Project Report for Systems Design and Engineering

University of South-Eastern Norway
Faculty of Technology, Natural Sciences, and Maritime Sciences

Subject: MPSE2201-1 19V Systems Design and Engineering	
Members:	
Navid Muradi	Jens Roksvaag Paulsen
Rahmat Mozafari	Kristoffer Grønsvik Andersen
Øzlem Tuskaya	Marius Kulik Balsvik
Lecturers:	
Jamal Mohammed Attaya Safi	
Gerrit Jan Muller	
Date: 08.04.2019	
We confirm that this work is entirely ours:	
Navid Muradi	***Jens Roksvaag Paulsen***
Rahmat Mozafari	***Kristoffer Grønsvik Andersen***
Øzlem Tuskaya	***Marius Kulik Balsvik***

Abstract

In this project we had the goal of developing a potential solution for the massive problem of ocean pollution that we currently face. We developed several concepts, touched many aspects of systems engineering, and chose the most feasible and best fitting one. This document can be considered as a supplement to our presentation on monday 8.4.19. The report will attempt to showcase in a more detailed way the development process as a whole, the changes that were made and the reasoning behind them.

Table of Contents

List of Figures

List of Tables

The Problem And The Task

The ocean is being filled up by garbage, plastics and other waste materials and a majority of this floating waste originates from the mainland through river systems. Humans produce and use plastic at a staggering rate and a big portion of this is of the kind that is meant to be thrown away and not re-used. This overuse of plastic in our daily life makes it abundant everywhere. The problem with many types of plastic are their inability to decompose naturally. Those types will never really disappear but will instead break down into smaller and smaller pieces called micro-plastic. Plastic floating around in the oceans is dangerous to marine life. If the wildlife tries to interact with the floating plastic it can lead to them getting trapped and/or suffocated. Some of the micro-plastic even ends up in humans after we eat the animals/fish and all the long-term effects of this are still not fully known.

A problem of this magnitude probably needs to be attacked at different angles and at different levels but this is clearly a market opportunity. We will therefore, probably as part of a bigger overall solution, practice systems design and our engineering skills in developing an autonomous system that can catch and contain macro-sized plastic floating in rivers.

1 Systems Engineering Model

The model we tried to follow in the project was the CAFCR model. This model decomposes the systems engineering approach into five different views. These views are *Customer objectives*, *application*, *functional*, *conceptual* and *realization.*

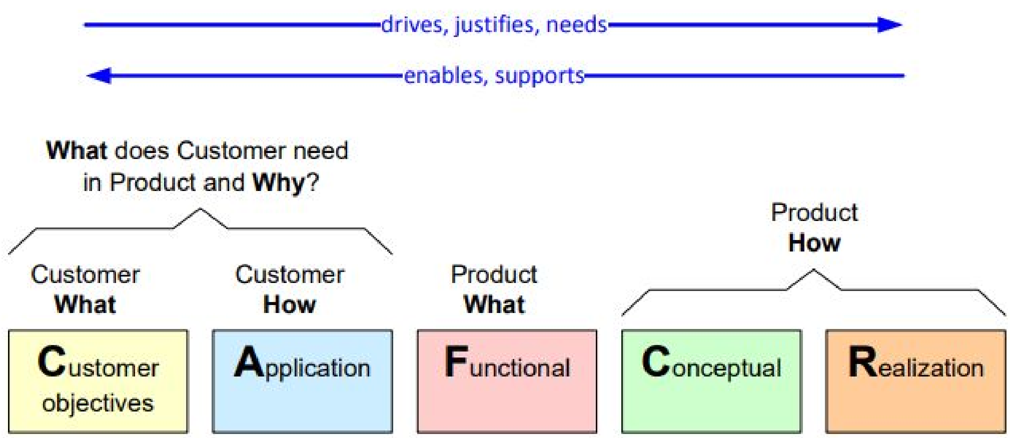


Figure 1: The “CAFCR” Model, *retrieved from [1]*.

Each of these views fulfill a different purpose which as an end goal should result in the development of a better fitting solution. The goal of the *customer objective* view is to explore what the customer wants, meanwhile the *application* view tells us how the customers realize these “wants”. These two combined lets us explore the needs of our customers. In the *functional* view we explore the whats of the product, this view explores the system needs which also includes non-functional ones. In the *conceptual* view and the *realization* view we explore the hows of the system. The goal of the *conceptual* view is to map the different aspects of a concept, meanwhile the goal of the *realization* view is to analyze the realization aspect of the system, in other words this view explores how the system should be realized. This is why the “how” of the system was divided into two views. Technology is constantly changing and old technology becomes outdated. This is why the conceptual view is maintained over a longer time period than the fast changing realization [1].

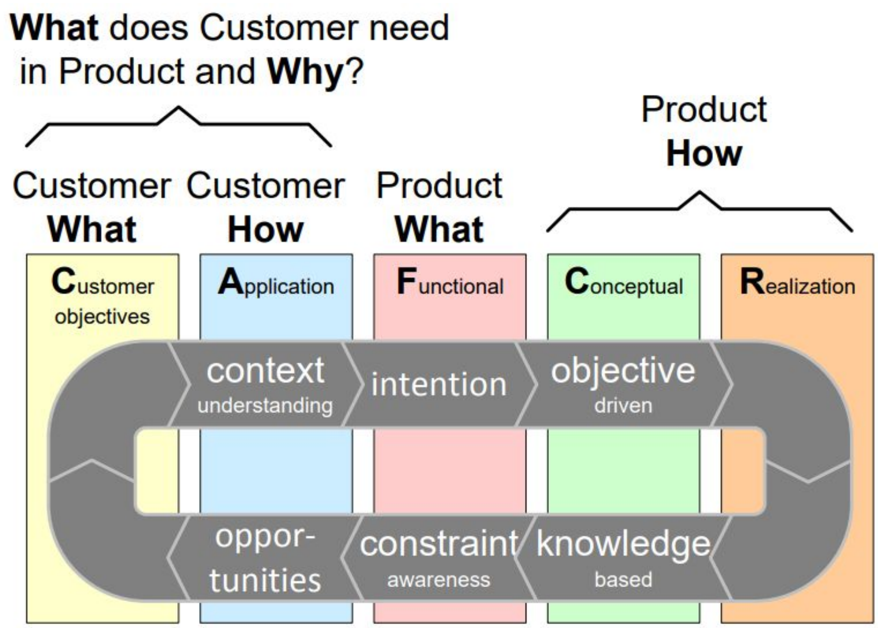


Figure 2: Iteration over the CAFCR, *retrieved from* [1].

Furthermore one last view that affects specifications and design is the operational view, this view explores the internal requirements of the company [1]. In this view one touches the business aspect of the system like sales and manufacturability. The CAFCR approach works in multiple iterations with main focus on integrating all the viewpoints. Frequently changing views through multiple iterations will enable us to better capture all needs and integrate the procured information into a better system. In addition the successive change of viewpoints will result in a more thorough understanding of the system.

2 Risk Management Process

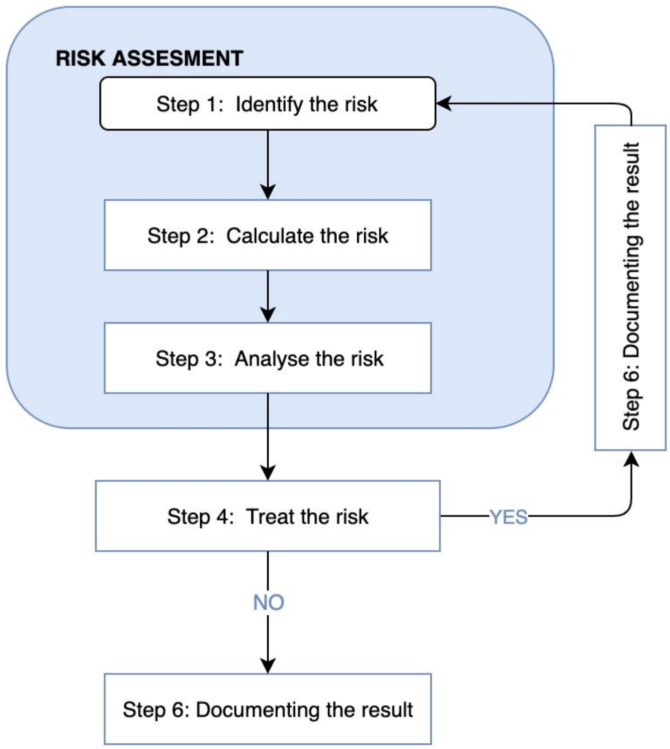


Figure 3: Risk Assessment Steps.

Risk are everything that can have negative impact to the system. Risks can emerge by wrong decisions from us and it can also stop the progress of the project. Therefore it's important to identify, calculate and analyze the risks and come up with mitigation strategies to reduce or eliminate the possibility of a risk. We used this figure above to make a risk management process. By using this process it helped us make a failure mode analysis that shows the risks with the impact to our system and the mitigation strategy.

2.1 Failure Mode Analysis

RISK MANAGEMENT MATRIX						RISK CALCULATION			
Type	Risk ID	Describe the identified risk	Impact of risk	Conseq	Likelih	Cons	Likel	RiskSc.	Mitigation Strategy
Environmer	R1	New requirements appear during the project	Slow down the delivery time	Trivial	Likely	1	4	4	Consider requirements through the project life-cycle
Financial	R2	Budget does not support suggested concept	Can not make it as we want, change things	Catastro	Possible	5	2	10	Work with system requirements trough the project to follow our budget
Technical	R3	All requirements have not been captured	Maybe not negativly impact	Significar	Quite Po	3	3	9	Consider requirements through the project life-cycle
Life-cycle	R4	Long delivery time of system parts	Slow down the delivery time	Catastro	Quite Po	5	3	15	Work with system requirements trough the project to follow our budget
Life-cycle	R5	System out of control	Drive on people	Catastro	Possible	5	2	10	Always test before going to next step
Life-cycle	R6	Not finished on time	Less earning	Catastro	Quite Po	5	3	15	Work with system requirements trough the project
Life-cycle	R7	Mechanical failure of system during testing	Slow down the delivery time	Significar	Possible	3	2	6	Design with safety factors
Technical	R8	Occlusion of sensor	Unnecessary visit to docking for emtying garbage	Catastro	Possible	5	2	10	Test it and have something over the sensor
Technical	R9	Malfunction in separation compartment	System will not sort	Significar	Possible	3	2	6	Use the best sorting option system
Technical	R10	System shut down	System will be damaged	Catastro	Not Like	5	1	5	Discuss concept with regards to requirements
Technical	R11	Lost connection between user app and system	Lose manual control, if something went wrong	Trivial	Not Like	2	1	2	Design with safety factors
Life-cycle	R12	Delivery of wrong system parts	Slow down the delivery time	Trivial	Possible	2	2	4	Give clear spesification of parts we order and check shipping documents from suppliers

Table 1: Table of Identified and Classified Risks

This figure was made in order to keep a record of all data. It shows our risk analysis and its impact to our system and what we can do to mitigate the risks. The risks were identified by using our risk management process and assigned a class such as life-cycle, technical, financial or environmental. Each risk is also given a risk ID that was plotted onto our Risk Matrix which helps to graphically represent the possible risks.

There are also two categories to calculate the risks. By calculating the likelihood and the consequences of the individual risks, an overall risk score was given to represent the severity of impact to the success of the project. New risks emerged through iterations and it was decided to revalidate the risks during iterations through the project.

2.2 Risk Matrix

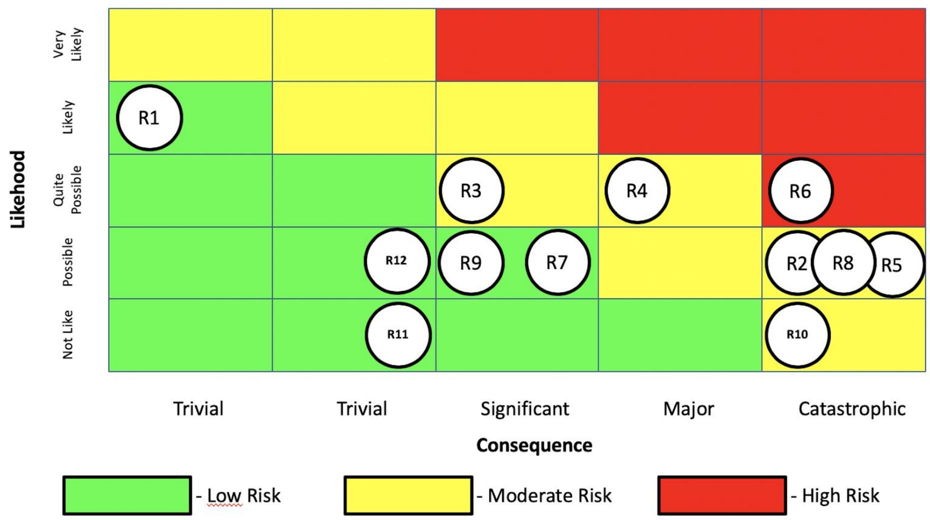


Figure 4: The Risk Matrix

This diagram was made in order to clearly visualize which risks were most critical. These risk identifications are taken from our failure mode analysis and put into this matrix true the calculations. The risk with the highest score was the system not finishing on time. This means that this risk is both quite possible to occur and the consequences of occurrence are catastrophic. The planned strategy was to make sure that other risks do not occur, risks like delivery of wrong parts or long delivery time of system parts, the budget does not support suggested concept and mechanical failure of the system. If we make sure that other risks do not occur then this main critical risks won't occur. We also made an Fault Tree Analysis for this critical risk, to see the main reason for occurrence.

This risk matrix helped the project members to easily get an overview of which risks we should most pay attention to. The risks was revalidated through the iterations and the mitigation strategy for the most critical risks was discussed.

2.3 Fault Tree Analysis

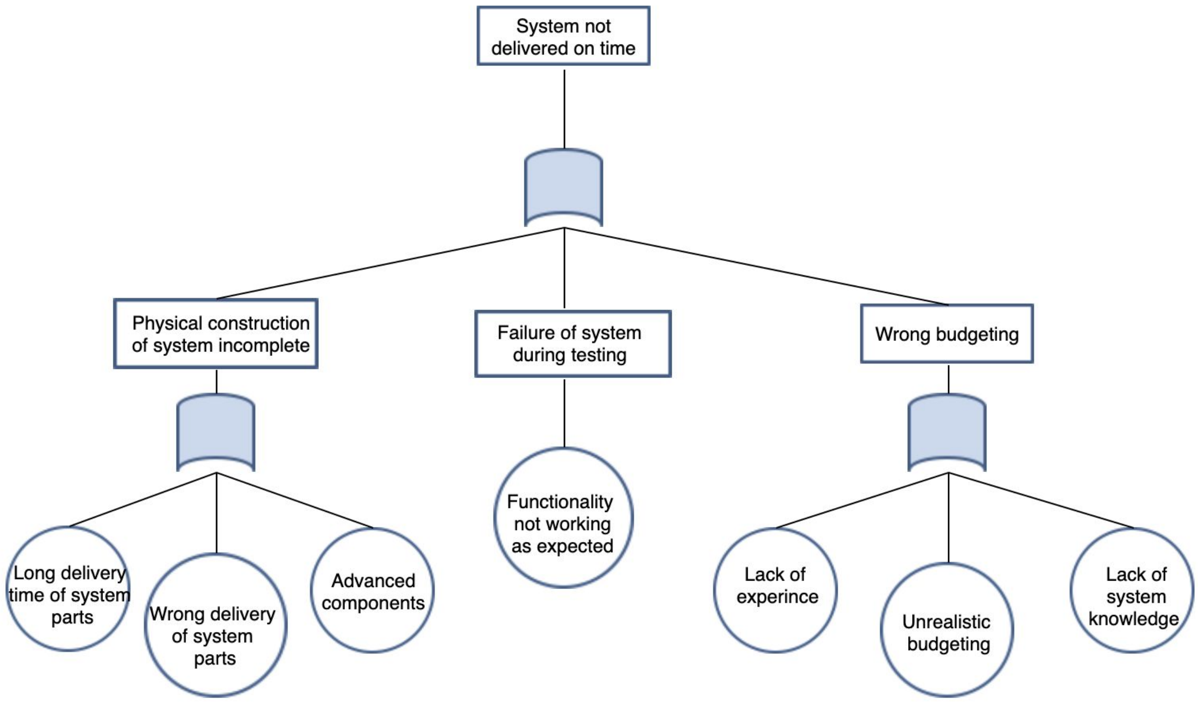


Figure 5: Fault Tree Analysis

Fault trees shows what is the underlying reason for the main risk. We chose the most catastrophic risk from the risk matrix and made a fault tree analysis. In this figure, we see the main cause of failure which is not finishing on time. We will consider these causes through the development life-cycle so this failure doesn't happen. We did also a lot of research to learn about the different causes like budgeting, ordering and sending good order specifications of the products, so wrong delivery doesn't happen. This figure helped us starting early with taking into account the main causes and reviewing the figure kept us reminded of these causes.

3 Market Opportunity

When looking for market opportunities we tried finding some potential customers for our system. We looked at potential customers whose interests would align with what our system would accomplish and found municipalities to be the most logical customer target. We looked at how our system would fit in with the municipalities already pre-existing waste management facilities. Figure 6 shows this.

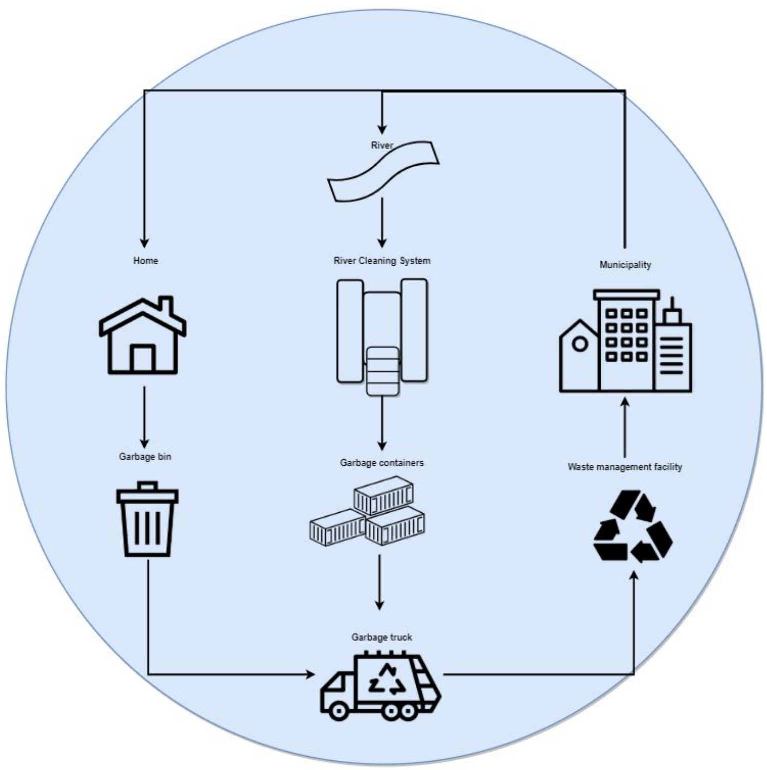


Figure 6: Our System As a Part of the Municipality Waste Management

Another potential market opportunity would be collecting and selling the waste ourselves. But waste carried downstream a single river in Norway, would not be sufficient to make enough profit to keep the current system maintained, and to expand the business producing more systems.

Next, it did not seem realistic either for an inexperienced team to pop up in asia pick out one of the most polluted rivers in the world, ask for funding in the millions, and only then start developing the system.

Especially since existing systems are already in place. If the plan was to place an autonomous system in the yangtze river, companies in shanghai would not have a big reason to fund our system. As an autonomous systems greatest advantage is the circumventing the hourly wage. In a city with billion dollar businesses paying minimum wage at $30 a month, this advantage is lost.
An assumption was also made that selling plastic in asia would not net as much profit as it would in the west.

Therefore, if the system was to make a profit, and also be initially sold in Norway, we first had to figure out a way for the system to be desirable for the many municipalities in Norway. Starting with Kongsberg, how could the municipality be convinced into buying a system solving this problem that seemingly solves itself from the municipalities view? For them plastic in the river is only a problem for as long as it is inside Kongsbergs border, after awhile it floats downstream outside the border and disappears from their point of view.

Because of this we need to convince the municipality by creating a cheap solution that has minimal effect on the daily life of their residents, and most importantly does not require big changes in their already existing waste management procedure. This is why the river cleaning system is tailored to suit the existing waste management procedure found, not only in Kongsberg, but in municipalities all over Norway.

Just as people sort their garbage outside their homes in bins, our system will do the same. The aim for this system is to require only one thing from the existing procedure, for the garbage truck to make a detour to pick up the collected river waste. The desired effect would be that, from the municipalities point of view the river is being kept clean at the cost of a new car, and logistically will have the same effect as a new house with garbage bins for the garbage truck to pick up.

3.1 Customer key drivers

We further created some key drivers to see what would be important for our potential system to have. This is to ensure that our system better fits the customer's needs and this way adds value to our end concept. As for our process, we first decided three of the most important key drivers and dissected these into what is needed to be to accomplished, what our system needs to do to accomplish this and further derived requirements for what our system will need to have to accomplish these needs.

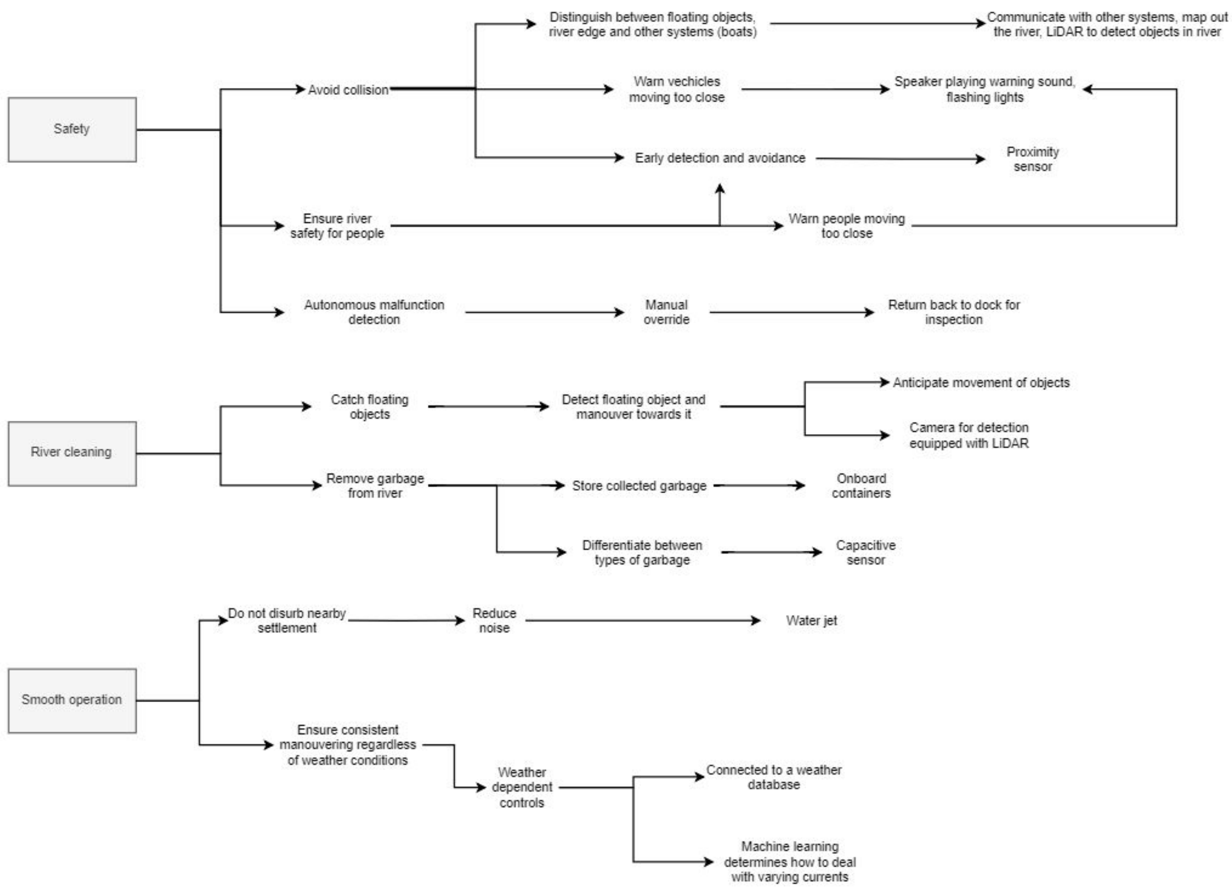


Figure 7: Customer Key Drivers

3.2 Customer Needs

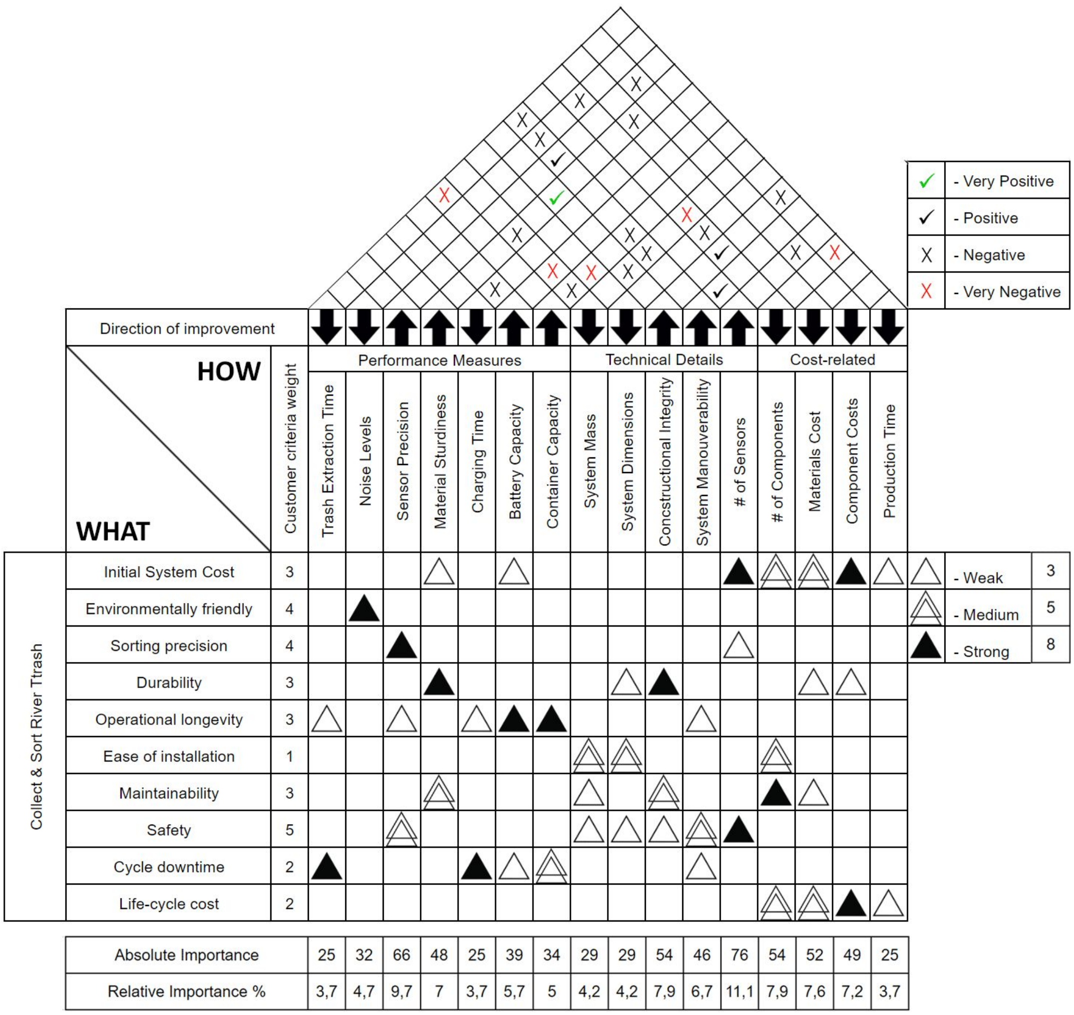


Figure 8: Quality Function Diagram.

This diagram shows the relationship between some central customer criteria and system specifics. Also represented is how change to individual system aspects influence the others.

4 Value Chain

To get a proper understanding of what activities our business would have to deal with, we created a value chain model. This is important since it helps us better understand how our business would work and what would be important points of attention when starting the business itself.

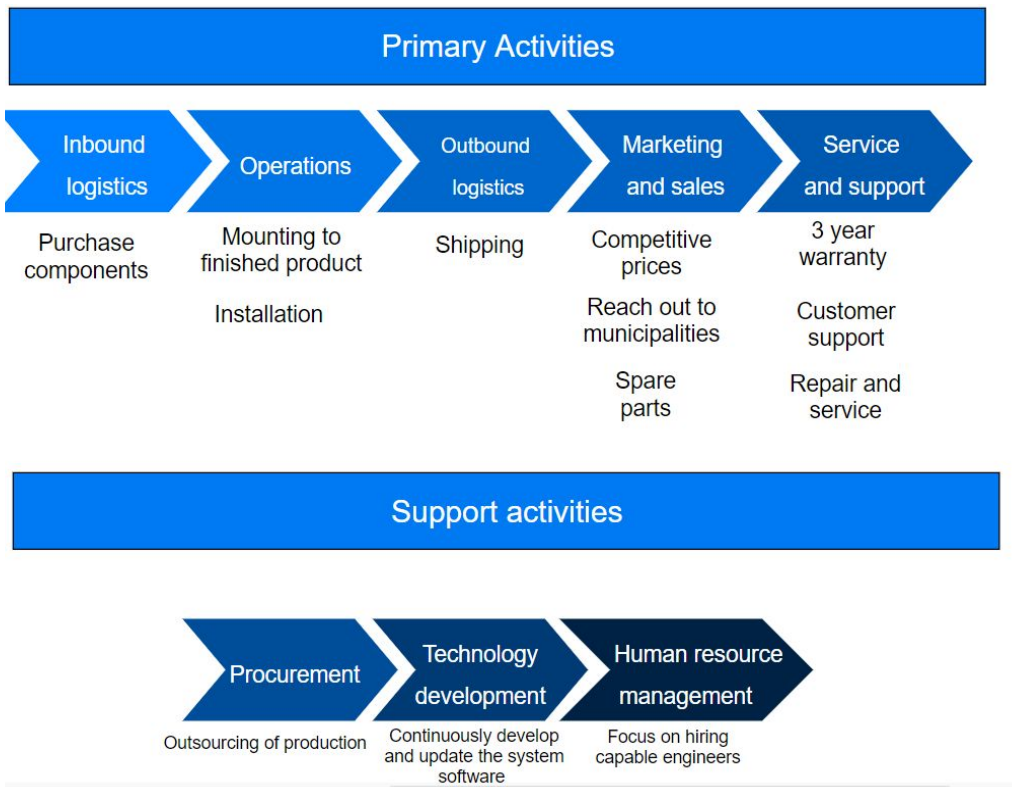


Figure 9: Value Chain of Our Business

To further elaborate on the model, our activities are:

Primary activities:

- Inbound Logistics:
    - We deal with the purchase of raw materials and components that are needed.
- Operations:
    - We deal with putting together all the components and raw materials into a finished product.
    - We offer customization for some of the parts of our system. Amongst these parts would be the container size.
- Outbound Logistics:
    - Once the system is ordered, all components and materials needed to put together the system is purchased, put together and sent out in a timely manner.
- Marketing and sales:
    - Keep the price of our system competitive.
    - Advertise our system through newspapers, social media and by reaching out to municipalities.
    - Offer the sale of spare parts and bigger software updates.
- Service and support:
    - We offer a 3 year warranty for the system in addition to always keeping the system up to date and offer smaller updates for free.
    - We also provide customer service to help our customers in case they have any questions or need help troubleshooting.

Support activities:

- Procurement:
    - Our components are procured through contractors in China that will either manufacture the components for our system for a reasonable price or order pre existing components. This further allows us to keep our pricing competitive. (Subject to change since this Chinese factories contribute to air pollution, which is the opposite of what our system is trying to do).
- Technology development:
    - We will keep our system up to date by having engineers continuously work to improve and update our system software. This guarantees our customers that our system will stay relevant for years to come.
- Human resource management:
    - We put focus on hiring capable engineers who understand the importance of communicating important information amongst each other and think critically. This ensures that everyone works together with the same goal in mind, but also think individually as well and come up with ways to improve our system.

5 Environment

To create a good solution we have to understand the environment our solution will operate in. We need to account for the impact our system will have on the surroundings and the demands it will receive in return. The width of the river will wary, as will the depth. The current will certainly change with time and there might be obstacles such as larger rocks or places with shallow water. The sides of the river may also differ greatly depending on where our system will be deployed. We will also have a focus on safety so that other parties that use the river don't get hurt. This includes people but also making sure to not harm wildlife by hurting or killing fish/birds/etc and trying to make the contained waste inaccessible for consumption by animals. To establish a better view of our system we used the context diagram model.

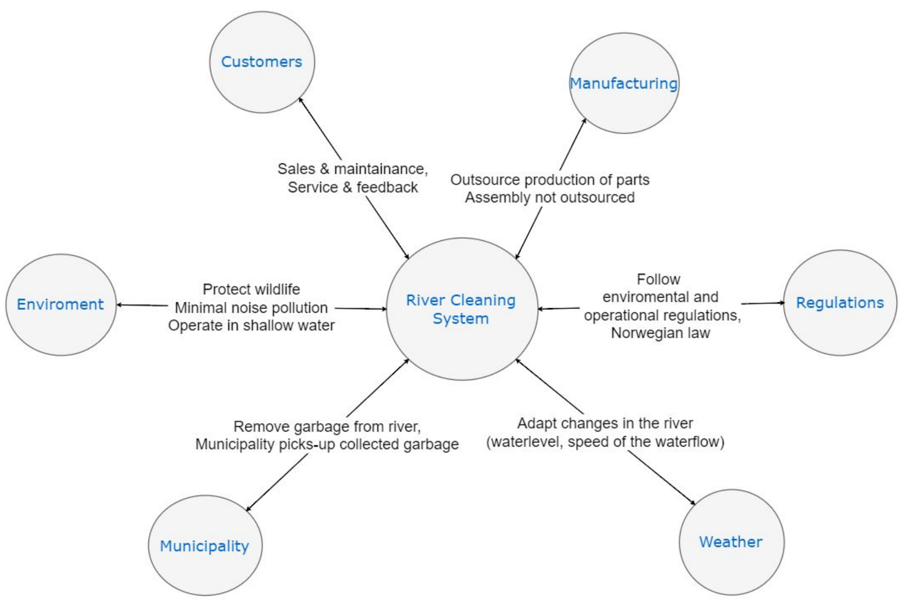


Figure 10: Context Diagram Of Our System

The context diagram gives us a view into what external factors we would need to take into consideration when developing our system and further how these factors would interact with our system.

6 Stakeholders

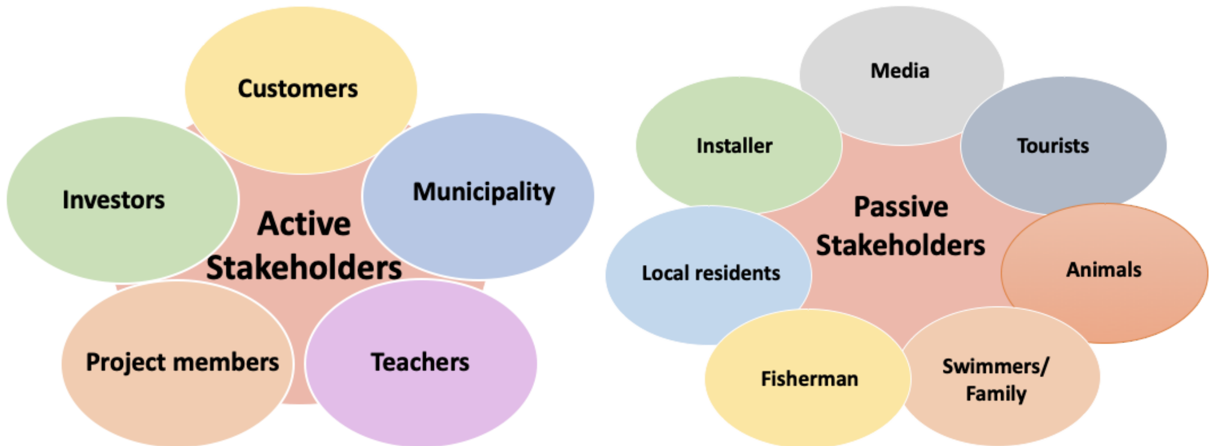


Figure 11: Active and passive stakeholders

Stakeholders are anyone who can affect or be effected by outcome of a project or through the system life-cycle. We identified our stakeholders true iterations and new stakeholders appeared during iterations. We have divided our stakeholders into active and passive stakeholders. Active stakeholders are stakeholders who are involved in our system, have an interest in the use of the system, who is responsible for the introduction and for those who involved in the development of the system. Passive stakeholders are stakeholders that are around our system, who can be affected or disturbed, who is responsible for the repair and also interest in successful finish of the system. Although we are prioritizing Norwegian municipalities as our targeted customer we need to account for the other parties our solution will come in “contact” with.

6.1 Stakeholder needs and concerns

All stakeholders have different needs and concerns depending on where in the life-cycle they are placed. We listed the major needs and concerns of each stakeholders. Later have these been translated into stakeholder requirements.

- **Internal/external customers:** Should receive an efficient and inexpensive system
- **Project team members:** Wants to satisfy their stakeholders and provide a good solution that fulfills the maximal amount of requirements
- **Teacher/Manager:** Wants a feasible concept that satisfies stakeholders and works well.
- **Government/Municipality:** Should receive an environmentally friendly system that efficiently gets rid of river plastic.
- **Sponsor:** Wants a successful system that provides good publicity.
- **Fisherman:** Should be minimally impacted by our system. Ideally notice no difference between pre and post implementation of the system.
- **Swimmers/Families:** A system that provides no danger and provides minimal disturbance.
- **Animals:** Should remain unharmed and unthreatened by the system
- **Tourist:** Should observe a system that doesn't cause a negative imprint on their perception of the environment. The system should be pleasant to look at.
- **Local residents:** Have a system that causes minimal noise pollution. Ideally be soundless to observers beyond the riversides.
- **Media:** Receive a system that does its job well for them to provide good coverage.
- **Subcontractor:** Receive easy to read and detailed specifications so the system turns out the way it's supposed to.

7 Requirements

Requirements are a primary focus of systems engineering and figuring out these requirements is the last thing one should do before moving onto the conceptualization phase. By exploring all aspects of a system before the requirements are set, will ensure the quality of requirements remain high. These requirements can be expressed both in text and through models. Some models that can be used are use case, business processes, interface descriptions, functional analysis and context diagrams.

In addition it’s important to keep in mind that placing all requirements on the same level of importance would be silly as you would not have any overview of which requirements are the most important. This could further lead to less important requirements taking just as much of our attention as for example a requirement that could break the system if not followed. Therefore for the set of requirements we have derived from the stakeholder needs, we decided to differentiate these into different levels of importance according to the MoSCoW prioritization.

MoSCoW can be divided into "Must Have" requirements, "Should Have" requirements, "Could Have" requirements, and "Won't have this time" requirements. Dividing these requirements into different levels of importance makes it easier to see what requirements are the most important and therefore should have more of our attention than for example the "Won’t have this time" requirements.

To further elaborate our ranking system, refer to this table.

M	This is for the “Must have” requirements. These are requirements that could kill the market value of our system if not followed.
S	This is for the “Should have” requirements. These are requirements that should be in the system, but can be omitted if absolutely necessary.
C	This is for the “Could have” requirements. These are the requirements that could add value to our system, but shouldn’t be top priority.
W	This is for the “Wont have this time” requirements. These are the lowest priority requirements and can be implemented if possible.

Table 2: Ranking of our Requirements

7.1 Stakeholder Requirements - SHR

SHR1	
Description: System shall be autonomous	Importance: M
	Derived from: Teacher

SHR2	
Description: System shall efficiently collect, contain and dispose garbage	Importance: M
	Derived from: Municipalities

SHR3	
Description: System shall use an environmentally friendly source of energy	Importance: M
	Derived from: Municipalities

SHR4	
Description: System shall not harm or disrupt wildlife	Importance: M
	Derived from: Fishermen Media

SHR5	
Description: System shall detect and avoid collisions with swimmers and boats.	Importance: M
	Derived from: Swimmers Fishermen

SHR6	
Description: System shall have good maneuverability for efficient garbage collection	Importance: S
	Derived from: Project Team Members

SHR7	
Description: System shall have minimal impact on environment	Importance: S
	Derived from: Media

SHR8	
Description: System shall be simple to implement	Importance: S
	Derived from: Customers

SHR9	
Description: System shall withstand environmental disturbance	Importance: M
	Derived from: Customers

SHR10	
Description: System shall require minimal maintenance to function continuously.	Importance: C
	Derived from: Customers

SHR11	
Description: System shall have low cost	Importance: C
	Derived from: Customers

SHR12	
Description: System shall have minimal noise pollution	Importance: C
	Derived from: Local Residents

SHR13	
Description: System shall minimally stand out visually	Importance: W
	Derived from: Tourists Media

SHR14	
Description: System shall have good stability	Importance: M
	Derived from: Project Members

SHR15	
Description: System shall have a high operational time for efficient garbage collection	Importance: S
	Derived from: Project Members

SHR16	
Description: System shall be energy efficient	Importance: C
	Derived from: Project Members

7.2 Functional Requirements - FR

FR1	
Description: System shall detect floating objects	Importance: M
	Derived from: SHR1 SHR2

FR2	
Description: System shall be able to maintain a speed of at least 5 km/h	Importance: M
	Derived from: SHR2

FR3	
Description: System shall detect and avoid contact with wildlife	Importance: M
	Derived from: SHR4

FR4	
Description: System shall detect and avoid disturbing human activities	Importance: M
	Derived from: SHR5 SHR12

FR5	
Description: System shall be able to reverse	Importance: S
	Derived from: SHR6

FR6	
Description: System shall be able to make 90 degree turns	Importance: S
	Derived from: SHR6

FR7	
Description: System shall be able to make weather dependent decisions	Importance: M
	Derived from: SHR9

FR8	
Description: System shall be able to stay operational for at least 4 hours.	Importance: S
	Derived from: SHR15

FR9	
Description: Our system shall have a control interface with a control app.	Importance: S
	Derived from: Use Case

FR10	
Description: Our boat system shall have a charging interface with the docking station.	Importance: S
	Derived from: Use Case

7.3 Design Requirements - DR

DR1	
Description: System shall have a microcontroller	Importance: M
	Derived from: SHR1

DR2	
Description: System shall not have a gasoline or diesel engine	Importance: M
	Derived from: SHR3 SHR7

DR3	
Description: System shall have a container	Importance: M
	Derived from: SHR2

DR4	
Description: System shall be composed of as few parts as functionally possible	Importance: C
	Derived from: SHR11 SHR10 SHR8

DR5	
Description: System shall have hulls that produce less turbulence	Importance: M
	Derived from: SHR14

DR6	
Description: System shall have optimized hull for less drag	Importance: W
	Derived from: SHR16

DR6	
Description: System shall have minimal amounts of protruding components	Importance: W
	Derived from: SHR13

DR7	
Description: System shall have motors	Importance: W
	Derived from: SHR1

DR8	
Description: System shall include a docking station	Importance: S
	Derived from: Use Case

DR9	
Description: Docking station shall have fast charging for minimal downtime	Importance: S
	Derived from: Use Case

DR10	
Description: Our system shall have a database	Importance: S
	Derived from: Sequence Diagram

7.4 Use Case

We further created a use case for our system to better understand how our system will work with external actors. We mapped some of our requirements into the use case and found some additional requirements for our system when creating the use case. The requirements which we derived from the diagram were also added to the requirements section of our report.

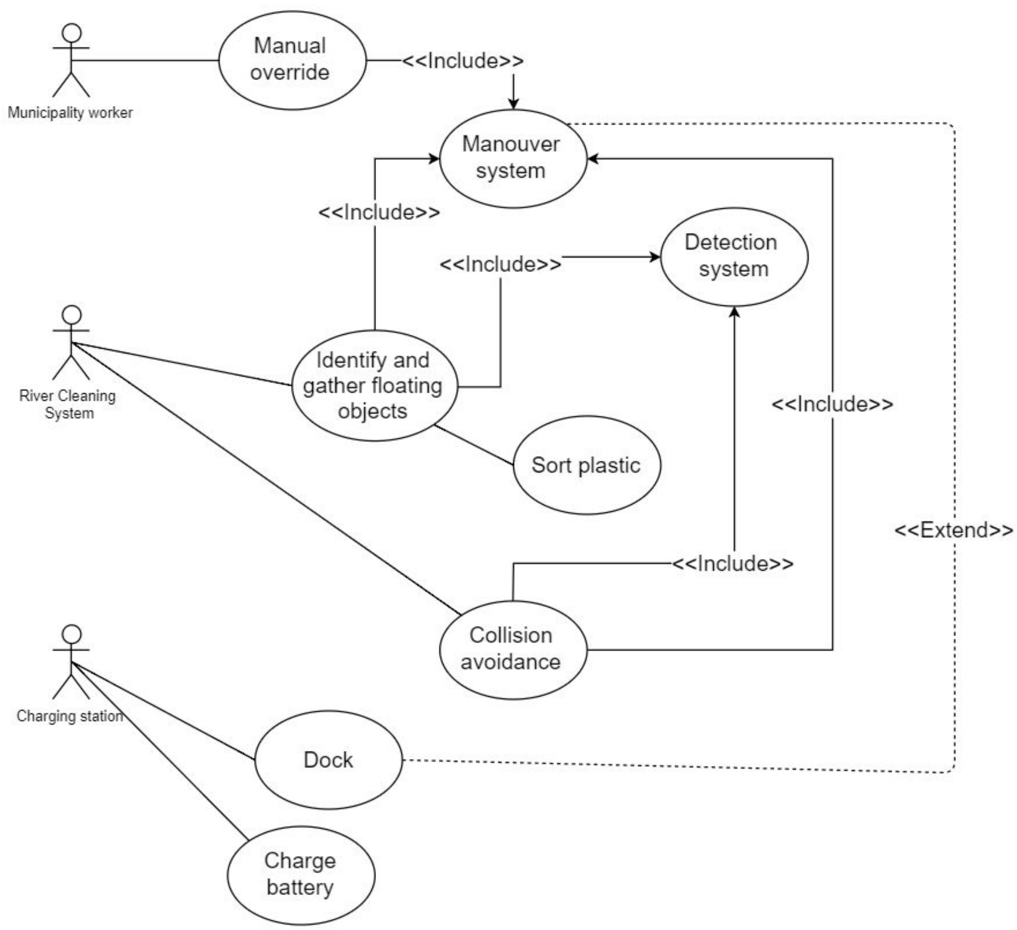


Figure 12: Use Case Diagram

7.5 Sequence Diagram

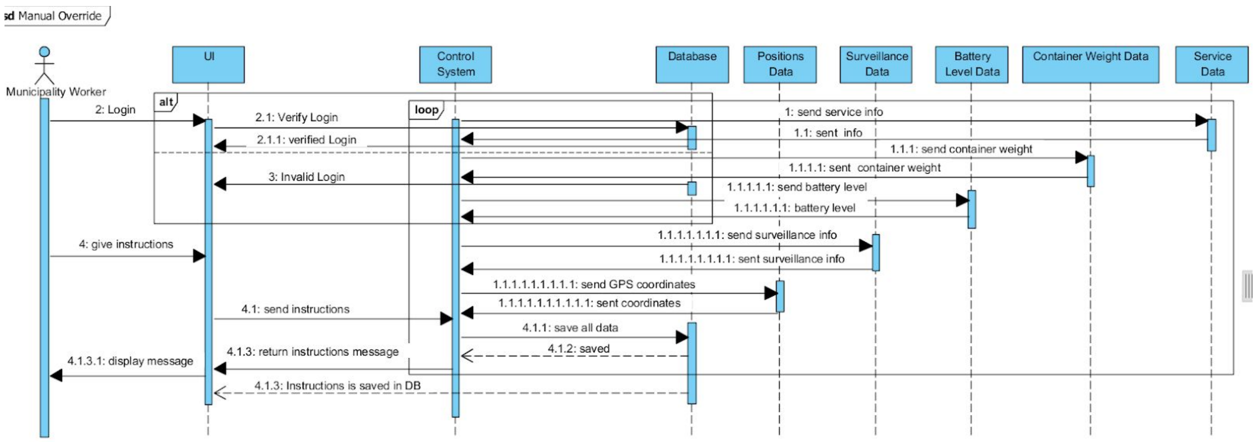


Figure 13: Sequence Diagram of Manual Override

We decided to make a sequence diagram for the manual override part of our system to show the interactions between objects in a sequential order. The x-axis shows objects and external objects and the y-axis shows lifetime of objects. The arrows shows the messages being sent between the objects and dasharrows shows the reply messages and the alternative is used to check the login verifications and the loop is running as long there is some instructions. This diagram is drawn to show the manual override of our system when user want to control the system manually and there are few steps to be done before the user can control the system. The system can manually override via an app from a smartphone and the user need to be signed in and then he can control the system, but we decided to save all the informations when the user signed in and the instructions he will give and this is because of security and if the user intentionally crash the system then we know who did it. We give the user opportunity to check everything from his screen and if something is wrong the system will give him a signal.

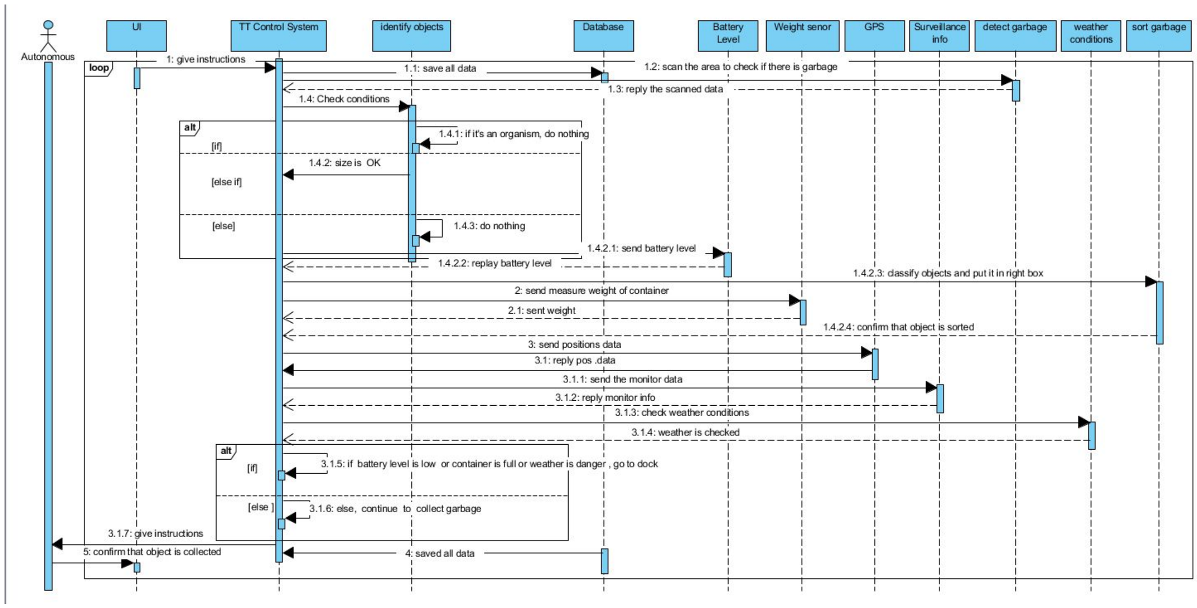


Figure 14: Sequence Diagram of Autonomous System

This is more complete sequence diagram of the system and shows the interactions between objects in a sequential order and shows the autonomous part of the system. When our system driving autonom in the river to collect garbage then our system needs specific data and there some steps must be done before the system collecting the garbage. In the x-axis we have actor, UI, control system (CS) and the rest is data and the y-axis shows the lifetime. UI sending instructions to CS to identifying the objects and checking the conditions and if it’s true then sending pickup instructions. When the object is collected then sending instructions to sort objects. If the weight sensor registering the max weight of container or the battery level is low then our system driving to dock station to emptying container or charge the battery and then driving back to clean the river. We are saving all the informations in database and we are using sensors to effectiveness our system and secure our system. The diagram shows the actions that occur when UI gives instructions and action are represented by messages.

7.6 Data Flow

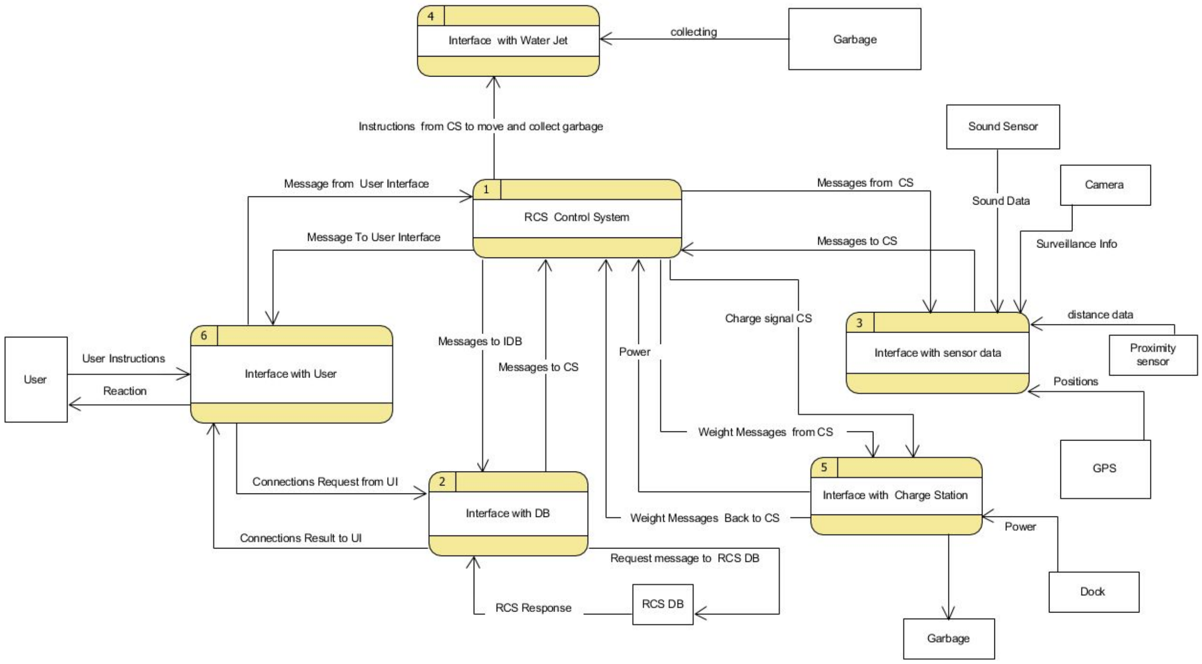


Figure 15: Data Flow Diagram

This data flow diagram shows the flow information that processed by our system in terms of outputs and inputs. Our focus in this diagram is that where data comes in and where it goes. The white boxes are external entities, the arrows shows the flow informations and the squares with id numbers are processes and we using the Gane and Sarson notation. This diagram visually graphical how data flows and showing processes that are involved in our system and id number representing the order of processes. RCS control system (CS) are the main process and it communicating with all other interfaces to get data, for example: RCSCS sending message to interface with sensor data (IWSD) to get new data and the IWSD have sensors that works as inputs then the IWSD sending new data to RCSCS. The RCSCS will sending instructions to interface with water jet to move and collect the garbage if there is a garbage otherwise do nothing.

7.7 Physical Block Diagram

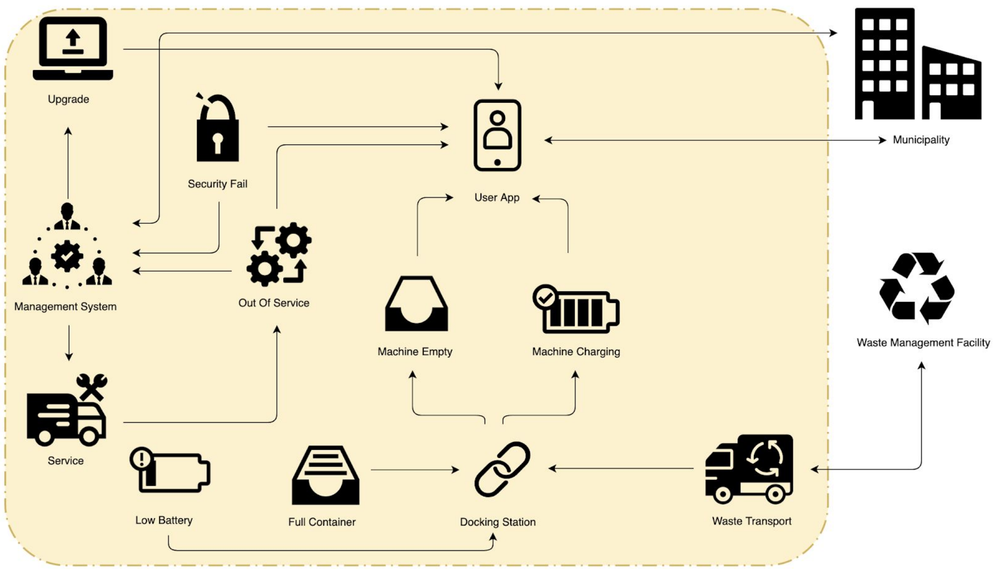


Figure 16: Overview of our System

This model shows the communication between our company and some of the life-cycle stakeholders. There will be a user app that can show the status of the system. If the battery is low or if the container is full it will automatically return to the docking station. And if the docking station is full, waste transport will come to empty it and drive the garbage to the recycling station. Information about what's happening at the docking station will be sent to the user app. This app will also receive information about security failure and whether or not the system is out of service, this information will also be sent to the management system. In case of errors, the service car will be sent to the river. We made this figure to have an overview of our system, for what is actually happening in what stage.

7.8 Functional architecture

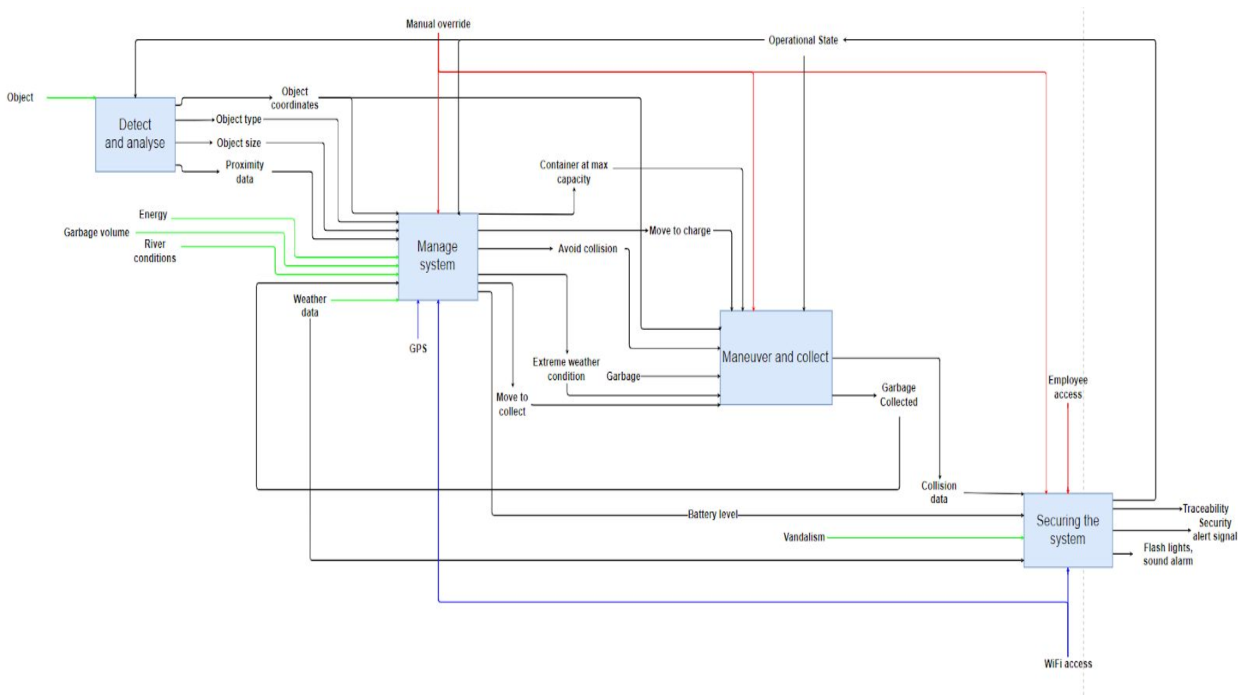


Figure 17: Functional Architecture of System

The diagram is color coded as such: Green for new inputs, red for operational inputs, blue for mechanisms, and black for outputs. The black lines remain as such even if they're later used as control signals, input signals or mechanisms.

Going into the functional architecture, we already had a concept in mind but wanted to stay as true as possible to an actual functional architecture where functions and their interactions are defined through this process. Because of this mindset we tried to keep it general to any autonomous waste management system in the river.

Our process making this diagram was first defining four functions, which we deemed necessary for a system placed in the river to deal with the task at hand, removing waste floating downstream.

From then on it was a chaotic process consisting of a lot of brainstorming to determine what was needed for these functions. During this process the “maneuver” function was expanded to become “maneuver and collect”. “Sort garbage” function was removed to become a sub-function of “maneuver and collect”, and a new function “manage system” was added.

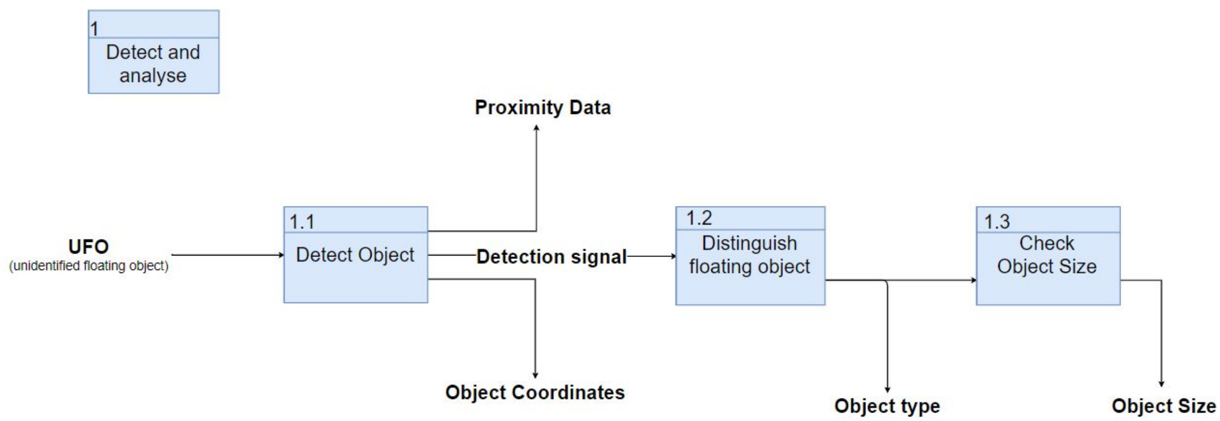


Figure 18: Sub Function Architecture of the Detection System.

The detect and analyze function needed to be broken down into a sub function as it took one single input and then made multiple outputs. Through this sub function analysis we wanted to put emphasis on the priority these different outputs have. Whereas the first subfunction is the detect object, the system figures out the distance between itself and the floating object and records the current coordinates. A crucial sub function within detect and analyze, is the distinguish floating object, where the system has to separate a living organism floating about like a duck, from a plastic bottle. The last subfunction, of detect and analyze checks the size of the object. By this point the system would know that it is not a living organism and has to determine whether it is a suitable size for the system. As the system is suited for soda bottles and boxes, simply picking up anything that passes through the previous criteria would be detrimental to the system lifetime. Because without checking for size the system would eventually encounter a log, the last thing the system should do is to charge right at it, wanting to pick it up and then destroying itself or valuable components.

8 Concept Exploration

When starting the semester assignment we had a very limited understanding of why we were doing the tasks/models we were assigned to do, so we just tried doing them to the best of our abilities. We started with a concept based on an existing one that is meant for the ocean which uses waves, winds and currents to contain floating waste both on top of and slightly beneath the water surface. It would have a floating cylinder with an impenetrable wall attached underneath which would contain but not trap the waste, allowing for any fish/etc to swim around it.

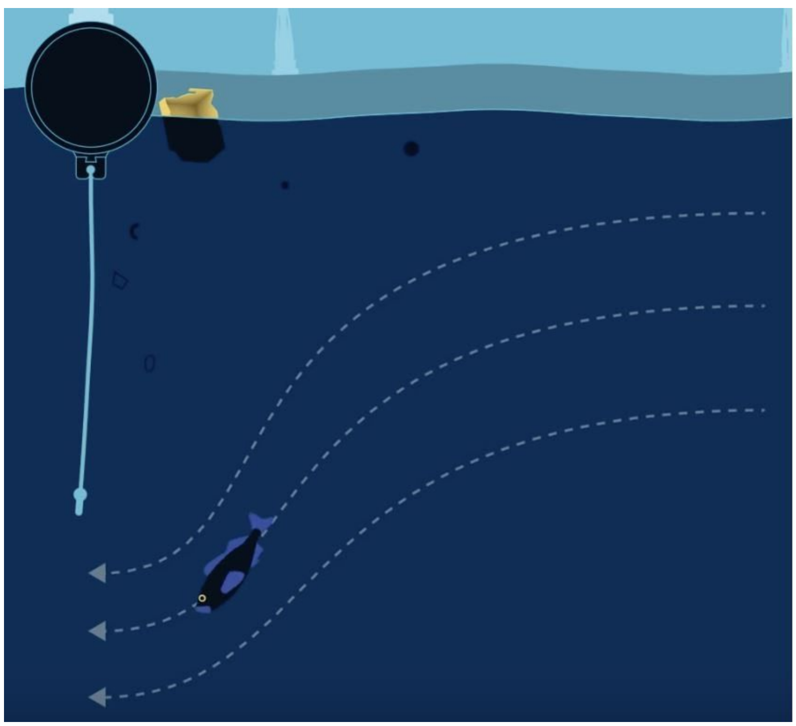


Figure 19: Ocean Cleanup Concept, retrieved from [4].

We visualized what our version of this could look like and which components it would require if it were to be placed in a river.

8.1 Concept I - Sea Sausage

When trying to implement the ocean cleanup concept into a potentially functioning concept in rivers, we imagined the system as mostly stationary during garbage collection so it would not have to deal with the massive drag that the catcher would cause.
We created a component block diagram to visualize what components the system would need.

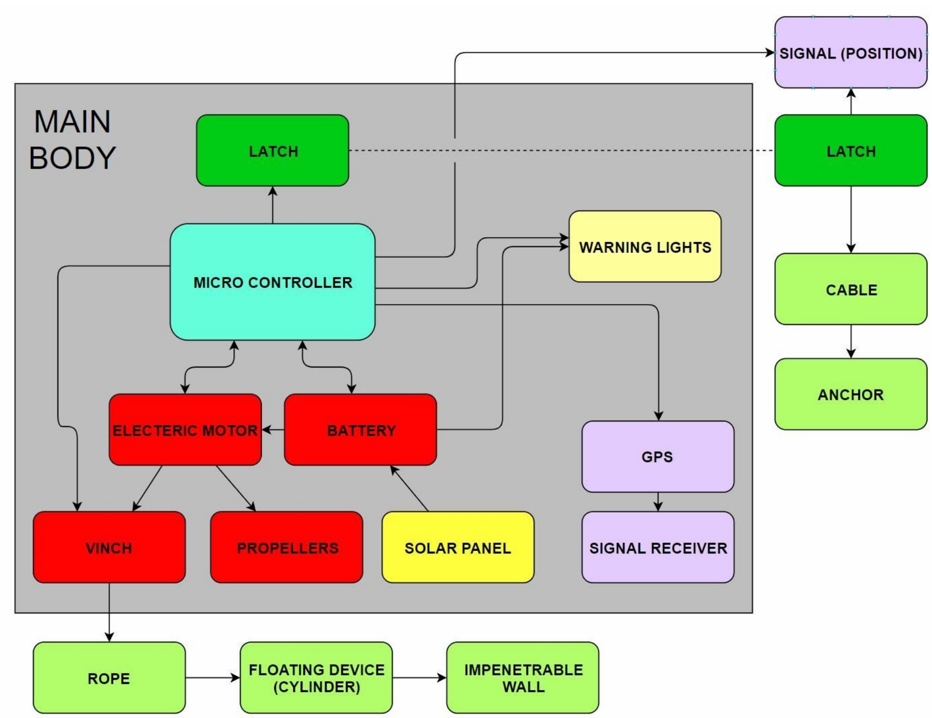


Figure 20: Component Block Diagram of Concept I

8.1.1 Dynamic Model of Concept I

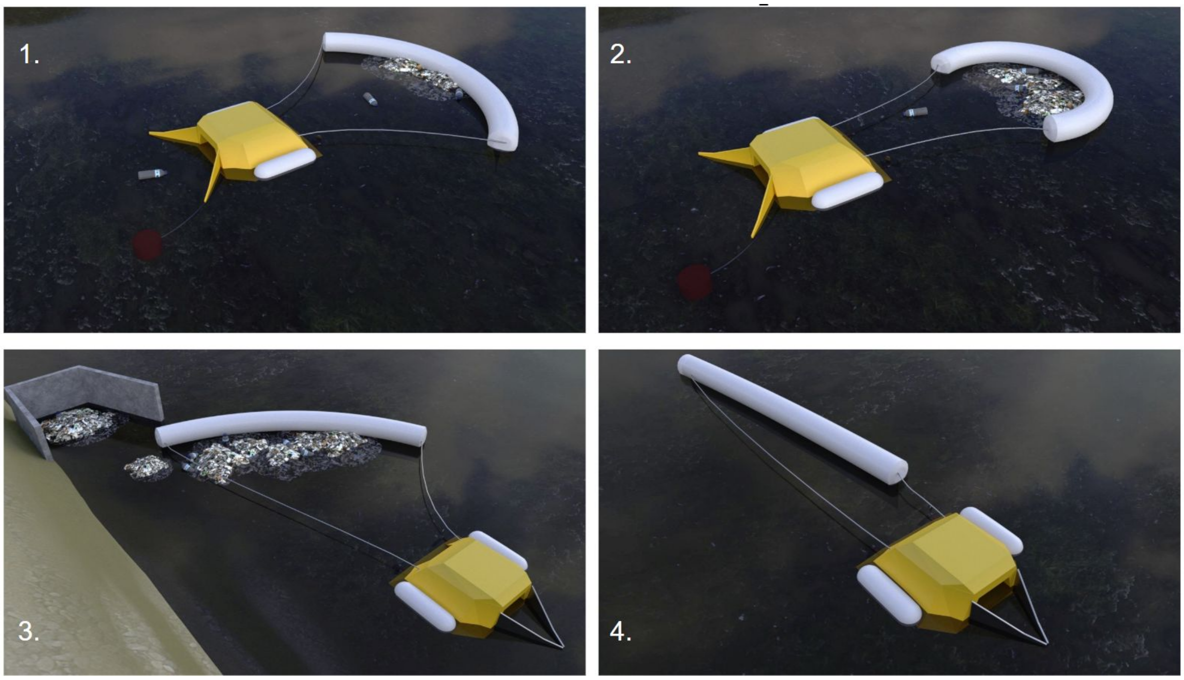


Figure 21: Dynamic Model Concept I

1. The machine is anchored in the river with no energy consumption in order to maintain position. The front port is open which maximizes the ability to gather garbage.

2. While the container is getting filled up, the wire system contracts the floating pipe in an effort to not spill any contained waste.

3. When the container needs emptying, the machine detaches from the anchor and floats down river to an on-shore separate installment. The wire system lets out more wire on one side allowing the current to push the garbage into the container.

4. The pipe and the front port is positioned in such a way to reduce drag while driving towards the anchor’s position in image 1 and the cycle restarts.

Part of the assignment was generating not one but multiple concepts in order to compare them. This is a central part of systems engineering as it attempts to prevent the development team from being too focused on one concept.

8.2 Concept II - Pac-Man

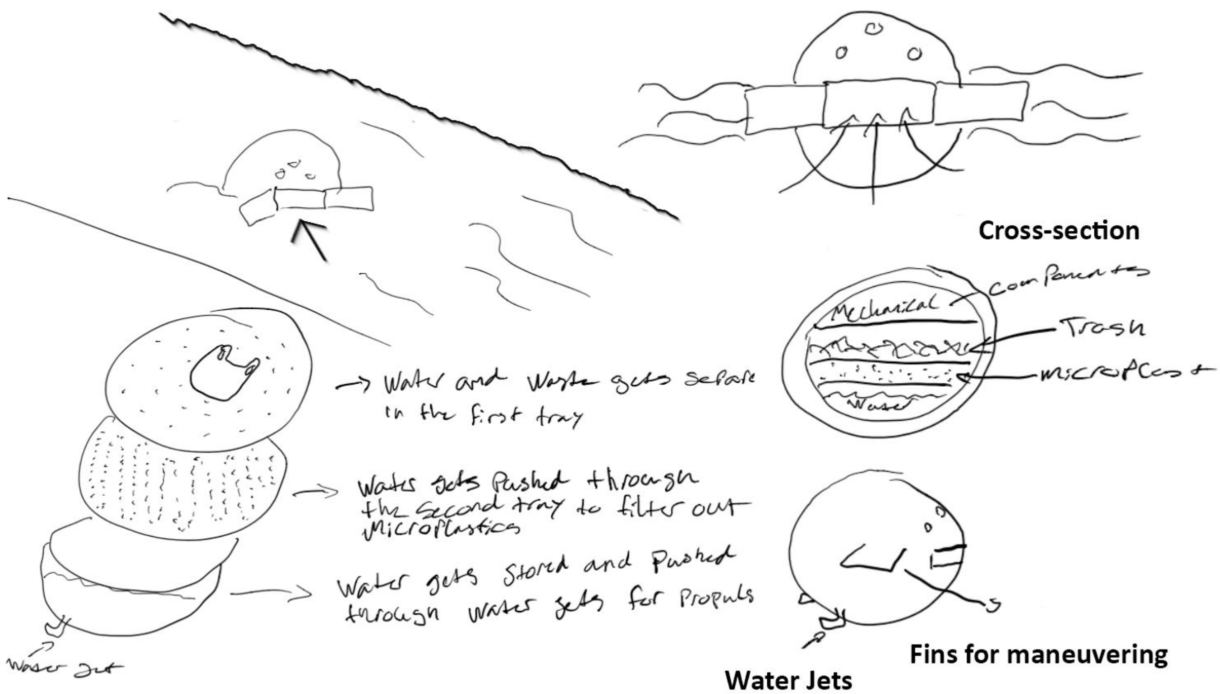


Figure 22: Concept II Dynamic Model

Our 2nd concept named Pacman utilizes water jet for propulsion and exterior fins on both of its sides for maneuvering. It pulls in and swallows water and garbage. This is then run through filters with holes of decreasing size effectively separating garbage/plastic and microplast. More concepts were created but were very loosely defined so we decided not to include them here. We utilized the pugh matrix and a design review to conclude that none of the concepts at this point in the project timeline were feasible. A major decision was by what method the system was meant to move, so we explored alternative ways of providing propulsion.

8.3 Concept III - Trash-Terminator 2000

Earlier when designing concepts we would create a concept as a whole package. Mentioned earlier Pac-man had a round shape with fins and opened its “mouth”, creating a vacuum sucking in the garbage and water. It would then filter the stored water for microplastic and sort garbage inside the body.

For these early concepts we had a set of requirements they had to fill, but our requirements at that time was simply not sufficient or researched enough. What this lead to was that every new concept new criteria would follow. These new criteria would add onto our set of existing requirements but would also lead to the concept being scrapped.

With Pac-man for example, we found through discussion that storing water in the system would lead to it being very heavy, and since the shape was round the propulsion of pacman would be a challenge as it had to displace a lot of water moving around, reducing speed, maneuvering and active time on the river. This of course was thought of after pacman was conceptualized. Here lies the problem, because it was designed as a finished concept from the start, how would we make changes to the concept?

Pacman’s functionality was defined from the start, any changes to it was a big challenge leading to the system being scrapped. While this can be one way to discover requirements, and unfortunately was how we found many of our requirements, starting from scratch over and over again was very draining on the groups morale.

Because of this and as the midterm presentation was closing in, we took a more careful approach to conceptualization. While the iterative process from before was draining and it felt as though we started from scratch every time, the group as a whole was wiser and we had a larger pool of definite requirements that we knew a dynamic river based system had to abide by.

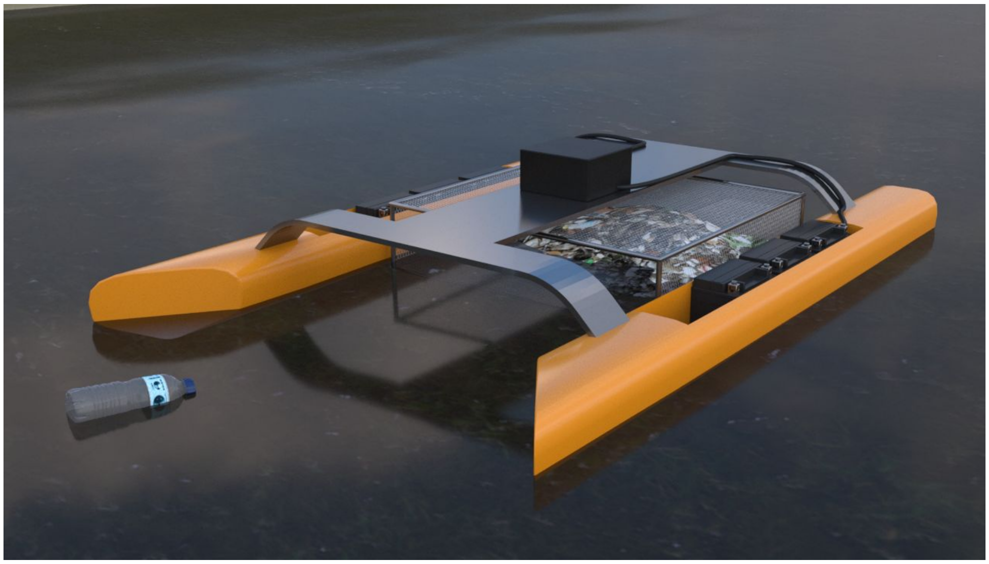


Figure 23: Illustration of Concept III

When creating Trash-terminator 2000, we took a step back, kept a clearer picture of the definite requirements in the back of our minds as to not make the same mistakes we made earlier. Then instead of conceptualizing the system as a package we started off by looking at different boat shapes. The shape alone had a set of requirements. It had to be stable while supporting the added weight the rest of the system would bring. Then because of the added weight, the buoyancy of the system is important, as through pacman we discovered that a system requiring a lot of water displacement when moving around will reduce the system effectiveness across the board.

Through this process we found that the catamaran shape would provide the most stability of any shape while still keeping the water displacement required to propel the system to a minimum. While we initially had a speed boat shape in mind, it later turned out that the catamaran shape was crucial to both Trash-terminators and the river cleaning systems' functionality because the shape is inherently well suited to accomodate a container and really any functionality you can imagine with the space left in the center of the two hulls.

With midterm right around the corner, the discussion around how it would collect plastic was cut short. While the idea of a conveyor belt was pitched, we kept it simple and put a container in the middle with and opening in front of the system where it would collect garbage like a manta ray collects fish. In this 2D model the main concern was the weight distribution of the system, as the system in itself was not terribly complex. Support beams across the two hulls were added to support the systems robustness.

Water jets were researched during the conceptualization of pacman. Mentioned earlier water jets have many positives which fulfills stakeholder requirements such as low noise pollution and its impeller does not stick out like a propeller does, which can harm fish. But for the catamaran specifically we felt that the water jet was the right choice since the catamaran shape is quite bulky and maneuvering around tighter parts of a river could prove to be difficult. With water jets the system can turn around with a fraction of space needed compared to regular propellers.

8.3.1 Concept III - 2D Layout

When designing the system our main concern was the weight of the system. W Due to insufficient time and having to scrap ideas multiple times, we created a rough 2D layout of the system with key components it should have before our midterm presentation.

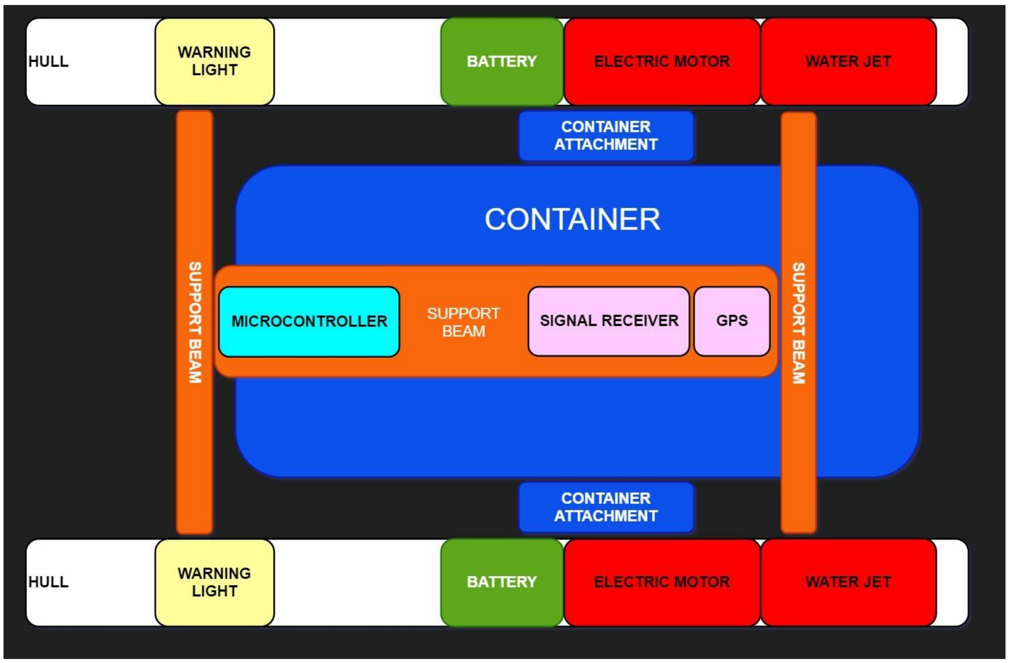


Figure 24: 2D Layout of Concept III

8.3.2 Concept III - Functional Analysis

When trying to further visualize the inner workings of our system we first mapped some inputs and outputs of our system and further tried to analyse how these would interact with functionalities in our system.

Figure 25: Black Box of Concept III

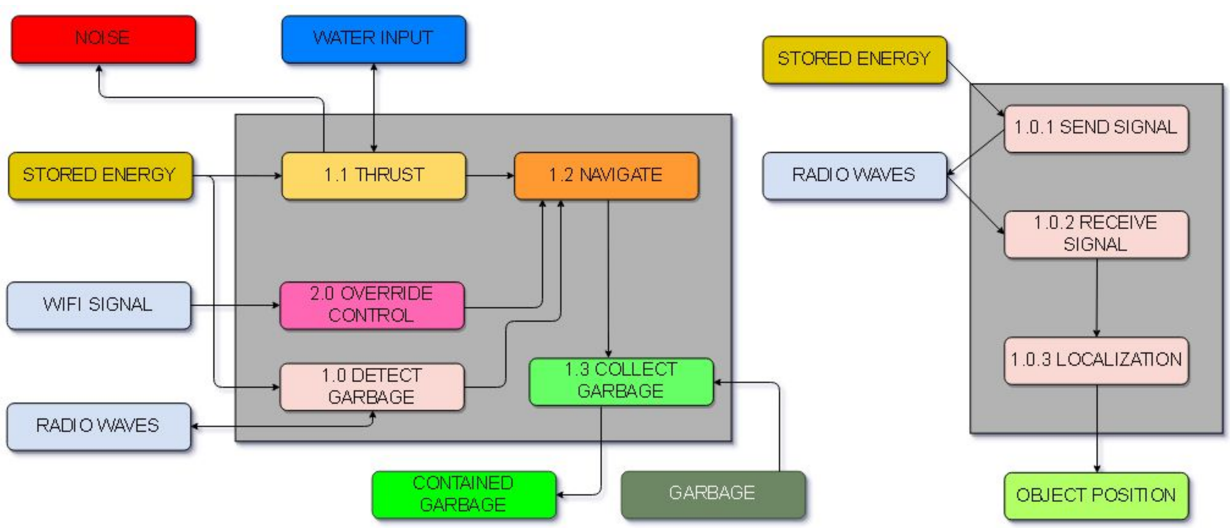


Figure 26: Functional Analysis of Concept III

9 Final Conceptualization

During concept exploration, the docking station was the last thing we would touch as it would need to interact and have interfaces with our boat system. We therefore found it logical to first create a solution for the boat system before we create the docking station around it. After our third concept we explored possible solutions for the docking station for the system. During the first three concepts, the Trash-terminator would collect waste indiscriminately, so because of this a separate sorting system was necessary.

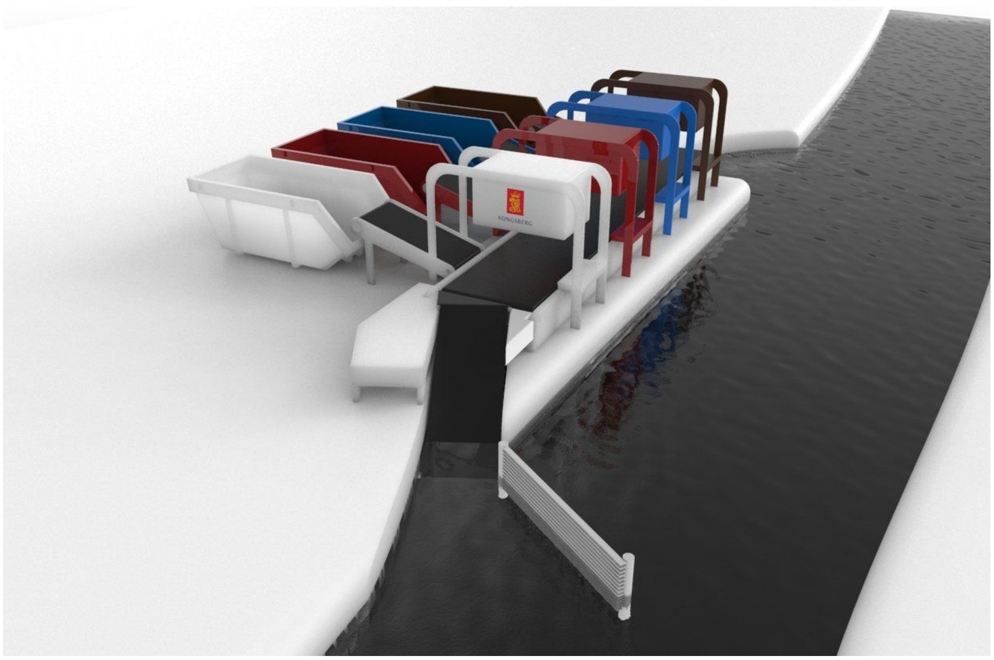


Figure 27: Sorting Station, retrieved from [3].

First and foremost dynamic system need a power source, and since the concern of this assignment is environmental it had been crucial from the start that the system's power source is environmentally friendly. With a battery powered system in mind throughout this assignment, a way for the system to charge up its batteries is necessary.

We briefly looked into a way to change batteries while the system was in operation, this way it could operate 24/7. But because we felt the necessary time and effort needed for this to be presented as a feasible concept, with all the moving and interlocking parts we had to figure out, this idea was scrapped.

What a river based, dynamic battery-powered system needs, is a dock. Much like boats are parked at the dock when they're not used, the system would have its own designated place to park and charge up the batteries before moving out to collect floating waste.

For Trash-Terminator 2000 this dock would not only charge batteries but would also be where the collected waste is discarded and then sorted. Then because we had decided on a sorting system by the dock we had to delve deeper, to figure out exactly how it would sort.

Looking around on the web a video[2] of a sorting container which would sort garbage, including plastic, through sound was what we based our initial sorting system on. The idea was to have an arrangement of multiple containers with this sound sorting system to sorting the different types of waste, before placing it in its respective container. Conceptually this seemed great, but we would soon after have to remind ourselves that in reality, garbage soaked in water does not make the same distinguishable sound that dry garbage makes.

We then looked at traditional waste management facilities to know how they sort garbage. After seeing how extensive the process of separating the mixed garbage was, and considering we were dealing with wet garbage we had to reconsider our design as this was no longer economically feasible with our budget in mind. Because of this we had to go back to exploring a new concept for our boat system.

The hardest part of any system we conceptualized was how to remotely differentiate plastic, as we felt it was not realistic to simply say that a smart algorithm can distinguish the floating waste.

Earlier when discussing possible ways to remotely detect plastic we looked at capacitive sensors, but ultimately decided against them as they only have an effective range at about 6 cm. However if we found a way for the system to sort plastic onboard, differentiating the waste at a distance was no longer necessary. This would leave the detection system with much easier and more realistic task of differentiating between living organisms and waste.

Trash-Terminator 3000 would like its predecessor collect indiscriminately anything it determined to be waste. This time however, by using the aforementioned capacitive sensor, placing it underneath a container with a tilting plate at the bottom we had the ability to sort the waste onboard. Conceptually this tilt-box was simple, by calibrating the capacitive sensors to look for plastic this tilt box had one job. If the waste was plastic the capacitive sensor would detect it, sending a signal to trigger the plate to tilt forward, if not it the plate would tilt backwards placing it on another conveyer belt, discarding it back into the river. This way the system would only collect plastic in the container.

Lastly the method of collection.

In the end we went with a conveyor belt, which was not the original solution we had hoped for. The group initially wanted to avoid using a conveyor belt as it was a pretty obvious choice looking at other existing river cleaning systems. We had from the start, gone through this process of making new creative concepts of collecting garbage trying to avoid using a conveyor belt.

However these concepts just made it clearer why a conveyor belt as a method of collection was superior. This put the group in a weird spot as we wanted to approach this assignment as realistically as possible, but still bring a unique system.

So how did the system end up with a conveyor belt if we tried to avoid using one?

By making the mistake of creating concepts with so much functionality predetermined, the least we could do was to make use of them. And the method of collection was one area were this aided us, as we had looked at so many real world examples, brainstormed and discussed this aspect when conceptualizing throughout this assignment.

By looking back at our earlier concepts, where each concept tried to be different from the last. The group had inadvertently explored the issues of collecting garbage in the river, since by conceptualizing like we did, it made it easier to imagine the concept in the context and theorize what could happen if something were to go wrong.

So what were the shortcomings we theorized? The Seasausages shortcoming was the container or, “catcher” itself. If anything caused it to sway, which is highly likely in a river, it would not be able to retain the garbage. As the motion of the “catcher” swaying back and forth before stabilizing itself would lose the collected garbage, and while doing that as the context is a river, the current would sweep away even more garbage.

With pacmans method of collection the fault lies within the fact that the whole system has to be designed around the method of collection for it to function, without being a big benefit over other methods.

The earlier iteration of Trash-Terminator had an open ended container, using this open end to collect garbage. Aside from not having a real way of keeping the collected garbage inside this open ended container, this method of collecting garbage had another big downside. It frankly does not fit our chosen context.

When collecting garbage floating downstream in Kongsberg, it is not necessary for the system to have a wide spanning “mouth” capable of collecting a large amount of garbage in one pass. It is an effective method when placed in a river like Citraum where the floating garbage is abundant on the river surface, but our context is Kongsberg and the floating garbage here is usually a stray soda bottle, or a beer can thrown by a drunk after a night out.

Determining these shortcomings turned out to be a set of pseudo-requirements of what we wanted to avoid. And because of these early concepts with their own unique way of collecting garbage, it was easy to communicate within the group what possible scenarios could arise within the river, how it would affect the concept, what should be done to remedy the problem, and if this was even relevant to our chosen context.

It was at this point we found that the conveyor belt did not suffer from any of these shortcomings where it would not put the collected plastic at risk of being released back into the river. In addition to this the conveyor belt was perfectly suited for the tilt box where it would drop the garbage to be sorted keeping only the plastic. In the end the uniqueness of the system was not more important than its functionality, so the conveyor belt became the clear choice.

9.1 Component Evaluation

During the conceptualization of our final concept, we decided to again re-evaluate some components to see how feasible they were compared to other types. We further used the pugh matrix model to find the best component solution for certain aspects of our system.

		Means of Propulsion					
Criteria	**Weight**	**Jet Drive**		**Prop. Drive**		**Air Drive**	
Cost	**15**	**2**	30	**5**	75	**3**	45
Operation	**25**						
Environment Dependency		**5**	125	**2**	50	**4**	100
Noise Pollution		**4**	100	**3**	75	**1**	25
Energy Efficiency		**2**	50	**4**	100	**3**	75
Manoeuvrability		**4**	100	**3**	75	**3**	75
Safety	**30**	**5**	150	**2**	60	**3**	90
Maintenance	**15**	**3**	45	**1**	15	**2**	30
Design	**15**						
Sturdiness		**3**	45	**1**	15	**2**	30
Temperature		**4**	60	**3**	45	**2**	30
Component Life		**5**	75	**3**	45	**2**	30
Sum			**780**		**555**		**530**

Table 3: Means of Propulsion Pugh Matrix

In our propulsion comparison pugh matrix we compared the jet drive to other propulsion types and we can clearly see that the jet drive scored considerably better in sections that mattered the most. The jet drive can work in most environments including shallow waters and compared to the air drive it wouldn't have a bulky fan on top which would be prone to collision and damage.

This could potentially open up dozens more rivers where our system could operate in. The jet drive is also much sturdier than a propeller drive and air drive since the impeller is protected by a metal casing around it and is stored inside the hull. The jet drive is also much safer as well. But a downside is the lower energy efficiency which indirectly also affects the weight of our system as the battery capacity has to be decided with this in mind. This also slightly increases the cost to keep the system running, but since electricity is so cheap, having a slight increase in energy usage in exchange for better overall safety, versatility and sturdiness of the system, we decided this to be a good tradeoff.

		Battery Type					
Criteria	**Weight**	**Ni-Cd**		**Li-Ion**		**Lead-Acid**	
Cost	**15**	**3**	45	**1**	15	**4**	60
Energy Density	**40**	**2**	80	**4**	160	**1**	40
Charge Cycle	**25**	**4**	100	**2**	50	**1**	25
Cell Voltage	**10**	**1**	10	**3**	30	**2**	20
Utilization	**10**						
Charge Temp.		**3**	30	**2**	20	**4**	40
Discharge Temp.		**3**	30	**2**	20	**3**	30
Overcharge Tolerance		**3**	30	**1**	10	**4**	40
Partial Charge Tolerance		**1**	10	**3**	30	**3**	30
Full Discharge Tolerance		**5**	50	**4**	40	**1**	10
Sum			**385**		**375**		**295**

Table 4: Battery Type Pugh Matrix

As for battery type, even though the Ni-Cd battery type scored the best, we still decided to go with the Li-ion battery since it scored much better in the most important specification, which is energy density while not scoring too bad in specifications like the cost and the charge cycle. In our system we found that the weight shouldn’t be compromised too much. The batteries weigh quite a bit, if we were to go with the Ni-Cd the weight of the system would increase considerably, which would directly affect the speed and the operational time of our system negatively.

Comparing these components in a pugh matrix has been quite helpful as it has created a much better understanding of our system, brought aspects of our system into attention which we hadn’t originally thought of. Actually finding and weighting important specifications raised a lot of questions and created a more thorough understanding.

9.2 Final Concept

Taking into consideration everything we have gathered so far from previous concepts, our models and our requirements, we found a final concept which we went with. A 3D illustration of this concept can be seen below in Figure 28.

Figure 28: 3D Illustration of Final Concept

The issue we found with the earlier iteration was that it would to dump harmful garbage back into the river as it would return any trash that wasn't plastic. It seemed unnecessary for the system to clean the river of a beer can can only to drop it back into the river as it wasn't plastic. Not only that, but it would be negatively viewed by the public doing so.

Our solution to this was to sort the most likely trash found in our context, which we determined to be cigarette butts, aluminum boxes and plastic bottles. Because of this, when sifting through the collected garbage instead of only tuning one tilt box with its capacitive sensors underneath, we could have three of them each tuned for one type of garbage.

9.2.1 System component layout

When deciding the layout of our boat system, one of our main concerns was the balance of the system. This is why we decided to split our system components evenly on each side. We did this because as a result the overall balance of our boat design would be much better. If we were to have a lot of the weight on either side, this would cause imbalance and lead to the system tipping over easier. If on the other hand we decided to have a majority of the weight in the center, it would cause a lot of tension on the support beams. Therefore we found that the best choice would be to divide the system weight evenly and store the components inside the hulls. In Figure 29 you can see the systems' onboard parts and how these were spread in our system.

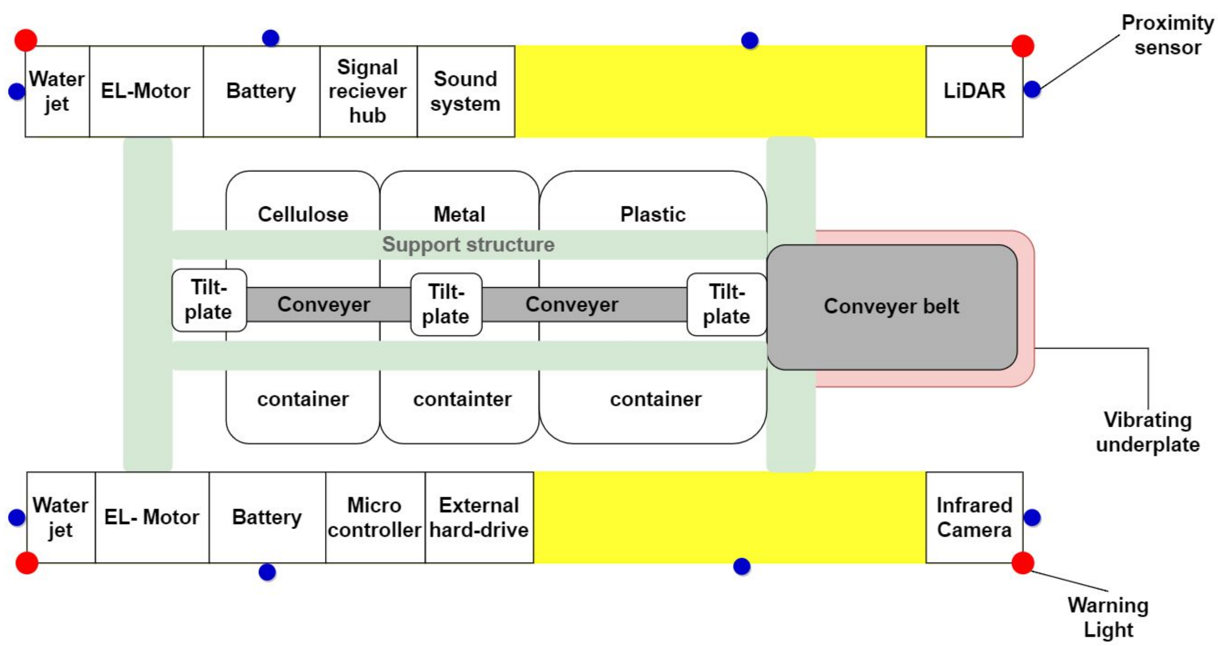


Figure 29: 2D Layout of Final Concept.

9.2.2 System Concept of Operation

We further decided to visualize how our system would work. Our system during operation will have an operational time of around 6 hours, during this time it will move up and down the river while avoiding external obstacles like swimmers, boats and ducks. During this time it will also move to collect plastic, metal and cellulose and sort these on board. When either the boat runs low on charge or the container is full, it will navigate to the docking station where it will then empty the container, charge back up to full and resume collecting, ideally within 30 minutes.

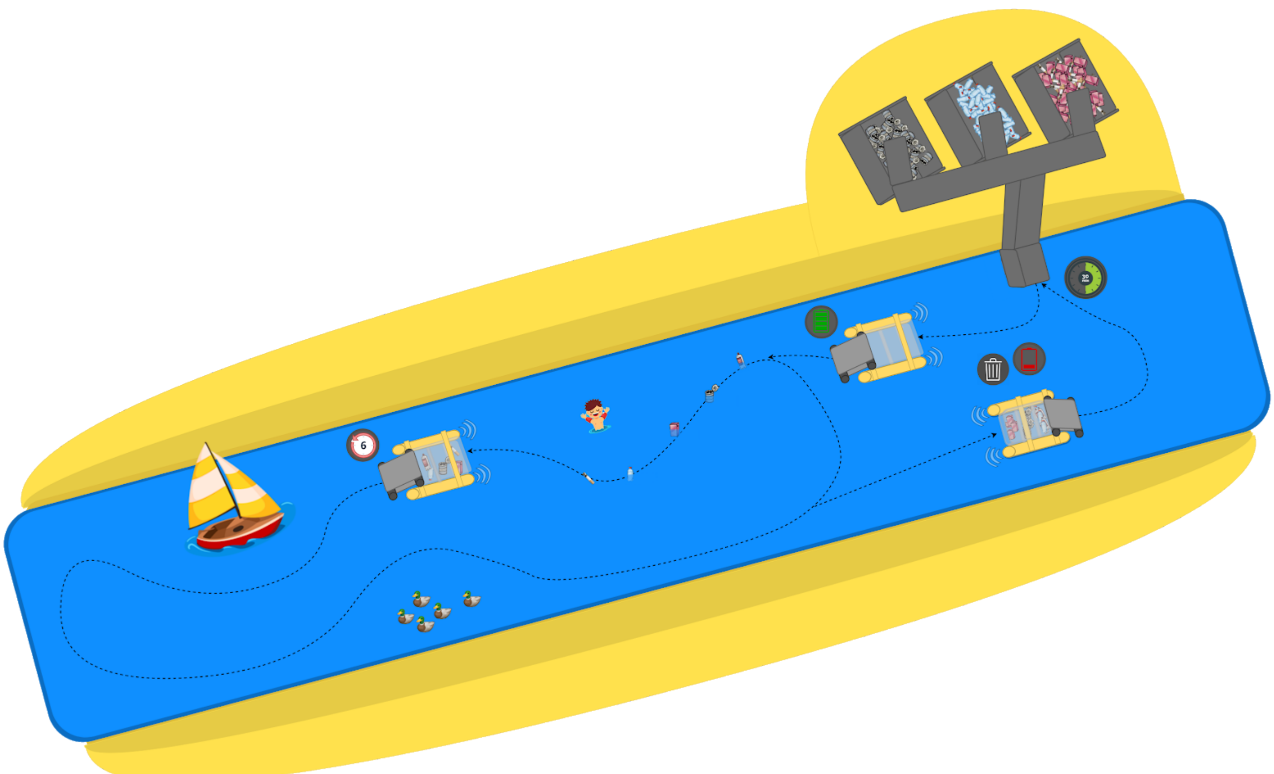
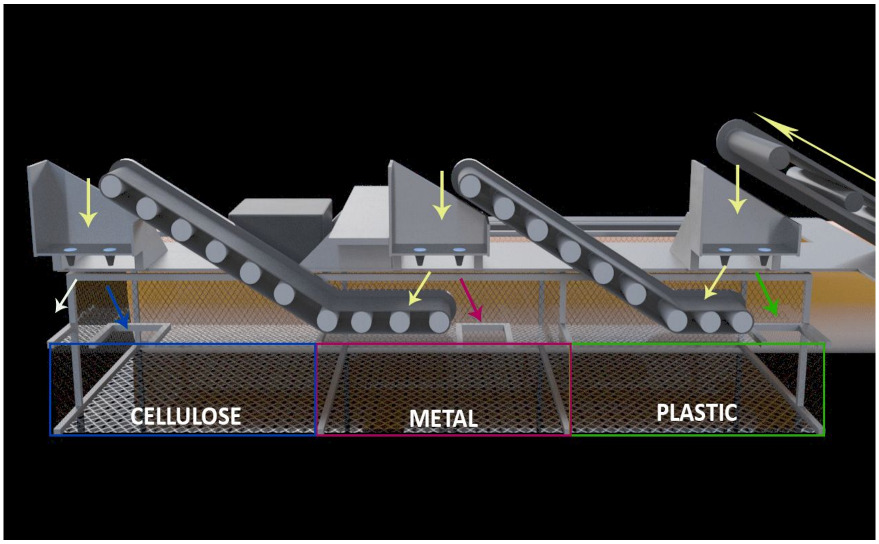


Figure 30: Concept of Operation



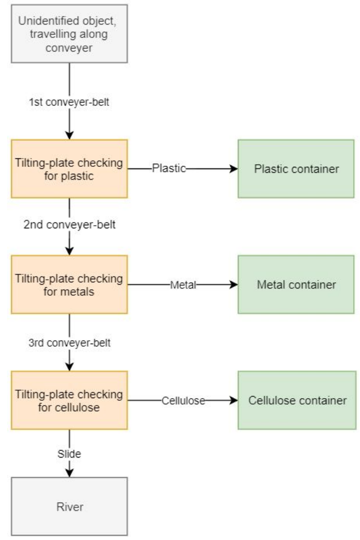


Figure 31: Onboard Sorting System

Figure 32: Flowchart of Onboard Sorting System

When our system collects garbage it will further sort these by using the capacitive sensors. The first box checks for plastic, the second box checks for metal and the third box checks for cellulose. Between each phase the boxes either drop the material onto the next conveyor or it dumps it into its respective container. The last plate dumps the material back out if it was neither one of these three types. These models will create a clearer understanding of how our system will work, which is very important for both project members and stakeholders/customers as everyone will be on the same wavelength.

9.2.3 Concept Evaluation

CRITERIA	WEIGHT %	CONCEPTS					
		TRASH TERMINATOR 2000		RIVER CLEANING SYSTEM		PACMAN	
		RATING	WEIGHT SCORE	RATING	WEIGHT SCORE	RATING	WEIGHT SCORE
COST	20	4	0.80	3	0.6	2	0.4
PROTECTING ANIMAL LIFE	10	4	0.4	5	0.5	5	0.5
COLLECTING	15	3	0.45	4	0.6	3	0.45
ENERGY CONSUMPTION	5	5	0.25	3	0.15	2	0.1
STURDINESS	10	3	0.3	5	0.5	4	0.4
GARBAGE DISPOSAL	5	3	0.15	4	0.2	3	0.15
ENVIRONMENTALLY FRIENDLY	10	5	0.5	5	0.5	5	0.5
MAINTENANCE	10	4	0.4	5	0.5	3	0.3
INSTALLATION	5	2	0.1	4	0.2	4	0.2
SAFETY	10	5	0.5	5	0.5	5	0.5
TOTAL SCORE			**3.85**		**4.25**		**3.5**

Table 5: Concept Comparison Pugh Matrix

We have used Pugh Matrix to evaluate our concepts against weight percent. We have three alternative concepts and our criteria is on the left side and the rating scale is from 1 to 5 where 5 is the highest. This decision matrix helped us to chose our best concept with the highest score. The criteria we decided is most important to our system and must be included.

9.2.4 Technical Budget

The main issue we faced when developing our concepts was the system weight. As our concept will have to remain operational for long durations, the weight will negatively impact the speed of the system, the energy consumption and the general stability. By budgeting weight for every component we created a rough estimate for how much our system should weigh, which can be used for further stress tests and other calculations. This is why we created a technical budget for our system's weight.

Item	Mass (kg)
2 x Hull	20
Microcontroller	2
4 x Warning Light	1
2 x Battery	70
2 x EL Motor	6
2 x Container Feste	15
Container	10
2 x Water Jet	10
Belt motor	1
3 x Belt	10
Camera	1
Rollers	20
Total	166

Table 6: Technical Budget for System Weight

9.2.5 Key Performance Parameters

We also had decided some key performance parameters for our system. These are parameters that should be met by our system, and final concept design was made according to these parameters. Also keep in mind that the garbage weight capacity is a rough estimate.

Size	L = 2.2m W = 1.2m H = 1m
Weight	166kg
Cost	300K
Garbage weight capacity	500kg
Maximum speed	6km/h
Maximum consumption	1.5KW

Table 7: Key Performance Parameters of Final Concept

10 Stress Analysis

In systems engineering models are helpful tools to develop a system. We made a functional CAD model of our system with the purpose of visualizing our concept. This really helped us to find dimensions and other quantitative information. With the software used (SOLIDWORKS 2018) we had a lot of options to find information after making the model. We decided to run a stress analysis of a bracket to get an accurate estimation of the part thickness.We also simulated where the waterline would hit our system to optimize hull size.

We decided to analyze one of the brackets made of 2014 aluminium alloy (The material has to be made more corrosion resistant). It is important the support brackets could withstand the weight of our system. The results shown in figure 33 below analyze the bracket with a thickness of 20 mm. The brackets are clearly able to withstand the stresses with a factor of safety above 3. Given that this is likely more than the maximum stress the bracket ever will endure, we are happy with the performance. Collisions could definitely destroy the brackets depending on the collision and deformation.

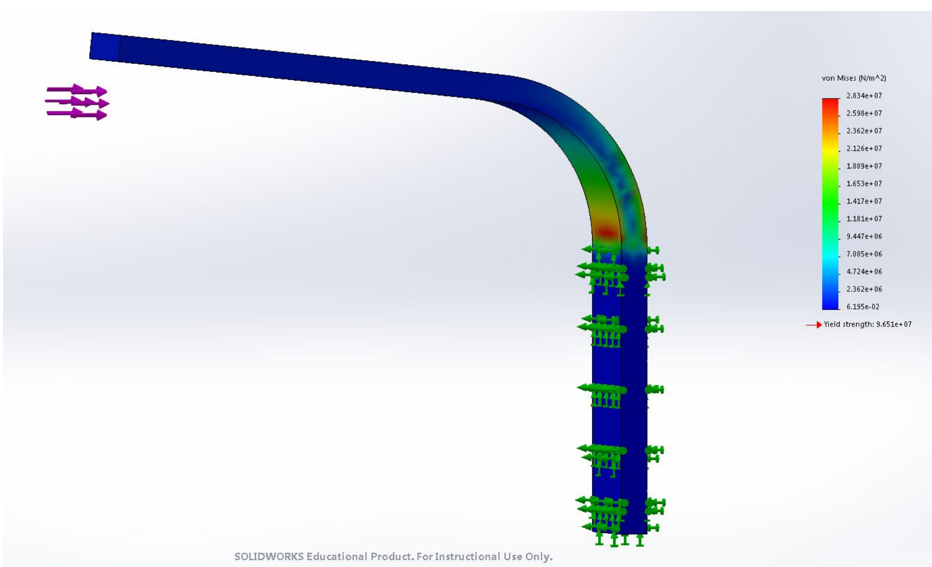


Figure 33: Bracket Stress Test

10.1 Hull Size Optimization

We chose to do a study on our system design in order to simulate the water line and to optimize the size of our hulls. The calculation could have been done easily on the hulls, but given that we have more components (Water jets, container) underwater this is an easier and more realistic way to to find the appropriate dimensions of our system.

Thanks to our CAD model we can use the known mass of our system to calculate how much water is displaced. We then set up a Design Study in Solidworks, temporarily removing everything above the simulated water line. After deciding a height of the hull that fits our system, we were able to use the width as a variable and run a study where the goal was to get a volume of 0.166 m^3. The same volume as displaced water, given that our system mass is 166kg. Below is the setup for the last iteration of our design study. The software is setup to find the integer (Width) that comes closest to 0.166m^3.

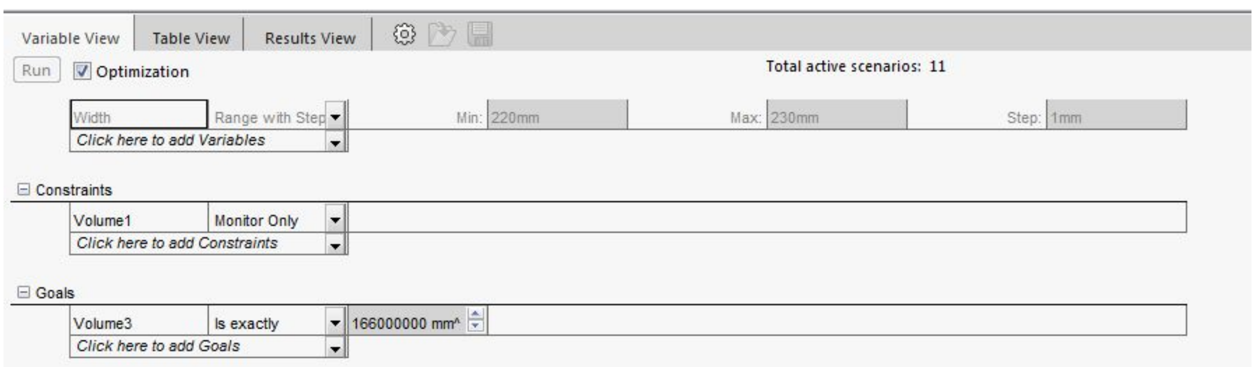


Figure 34: Dimensions Setup

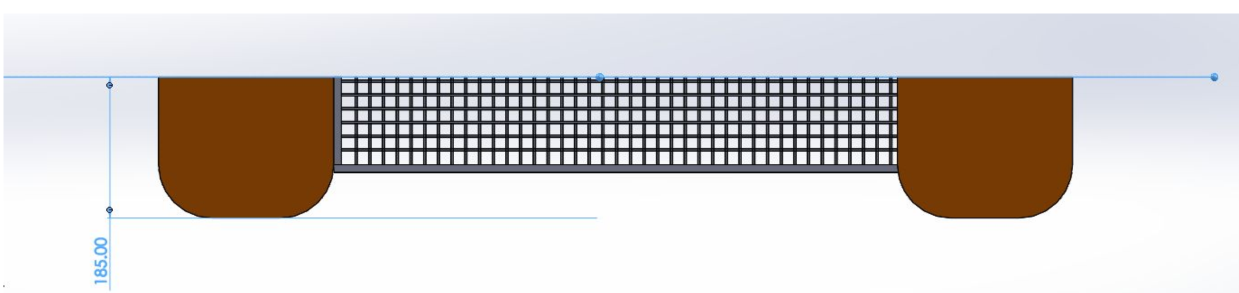


Figure 35: Hull Water Depth

13 of 13 scenarios ran successfully. Design Study Quality: High

		Current	Initial	Optimal (0)	Scenario 1
Width		226mm	226mm	226mm	220mm
Volume1	Monitor Only	166237584.3 mm^3	166237584.3 mm^3	166237584.3 mm^3	161836027.8 mm^3
Volume3	Is exactly 0.166	166237584.3 mm^3	166237584.3 mm^3	166237584.3 mm^3	161836027.8 mm^3

Figure 36: Optimal Hull Dimensions

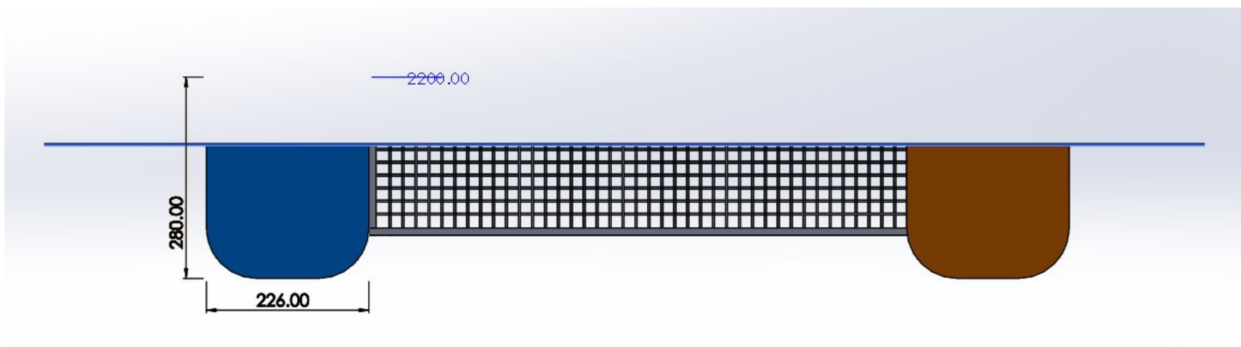


Figure 37: Hull dimensions visualized

Conclusion: Using Solidworks as a tool we saved a lot of time finding the water line. If changes were to be made to our system we can easily re-run the study and save hours. Time is also saved by doing stress analysis digitally, done by hand it takes a lot longer.

11 Financial, Economics, Cash flow

In every system development, money is an imperative factor. In companies cash usually flow in and out in big quantities, some sections are probably limited while others waste money. During the development of a system it is essential to leave room for experimenting without it interfering with the goal of the system. By applying good system engineering philosophy, we can manage expenses without limiting development, leading to reduced risk and improved overview of the cash flow. This is done by, estimating loss and profit, planning, iterative reviews and risk analysis.

In development of modern systems, it is difficult to get a good estimate of future profits/losses. This is one of the reasons systems engineering has entered the field of engineering. Because a good systems engineer should for example be able to estimate material cost on the spot.
Risk analysis which was mentioned earlier is a method that can increase the chances of meeting budget goals or time goals of a project. This is because one develops the system while taking the addressed risks into consideration, so one always knows what risks are actual and should actively be avoided.

Example:

1. CAD designer needs access to better software
2. Systems engineer provides information to both parties regarding usage and alternative software.
3. CFO of the company needs information to evaluate cost/benefit.

In our project we are systems engineers. The CFO is Jamal which wants the system to be efficient, that is why we ourselves analyze cost/benefit. Benefits are analyzed from the customers, aka Norwegian municipalities point of view.

When we first started this project we had planned an on-shore waste-sorting station, but after cost/benefit analysis we decided on another solution, offshore sorting. We decided to sort the

garbage inside our system during operation to reduce costs. We wanted our system to be cheap enough to make sales to almost every Norwegian municipality, with one system for every river, lake or whatever they want to cleanup on water.
A more expensive solution would have made our system into a less attractive solution for our customers.

11.1 Cash Flow

	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4
Investments	150k	150k	350k	350k	600k	300k	100k	100k
Unit Sales	0	0	0	1	4	5	7	7
Salary	130k	130k	180k	180k	270k	290k	290k	290k
Misc. expenses	20k	20k	20k	20k	30k	40k	40k	40k
Material and components	0	0	150k	150k	600k	750k	1.05k	1.05k
Income	0	0	0	250k	1.2k	1.5k	2.1k	2.1k
Quarter profit	0	0	0	0	300k	420k	720k	720k
Quarter loss	150k	150k	350k	100k	0	0	0	0
Cumulative Profit/loss	150k	300k	650k	750k	450k	30k	690k	1.41M

Component and material cost per unit: 150.000 Nok
Sales price per unit: 300.000 Nok

Table 8: Cash Flow Diagram.

For our imagined investor this project we landed on kverva. Our reasoning for this was that they're an investing firm, their focus is maritime, mainly seafood. It is then in their interest both as an investing firm, as we believe we have a great market opportunity placing our system inside the already existing waste management of municipalities, but also because keeping the oceans surrounding Norway clean will benefit their already existing businesses and in addition reflect positively as environmentally friendly.

References

[1] Gerrit Muller, *Overview of CAFCR and Threads of Reasoning*, April 4. 2004.
Last accessed 13.04.19

[2] Joshua Drubin, Sorting trash can, September 22. 2013
https://www.youtube.com/watch?v=m22jhrKHFWo&fbclid=IwAR20MIUvMO--qw5mGCLmcE0YbueydosP66xqykcQY59MMqAa03iba-fRoUY

[3] Tore Stensvold, *5 NTNU-studenter fikk 48 timer: slik kan havet bli fritt for plast innen 2030,*
https://www.tu.no/artikler/5-ntnu-studenter-fikk-48-timer-slik-kan-havet-bli-fritt-for-plast-innen-2030/436253?fbclid=IwAR2ho4_4VJpOX84T2U659ijRerp9N_krHTWPn3LHPhK6WFr8G9OrEkEgPfc.
Last accessed 17.04.19

[4] *The Ocean Cleanup Technology, Explained,* July 21. 2018.
https://www.youtube.com/watch?time_continue=41&v=O1EAeNdTFHU

[5] Gerrit Muller, *CAFCR: A Multi-view Method for Embedded Systems Architecting; Balancing Genericity and Specificity*, September 9. 2018.
Last accessed 22.04.2019