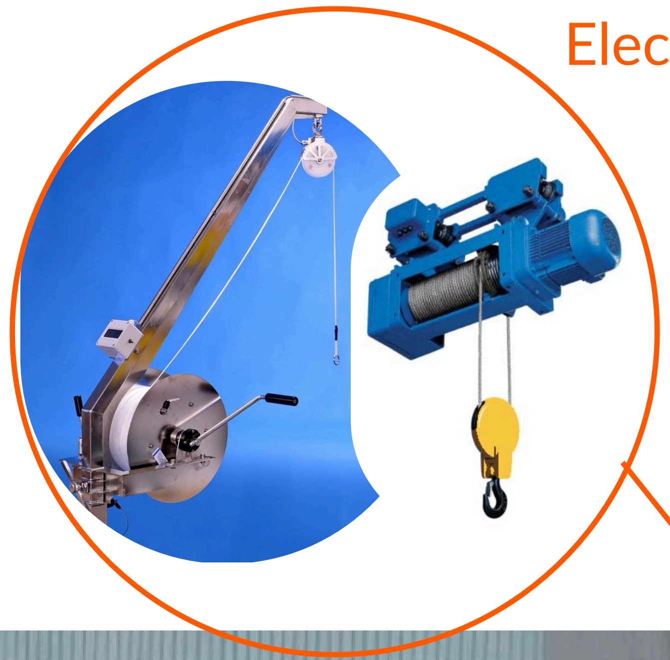
Critical points

- Can the containment boom keep the trash from escaping?
- Which collection process is more ergonomic to use?

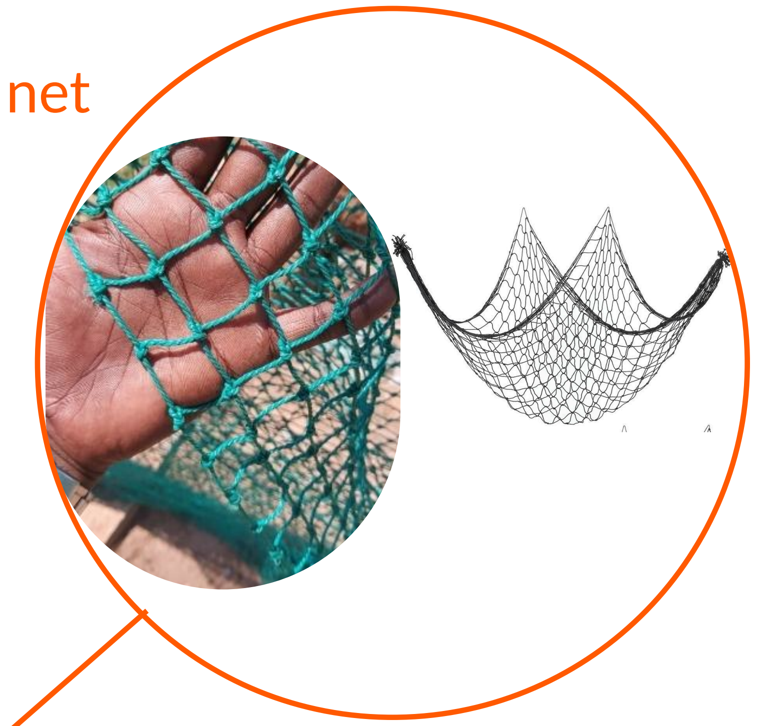
Design parameters followed from the morphological chart

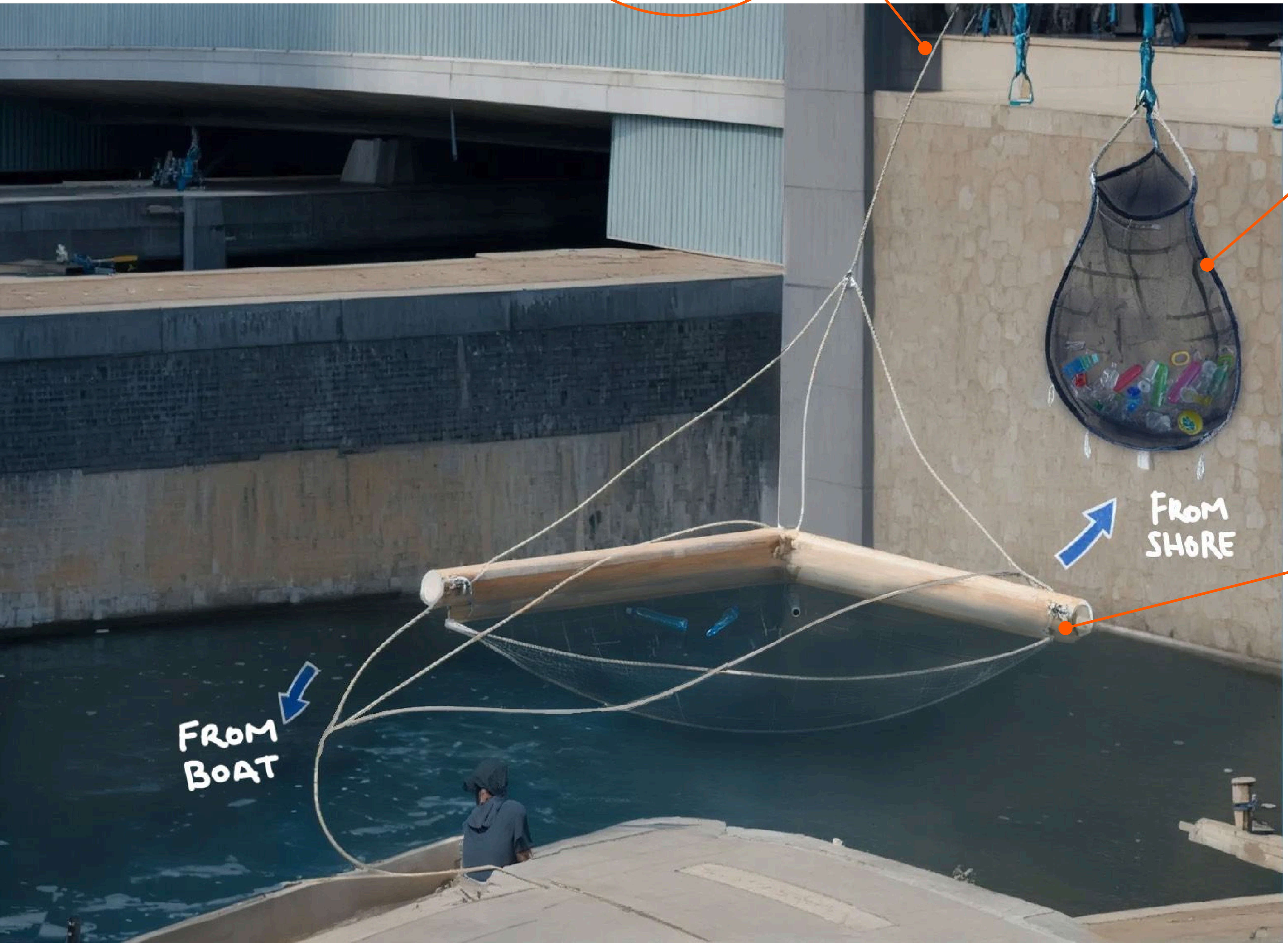
Concept 2
Focus on ergonomic retrieval

Electric or manual pulley

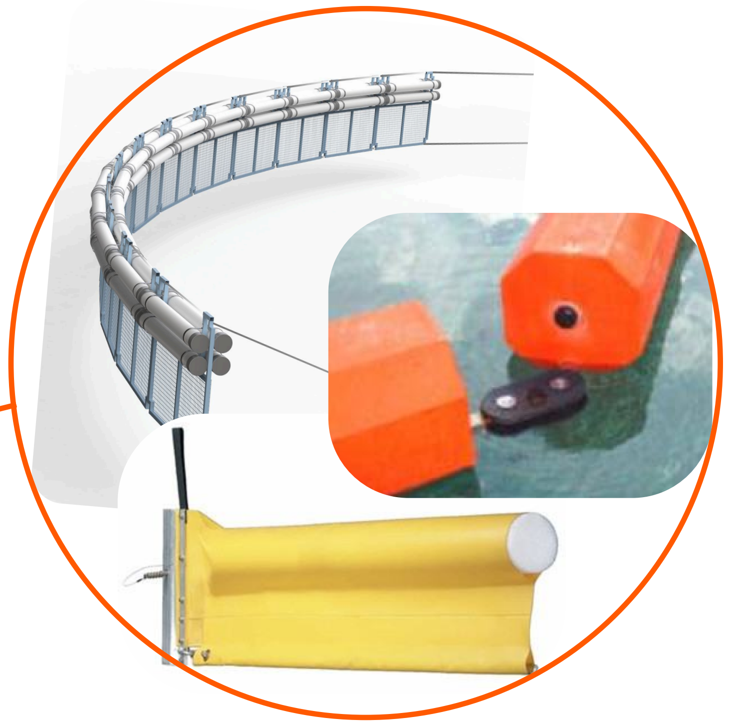


Lightweight net





Modular and adaptable floating booms



Design variables
- Tension of net
- Locking net in place
- Mounting solutions
- Connecting solutions within booms
- Depth of booms

Critical points
- How to secure net in position and also allow retrieval?
- How to make it possible to be retrieved both from the shore and from a boat?

behaviour	standy	moves	moveable	
location	when canals go from wide to narrow	corners	on the foot of a bridge	house boat
societal behaviour	next to train station	next to social spots	party areas	tourist attractions
driving force	HUMAN	MECHANICALLY CONTROLLED BODY	WATER CURRENT	WIND

Design parameters followed from the morphological chart

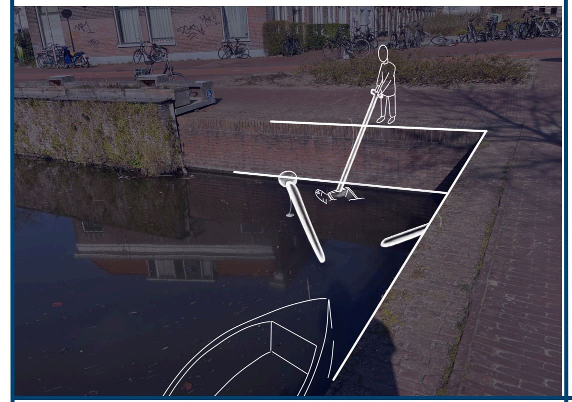
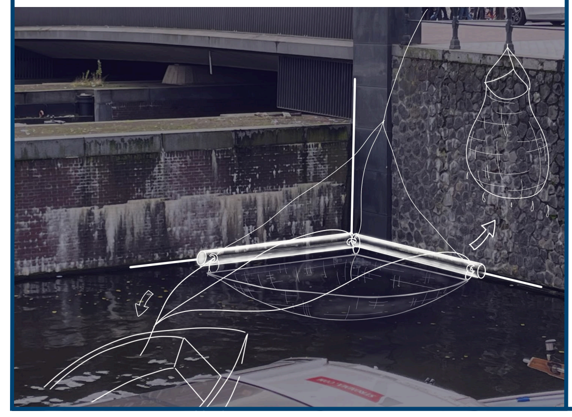
Concept evaluation

To support an informed and balanced decision-making process, two evaluation methods were applied: a **pros and cons** analysis and a **concept evaluation matrix**.

The pros and cons list provided a qualitative overview of each concept's advantages and limitations, while the matrix enabled a structured comparison based on key criteria such as feasibility, modularity, user interaction, and scalability.

The concept evaluation matrix, a commonly used tool in the Delft Design Guide, visually represents how well each concept meets the defined criteria using a color-coded system: green (full compliance), yellow (partial fulfillment), and red (requirement not met).

Both of these methods were complemented by discussions with fellow designers from Noria and TU Delft faculty, ensuring that the assessment incorporated both practical and academic perspectives.

	Pro's	**Con's**
Concept 1 	• Tailor-made • Easy installation and removal • Easy collection from street and water	• Collection is not ergonomic • Water is an issue
Concept 2 	• Tailor-made • Easy installation and removal • Net can be fully removed for easy manouver • Water level is no issue	• Heavy load to pull out • It does not prevent trash from escaping

List of pro's and con's for each concept

	Concept 1	Concept 2
Effectiveness in Waste Retention	yellow	red
Ease of Installation and Maintenance	green	yellow
Ergonomics and User Safety	red	green
Modularity and Scalability	green	green
Cost and Feasibility	green	yellow
Public Visibility and Educational Value	yellow	yellow
Alignment with Stakeholder Values	green	green

Concept Evaluation Matrix

Chosen Concept Direction: Waste trap with submerged container

Rather than selecting one of the two initial concepts, the decision was to develop a **hybrid direction** that combines **key elements from both**, while **building upon** previous insights gained from **Noria's existing passive system**, The Canal Cleaner.

This approach aligns with the principle of **starting from a simple**, proven principle and **incrementally improving** it through iterative prototyping and field testing.

The resulting concept merges several components: **manual retrieval** for low-tech operation, a **submerged mesh container** for capturing, draining waste and ergonomic access, and floating booms for **passive guidance** with a trap design.

One trade-off of this direction is that the system can only be emptied from the shore, which may limit placement flexibility. However, this limitation is outweighed by the concept's simplicity, feasibility, and potential for meaningful public engagement and further adaptation.

3.3 FIRST ITERATION

The first design iteration process focused on **exploring potential trap shapes** and **constructing** an **initial prototype** to **validate** previous findings from research, and whether the **proposed shape** and functionality effectively capture floating waste.

To structure the process, **the system was divided into subsystems**, enabling a focused investigation into specific design characteristics and development aspects.

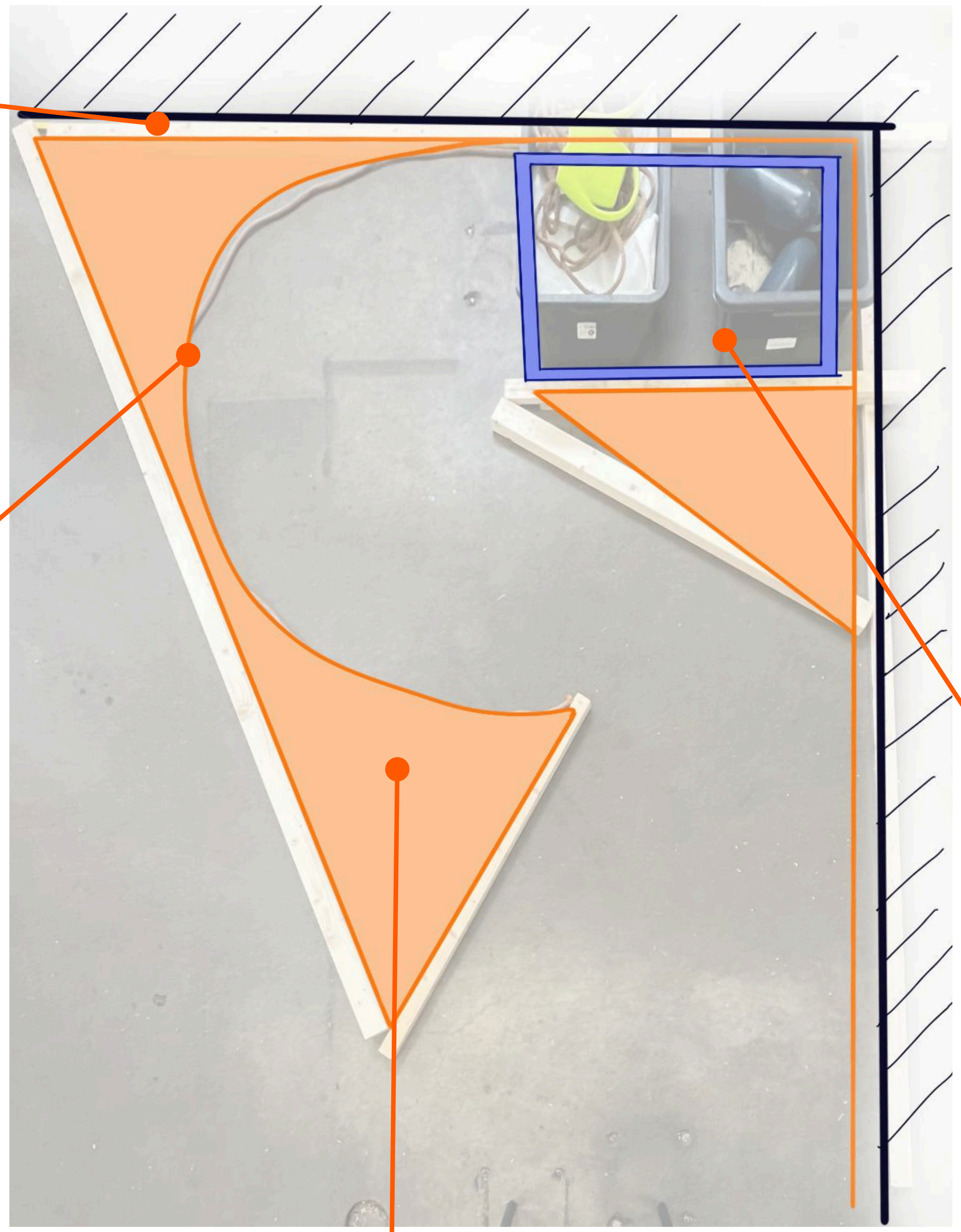
The following **research questions** were formulated for **each subsystem** to guide the prototyping and validation phase.

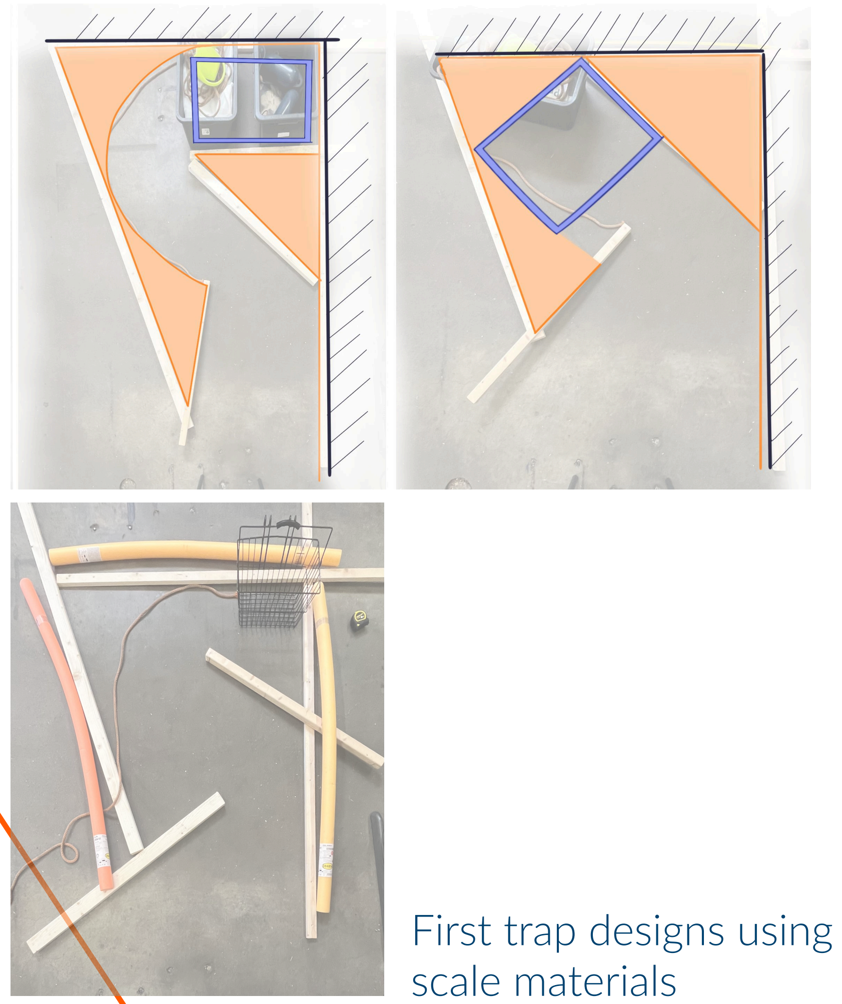
ATTACHMENT METHOD

- How is the system is kept in place?

FUNNELING SYSTEM

- How does the system enable waste entry while preventing its escape?





First trap designs using 1:1 scale materials

FLOATING SYSTEM

- How does the system keep itself afloat?
- Does it need to support other loads
- What about under different weather conditions?

COLLECTING SYSTEM

- Does waste travel and collect itself on the container area?
- How deep does the container need to be submerged into the water?
- How long does the container's handle need to be to be reachable?

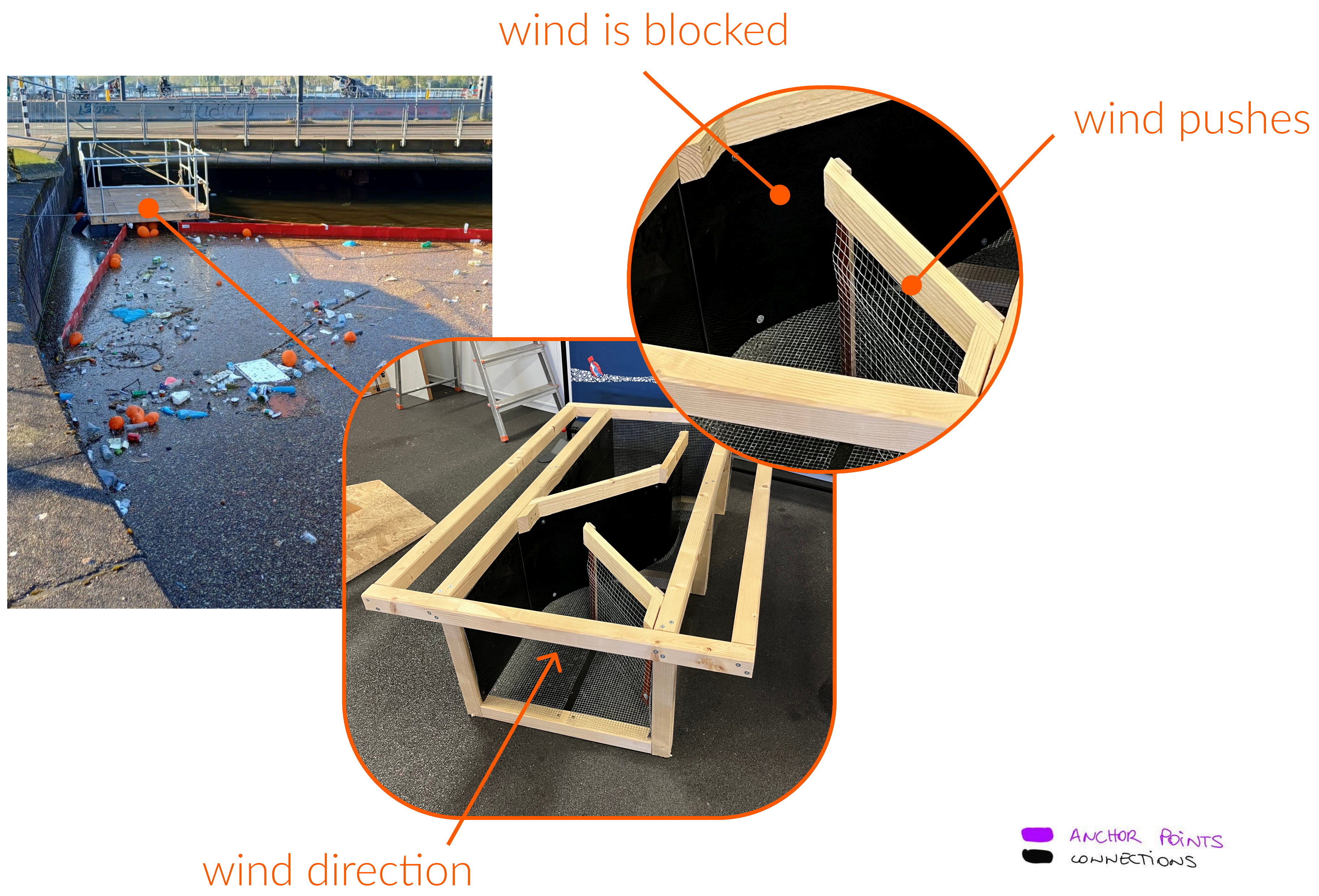
FUNNELING SYSTEM

How does the system enable waste entry while preventing its escape?

A key design challenge was determining how the system could allow floating debris to enter the trap while preventing it from escaping. The chosen approach was a passive funneling mechanism inspired by Noria's Canal Cleaner, which uses wind and water currents to guide waste into the trap. Angled collection arms help retain the debris once it enters.

Design decisions were influenced by previous learnings from the Canal Cleaner project and include:

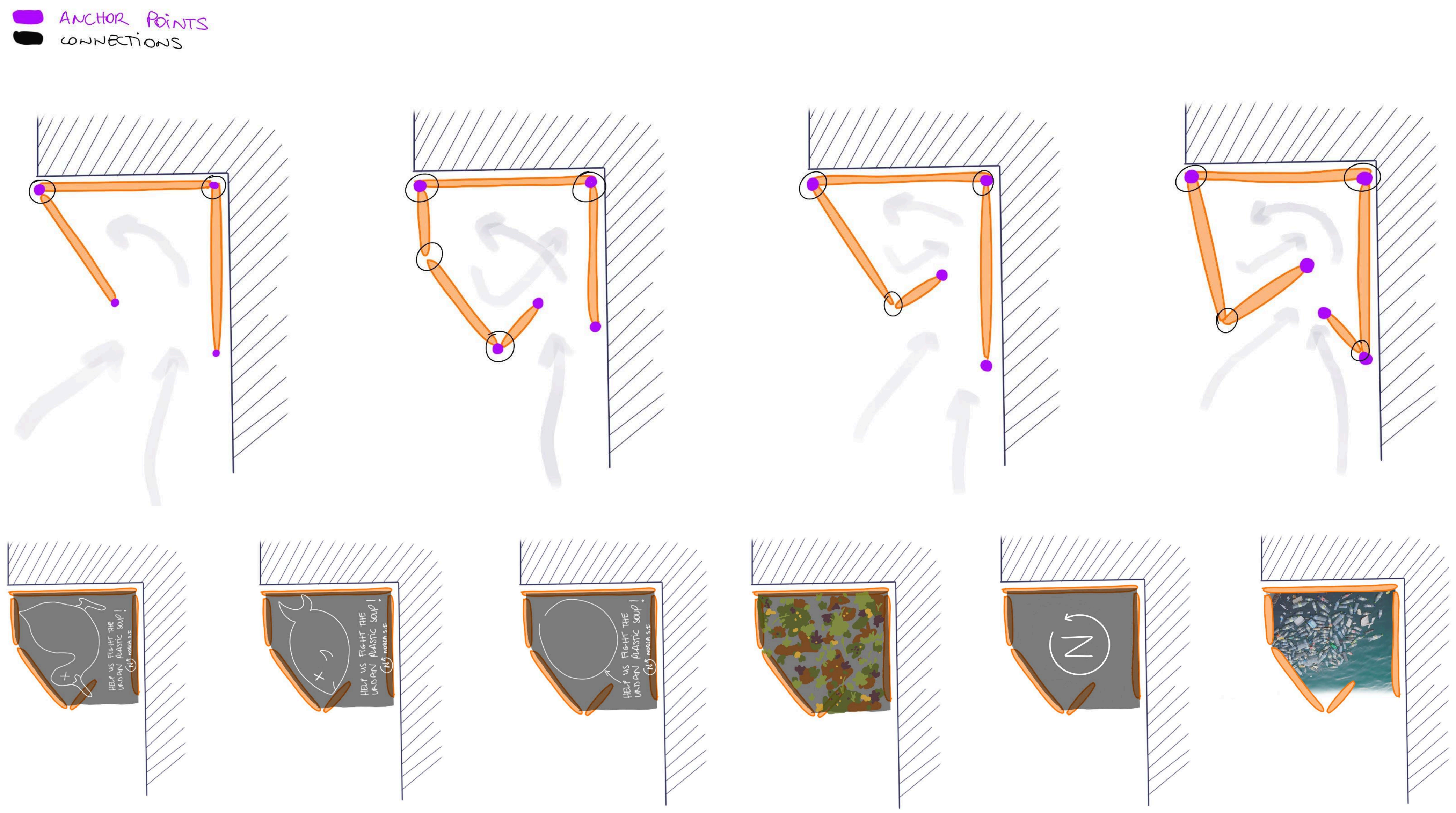
- The **front arm** features a depth made of galvanized **steel mesh**, **allowing wind to push** debris through.
- **Subsequent arms and the main structure** are constructed with a windproof surface to **direct airflow in one direction** and enhance containment.
- All **corners are rounded** to prevent debris buildup and to guide waste efficiently toward the collection point.



CanalCleaner trapping system from the inside

Aspects to be validated through testing:

- How does the system perform under different environmental conditions? Orientation and prevailing wind directions vary significantly between locations and need to be assessed.
- What are the minimum and maximum sizes of debris the system can effectively target?



Exploring shapes, connection possibilities and aesthetics

ATTACHMENT SYSTEM

How is the system kept in place?

An essential aspect of the design is **how the system remains securely in place** within the canal environment. Based on preliminary research and consultations with Noria, several attachment strategies were identified, with choices depending largely on the specific characteristics and constraints of each location.

The **main considerations** for choosing an attachment method are:

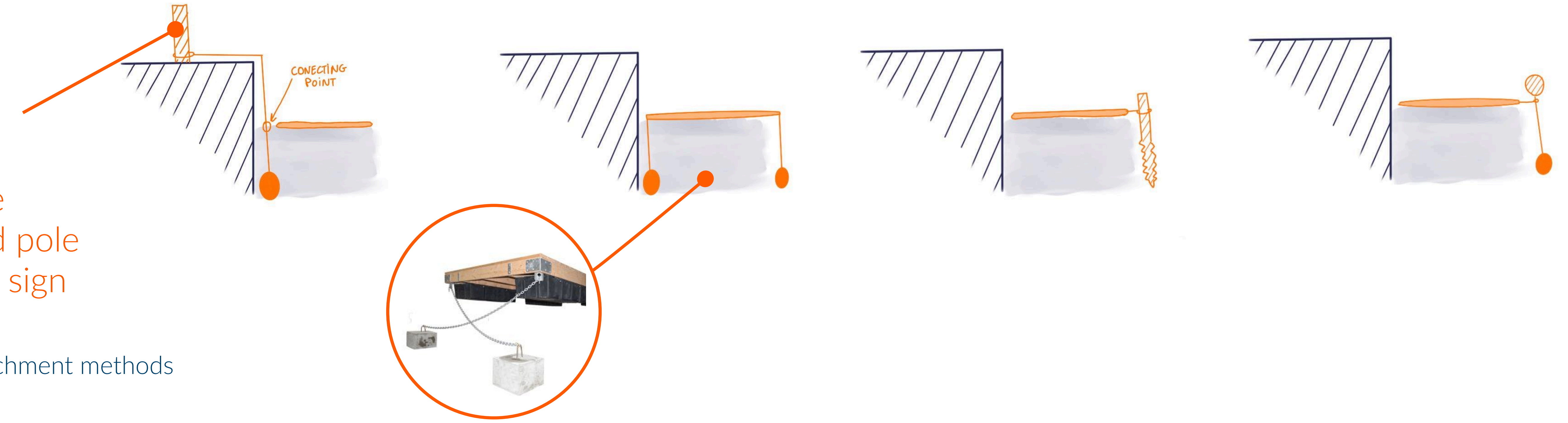
- Flexibility to adapt canal edge types and available infrastructure.
- Ensuring ease of installation and removal for maintenance or relocation.
- Use of materials and connectors that resist weathering and water exposure.

For the **first testing round** of this project, the prototype is installed using the **first attachment method** below, to facilitate quick deployment and easy adjustments.

Aspects to be validated through testing:

- How many attachment points are needed for stability?
- How can the system be protected from detachment due to water movement, wind force or vandalism?
- What procedures ensure a safe and ergonomic installation and removal process for installation or maintenance personnel?

1. Tensed cable from the top
2. Weighted boom
3. Attachment to wooden poll in water
4. Attachment to buoy



- Tree
- Fence
- Bridge
- Added pole
- Traffic sign

Possible attachment methods

FLOATING SYSTEM

How does the system keep itself afloat? Does it need to support other loads? What about under different weather conditions?

The floating system supports the structure above water, maintaining the correct position and height for trash collection. It also ensures stability in case of turbulent water and protect structure from scratches against canal walls or collisions with boats.

Design considerations include:

- Selecting appropriate materials for additional buoyancy: options include foam inserts, plastic pontoons, and inflatable elements.
- Positioning the flotation elements to maintain balance and prevent tilting.

For the first prototype, the main structure is constructed from wood, which is already a naturally buoyant material. Because of this, the floating system is not expected to bear significant additional weight but instead serves balance, positioning, and impact protection.

Aspects to be validated through testing:

- How should the floating system be distributed through the structure?
- How much additional buoyancy is required depending on structural changes or added modules?

COLLECTING SYSTEM

Does waste travel and collect itself on the container area? How deep does the container need to be submerged into the water? How long does the container's handle need to be to be reachable?

The collecting system is the component where the trapped waste is kept in place and awaits to be emptied. Its design must ensure efficient and ergonomic retrieval while minimizing exposure to waste and water to the operator.

Design considerations:

- The reach and position of the handle must be adaptable depending on the local context.
- The container is designed to be robust, hygienic, and resistant to corrosion. It must also drain excess water.
- The container must be shielded from wind influence.

Aspects to be validated through testing:

- Is manual retrieval feasible and practical in public spaces?

Alternatives to manual retrieval

To improve the scalability of the system in various urban contexts, several alternatives to manual retrieval were explored. These include simple mechanical additions such as a telescopic handle for the retrieval container or a stick equipped with a hook for lifting the container. Additionally, a potential manual pulley was considered to facilitate access and reduce physical strain during retrieval.

Beyond these solutions, possibilities for integrating mechanical retrieval methods include compatibility with municipal waste collection vehicles, like rear-loading trucks or top-loading cranes. Such adaptations could streamline emptying procedures and align the design with existing urban waste infrastructure.

Prototyping the collection system

Alternatives to manual retrieval

PROTOTYPE 1

Following the design decisions for each subsystem, an initial prototype was constructed and subsequently deployed in the water. The visual representation below provides an overview.

COLLECTING SYSTEM

Submerged basket attached to a rope, that collects captured floating debris on its surface.

FUNNELING SYSTEM

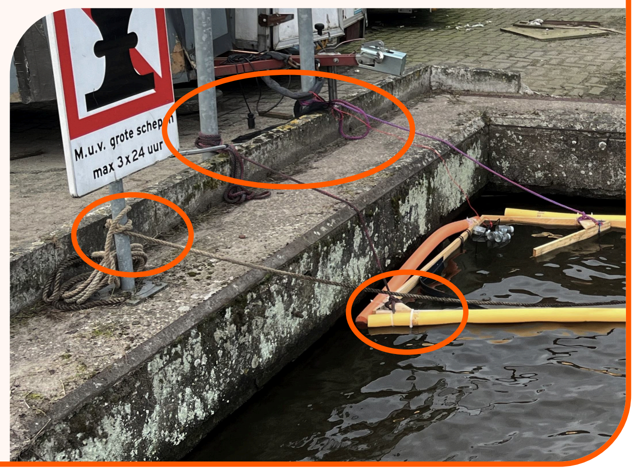
Rounded corners, first trapping arm with mesh letting wind inside, the rest of the structure is shielded from the wind going 30 cm deep into the water.

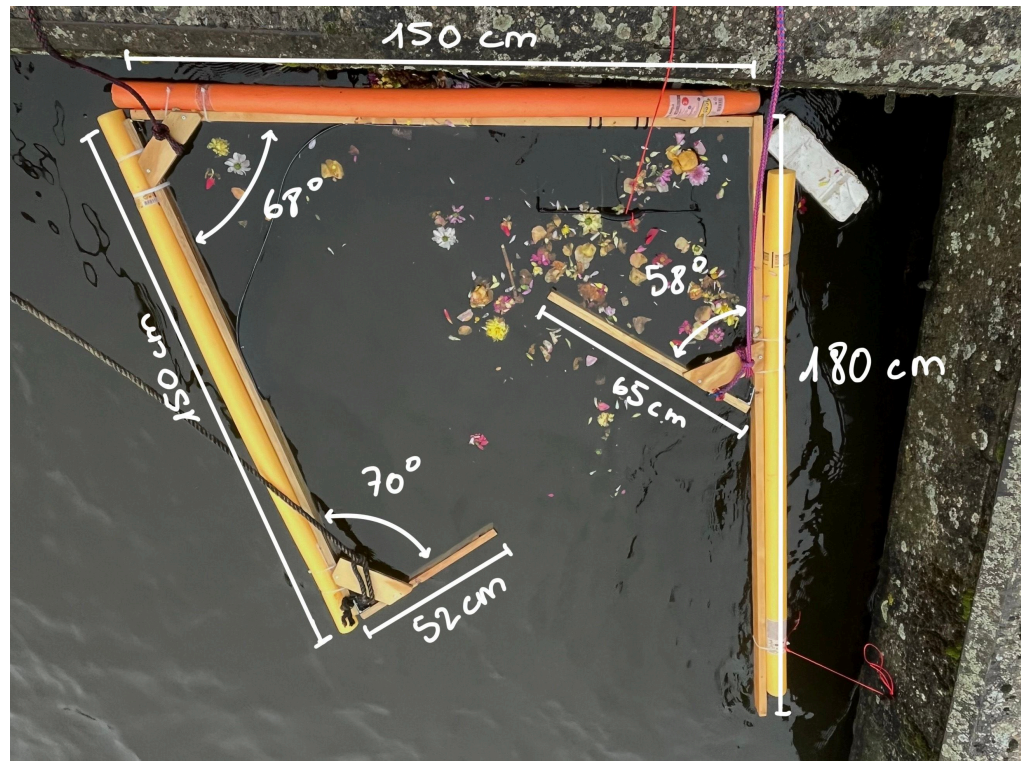
FLOATING SYSTEM

Polyethylene swimming pool noodles for buoyancy and bumping protection

ATTACHMENT METHOD

Connected to three public attachment points (signage poles) with ropes. No permanent lock.





Prototype 1 dimensions

VALIDATION 1

Initial Water Deployment

Goal

The objective of this initial testing round was to **evaluate** the **effectiveness** of the trap design in **capturing** and **retaining** floating debris and to **determine** the **maximum height** difference **between** the **water** level and the **shore**, to ensure that the basket remains accessible for retrieval. These insights guided key design adjustments for the next iteration.

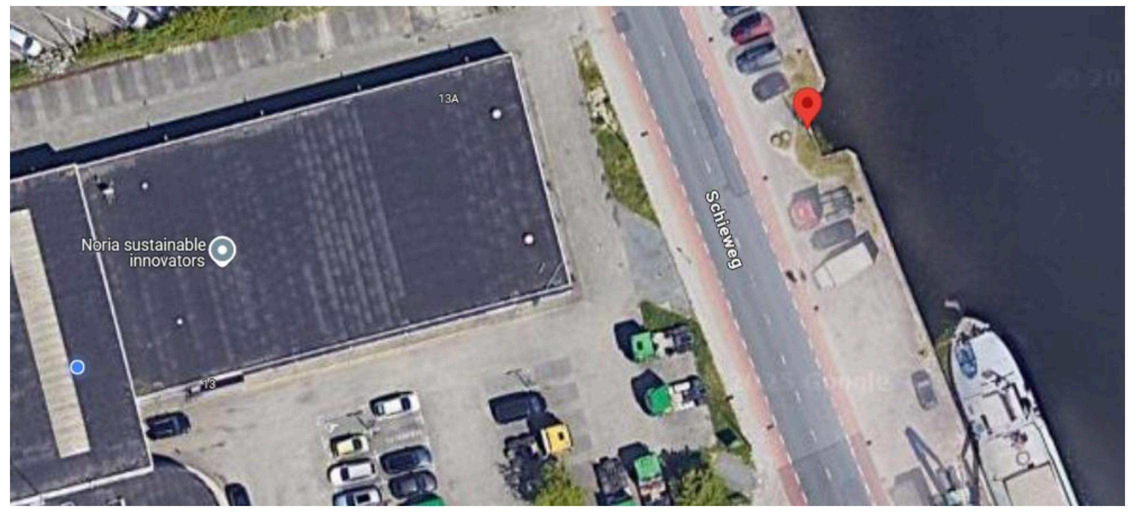
Method

A rapid prototype was deployed in real-life canal conditions for four consecutive days. Both **passive observations** (natural waste accumulation) and **active tests** (manually introducing floating debris) were conducted to assess how well the design guided debris into the trap and whether retention was maintained over time. Particular attention was given to structural stability, resistance to vandalism, and overall durability under varying wind and weather conditions.

Setup

The prototype was installed at Schieweg 13 in Delft, directly in front of Noria's office, from Friday, 21 February 2025 at 14:00 until the evening of Monday, 24 February 2025.

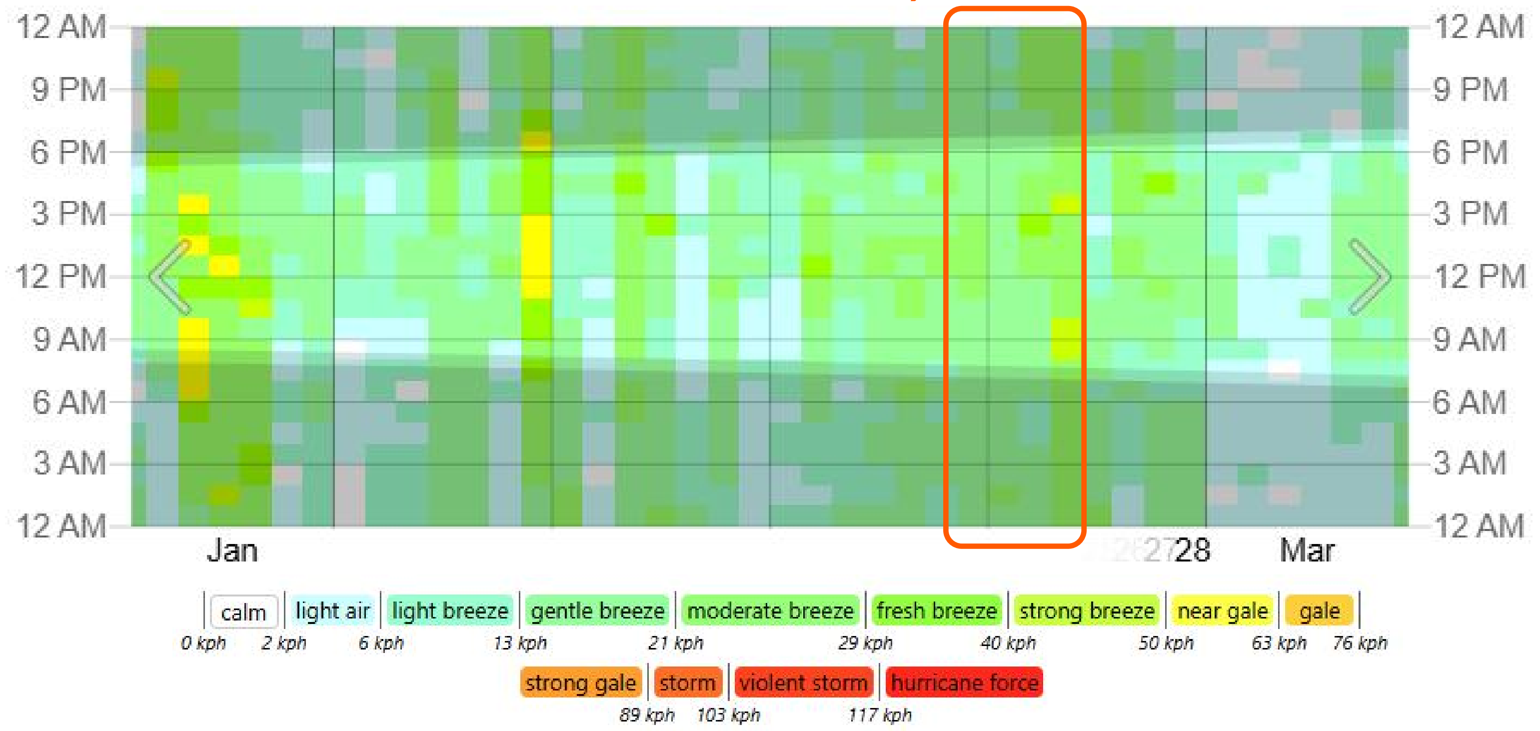
It was oriented North/Northeast, with prevailing winds coming consistently from the South throughout the testing period. As shown in the graph below (red), wind speeds ranged between 29 and 50 km/h. These environmental conditions provided a realistic context for evaluating the influence of wind direction and intensity on the system's ability to guide and retain floating debris.



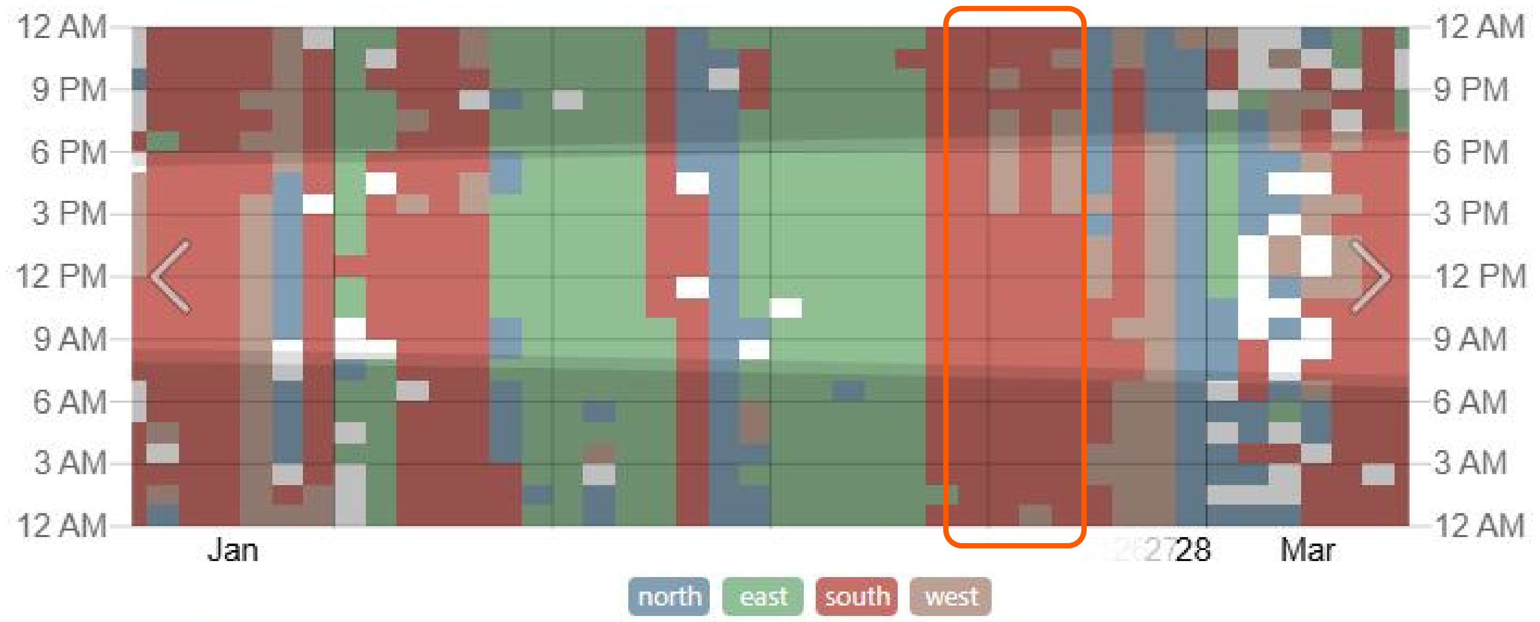
Schieweg 13, Delft

System facing the Northeast

21- 24 February 2025



The hourly reported wind speed, color coded into bands according to the Beaufort scale. The shaded overlays indicate night and civil twilight.

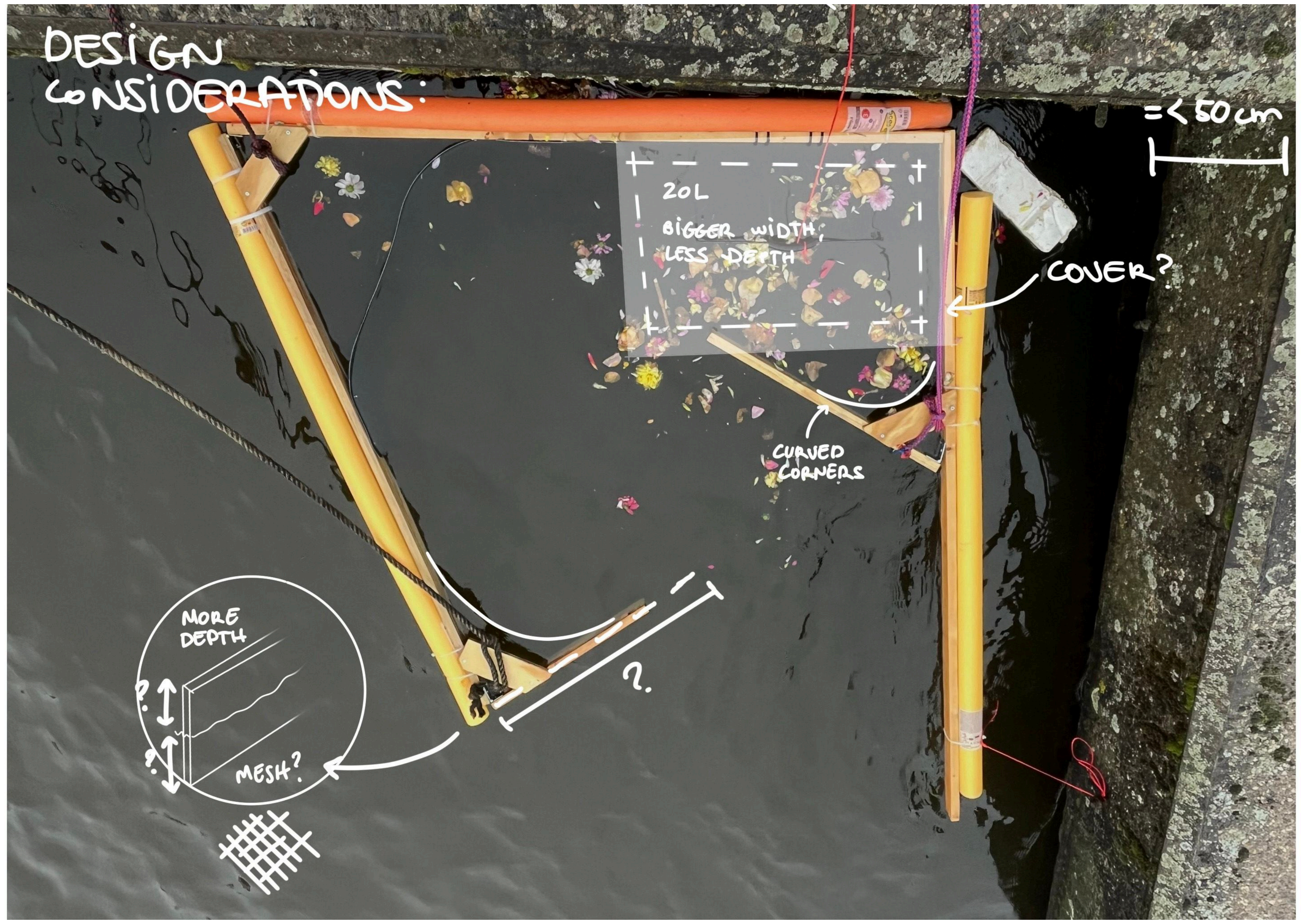


The hourly reported wind direction, color coded by compass point. The shaded overlays indicate night and civil twilight.

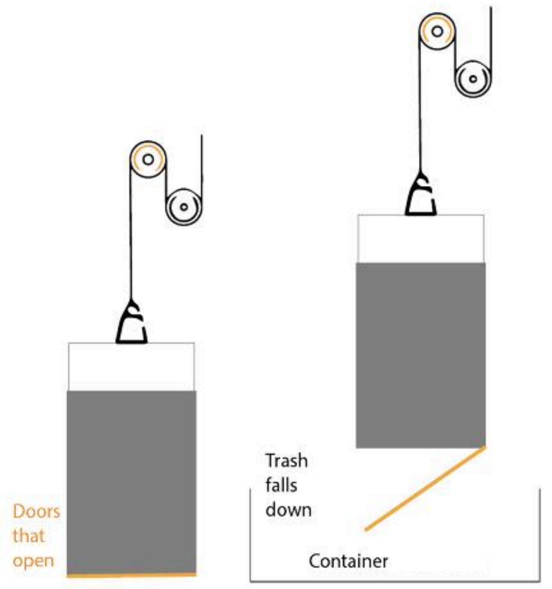
Weather conditions during the prototype deployment. Weatherspark (2025).

Findings

Sub-system	Key findings
Funneling System	• Wind direction aids waste collection. Good positioning of system. • Shape appears effective in guiding debris into the system. • Angled arms could be extended to improve retention. • Increasing the arm depth may reduce plastic drifting away. • Curved edges enhance waste retention and should be used consistently. • Retention not guaranteed over time; waste eventually escapes. • Explore wind-blocking strategies to optimize retention without obstructing flow or access.
Attachment System	• System remained stable and secure for three days without supervision. At the fourth day the system disappeared. • Installation methods need to be adapted for real canal environments.
Floating System	• Overall system floats well and maintains structure. • Depth and stability should be improved to minimize waste drifting out. • Needs further testing under other weather, current, and boat-induced turbulence conditions.
Collecting System	• Basket is lightweight and easy to retrieve. • Current basket dimensions should shift toward wider and shallower proportions, maintaining volume. • Basket area is most affected by disruptive wind, need to further test wind barriers. • Bottom-opening mechanism (inspired by underground bins) could help with emptying. • Suggest daily emptying frequency for optimal performance. • System may be too accessible, allowing anyone to remove the basket, placing a nearby public bin could mitigate misuse. • Handle placement should be as close to shore as possible for ergonomic emptying.



Design takeaways from testing the first prototype



Inspiration for future development of the collection system

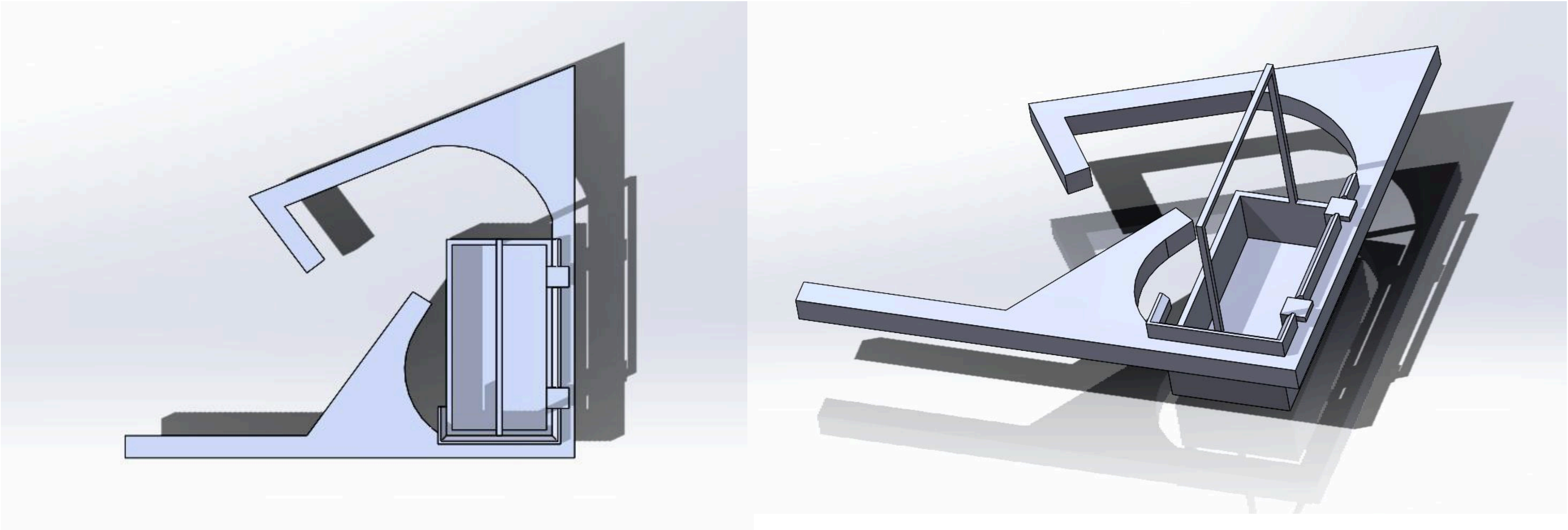
3.4 SECOND ITERATION

After compiling the findings from the first round of testing, the concept was refined to incorporate the key design learnings. These insights informed a revised direction, which was translated into updated sketches and an initial 3D model.

Selecting a structural strategy

As the concept evolved, new development challenges emerged, most notably, the question of structural integrity.

Choosing an appropriate structural configuration became a critical decision before continuing with the detailing phase. The system's form not only **influences** its **durability** and **usability** but also impacts **transport**, **deployment**, and **maintenance**. To guide this decision, a comparative analysis of four structural approaches: solid, foldable, modular, and inflatable, was conducted using a pros and cons analysis.



First 3D models in SolidWorks

Structure option	Pro's	Con's
One solid unit	• Quick and easy installation • It can be tailored-made • Few points of failure	• Takes up more space for transportation and storage, or might not fit • Not adaptable after manufactured • Heavy
Foldable, with hinges on connections	• Easy to transport to other locations • Hinges can be adjusted depending on location or needs of environment • It can be tailored-made	• Prone to rust or wear in wet environments • Expensive • Less structurally stable
Modular	• Easy to transport to other locations • Standardized • High flexibility for location	• Possible weak points in between joints • More possibilities of failure
Inflatable	• Quick and easy installation • Easy to transport to other locations • Ideal for temporary set-ups • No need for floaters • Cheap	• Not adaptable after manufactured • Need for an air pump for installation and maintenance • Fragile • Regular checks

Deciding the structural integrity of the system

Decision and constraints

The final decision was to use a **solid unit** configuration for the second round of testing.
The primary goal of this round was to evaluate the model in a real-life setting. Therefore, simplifying the structural integrity into a solid unit was the most practical option, allowing for rapid prototyping.

To place the prototype in an appropriate location under scope, there was a **tight deadline** with the **municipality of Delft**, which allowed only two weeks for building and another week for testing.

To ensure long-term flexibility, the solid frame will be designed with **detachable joints**, enabling it to be **disassembled into transportable segments**. This hybrid strategy balances the immediate need for robustness and speed with the future requirements for easy relocation, storage, and scalability.

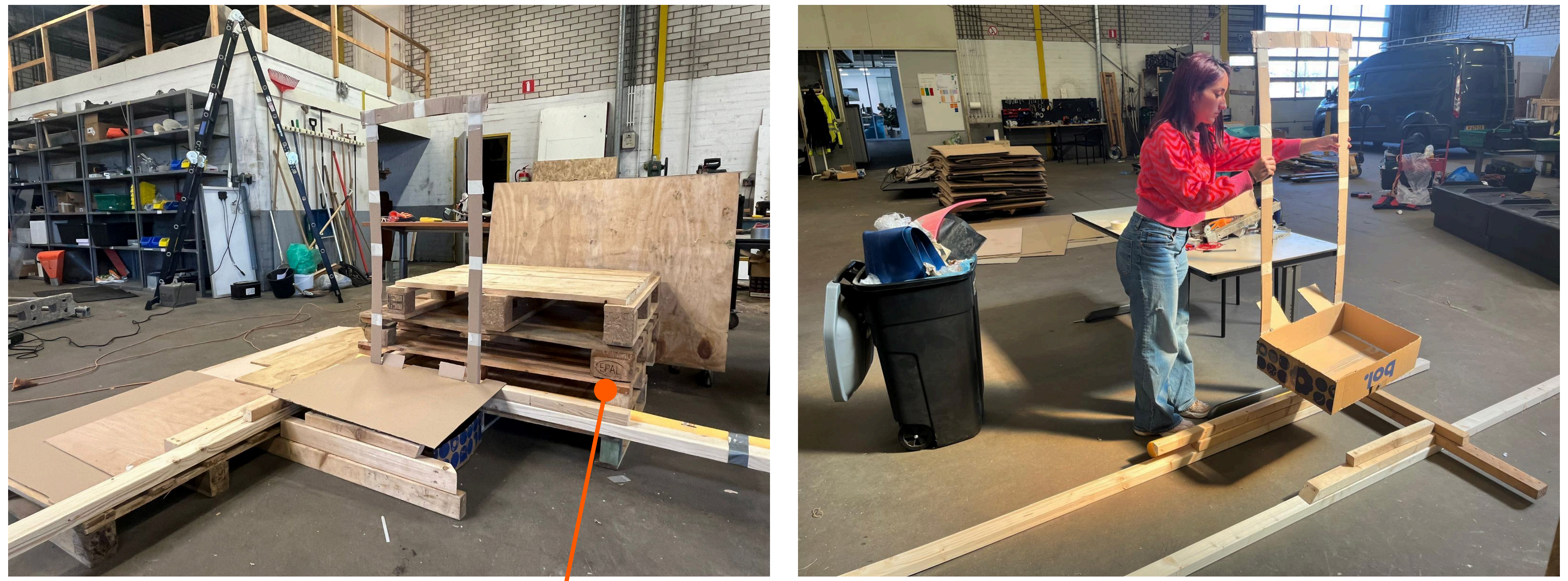
Conceptualizing and building

Once the decision of going for a solid structure was made, the focus shifted to the materialization and detailing of the second prototype. This phase involved translating ideas into different concepts and 3D models, which were then validated through full-scale cardboard mock-ups. The **iterative process** of **modeling and prototyping** allowed for **continuous testing, adjustment**, and **refinement** of the design.

Exploring design features

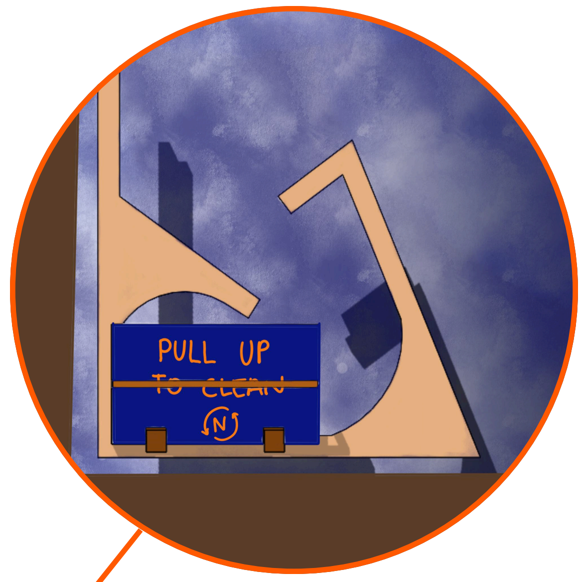
Early design considerations were adding a lid on top of the collection basket. The idea was to make the emptying process more hygienic and to shield trapped debris from wind. Several configurations were explored, as seen below.

In parallel, different handle designs for the basket were also developed and evaluated to improve the ergonomics of the retrieval process, ensuring the system could be emptied easily and comfortably by a single user.

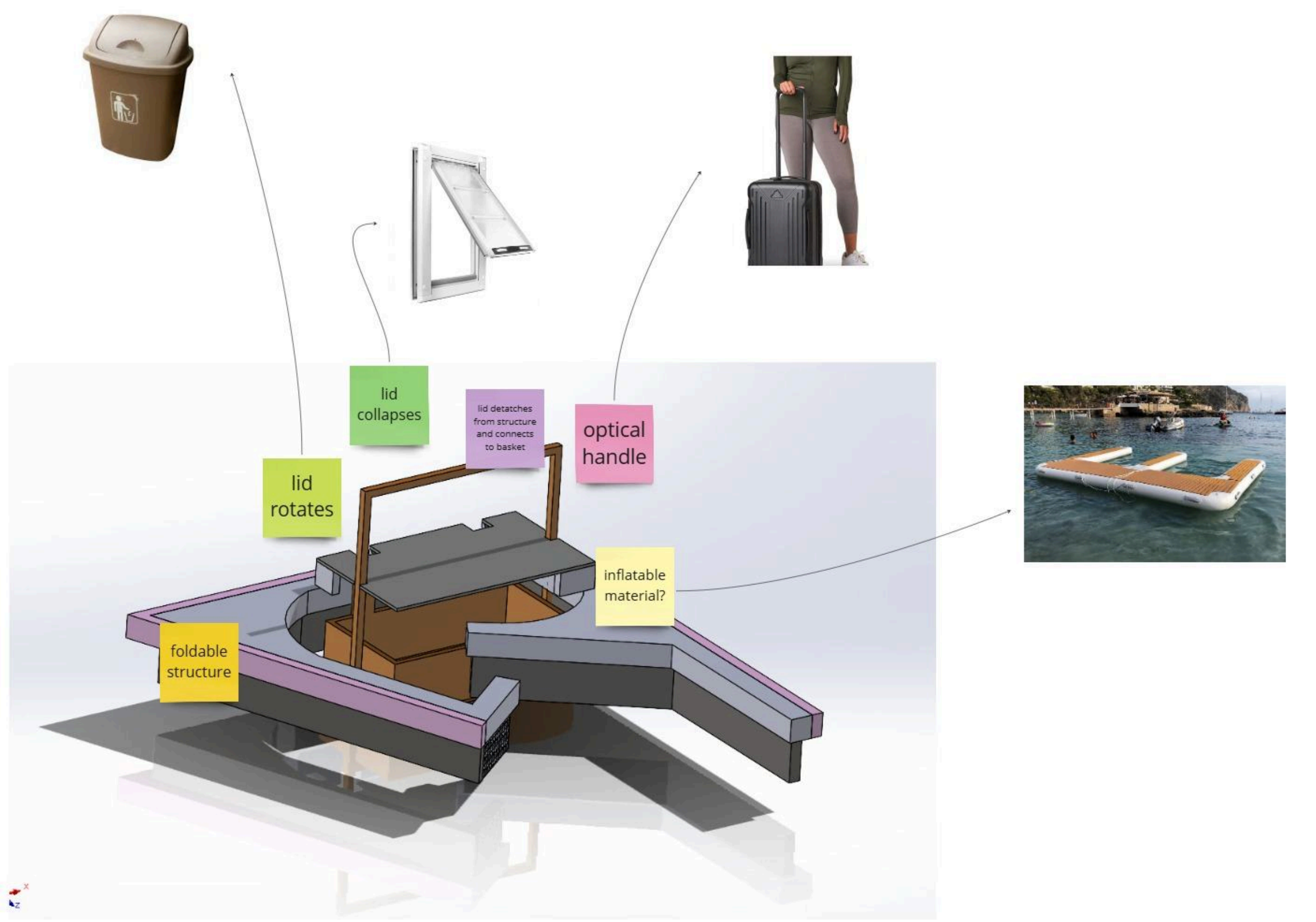


Testing dimensions and interaction with a cardboard prototype and pallets

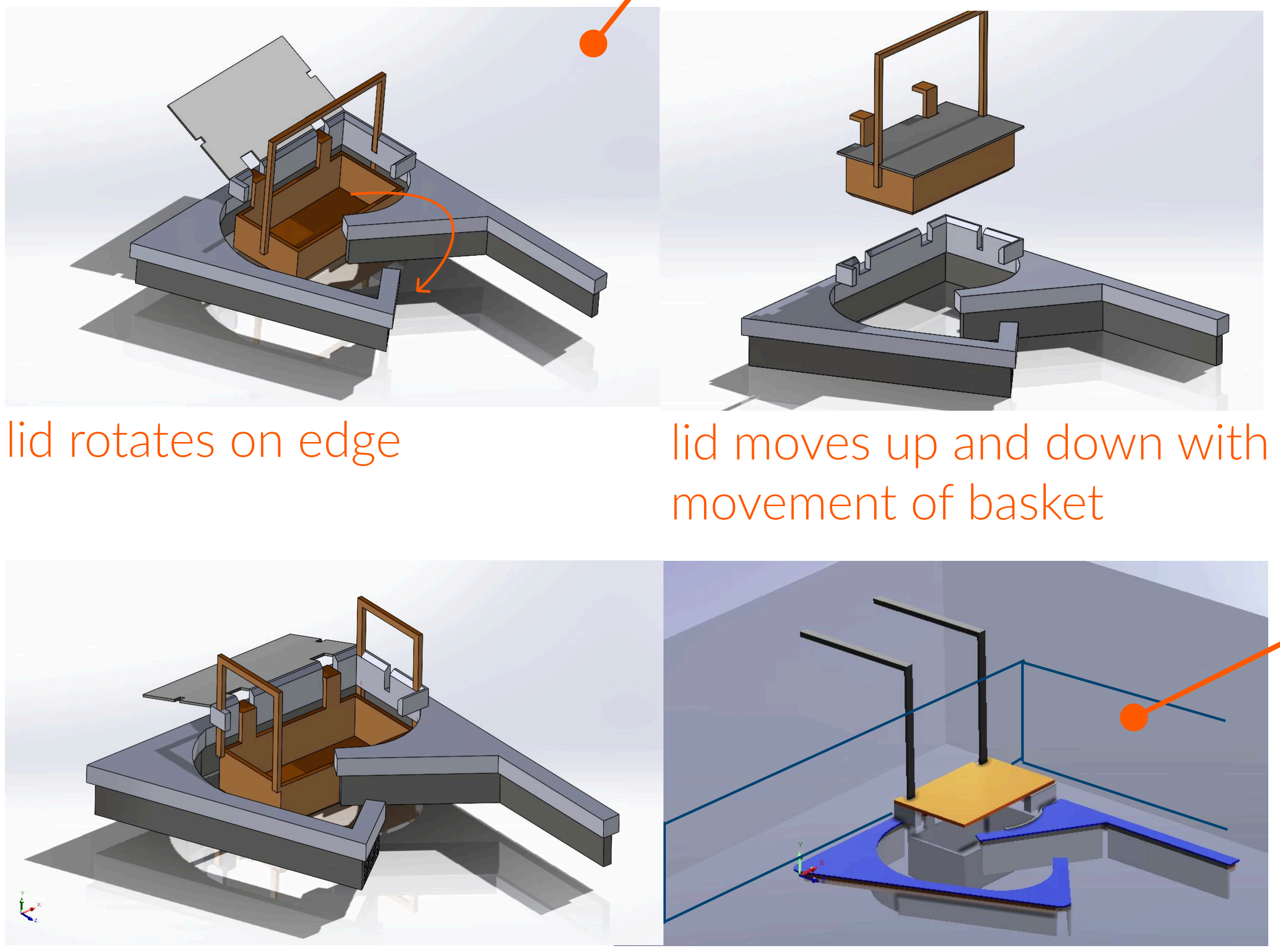
simulating different shore heights with pallets



vision



From brainstorming solutions to development

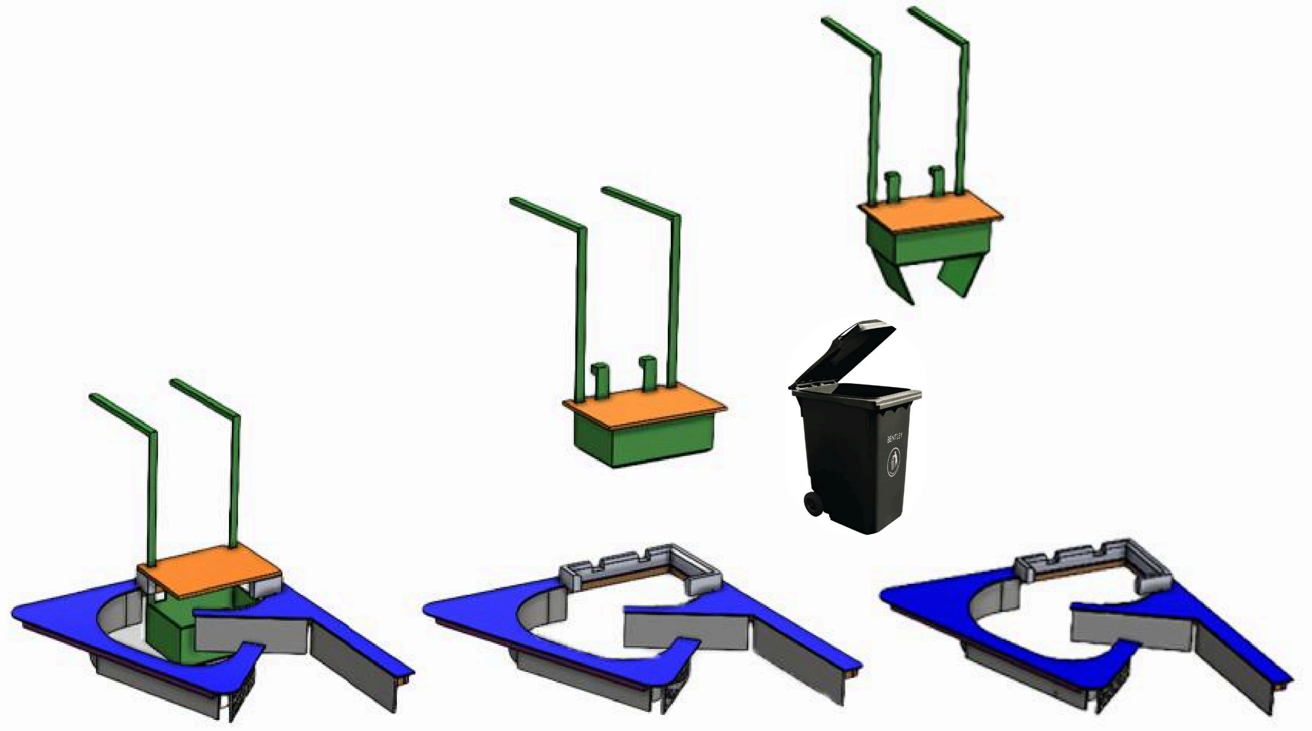


lid rotates on edge

lid moves up and down with movement of basket

two handles

handle to the shore

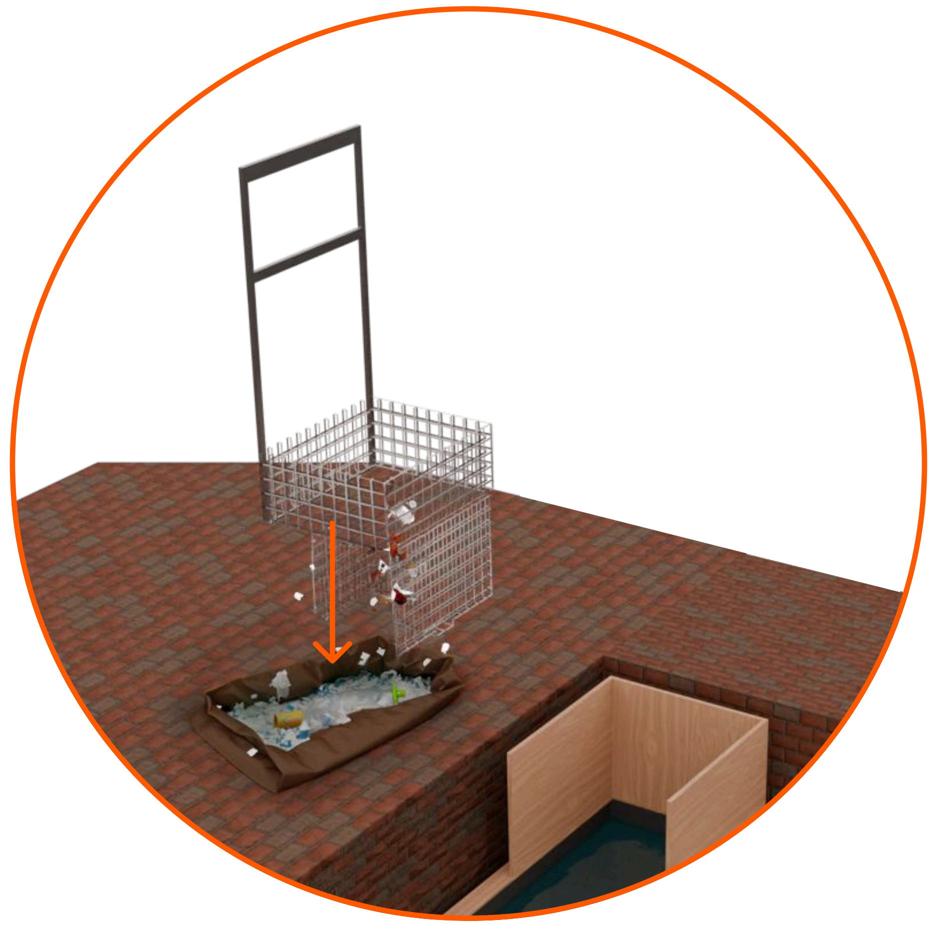


Design choices

After testing different design ideas through full-scale cardboard prototypes and reflecting on their performance, several key design decisions were made.

One adjustment was removing the lid initially proposed for the collection basket. While the lid was intended to improve hygiene and reduce wind disturbance, it added unnecessary weight. Instead, the main structure incorporates **higher guiding walls** that **direct the container** into position when it is taken in or out of the main structure.

In terms of handle placement, various configurations were explored to find the an ergonomic solution. The final design features a **handle shifted toward the edge** of the container, allowing it to be positioned closer to the canal edge. This **enhances reach** for the operator and improves the ease of retrieval.

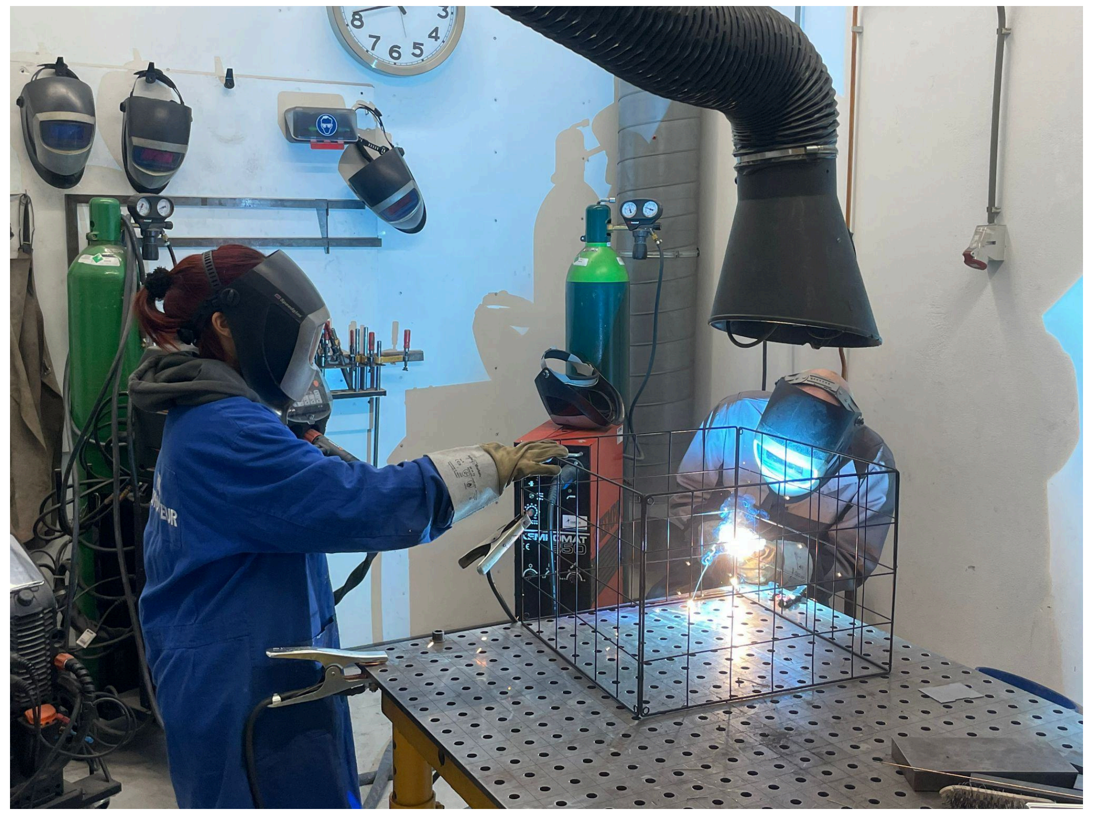


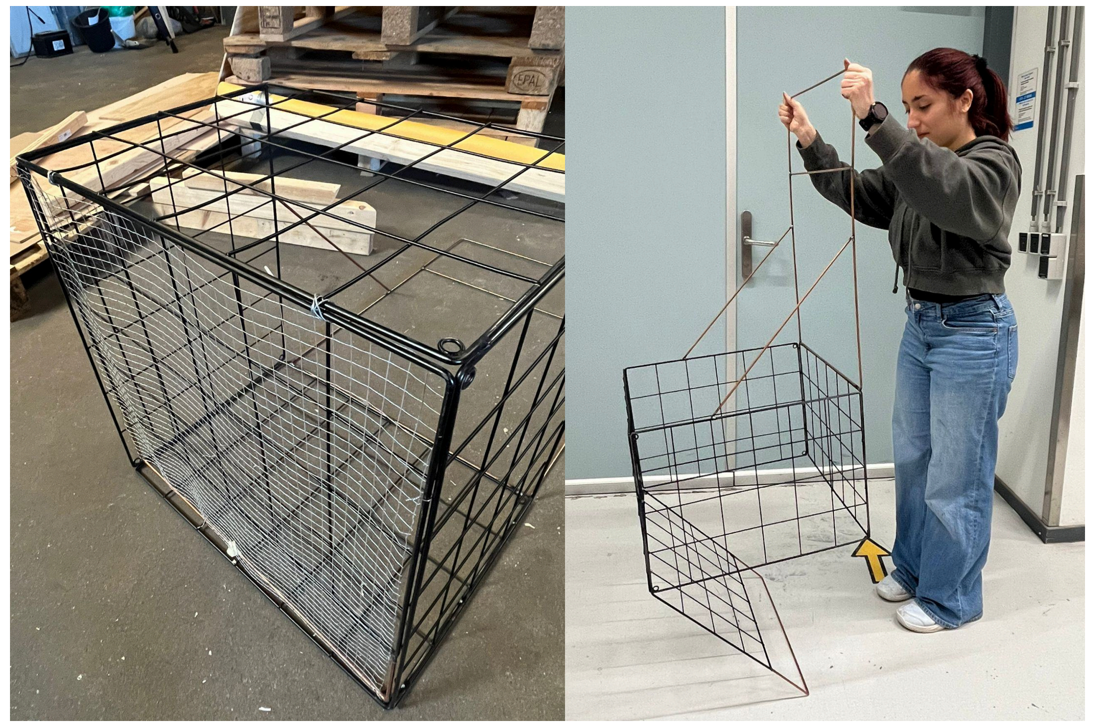
Final concept rendered

PROTOTYPE 2

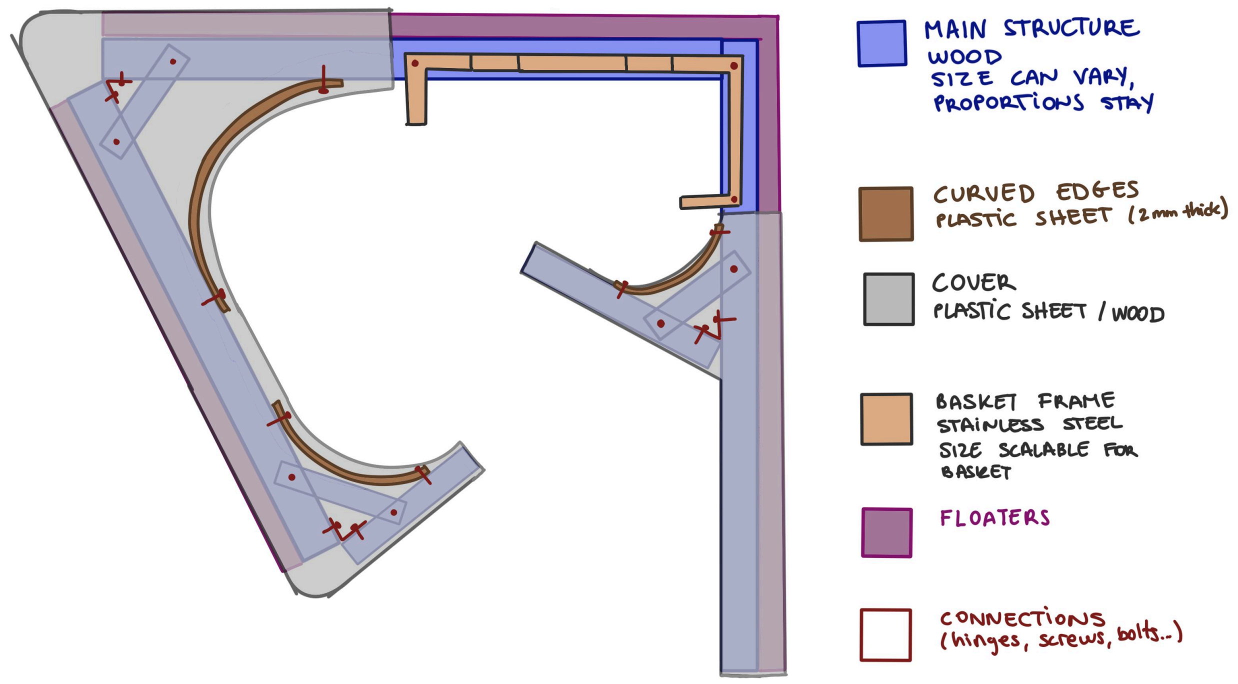
The final concept was translated into a second prototype, meant for real-life testing in the center of Delft.

To bring the model to life, materials were selected based as seen below.
The collection basket was constructed from wired stainless steel panels and welded together jointly with the handle.



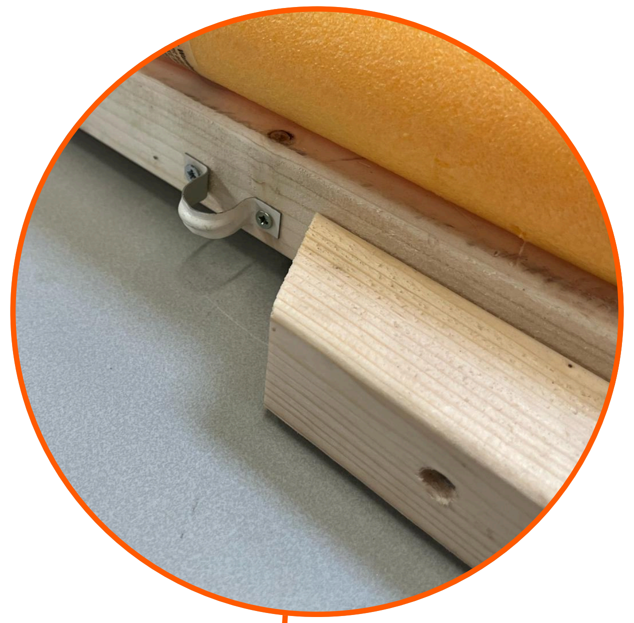


Soldering the container together



Choosing materials for each component

Prior to deployment at the location of the second testing round, preliminary testing was conducted at the Schie to assess buoyancy, assembly, and usability. This early test was essential for fine-tuning details such as the distance between the basket handle and the shore, ensuring that it remained comfortably within reach for operators during retrieval.



- Rope attachment rings
- Bumbers

legs to stand on land

Building the main structure

Testing components in the water before final deployment

Selecting new testing location

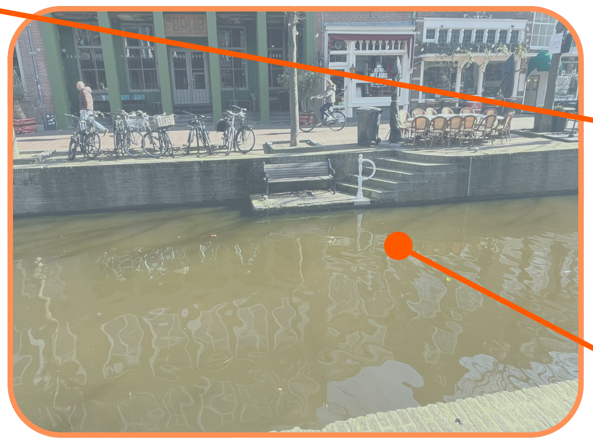
In **parallel** to the **prototyping** process, several locations were identified as suitable for the second round of testing. These sites were selected because they meet key design requirements: appropriate canal depth, a 90-degree corner for optimal placement, possibilities for non-destructive attachment, and a central location in the city to ensure public visibility.

Permission for placement was requested from the Municipality of Delft during the prototyping phase, with approval initially pending. Preferred locations that meet all design criteria are highlighted in green.

Ultimately, the location at **Hooikade 13** received **official municipal approval** for the testing of Prototype 2.

The approval document from the Municipality of Delft can be found on the Appendix E.








Location	Canal depth	Attachment options	Corner angle
Sint-Jansbrug. 89 Oude Delft	62 cm	• Bridge railings • Pole • Bike parking poles • Tree	90 degrees
Delft Sation, next to Quay Wall Parallelweg 24 2613 SL Delft	105 cm	• Stairs • Public light • Quay Wall	90 degrees
12 Hippolytusbuurt Delft, (in front of Poostkantoor)	20 cm from bench 112 cm from street (135 cm width)	• Public bench • Pole • Tree	90 degrees
In front of Vermeer Huis (Voldersgracht 21, 2611 EV Delft)	66 cm	• Public trash can • Pole • Bridge railings	>90 degrees
Next to Eetcafe de Ruif (Kerkstraat 22-24, 2611 GX Delft)	57 cm	• Tree • Bridge railings	>90 degrees
Oude Delft, in front of Cafe Tango (Nieuwstraat 2, 2611 HK Delft)	168 cm	• Bridge railings • Public street light • Tree	>90 degrees
Delft station	190 cm highest 160 cm lowest	• Public bench • Public light • Public street light	>90 degrees
In front of Huszar, Hooikade 13, 2627 AB Delft	70 cm	• Metallic ring for boat mourning • Huszar's boat terrace	90 degrees

VALIDATION 2

Second Water Deployment

Goal

The objective of this second testing round was to validate key design decisions made after the first iteration.

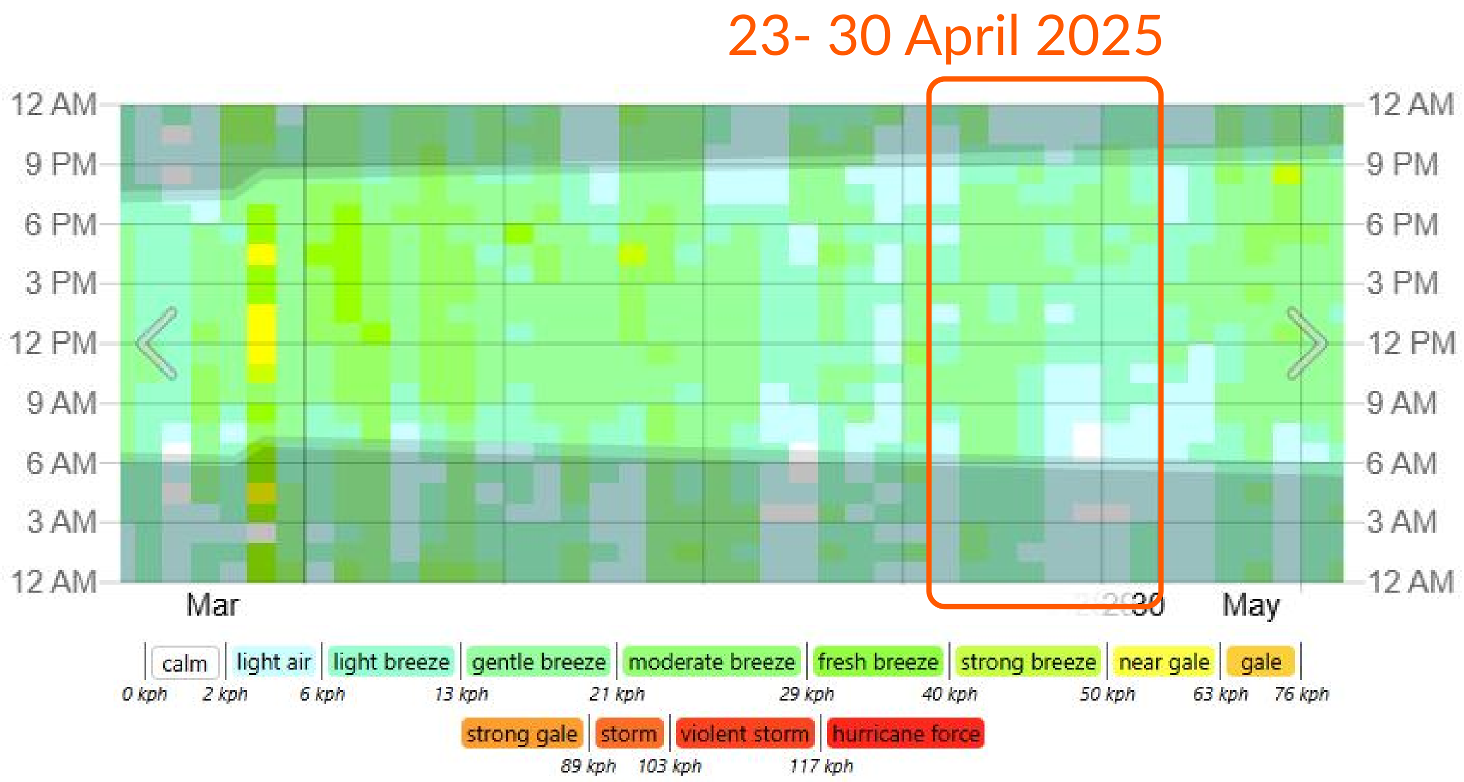
Specifically, the test aimed to **assess** the **basket design**: size, height, usage interaction and weight; the **system's aesthetic integration** within the urban canal environment, its **capacity to capture** and **retain** floating debris, and to gather initial **public feedback** regarding the system's visibility, purpose, and **perceived value**.

Setup

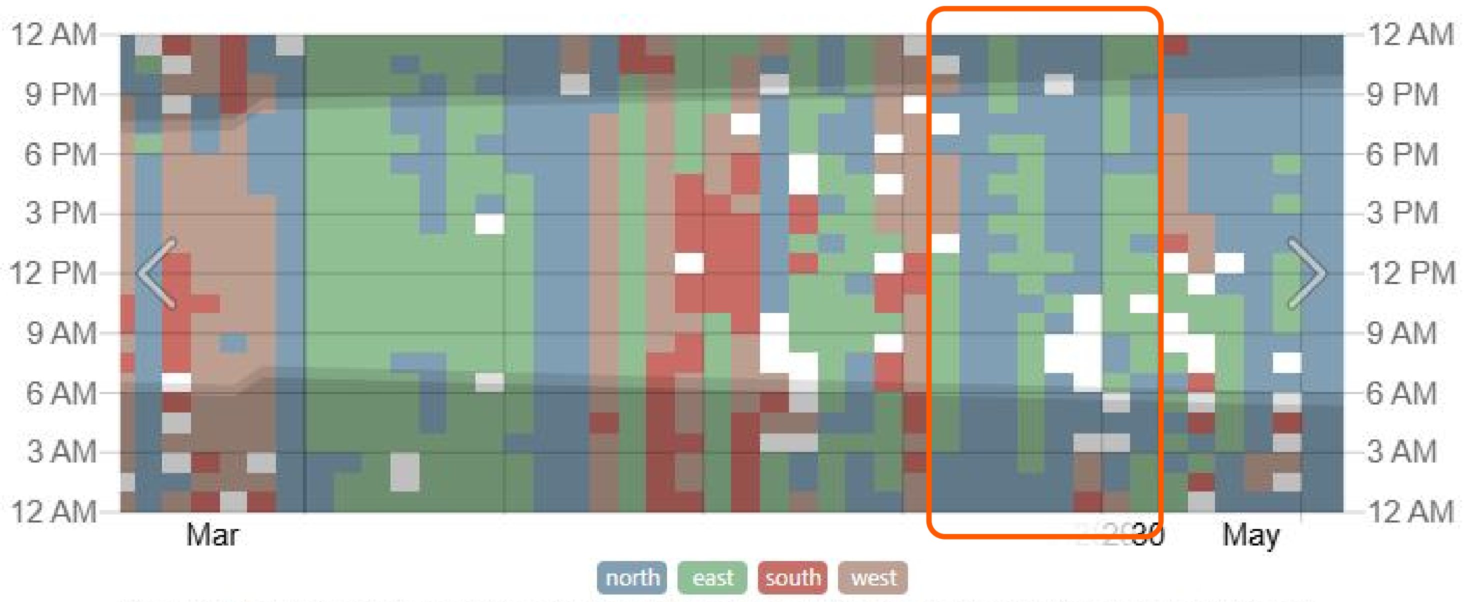
With **approval** from the **Havenmeester of Delft** and support from the adjacent restaurant Huszar, the system was installed at Hooikade 13, from Wednesday, 23 April to Wednesday, 30 April 2025.

During this period, **weather conditions differed notably** from the first test: wind came from the North-East and ranged between 3–21 km/h, corresponding to a "light breeze" or "gentle breeze" on the Beaufort Wind Scale. In contrast, the previous deployment faced South winds at higher speeds of 29–50 km/h.

Testing under these milder and opposite wind conditions offered valuable **comparative insight** into performance across **different weather scenarios**.



The hourly reported wind speed, color coded into bands according to the Beaufort scale. The shaded overlays indicate night and civil twilight.



The hourly reported wind direction, color coded by compass point. The shaded overlays indicate night and civil twilight.

Weather conditions during the prototype deployment. Weatherspark (2025).

Testing setup.

Method

Unlike the first prototype built in one solid structure, this model was fabricated in **modular sections**, **transported by van** to the site, and **assembled on location**.

Over seven consecutive days, **three different tests were conducted.** Supplementary data to these three tests was collected through daily visual inspections of naturally accumulated debris.

Test 1: Controlled debris capture

A total of **fifteen items**, both organic (e.g., fruits) and inorganic (e.g., plastic bottles) were **introduced** upstream at **three distances from the trap entrance** (1.5 m, 3 m, and 5 m).

The test lasted 1.5 hours and was recorded using a time-lapse camera to enable analysis of item movement and capture dynamics. The percentage of items retained versus those that escaped established a **quantitative capture-rate** benchmark.

All items were retrieved and properly disposed of after testing.

Test 2: Ergonomic retrieval tests

Five participants retrieved and emptied the basket while their performance was **timed** from first spotting the device, through unlocking, emptying the container, transferring its contents to a waste bag, and depositing the bag's waste into a public bin.

After completion, participants **rated three criteria** on a 1–5 scale: **physical strain** (1: no strain, 5: very demanding), **intuitiveness** of interaction (1: not intuitive, 5: very intuitive), and **perceived safety** (risk of falling into the water) (1: very unsafe, 5: very safe).

Test 3: Public perception survey

Passers-by and clients at Huszar were invited to complete a short questionnaire (via QR code) that measured **awareness of plastic pollution**, perceived **usefulness of the device**, and its potential long-term **value in the city**. A minimum of ten responses was required, with a target of thirty.

Survey's question are provided in the Appendix G.

Test 1 set-up

Test 2 set-up

Test 3 set-up

Findings

Test 1: Controlled debris capture

- **Capturing efficiency**

The controlled test showed a **60% capture rate**, with most items successfully entering the trap within 10 minutes of introduction, even under mild wind conditions. The resting **40%** of debris bypassed the trap, **drifting toward the opposite corner** of the canal.

This observation suggests that the current prototype is not sufficiently sized or positioned to handle the full width of the testing site. To improve capture efficiency, future iterations may require either a wider model, positioning of guiding floating lines towards the entrance of the trap, or the installation of a second trap at the opposite corner.

Accumulated waste in the opposite corner

- **Debris movement**

Lightweight plastics with large surface areas (e.g., film wrappers) traveled quickly and were captured within 5–10 minutes, even with light wind. Heavier or water-absorbing materials such as cardboard and glass moved significantly slower. Once saturated, cardboard became almost stationary.

- **Structural resilience**

Throughout the week-long deployment, no parts were damaged or stolen, even though the prototype remained in a public location, indicating a promising level of robustness against environmental wear and vandalism.

Collected items

Test 2: Ergonomic retrieval tests

- **Physical strain**

The act of **lifting the container** from the water received an average score of **2/5**, indicating a **low physical effort**.
Opening and emptying the container scored **3/5**, revealing room for improvement in ease of handling the basket.

- **Safety perception**

Participants felt moderately safe, **4/5**, when **pulling the basket up** from the water, with some **concern** about balance or **proximity to the water**'s edge. However, the act of emptying the basket scored 5/5, showing that the setup allowed for a safe and controlled disposal process once the basket was secured.

- **Intuitiveness**

Unlocking the basket from the main structure was perceived as **largely intuitive**, with a rating of **4/5**.
In contrast, **opening the basket** for waste disposal received a **3/5**, suggesting the mechanism could benefit from clearer use-cues.

"There could be **clearer usage cues** for unlocking the basket from the system"

"I found the usage **simple**, **fun** and **easy**. The only thing that worried me was **getting wet and dirty**"

Quotes from Test 2 from participants

Test 3: Public perception survey

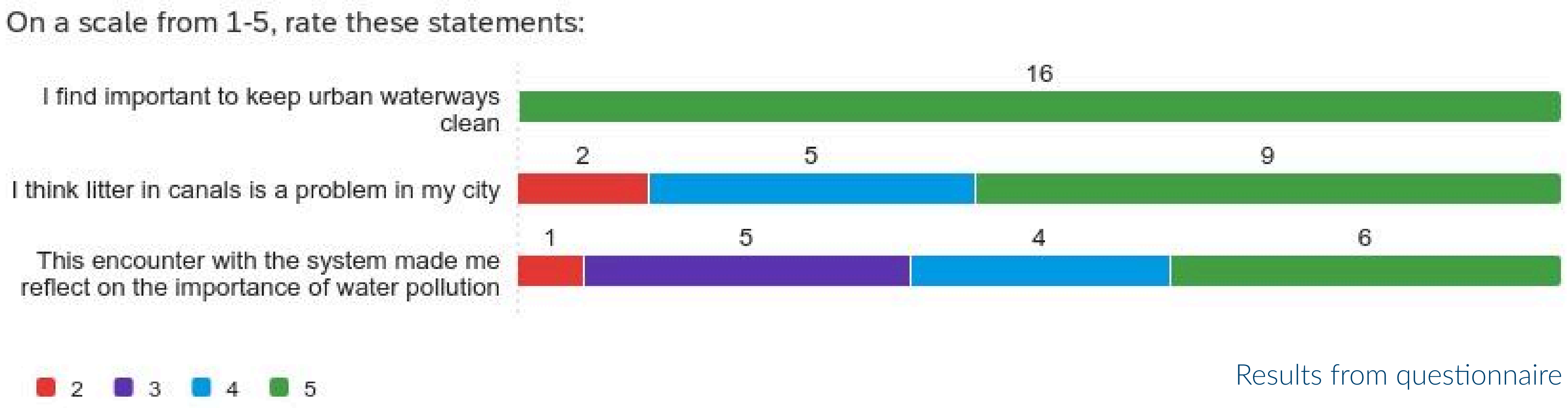
A total of 16 participants completed the public awareness questionnaire during the testing period. The results indicate that the **system was generally well understood** by the public, both in function and intent.

Five respondents described the looks of the system as eye-catching and other five noted it appeared functional. On the other hand, three individuals did not notice the system at all.

Encouragingly, nearly all **respondents correctly identified the system's purpose** as a tool for cleaning water or collecting waste. Only two participants misinterpreted it, one assuming it was a fishing device, and another an art installation.

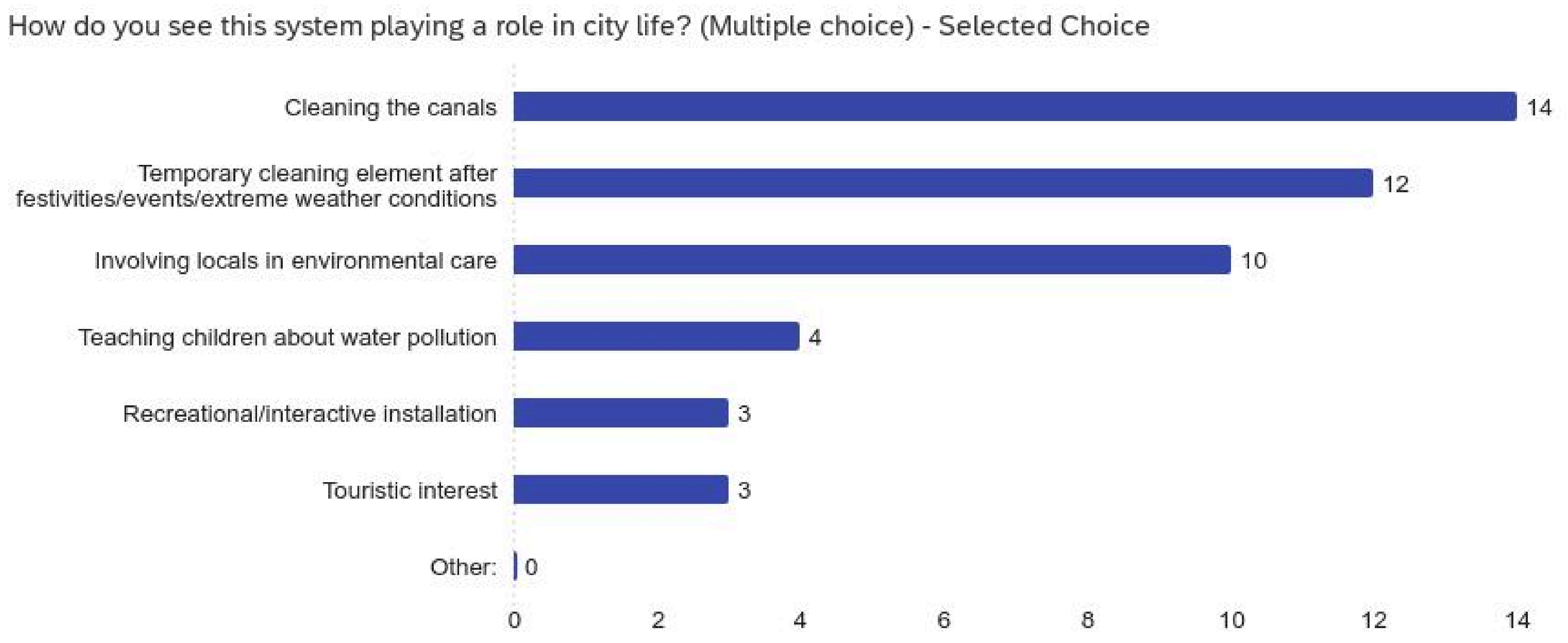
Participants expressed a **strong consensus on the importance of clean urban waterways**: all 16 respondents rated this issue 5/5 in importance. Nine out of sixteen also rated the general issue of urban litter as 5/5 in importance. Furthermore, six participants indicated that encountering the system made them reflect more deeply on the problem of water pollution (rating this reflective impact 5/5), suggesting that the system has **potential** not only as a functional intervention but also as a **tool for raising awareness**.

When asked about responsibility for maintenance and retrieval, a clear majority (14 out of 16) stated that municipalities and water authorities should manage such systems. Secondary suggestions included private waste management companies (7/16), local neighbors or adjacent property owners (6/16 each), and volunteer or community-based cleaning initiatives (5/16).

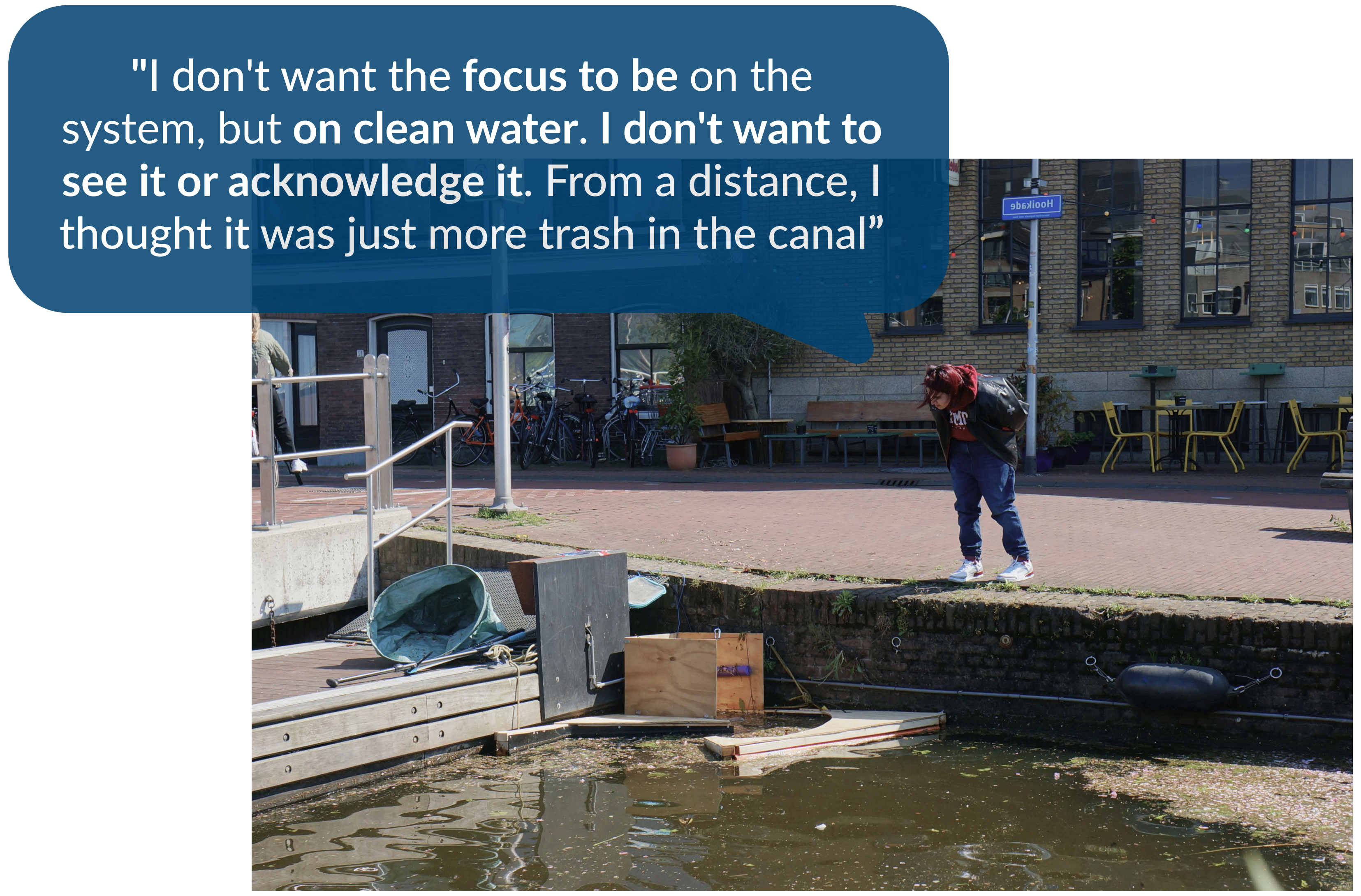


Results from questionnaire

All results from the questionnaire can be found in the Appendix G.



Envisioned role of the City Cleaner by the respondents of the questionnaire



Quote from participant

Additional findings

During the week when the prototype was deployed, **engagement with the public** was **consistently positive**.

Multitude of passers-by expressed curiosity and enthusiasm, often **initiating conversations** about urban water quality and the role of design in environmental issues. Particularly, a nearby boat resident emphasized the project's relevance to younger generations and its **potential to inspire community action**, suggesting an opportunity for deeper collaboration with local residents.

Sparking conversations

The **stakeholders** involved during the process were also pleased. Both the owners of the Huszar café and the Havenmeester of Delft **provided practical support** and **expressed interest** in continued involvement.

Involvement of stakeholders

The **project's visibility extended beyond the testing site**. An interview-style **article was published** in the regional **newspaper AD Delft**, bringing the prototype and its mission to a broader public audience.

This media exposure significantly amplified the project's reach, validating its relevance and positioning it as an innovative development. The coverage showcased the system's potential as a scalable, community-driven solution, and marked a **milestone** in terms **public recognition**.

The full version of the article can be found on the Appendix F.

AD

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NIEUWS REGIO SPORT SHOW KIJK PODCAST PUZZEL

Wijzig Delft ▸ Net Binnen 112 nieuws Van de lezer Uit-tips Eten en drinken Regiosp

PREMIUM

Anna Belenguer Martí met haar ontwerp van The City Cleaner © Nico Schouten

Anna's 'City Cleaner' gebruikt wind en stroming voor afvalvrije Delftse grachten

Varend en wandelend onderzocht Anna de beste manier om afval uit de Delftse grachten te krijgen. Het resultaat: een houten constructie bij de Hooikade. Het ontwerp doet wat het moet doen, maar ze wil het nog verfijnen. Tot haar spijt gaat de constructie woensdag alweer weg.

Maurice Gispen 30-04-25, 04:00

The City Cleaner on the News. Gispen, M. (2025)

4 Final concept validation

This chapter **evaluates** the proposed final concept through three criteria: feasibility, desirability and viability, validated with the expertise from various Noria employees and a consultation with a employee from the Municipality of Rotterdam.

3.1. FEASIBILITY

This section evaluates the feasibility of the City Cleaner by examining its real-world **functionality**, **material choices**, environmental **performance**, and **potential risks**. The insights are drawn from both previous controlled tests in urban canals.

Can it be built and function effectively?
Yes. The system was built using common, accessible materials and assembled using straightforward manufacturing techniques (woodworking, welding, and manual fitting). Both canal tests confirm that it can be built **quickly** and **cost-effectively**. The prototypes functioned successfully in open water for multiple days without human intervention.

Does the system catch waste under real conditions?
Yes, initial tests confirmed the ability of the system to guide and collect floating debris (e.g., plastic wrappers, cups, and foam pieces). Observations showed:

- Waste successfully funneled into the basket with the help of wind and flow.
- Some debris exited the system over time, suggesting a need for further retention improvements or further research in how to prevent it.
- The curved arms and partial submersion enhanced waste guidance and capture.
- Wind shields around the basket prevent waste escape.
- The submerged container collects the captured debris and allows easy disposal.

Is the system compatible with older city canal infrastructures?
Yes. The system is specifically designed to be compatible with historic canal environments. It can be installed without any destructive alterations to the existing infrastructure and operates without the need for electricity or digital connectivity. This makes it particularly suitable for older city centers where preservation and low-impact solutions are essential.

Before

- Smelly and dirty
- Restaurant calls for cleaning service on-demand

After

- 60% gets trapped
- Visually cleaner, other corner still accumulates waste

Before VS after deploying the City Cleaner during the testing phase 2

Materials and Construction: Is it durable, safe, and easy to maintain?

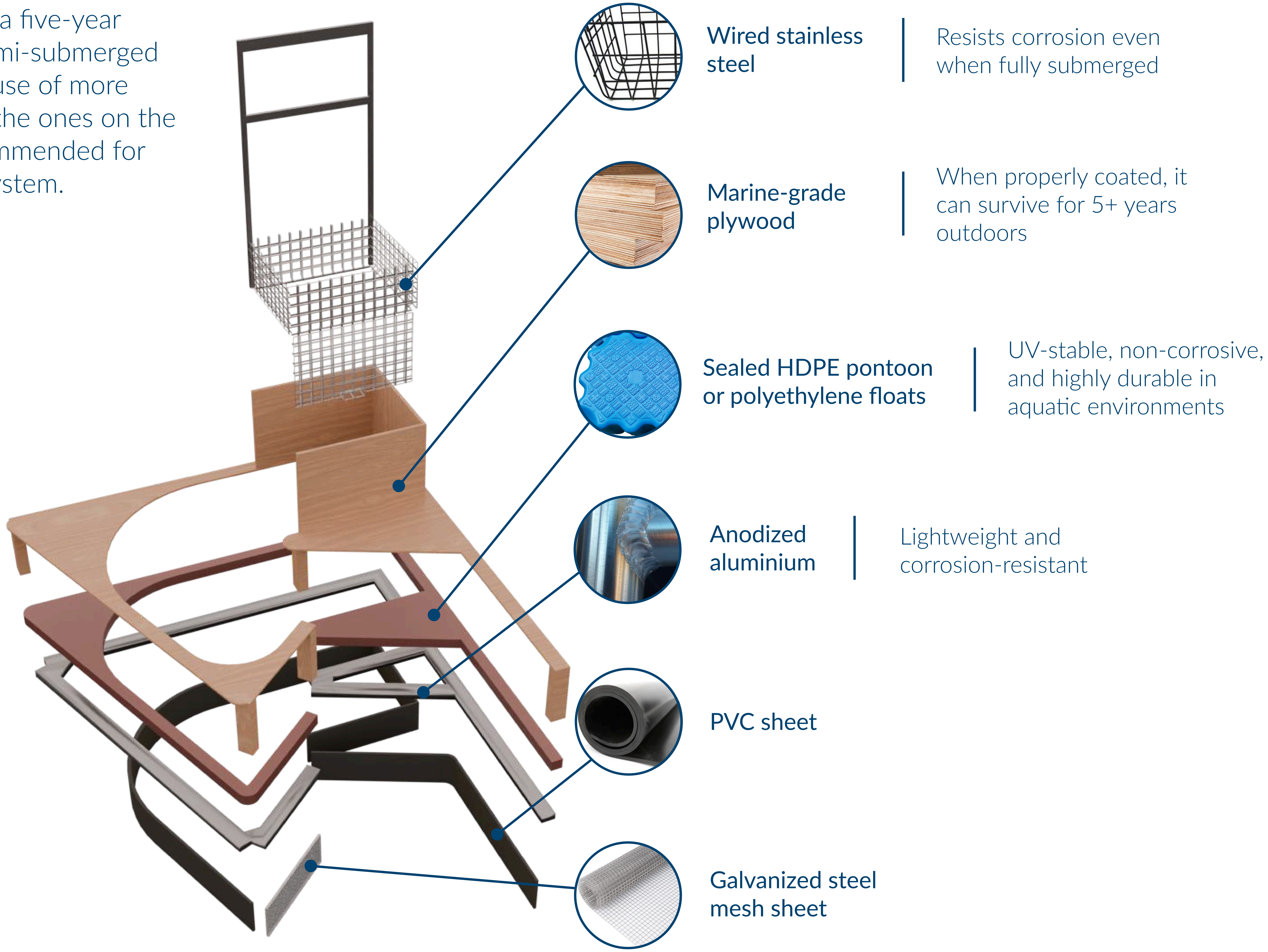
For the prototyping phase, materials were selected based on ease of construction and affordability. These included polyethylene foam tubes for flotation, wired stainless steel for the collection basket, and pine wood for the main structure. While these worked well for short-term testing, future deployment over a **5-year lifespan** in canal conditions will require more durable alternatives.

Key factors for long-term feasibility include:

- Weather and corrosion resistance
- Modularity for part replacement
- Safe manual handling and retrieval
- Minimal maintenance in urban water conditions

Recommended materials for 5-year lifespan

To ensure durability over a five-year period in outdoor and semi-submerged canal environments, the use of more robust materials such as the ones on the following image are recommended for future iterations of the system.



Exploded view of model with recomended materials for future development

3.2. DESIRABILITY

This section explores the desirability of the City Cleaner by examining its **public reception**, user **interaction**, **educational value**, and **community engagement** potential. Insights are drawn from observations during testing and feedback from passersby and converstations with stakeholders.

Do people want to engage with and support this system?
Yes. During the second prototyping phase in Delft, the system attracted attention from passersby, sparking interest, conversations, and photographs. These spontaneous reactions show that the design stands out and has the potential to become a familiar and appreciated presence in the city. Its visibility not only raises awareness about urban water pollution but also signals that collective care is both possible and welcomed.

Can the system spark local involvement or community collaboration?
Definitely. The City Cleaner is designed not just as a functional device, but as a catalyst for community engagement.

In the recommendations chapter, there are several ideas that could be implemented in future iterations on how this value might be utilized.

What is the educational or social value of the system?
The system offers a **good opportunity** to play a role in **education**. Its placement in central, visible locations makes it ideal for school visits, where children can learn about clean water, waste management, and sustainability. A family of such systems could be strategically designed to engage children through playful shapes, clear information, or even a scavenger hunt concept across the city.

This could **position** the system not only within environmental agendas but also within educational or **recreational budgets**.

Vision

Is it user-friendly, safe, and intuitive?
Yes. The design prioritizes ergonomics and ease of use. The container's handle was deliberately placed closer to the canal edge to improve reachability and comfort for the operator. The guiding structure eliminates the need for additional moving parts, reducing complexity and weight during retrieval.

However, one remaining concern is the potential risk of someone falling into the water while operating or interacting with the system. This is a point that would benefit from further consideration and mitigation in future iterations.

LEARNING TOOL

ENGAGE COMMUNITIES

SCHOOL EXCURSIONS

VISION

DAILY LIFE

FAMILY OF SYSTEMS

PRIVATE AND PUBLIC

POSITIVE TOURISM

TEMPORARY

BRIDGING THE GAP BETWEEN CITIZENS AND THEIR ENVIRONMENT

MODULAR

3.3. VIABILITY

This section evaluates the viability of the City Cleaner system by examining its **scalability**, **funding** potential, and **strategic value** to cities and partners. Insights are drawn from the prototyping process, stakeholder discussions, and the broader urban context in which it would be deployed. These findings are compiled using the **Business modelling method** (Osterwalder, A & Pigneur, 2010).

What is the core value proposition (offering)?
Unlike Noria's existing systems or other market solutions, The City Cleaner is a passive, and lightweight waste trap designed on a human scale. Rather than focusing solely on collection, it prioritizes interaction; offering an easy, ergonomic retrieval process that invites collaboration. Its approachable presence in the water raises public awareness, encourages civic participation, and creates opportunities for education.

What would it take to implement the City Cleaner at scale?
The second prototype was developed within two weeks, proving that low-cost, rapid production is achievable using locally sourced materials and accessible construction methods. Based on the current state of development, an **estimated 400** additional **hours** of work would be needed to finalize the system's design before a market-ready launch.

Next steps include:

- Possibility of engineering a modular version that can be adapted to different canal depths and widths.
- Optimizing components for efficient assembly and transport.
- Finalizing material specifications for long-term outdoor use.
- Developing clear manuals for manufacturing and installation.

Who are the target customers?

- **Municipalities / Water Authorities**

Primary buyers for public deployment .
Interested in clean water, visible efforts, and citizen engagement.

- **Private Property Owners Along Canals**

Cafés, restaurants, cultural venues, offices.
Want to show social/environmental responsibility to their clients or visitors.

- **Local Community Groups / Schools / NGOs**

May not buy the product, but could sponsor, adopt, or promote it.
Ideal for educational or neighborhood engagement programs.

- **Event Organizers or Tourism Entities**

Could use the system as part of events (e.g. cleanup days, floating festivals) to increase visibility and participation.

How will the initiative be financed and sustained?
The City Cleaner can be sustained through a mix of **public** and **private revenue streams**.

Optional services, such as maintenance contracts, waste data analysis, or educational workshops, offer additional income streams.

By aligning with various municipal agendas such as sustainability, education, recreation, and corporate social responsibility (CSR), the system positions itself as more than just a cleaning solution. It becomes a versatile civic asset that supports broader community goals and justifies long-term investment.

A breakdown of production and operational costs is provided in the following chapter, Cost Prize Estimation.

COST PRIZE ESTIMATION

Selling

To estimate the selling price of one City Cleaner system, the total costs incurred by Noria were calculated. These are grouped into two main categories:

1. Development Costs: These are one-time investments required to bring the product to market, such as design, prototyping, testing, and engineering time. These costs are distributed across the number of units expected to be sold, meaning they are amortized per unit depending on production volume.
2. Fixed Costs: these costs are incurred every time a new City Cleaner is produced. Unlike development costs, they do not depend on the total number of units sold.

- Material Costs: costs for purchasing all materials needed for one unit
- Labour Costs: costs of building one unit (per hour)
- Office Costs: includes costs like electricity, office equipment, administration costs and licences.
- Installation Costs: costs from installing and removing the system on site.

TOTAL COSTS SUMMARY:		
Total Development Costs	**€**	**22,600.00**
Material Costs	€	1,500.00
Labour costs	€	1,080.00
Office costs	€	255.52
Installation	€	360.00
Total Fixed Costs	**€**	**3,195.52**

Selling price calculation

The final unit price is calculated by adding:

- The fixed cost per unit, and
- A proportional share of the development costs, based on expected sales volume.

For this analysis, a sales scenario of 10 to 20 units over a two-year period was assumed. Based on this projection, the **minimum total cost per unit for Noria** (excluding profit margin and optional services) **ranges between**:

- **€4,325.55** (assuming 10 units sold)
- **€5,455.52** (assuming 20 units sold)

Note: These values represent internal cost for Noria, **not the final client purchasing price**.

22600€ / 10 u

OPTION OF SELLING:		
#ASSUMPTION1	units	
Possible sale in 2 years	10	
Development costs p/item		€ 2,260.00
Profit margin		none
Total cost		**€ 5,455.52**
#ASSUMPTION2		
Possible sale in 2 years	20	
Development costs p/item		€ 1,130.00
Profit margin		none
Total cost		**€ 4,325.52**

Additional Costs

If a client wishes to include additional services such as long-term maintenance and insurance coverage (e.g., for the full expected lifespan of the product—5 years), these extra costs are added on top of the base cost.

Example Calculation (Based on Assumption of 10 Units Sold):

- Base unit cost: €4,325.55
- Maintenance over 5 years: €2,025.00
- Insurance over 5 years: €6,000.00
  → Total cost: €12,350.55

These extras would be presented as optional add-ons in the client offer.

OPTIONAL EXTRA COSTS PER LIFESPAN (5 YEARS):			
		N hours	€/hour
*Mantainance		45	€ 45.00
	SUBTOTAL		€ 2,025.00
		months	€/month
**Insurance		60	€ 100.00
	SUBTOTAL		€ 6,000.00

45h = (3h per visit * 3 times a year * 5 years)

Leasing

Leasing the City Cleaner system presents an alternative to direct purchase, particularly attractive for municipalities or private organizations with short- to mid-term waste management goals.

However, calculating a leasing price is more complex than estimating a selling price, as it requires **factoring in time-based use, system employability, and return on investment over time**.

Emplotability assumption

For this analysis, we assume the City Cleaner has an expected lifespan of 5 years, with 80% employability, meaning the product is actively deployed and generating value for **4** out of those 5 **years**. The remaining time accounts for transport, maintenance, seasonal gaps, or periods between leases.

Monthly lease calculation

Based on this assumption, factoring all of the costs involved in the process **excepting profit margin, the total leasing cost** per month for a City Cleaner would be **€335.76**, with an optional additional charge of €100 for insurance per month.

TOTAL COSTS per MONTH:

Development Costs	€	22.14
Production costs	€	83.20
Finance costs	€	16.64
Fixed cost coverage	€	3.63
Risk margin	€	4.16
Mantainance costs	€	205.99
Profit margin	none	
Total Costs per month	**€**	**335.76**

OPTIONAL

Insurance	€	100.00

Pricing benchmarks

Based on common Dutch government contract models, the annual lease price typically ranges between 20–25% of the purchase price. This results in a financial tipping point: the moment when renting becomes more expensive than purchasing outright.

This means:

- If a municipality rents a unit for less than 3–4 years, leasing is financially advantageous.
- For projects expected to last beyond 5 years, purchasing becomes more cost-effective.

Selling VS leasing

Each option offers specific advantages and trade-offs, depending on Noria's short- and long-term goals.

Option of **selling**: best for early-stage revenue.
Pro's:

- Fast income recovery
- Simpler logistics, no return required
- Suitable for long-term municipal installations

Con's:

- Requires more units to be produced
- One-time revenue only
- Weaker long-term client connection

Option of **leasing**: best for sustained growth.
Pro's:

- Recurring income stream
- Fewer units needed (higher reuse)
- Attractive for short-term or low-budget clients
- Encourages long-term client relationships

Con's:

- Slower return of investment
- Requires service and maintenance structure
- Must manage system downtime

Potential implementation locations in the Netherlands

Delft as baseline
10 suitable locations in Delft.
Delft has a historic canal network typical of many Dutch cities: narrow, low-speed water, 90-degree corners, bridges, dead-ends, and limited boat traffic in some parts.
Area of Delft's historic canal network (roughly): 5–6 km total canal length.

Let's assume: ~2 suitable locations per km of canal in such environments.

Similar Cities in the Netherlands
There are at least 15–20 cities with old centers and canal morphology like Delft's, many are even larger and more complex. Some good analogues can be seen on the map on the right.

Assuming:

- On average, 5–10 km of comparable canal per city.
- 2 suitable spots per km, as in Delft.

Rough Calculation

- 20 cities × 5–10 km of canal = 100–200 km
- 2 suitable locations/km → 200–400 potential locations nationwide

Conservative Estimate
There are **200–400 suitable urban locations across the Netherlands** for City Cleaners.

This doesn't include opportunities in smaller towns, or less urban waterways (where function may work but visibility or interaction is less valuable).

RISK ANALYSIS

What does make this project not viable?
While the City Cleaner shows strong potential, several factors could challenge its viability.

The primary concern is the risk of limited long-term engagement, without a clear ownership model, regular maintenance may be neglected.
Additionally, deployment still requires municipal approval and coordination, which can delay implementation.
Vandalism or misuse in public spaces could also affect durability and public perception.

The main risks are outlined and assessed in the risk analysis matrix below, helping to guide mitigation strategies and ensure the project's long-term success.

Severity →

Likelihood ↑	Minor	Moderate	Significant	Mitigation plan:
Likely	Clogged container	Neglected container (not emptied on time)		
Possible	Unlocking problem	Too costly for perceived value	Ineffective waste collection	Conduct more real-life testing and iterations
Unlikely	Lack of engagement Legal barriers	Not replicable across locations Theft or missuse	High mantainance effort Injury while emptying	Improve handling Create user protocols Safety instructions, insurance coverage for accidents

5 CONCLUSIONS

This chapter **reflects** on the final concept by summarizing the development process, key outcomes, and lessons learned. It highlights the concept's strengths and limitations, situates it in relation to current plastic-catching methods, and discusses its potential impact.

THE CITY CLEANER

A SOLUTION FOR CLEANER CANALS AND ENGAGED COMMUNITIES

The City Cleaner is a waste-catching system designed to remove plastic from urban waterways while sparking awareness and participation. More than just a catching-system, it is a symbol of care, collaboration, and commitment to better public spaces.

Unlock and pull

Drain

Empty

Dispose

Key benefits

Compared to conventional manual collection or large-scale infrastructure, this system offers several advantages:

- **Continuous passive collection**: Operates throughout the day without human input or energy use.
- **Context sensitivity**: Designed for narrow, complex canal systems where larger solutions are unfeasible.
- **Visibility & Awareness**: Positioned in the public eye, it functions as both intervention and communication tool.
- **Low-Tech maintenance**: Emptying the basket can be managed by local staff, volunteers, or service providers.

How It works

- **The System**: A floating trapping structure guides debris to a submerged collection basket.
- **The Message**: The system invites curiosity conversation and participation. .
- **The Maintenance**: Weekly retrieval is simple, with either outsourced or community-led emptying routines.

Who is it for?

This system supports different stakeholder goals:

- **Municipalities**: Improve urban water quality, make environmental efforts visible, and engage the public in sustainability.
- **Private Institutions** (cafés, NGOs, schools, event organizers): Demonstrate social responsibility, activate community involvement, and generate positive visibility.

FINAL CONCLUSIONS

The City Cleaner can effectively capture floating waste

Under light wind conditions, the prototype captured approximately 60% of both organic and inorganic waste items introduced at varying distances, demonstrating that even a modestly-sized, low-tech solution can make a tangible impact in canal environments.

This confirms the prototype's potential as a passive collection tool that complements more industrial-scale systems.

Public engagement and awareness were significantly boosted

The system did more than catch waste, it caught attention. Over 60% of survey respondents immediately recognized the system's purpose, with many describing it as "eye-catching" or "functional." Several reported that it made them reflect on water pollution. Local residents and stakeholders expressed enthusiasm, and regional media coverage (AD Delft) further validated the project's relevance and potential reach. This shows the strength of the design not just as a tool, but as a conversation starter.

Maintenance is possible but needs refinement

The user tests showed that just one person can perform the retrieval tasks, but not without moderate physical strain and variability in perceived safety. These insights provide clear direction for improving ergonomic aspects, especially in future versions intended for community-led or private owners.

Scalable and Community-Adaptable

Interest from restaurant owners, the harbormaster, and passers-by revealed a strong local willingness to support or host similar systems. The flexible, modular nature of the design opens doors to adapting it to different environments, whether as a standalone awareness piece, a local cleanup hub, or part of a distributed citywide system.

DESIGN REQUIREMENTS ASSESSMENT

This chapter evaluates whether the final design meets the **requirements defined during the initial problem statement**. Each requirement is assessed based on the outcomes of prototyping, testing, and design decisions made throughout the project.

A color code is used to indicate the extent to which each requirement has been fulfilled: green (requirement has been met), yellow (partially met or requires further refinement), and red (not been sufficiently addressed).

	Design requirements	
Must-have	1. The system **collects floating waste**, with a focus on organic and plastic waste.	
	2. The system **faces** the most common **wind direction** of the selected area, (with it being south-east in Delft).	
	3. The system must **fit into narrow canals**, (<6 m widths and ~1.3 m heights).	
	4. The system is **mounted in 90 degree corners**, where waste naturally accumulates by itself.	
	5. The system is **installed in city central areas**.	
	6. The system is passive: **it does not use energy** or power.	
	7. The system is **safe for public interaction**.	Only authorized people can empty the system. There are still some safety concerns.
	8. The system is **easy to access** and generate **low physical effort for retrieval**.	
	9. It is **durable in outdoor** urban canals for extended use.	
	10. It **does not obstruct boat traffic or wildlife**.	
	11. Designed for **low-cost production**.	
	12. The final development cost of the system must not exceed €2,000	If 11 units are sold in 2 years or more
Should-have	13. The system **encourages public curiosity and engagement**.	
	14. It is **easy to install without special tools**.	
	15. It **supports community interaction**.	
	16. **Easy to maintain and clean**.	
	17. It **adapts** to various **canal shapes**.	Shape fits in scoped locations but is not adaptable
	18. **Circular design**.	Not a core focus during development. However, the system is designed for easy disassembly

5.2 RECOMMENDATIONS

Design improvements

1. **Height-regulating handle with enhanced grip**
   - Basket with adjustable handle length. Adaptable to different shore depths.
   - Thicker handle to help with handling.

*Weight and instability are a concern

2. **Open/close mechanism for basket gate from grip area**
   - Create a pull-release mechanism with a cable from the handling area of the basket
   - Gate opens without the operator getting in touch with the waste

3. **Smoother and more natural-looking shape**
   - Get rid of all sharp edges by redesigning the cover with more curves
   - Explore possibility of adding vegetation on cover

4. **Poster-stand integrated on structure**
   - To be able to place information about the system or creating interaction with whoever encounters the system

5. **Integrated accessory holder on structure**
   - To save complementary elements like gloves, manual scooper, trash bags...

6. **Clearer use queues**
   - Color-code surface areas of interaction. Example: on handle (where to grip, where to unlock basket from the system, where to pull cable to release gate...)

7. **Easier to disassemble and modular**
   - Divide shape in modules that can be connected and disconnected from each other with ease.
   - Create the possibility to repeat modules to adapt to bigger locations

8. **Resting area at the frame for basket drainage**
   - When retrieving the basket full of water and waste, basket could sit on the structure to let it drain, before being pulled out and emptied

A Community-Driven Deployment Model

Estimating the number of suitable locations for placing a system like the City Cleaner highlighted the challenges involved in **finding appropriate sites** due to the complexity and variability of urban canal environments. The **process** can be **slow**, often requiring significant time from identifying the location features on sight to **obtaining approval** from a public entity, such as a municipality.

A more scalable and effective approach would involve community-driven identification rather than relying solely on centralized planning by Noria.

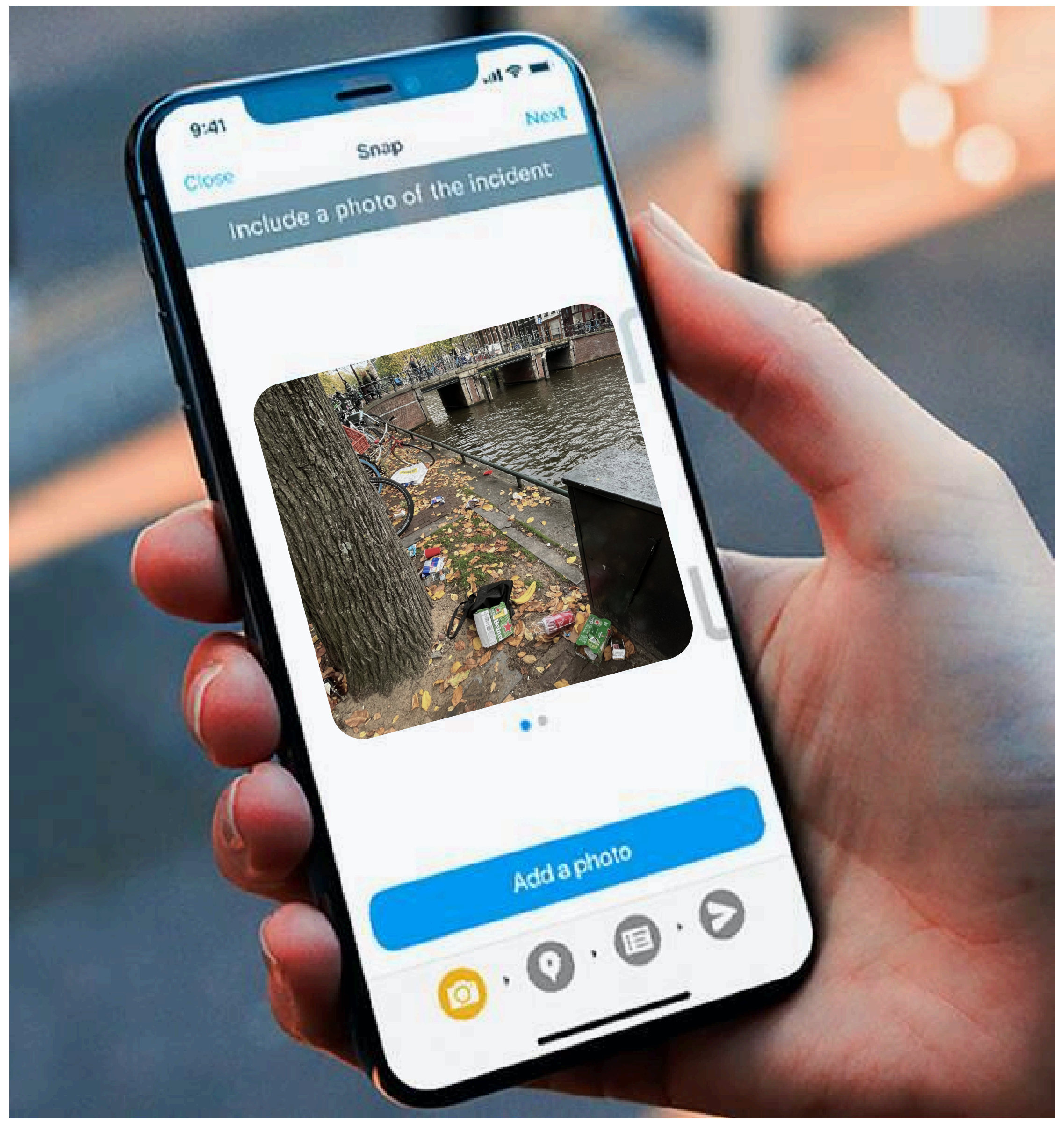
The City Cleaner could become part of a participatory system: a **network** of floating installations that are **requested by local citizens**, canal walkers, property owners, and community groups.

Benefits

- Scalability: Citizens become scouts and ambassadors, allowing the system to grow organically and reach locations that central planners might miss.
- Increased Engagement: Locals are more likely to care for a system they helped install or requested, reducing vandalism and neglect.
- Data and Insights: Requests and reports can feed into a central database, helping Noria or cities map pollution hotspots and understand seasonal or behavioral trends.
- Storytelling Potential: Each unit could carry a short story of who adopted it and why, turning each object into a local symbol of care.

Long-Term Vision

Over time, a network of City Cleaners could emerge, each one embedded in a local community, contributing not just to waste collection, but to public education and **pride**. The system could be supported by a central platform that tracks impact, connects adopters, and provides maintenance tips or updates.



Vision

Integrating Multi-Functional Add-Ons

To enhance the long-term value and appeal of the system beyond waste collection, future iterations could explore the **integration of modular ecological** or **aesthetic components**.

Examples include attaching green modules with floating or climbing plants to promote biodiversity and improve the visual quality of the canals, or incorporating a "fish hotel" structure beneath the trap to provide shelter and areas for aquatic life. These additions could increase public support, foster greater urban ecological health, and align with broader sustainability goals by transforming the system into a multi-functional element within the city's infrastructure.

Design recommendations for safety and maintenance:

- All edges and contact points should remain rounded.
- Handle should remain within 0.5 m reach from the shore for ergonomic retrieval.
- Locking attachment points and routine inspection schedules should be part of the deployment plan.
- Daily or bi-weekly emptying, depending on location and season, is advised for optimal performance.

Conceptual recommendations for future iterations

Future iterations could incorporate **participatory elements**, such as a manually powered feature that activates when someone spots floating trash: "Do you see waste? Power it up!" This invites residents to take direct action, transforming the system into a shared responsibility integrated into everyday urban life.

Additionally, a mobile "family" of systems could rotate between Dutch cities, creating event-based installations that draw public attention and encourage civic pride. This sense of novelty, combined with the system's visibility, can foster stronger connections between citizens and their waterways.

REFLECTION

At the start of this thesis, I knew I wanted to address the issue of plastic pollution, but the path forward was unclear. Initially, the problem was overwhelming in scope, and it quickly became evident that this project would not be about solving it entirely, but rather about contributing a small, thoughtful step in the right direction.

Over time, the project evolved from a broad vision into a very hands-on, iterative process of prototyping, testing, and learning by doing. I designed and built two working prototypes entirely on my own, and tested them in real-life conditions, an ambitious and at times challenging decision that became one of the most insightful and rewarding parts of the process.

This project also pushed me personally in ways I had not anticipated. I had to scope a vague, complex problem into a manageable design question. I worked with physical materials, tested in unpredictable outdoor environments, and adapted each time things didn't go as planned.

I also initiated and carried out stakeholder engagement independently, involving city residents, municipal workers, and others whose perspectives were very valuable. Their insights reminded me that even small interventions can have a significant impact when they are in the right context and implemented with care.
The main highlight was seeing the project featured in the newspaper, an unexpected but affirming moment that I was on the right path.

The City Cleaner does not give the definitive solution to plastic in the canals. But it is a first step, a conversation starter, a concept that helps visualize what could be possible.

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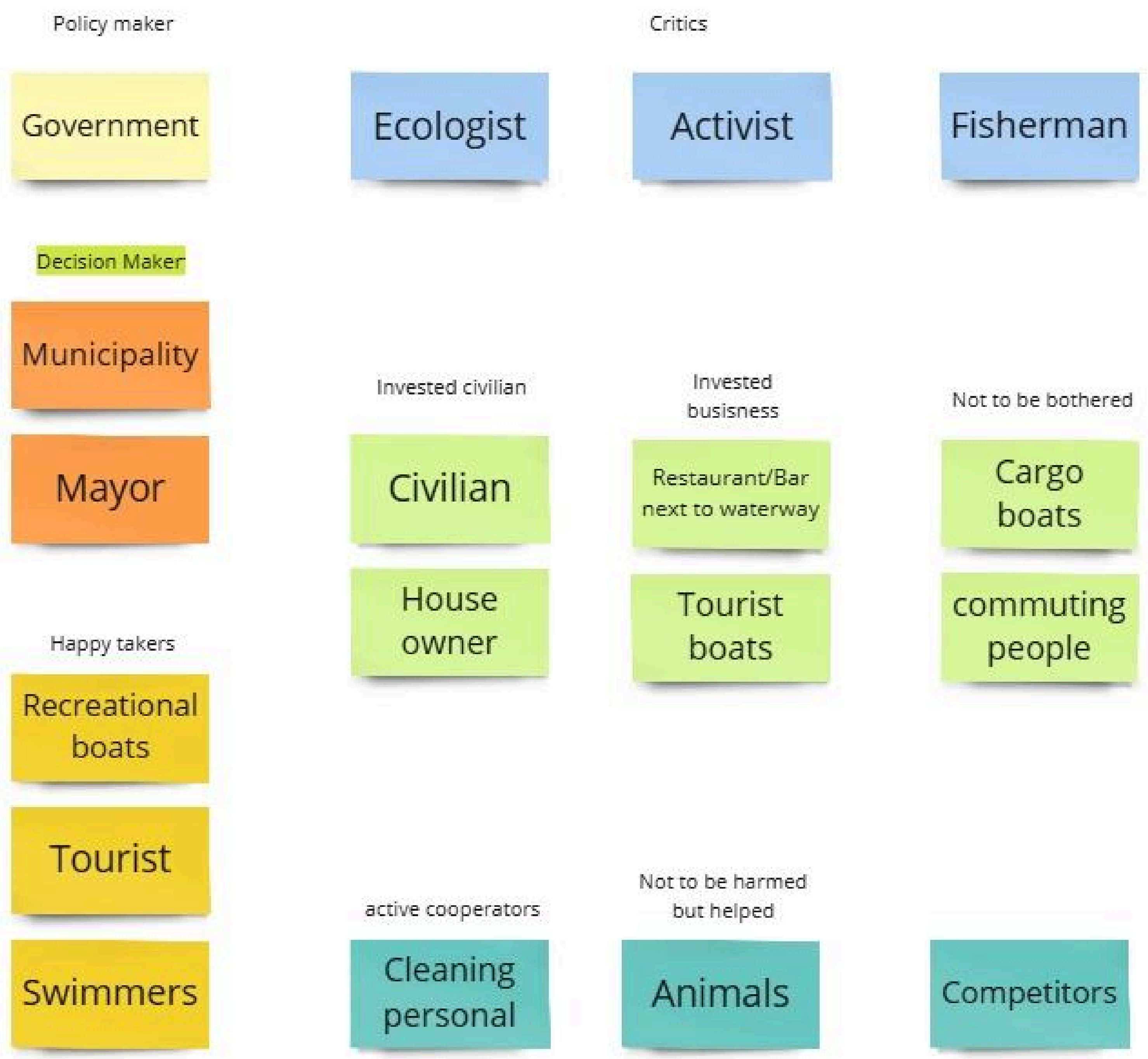
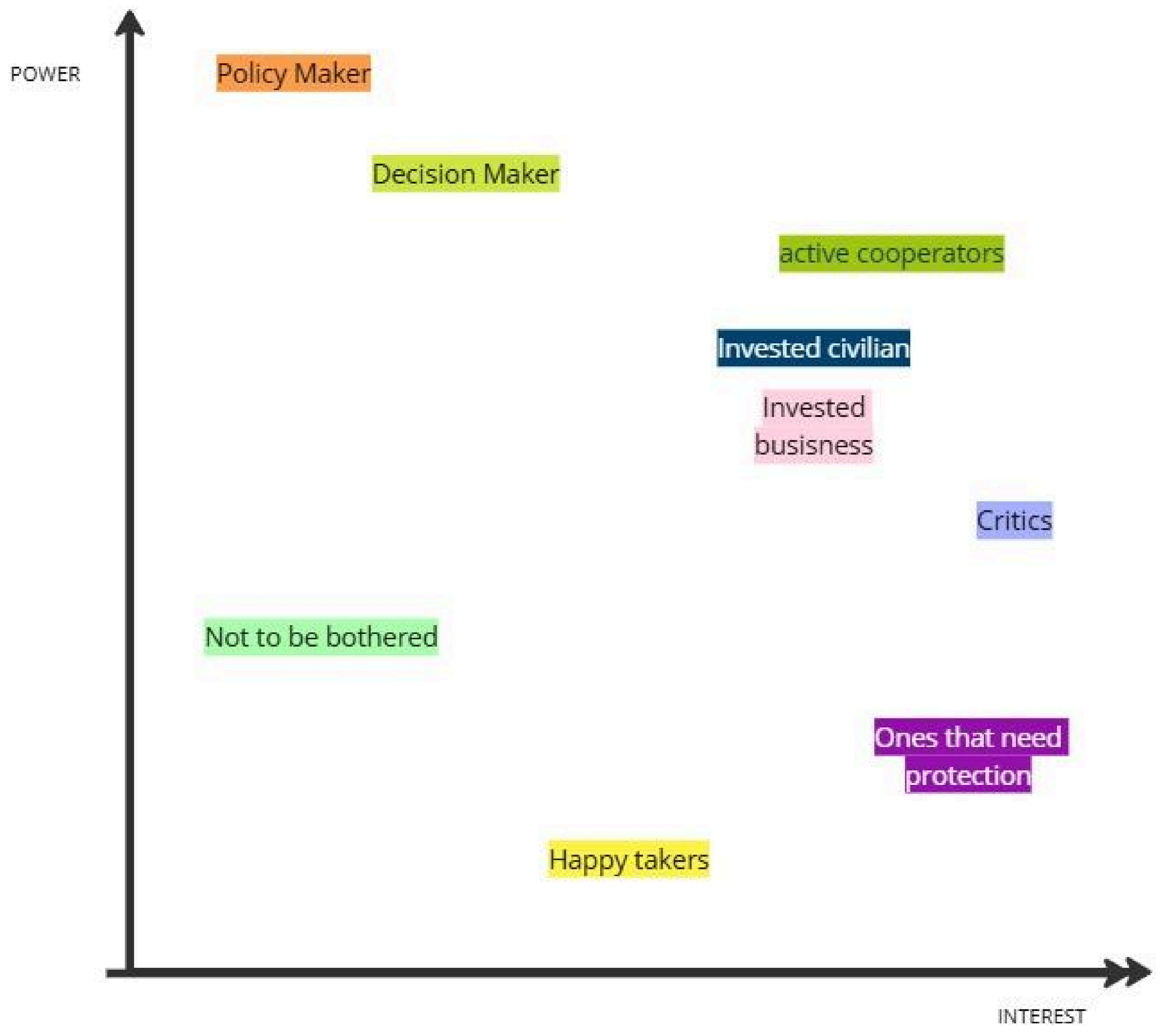
APPENDIXES

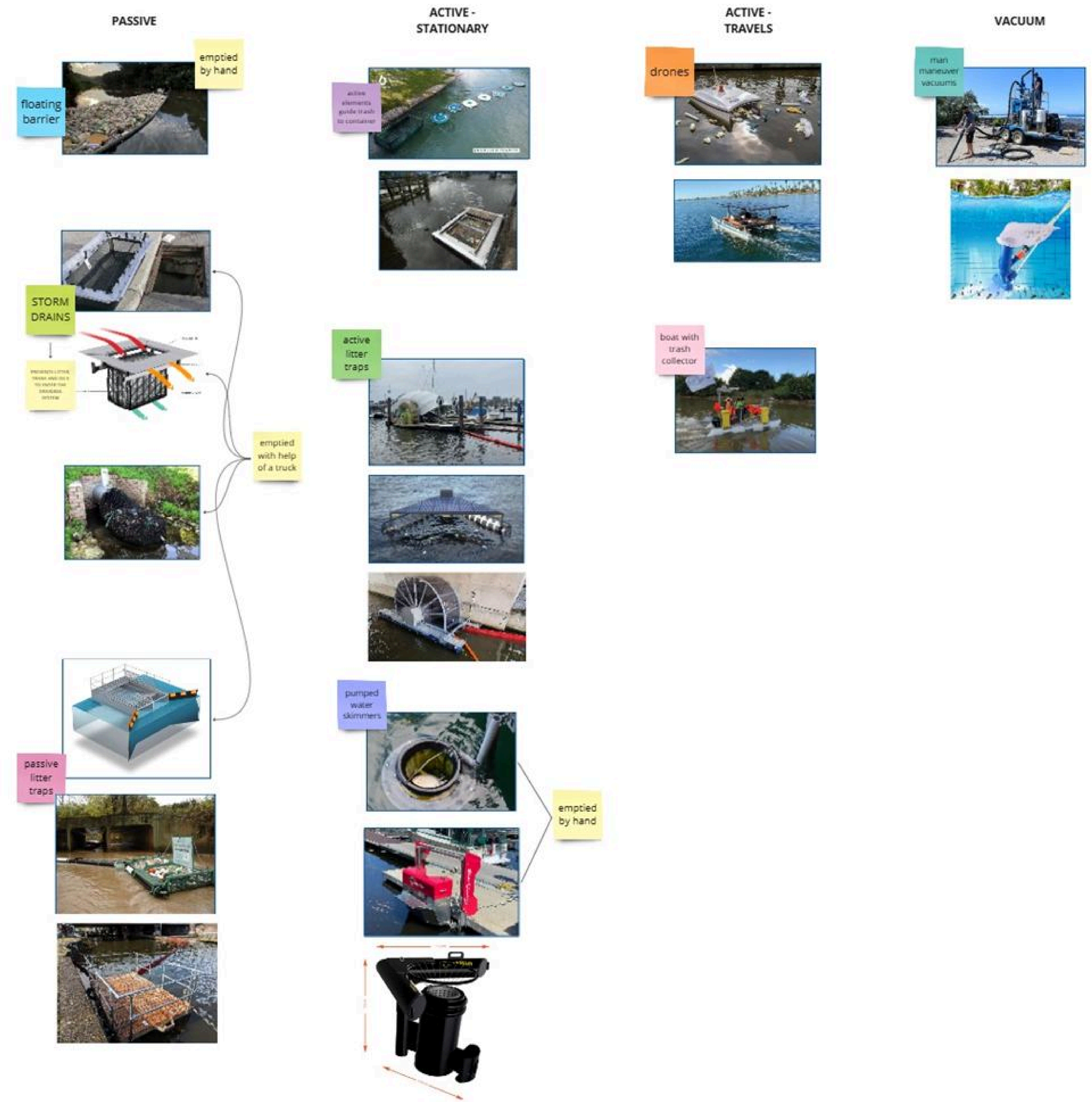
A) STAKEHOLDER ANALYSIS



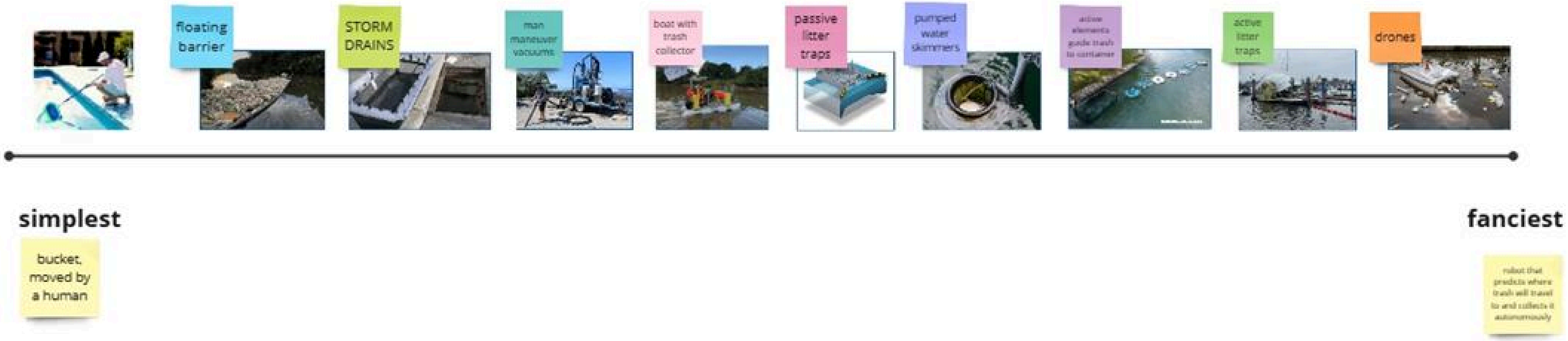


B) COMPETITORS ANALYSIS

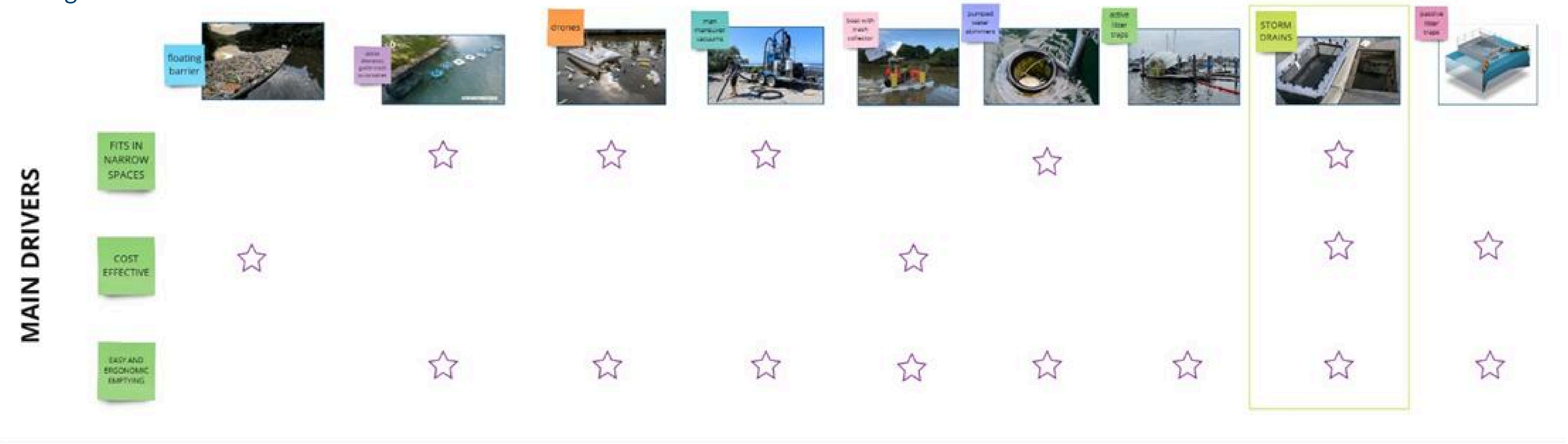
Classification of existing solutions by work principle



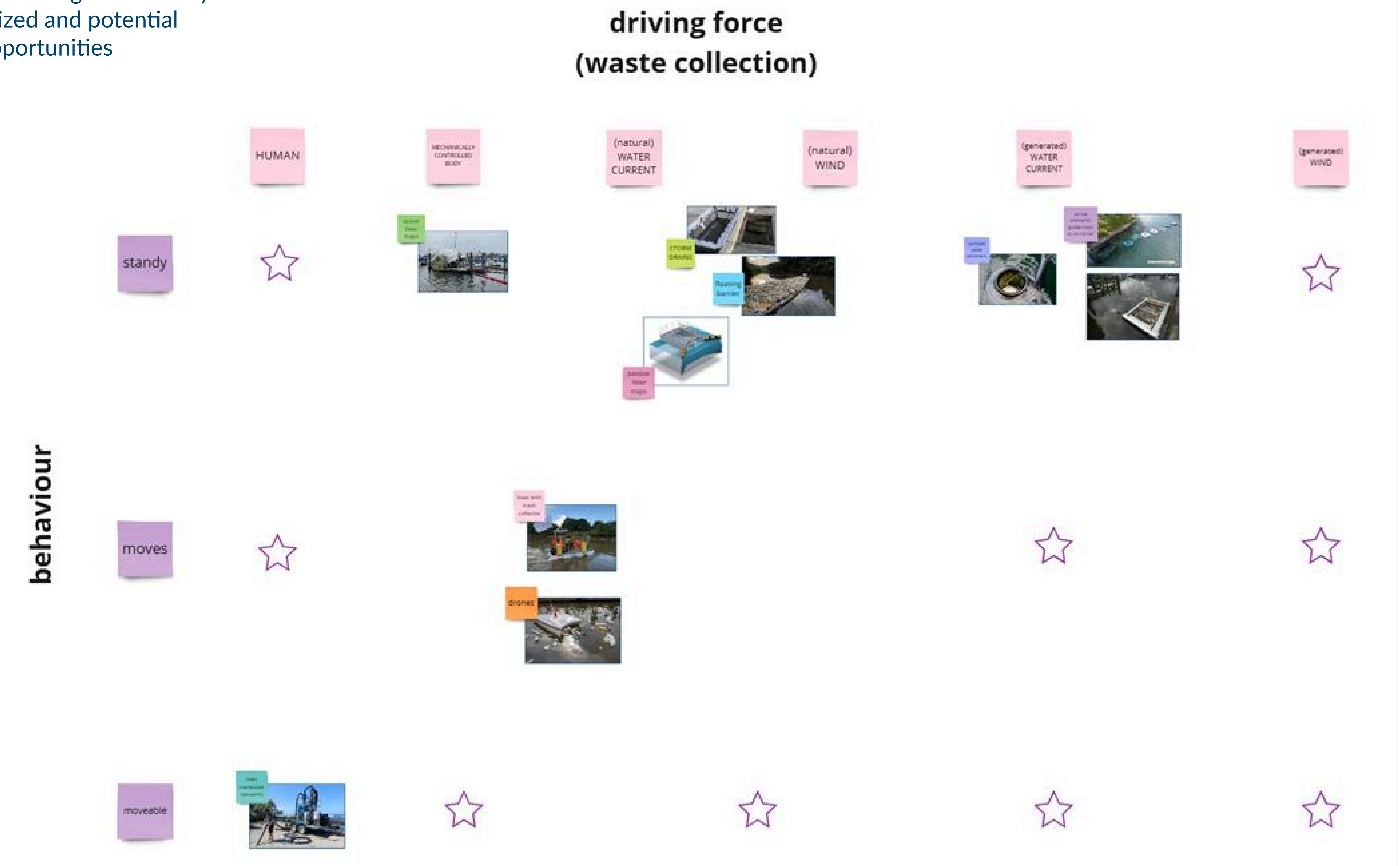
Classification of existing solutions by level of complexity



Analysing the three main drivers of the project on existing solutions



Classification of existing solutions by driven force utilized and potential development opportunities

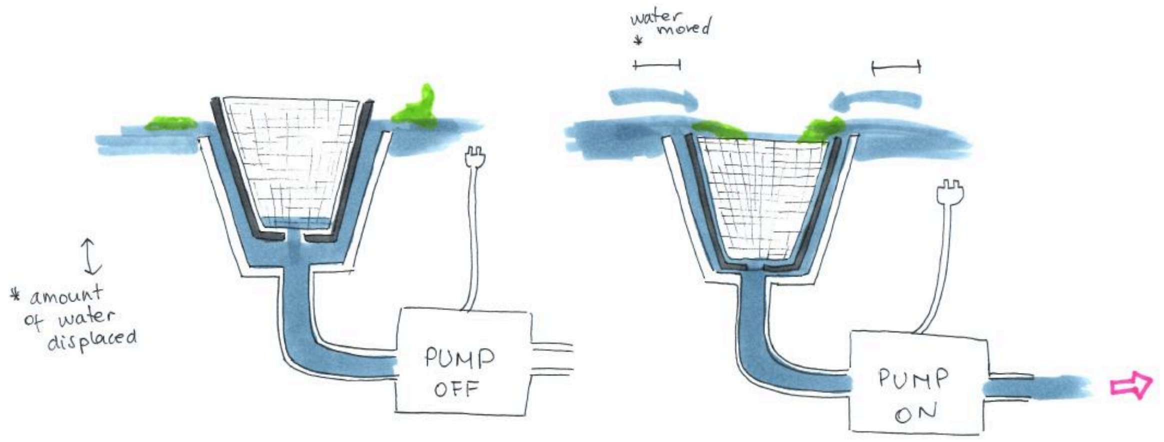


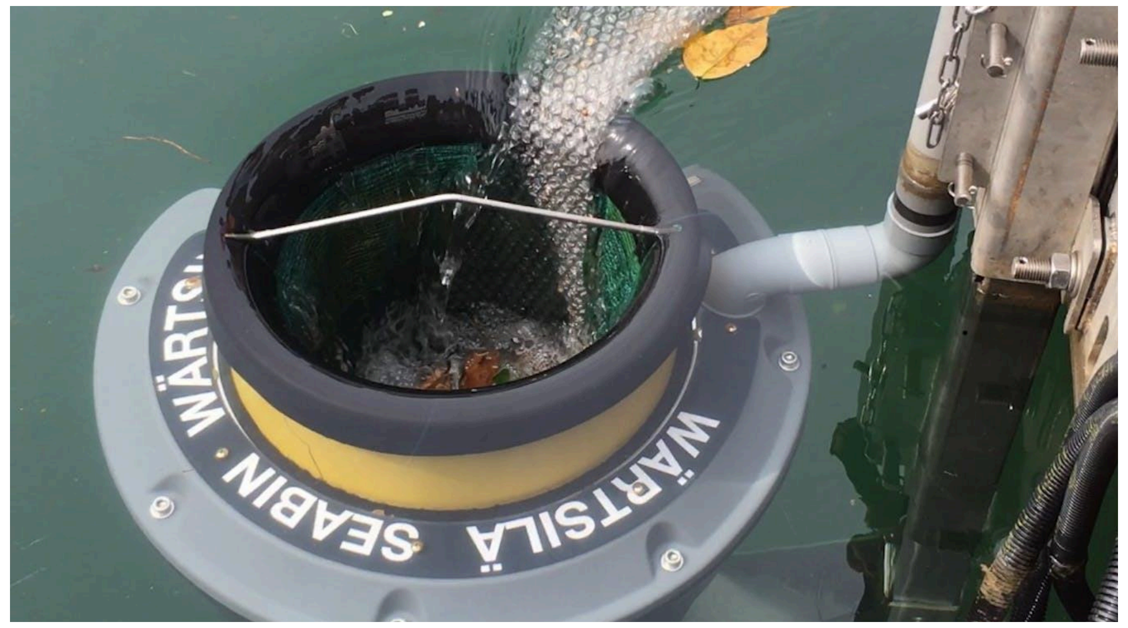
C) WATER PUMP EXPERIMENT

Electric water pump experiment

To explore the posibility of integrating a powered system into the project, an experiment using an electric water pump was conducted. **Inspired by the Seabin project** and **swimming pool skimmers**, a preliminary analysis of its working principles was performed before setting up the test.

The experiment included three small variations to understand the behavior of electric water pumps, the dynamics of floating debris and water flow, and the challenges associated with stabilizing objects in water.





The Seabin project (2024)

Experiment Setup and Objectives

The core idea was to evaluate whether an electric water pump could create a water flow strong enough to direct floating debris into a trash collection bucket. A black plastic bucket was used as the collection point, positioned at water level to interact with the water's surface.

Key Learnings

1. Stabilizing Objects in Water

Achieving a stable and controlled position for objects in water proved to be more difficult than anticipated. The bucket tended to float unless intentionally submerged, at which point it filled with water and began to sink. The desired position, with the bucket aligned at water level, required external floaters to maintain stability.

This highlights the importance of **incorporating buoyant materials** or adjustable floatation devices into the design **to counteract water forces** and maintain the system's orientation.

2. Structural Integrity

The force generated by water movement was stronger than anticipated, causing the mounting system to break. This highlights the **need for robust, weather-resistant materials** and a design that can withstand continuous water pressure and dynamic forces.

3. Water Pump Performance

The initial water pump, with a flow rate of 1,300 liters per hour (l/h), lacked the power necessary to generate a meaningful water pull. This pump, costing €9.00, was unsuitable for the project.

Consequently, a more powerful pump with a flow rate of 3,800 l/h and a power rating of 650 W (€60.48) was tested. While its performance was better, the difference in suction power compared to the first pump was less significant than expected. Nevertheless, this pump could still be a viable option for further testing.

For reference, the Seabin's pump allegedly works with 500 W / 4 A.

Test set up with 1300 l/h pump

Testing smaller areas of suction to create higher pull

Test set up recreating the Seabin

Several factors were identified that could have influenced the pump's performance:

- Hose Resistance: The 3-meter-long hoses used likely created resistance, reducing the pump's suction efficiency. While this setup was representative of real-world applications, shorter hoses might improve performance.
- Bucket Positioning: By reducing the water surface area interacting with the pump (e.g., narrowing the circumference of the bucket's intake), the system might enhance suction power and direct debris more effectively.
- Directional Water Flow: The water expelled by the pump could be strategically used to push floating debris toward the collection point, enhancing the system's overall efficiency.

Considerations

- Future tests could explore pumps with varying power and flow rate specifications to determine the optimal balance for this application.
- Submersible pumps are more efficient and quieter but require more maintenance and are costlier.
- Non-submersible pumps are easier to maintain and less expensive but are less efficient and noisier, making them more suitable for shallow-water applications.

Alternative Methods to Create Water Flow

Besides electric pumps, other methods could be studied to generate water flow:

- Propellers or motors
- Water jets
- Gravity-driven systems: water flowing downhill or through sloped channels can create sufficient movement without mechanical components.
- Natural currents and wind: utilizing natural forces like wind, combined with strategically placed barriers or booms, could direct debris without additional energy inputs.

Main Takeaways

While creating a pull in the water could increase waste capture efficiency by attracting more waste in less time, further development of this approach will not be pursued due to complexity of successfully integrating a powered systems onto the project's time-frame. Instead, this project will aim to focus on containing waste at its source to prevent it from traveling to larger waterways and causing greater environmental harm.

While this method may not achieve the same level of capturing efficiency as powered solutions, it will contribute to a significant positive impact by intercepting debris before they spread further and creating awareness about plastic pollution in highly densely populated areas.

Next Steps

Moving forward, the **project will focus solely on embracing natural forces**, studying wind patterns, natural currents, and areas where waste naturally accumulates. This decision not only simplifies the system but also eliminates the need for power sources, **prioritizing low-maintenance, affordable, and scalable solutions**.

By focusing on containment rather than maximizing catching efficiency, the project seeks to deliver a simple yet practical system that aligns with its environmental and logistical needs.

D) BRAINSTORM SESSION

Brainstorm session

Small catching system for city centers

Rules (5 minutes)

Criticism is postponed

Try not to think of utility, importance, feasibility. No critical remarks upfront. Avoid participants feeling attacked.

Freewheeling is welcomed

The purpose is to express any idea that you can think of; ‘the wilder the idea, the better’.

Quantity is wanted.

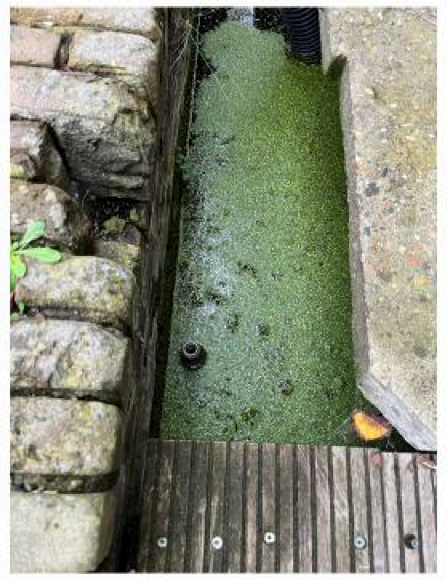
Try to think of as many associations as possible. The objective of this rule is to attain a high rate of association.

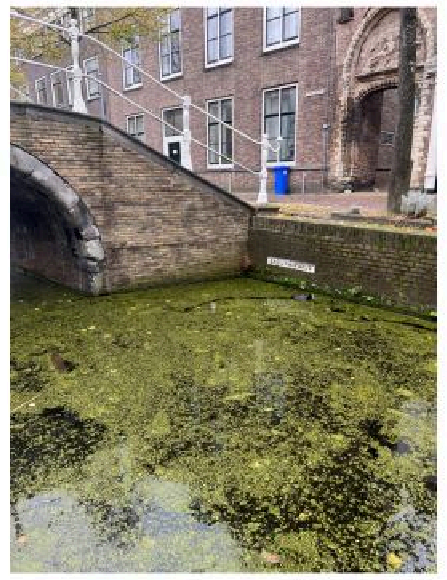
Combination and improvement of ideas

Build upon the ideas of others.

Contextualisation (5 minutes)

Noria already has two catching systems in their catalogue, but they are too big to be installed in city areas where **canals are narrow**, there is **continuous boat traffic** or there are **different obstacles like boats disrupting the canal shapes**.



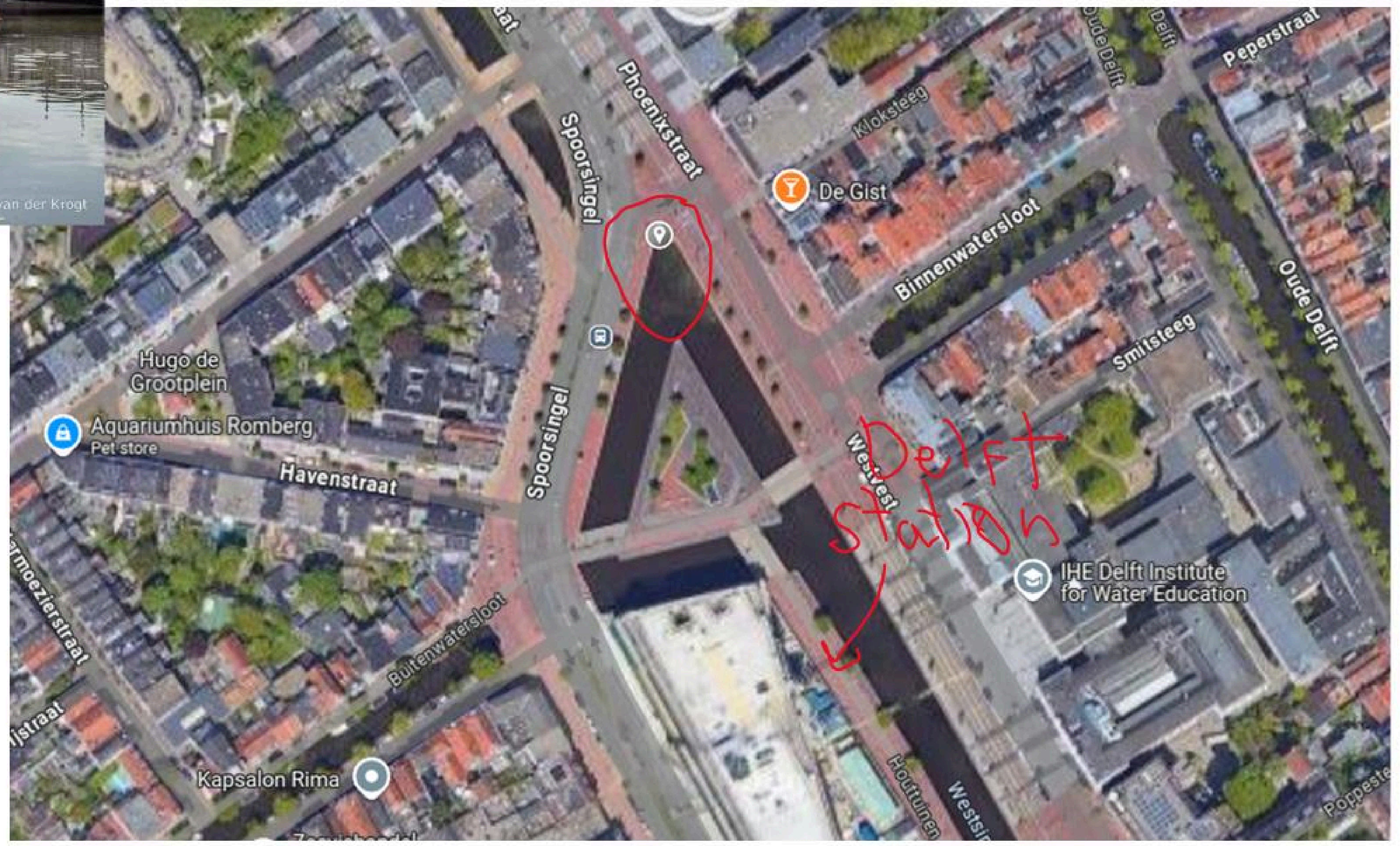


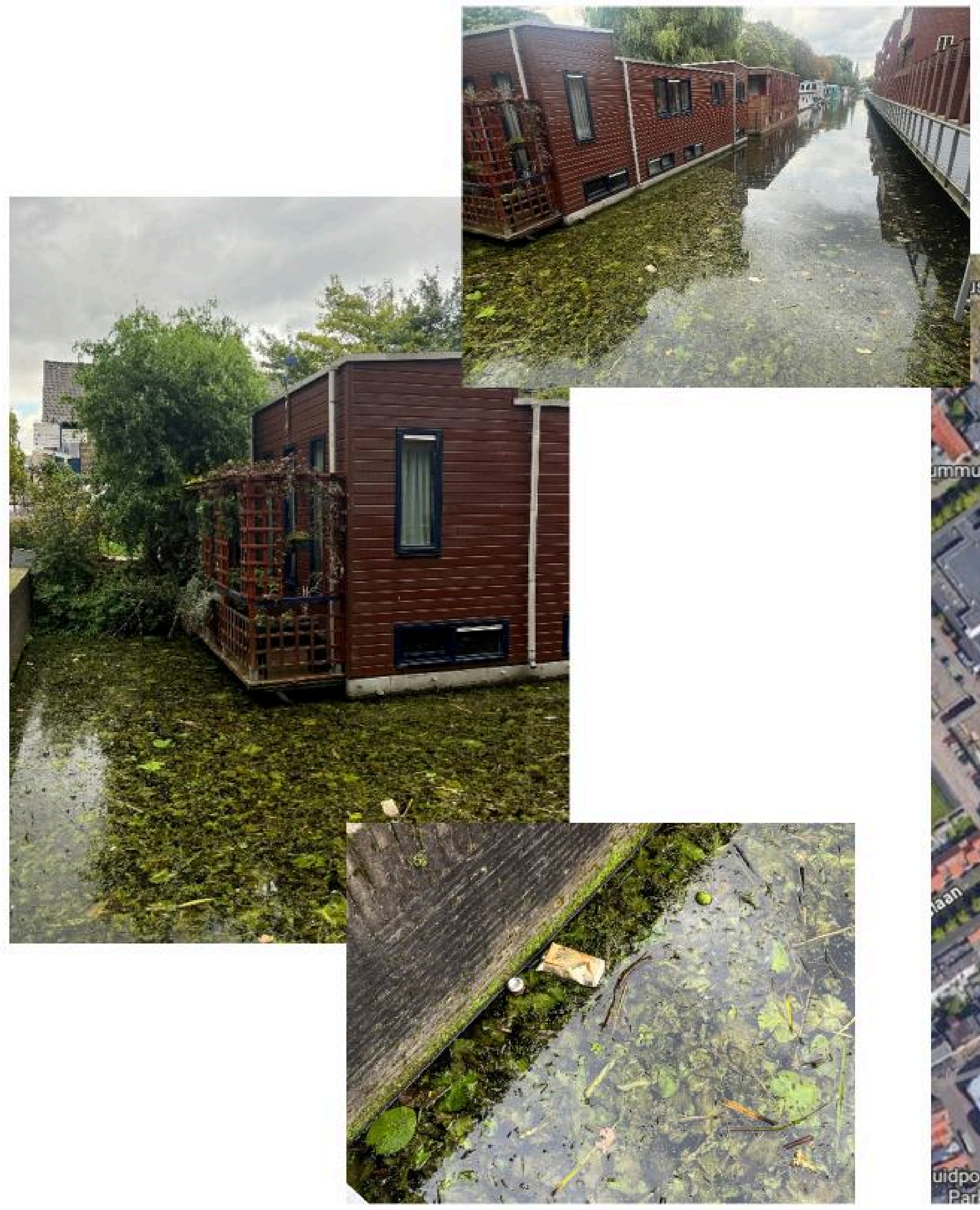
location

- corners

societal behaviour

- next to train station
- next to social spots
- tourist attractions





location

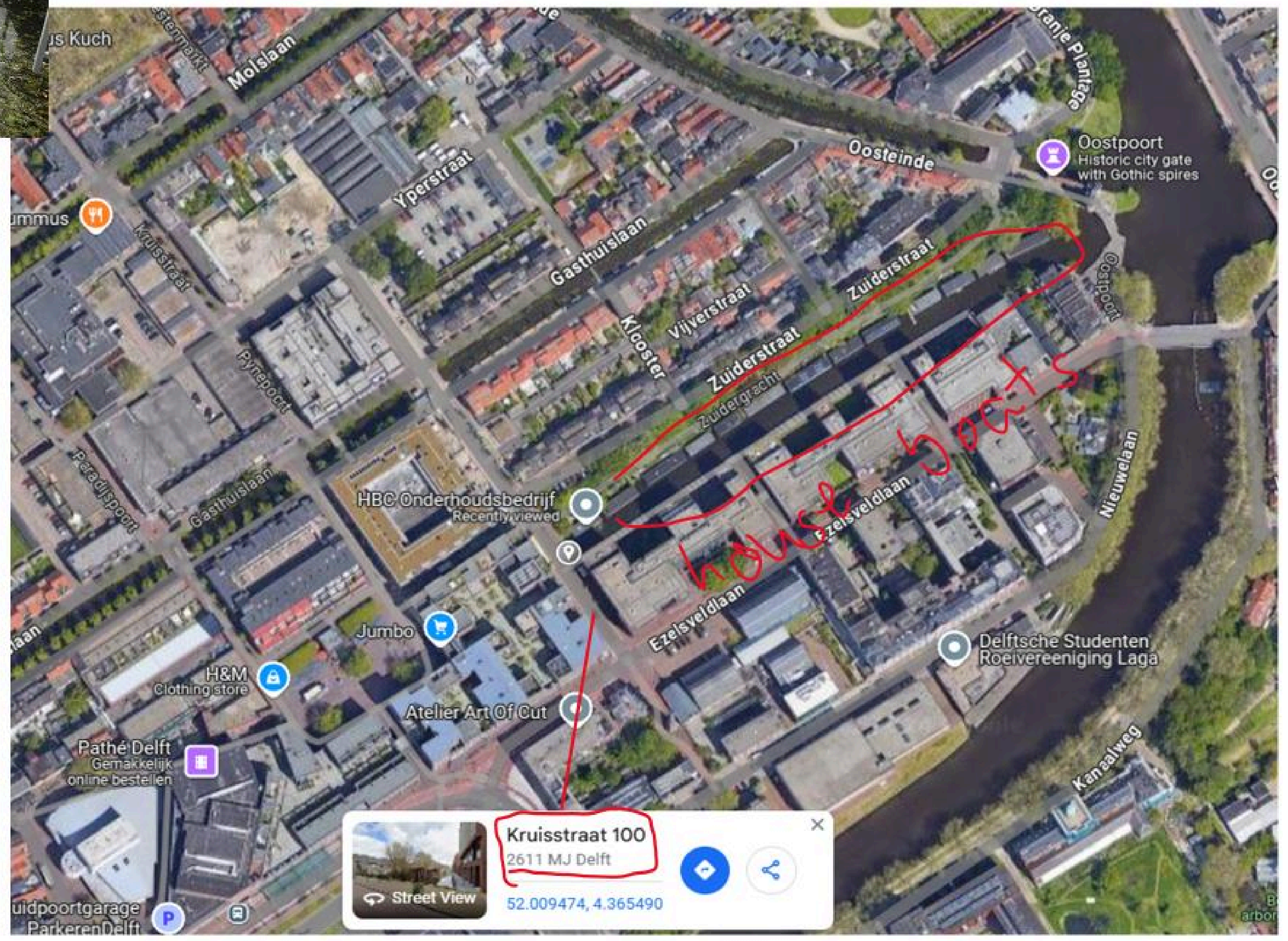
corners

house boat

societal behaviour

next to social spots

tourist attractions



Provocative questions

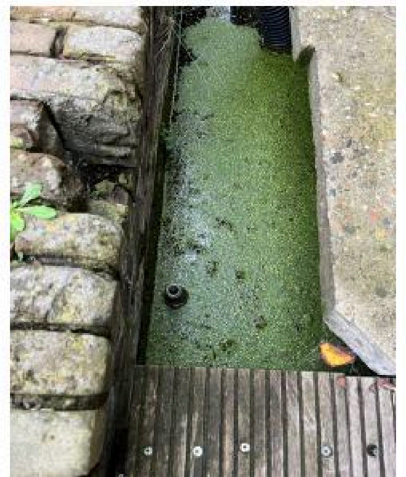
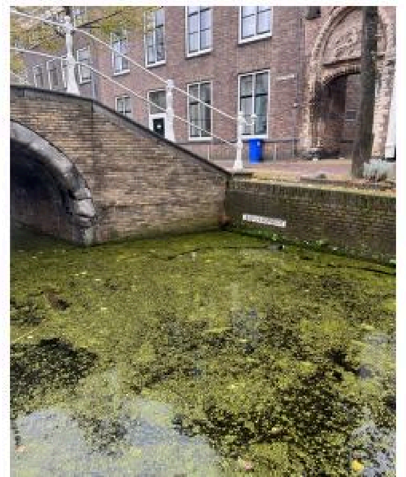
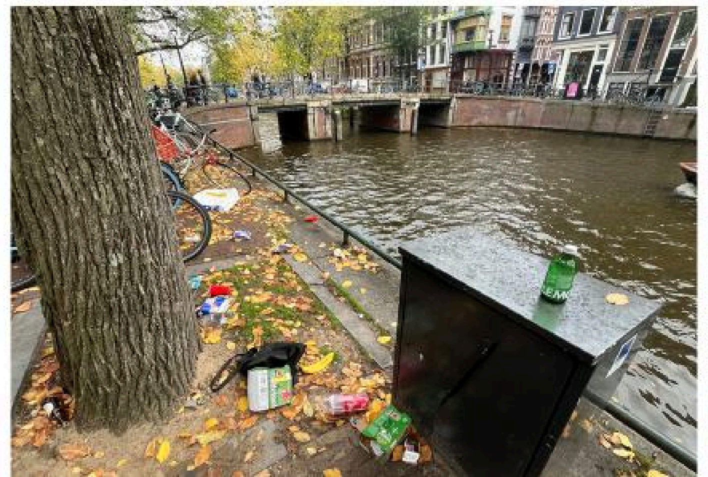
1. Provocative question is presented
2. 5 min - Brain writing and/or Sketching
3. 10 min – Share ideas and merge
4. Repeat two other times (45 min)

5. Together combining/ merging ideas (15 min)

Provocative question 1

- What elements of a canal's unique environment might actually enhance our design instead of limiting it?

  *Think about
  - Canal shape
  - Obstacles
  - Tight spaces
  - Social hubs


Provocative question 2

- How could the system capture trash even when there's minimal water movement?

  *Think about
  - Power sources: human? machine?
  - Does the system consist of multiple elements?

Provocative question 3

- If emptying the system was as simple as possible, what would that process feel and look like?
  *Think about
    - Who takes care of the emptying?
    - Do you need equipment?
    - How often?
    - How ergonomically is it?

Converge

- Selection of the most promising ideas
- Evaluation
- Ideas on how to move forward

E) TESTING PERMIT FROM THE MUNICIPALITY OF DELFT

Klant Contact Centrum

Vergunningen en Vorderingen Sociaal Domein
Postbus 78
2600 ME Delft
Internet (ook voorafspraken): www.delft.nl
Telefoon: 14015

Retouradres : Gemeente Delft, Klant Contact Centrum, Postbus 78, 2600 ME Delft

Mevrouw A. Belenguer Marti
[redacted]

Datum
16-04-2025
Ons kenmerk
D2025-116069
Dossiernummer
Z2025-001523
Uw brief van
D2025-116069
Uw kenmerk
Z2025-001523
Bijlagen

Onderwerp
Plaatsen "Waste trapping system for urban waterways"
d.d. 23 t/m 30-4 en 19 t/m 26-05-2025 Hooikade 13

Geachte heer/mevrouw,

U heeft op een ontheffing aangevraagd voor het plaatsen van een voorwerp over of boven openbaar water. U gaat een " Waste-trapping system for urban waterways" boven het water aan de Hooikade ter hoogte van nummer 13 plaatsen. Het betreft een project door een student Integrated Product Design van de TU Delft. Het systeem wat wordt geplaatst is een pilot versie en zal met verschillende touwen aan de bestaande metalen ringen die aan de grachtenwand hangen worden bevestigd.

Wat hebben wij besloten?
Wij hebben besloten u de gevraagde ontheffing te verlenen.
De ontheffing is geldig van 23 april tot en met 30 april en 19 mei tot en met 26 mei 2025 en is alleen geldig voor de locatie Hooikade ter hoogte van nummer 13.

Waarom hebben wij dit besloten?
Wij hebben uw aanvraag getoetst aan de bepalingen in de Verordening Openbaar Gemeentewater Delft (VOGD)

Voorwaarden van de ontheffing
- U mag de vaarweg niet versmallen
- U moet zich houden aan de voorschriften en regels genoemd in de bijlage. Als deze niet worden nagekomen, kan dat leiden tot het intrekken van de ontheffing.
- U bent 24 uur bereikbaar in verband met eventuele calamiteiten.
- Bij overlast moet het object direct verwijderd worden.

Kosten
Er zijn geen kosten aan verbonden.

Bezwaar maken
Bent u het niet eens met dit besluit? Dan kunt u binnen 6 weken na dagtekening een bezwaarschrift indienen.
Op www.delft.nl/bestuur-en-organisatie/klacht-en-bezwaar/bezwaar-maken leest u hoe u dit kunt doen.

Vragen?
Heeft u nog vragen over de ontheffing of deze brief dan kunt u contact opnemen met het klantcontactcentrum (KCC) via het contactformulier op www.delft.nl/contact of via telefoonnummer 14015.

Hoogachtend,
Het college van burgemeester en wethouders van Delft,
Namens het college,

Mevrouw M.M.E. Link, Afdelingshoofd Burgerzaken en Vergunningen & Vorderingen Sociaal Domein.

F) NEWSPAPER ARTICLE

PREMIUM

▲ Anna Belenguer Martí met haar ontwerp van The City Cleaner © Nico Schouten

Anna's 'City Cleaner' gebruikt wind en stroming voor afvalvrije Delftse grachten

Varend en wandelend onderzocht Anna de beste manier om afval uit de Delftse grachten te krijgen. Het resultaat: een houten constructie bij de Hooikade. Het ontwerp doet wat het moet doen, maar ze wil het nog verfijnen. Tot haar spijt gaat de constructie woensdag alweer weg.

Maurice Gispen 30-04-25, 04:00

Hoe krijg je afval uit de gracht zonder eindeloos met je handen in het water te graaien en zonder elektriciteit te gebruiken? De Spaanse TU-studente Anna Belenguer Martí houdt zich hier al maanden mee bezig voor haar afstudeerproject The City Cleaner. In haar thuisland is ze vooral gewend aan de zee - een wereld van verschil met de talloze grachten en dijken in ons kikkerlandje.

Daarom wandelde ze uren door de Delftse binnenstad, ging ze mee met vrijwilligers die vanaf de voormalige Canal Hopper vuilnis uit het water halen en dobberde ze staand op een plankje door het water. Alleen op die manier kon ze genoeg inspiratie opdoen voor haar ontwerp. De plek die het meest haar aandacht trok was de hoek bij de Hooikade.

Ideaal

„Hier fiets ik elke dag langs als ik van huis naar de universiteit ga. Bijna elke dag drijft hier afval." Daarnaast kan volgens haar ook de binnenstad een opruimhulp gebruiken, maar door het drukke vaarverkeer is het niet zomaar mogelijk hier een installatie in het water te leggen. „In de Canal Hopper moeten vrijwilligers soms best ver uit de boot hangen om iets te kunnen pakken, dat is niet ideaal en het zou niet nodig moeten zijn."

Bij het Delftse bedrijf Noria Sustainable Innovators gaven ze haar een opdracht. „Zij hebben twee ontwerpen die vooral te gebruiken zijn in grote wateren, die niet bruikbaar zijn in de binnenstad." Al snel ziet ze dat een 90-graden-hoek dé plek is waar afval vanzelf naar toe drijft.

▲ The City Cleaner heeft een week bij de Hooikade gelegen. © Nico Schouten

Dus besluit ze gebruik te maken van de stroming en de wind. Als die een handje helpen, maakt zij de constructie waar het plastic instroomt zonder er nog uit te kunnen. Met hout en 'zwemnoodles' drijft het in het water.

In de hoek liggen een ballon en een kwarkbakje. Nu is het alleen nog een kwestie van het roestvrijstalen mandje naar boven halen en die boven een herbruikbare vuilniszak te legen. Ze demonstreert het behendig.

In de week dat haar installatie in de gracht dobbert, is ze vijf keer per dag langsgegaan om het mandje te legen. De eerste dagen was dit hard nodig, inmiddels lijkt er minder afval te zijn. Of dat komt doordat de installatie genoeg inzamelt of door de stroming en het weer, kan ze (nog) niet beoordelen.

Condoom

„Ik heb nu niet langer dan zes maanden voor mijn afstudeerproject helaas." Had ze meer tijd, dan kon ze bijvoorbeeld een volgende oplossing voor de grote hoeveelheden kroos in het water zoeken. „Nu blijft veel plastic liggen omdat het stilstaat in het kroos."

"

Nu blijft veel plastic liggen omdat het stilstaat in het kroos

- Anna Belenguer Martí

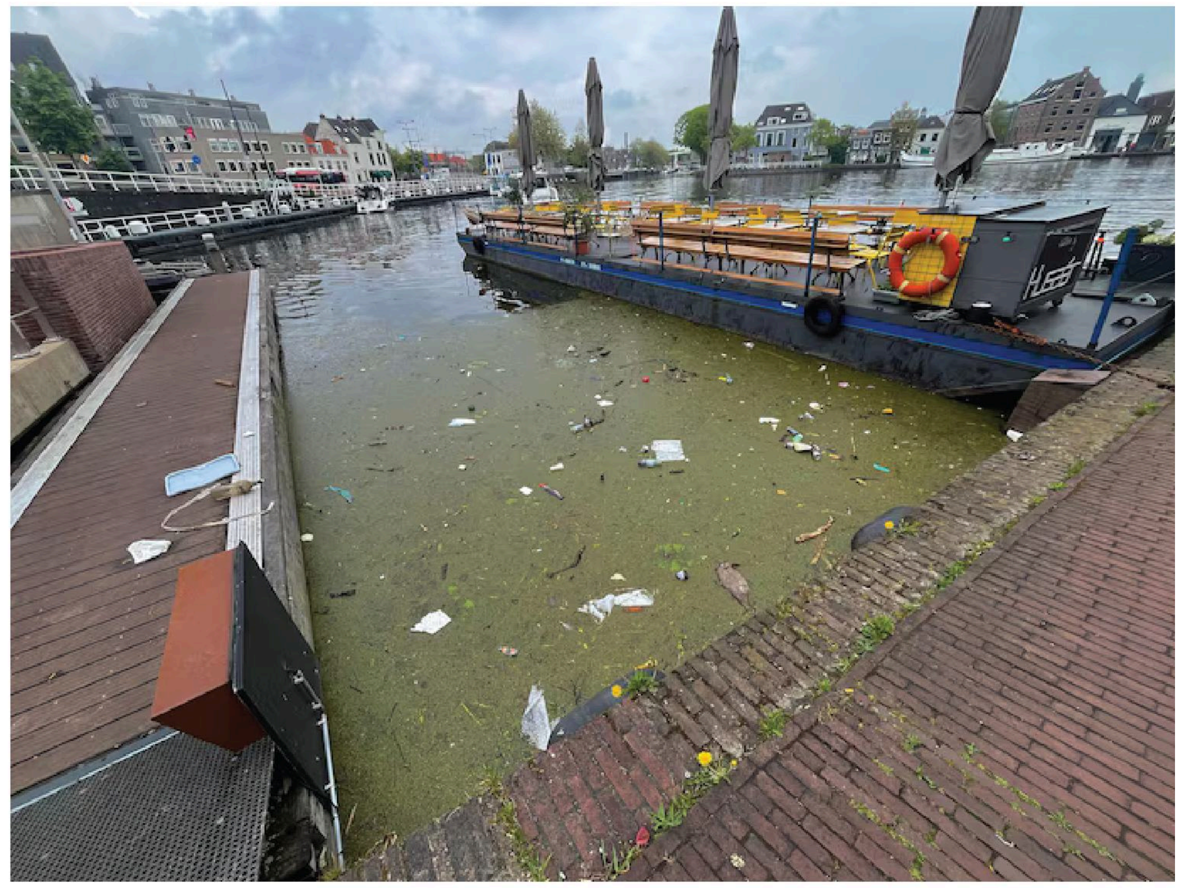
Tijdens haar bezoekjes maakt ze foto's en aantekeningen en analyseert ze haar bevindingen. Dat moet straks allemaal in haar scriptie verwerkt worden. Naast verpakkingen vond ze ook een condoom, een dode rat en een dode vis.

Ze is realistisch over de kleinschaligheid van haar ontwerp. „Ik denk niet dat ik hiermee het hele afvalprobleem kan oplossen. Maar door met voorbijgangers in gesprek te gaan en de zichtbaarheid van mijn ontwerp in het water, hoop ik dat iedereen zich wel wat bewuster wordt." Vooral omdat het volgens haar moeilijk is één iemand verantwoordelijk te houden voor vuil in het water.

Het liefste wil ze haar ontwerp misschien verhuren tijdens evenementen of een vaste plek in de stad geven. Op woensdag haalt ze de installatie weg, zoals afgesproken met de havenmeester. De eerste indruk van de gemeente Delft is dat het ontwerp 'mooi en eenvoudig' is. Mocht er meer tijd nodig zijn, dan is er ruimte om het hier over te hebben, laat een woordvoerder van de gemeente weten.

Lees ook
Kadaver aan boom en overal troep: warme dagen in park zorgen bijna altijd voor discussie

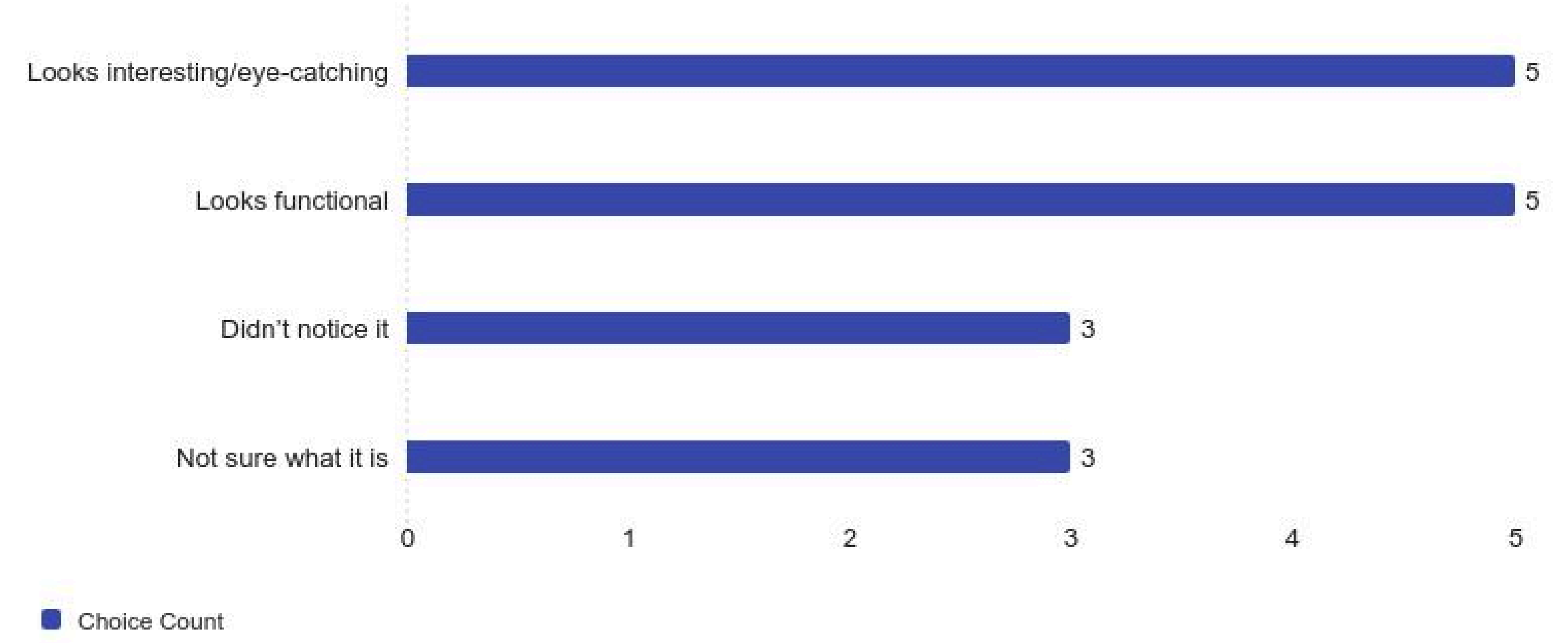
Vrouw van cabaretier Pieter Jouke kreeg borstkanker: 'Dat hele klimaat kon me niets meer schelen'



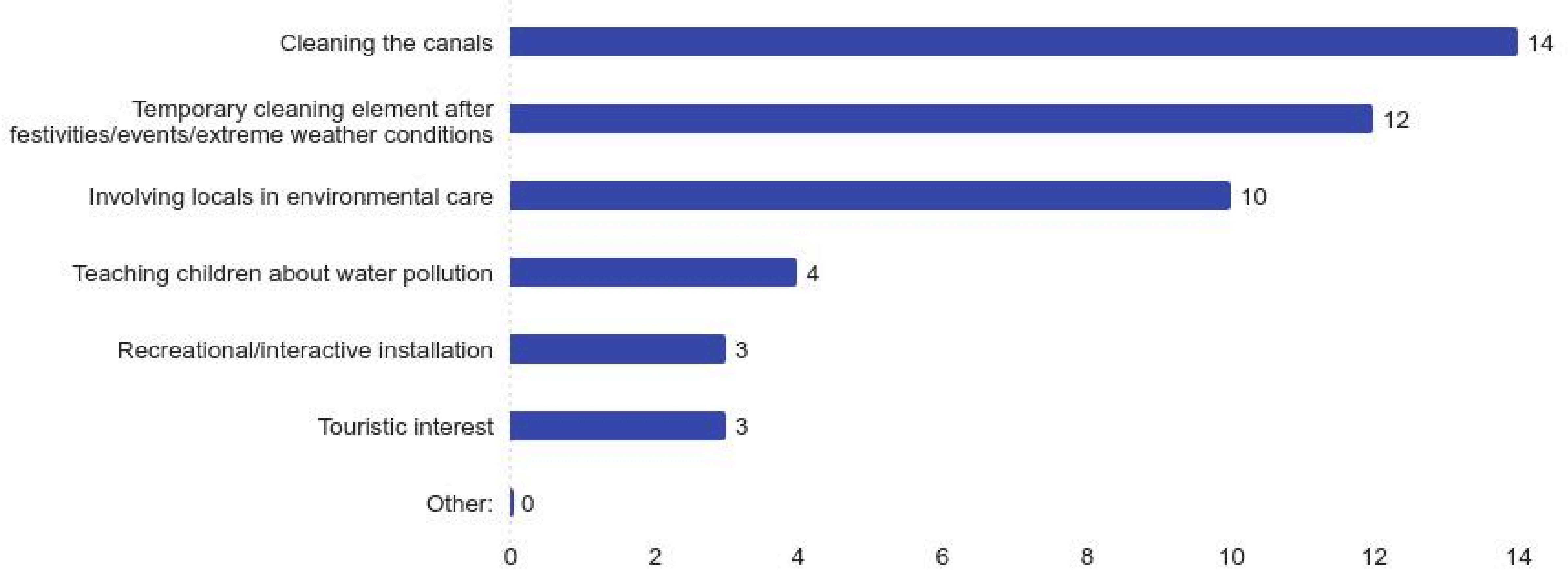
▲ Het water bij de Hooikade voordat Anna The City Cleaner installeerde. © privéfoto

G) SURVEY RESULTS

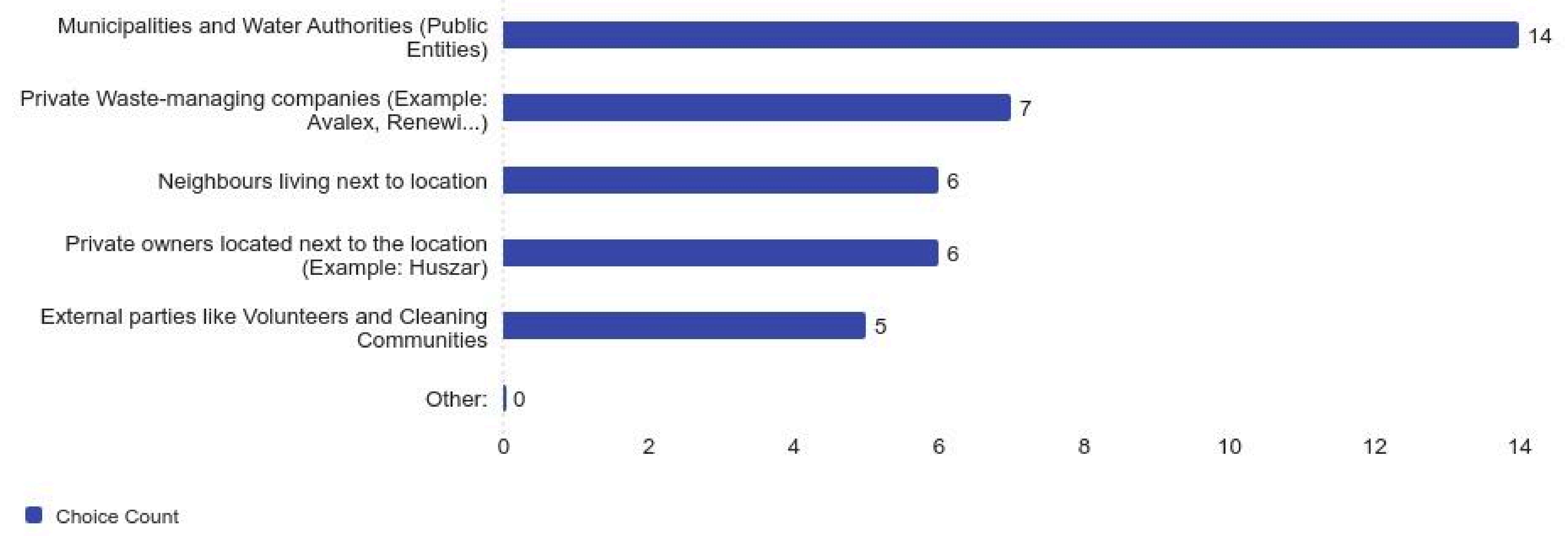
What was your first impression when you saw this system in the water? **81 % SAW THE SYSTEM**



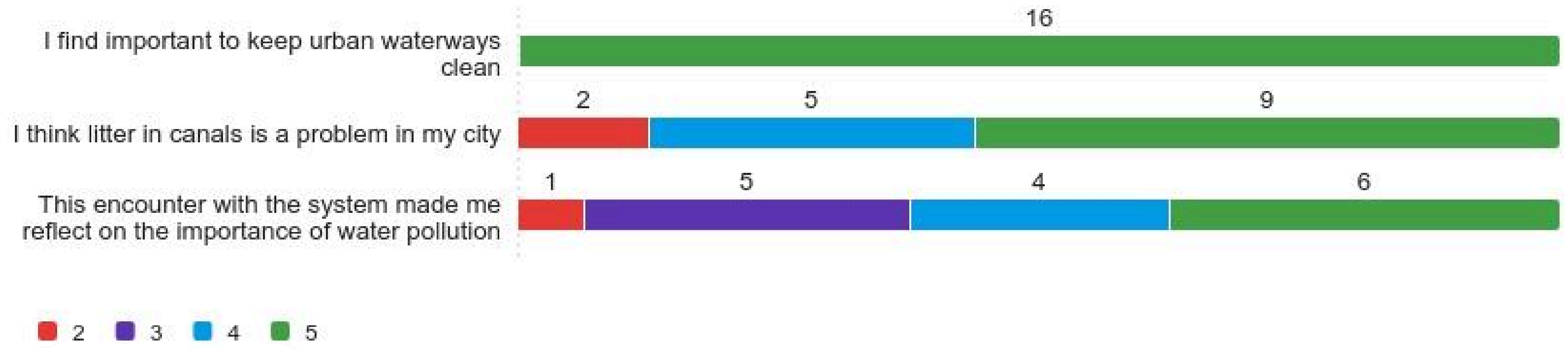
How do you see this system playing a role in city life? (Multiple choice) - Selected Choice



Who do you think should take responsibility for retrieving trash in urban canals? (Multiple choice) - Selected Choice



On a scale from 1-5, rate these statements:



What do you think this system is for? **87 % RECOGNIZED IT AS A CLEANING DEVICE**