Glan Net: Concept Design

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Executive summary

The ambition of this document is create a smart device capable of reducing pollutants from entering the ocean. The criteria of evaluation will be concerned with technical and economical variables. Prior to this report, a standards IP, benchmarking and user need-finding report was conducted and led to the development concept ideas and gather user opinions and data based on intellectual properties and potential competitors. In this present document, four concepts have been developed individually by each Project Team member, namely "Litter Isolation Device" ; "Smart Grate" ; "Trap Door Net" ; "Rigid Smart Net", which all answered to the identified problem of Water Pollution coming from Storm Pipes. The literature review on Storm Pipes which has been carried out is presented in Introduction. Following these four in-dept Concept development, a Design Evaluation using Pugh Matrix allowed us to choose the best and more suitable Concept in respect of our requirements. This final Concept is the fourth one: a Smart Rigid Net and has been refined to determine which lifting system, net material, railing type, etc. are best towards specific characteristics such as "cost" and "durability". The Concept evaluation and development along with the paper prototype will prove very useful in the future when setting out manufacturing plans and embodiment designs for the final products.

Contents

1 Introduction

The Glan Net project carried out by Arthur Odlum, Aimee Goodwin, Yann Blake and Taron Wright aims to target and tackle the major problem of water pollution. Previously the problem statement that was being addressed was to ”extract litter from *any* water ways in urban areas as litter damages ecosystems”. Following systematic literature review this problem statement has become more precised and narrowed down to the scope of storm pipes. The systematic literature review was carried using the key words ”litter + rivers” and ”litter + ocean” and revealed: first, that the main source of ocean pollution are rivers ; and secondly, that the principal flow of litter going into rivers comes from storm pipes in urban areas.

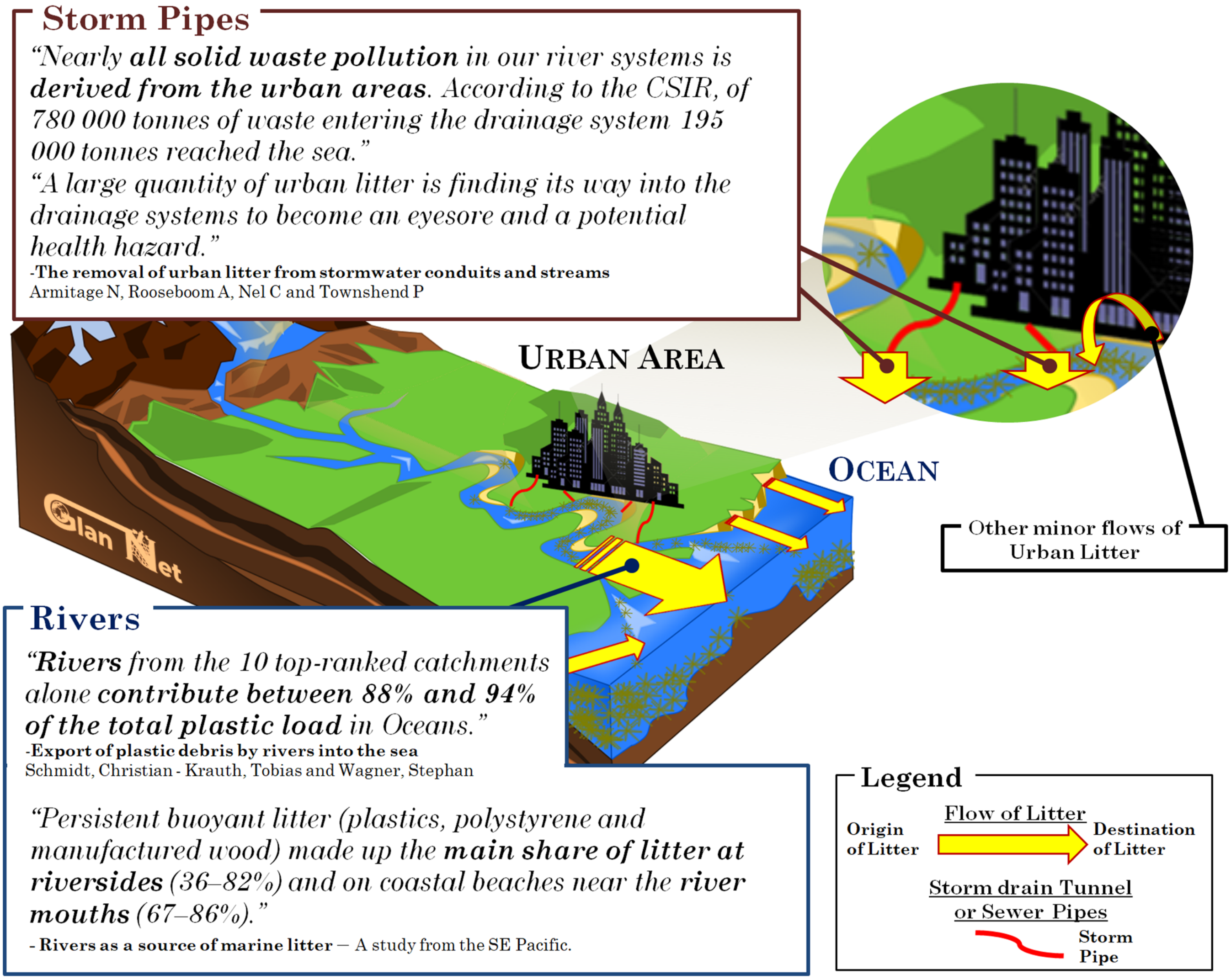

Figure 1: Diagram describing the pathway of water through waterways and demonstrating that the major initial source of litter comes from Storm Pipes.

Several research programs - as shown in Figure 1. where three excerpts from project publications are presented - emphasize on the importance to deal with the flow of urban litter coming out of Storm drain Tunnel or Sewer Pipes from Storm pipes, on a world scale. On Ireland's scale, a survey conducted by Irish Business Against Litter (IBAL) shows that only 16% of coastal areas and waterways are clean, with the River Tolka, the River Barrow and Cork Harbour being 'heavily littered'.

Once the problem has been clearly identified and attested by several reliable scientific sources, the development of new concepts suitable to solve this new problem statement is being carried out through this present report. Four different concepts that apply to Storm Pipes are developed by each member of the project team with the following structure: a general description, the features of abstraction, functions, requirements, possible solutions and possible combinations. The project team all together then evaluate and compare the 4 concepts against each other. The detailed concepts are being weighted and scored under a number of different headings and from which a final concept is chosen. This concept will then be adapted into a prototype which will allow the main features to be tested and refined or changed if required.

1.1 Definitions

The qualification of an **unwanted material object** of any size may take several different names depending on the context, the level of language use and the type of objects or the environment in which it is found. Therefore, the following words exist: rubbish, garbage, trash, waste, refuse, recycle and litter. According to the definitions of all the previously stated terms from *The American Heritage Dictionary of the English Language*, it appears that the word litter is best-suited to qualify the pollution in the rivers and similar environments:

"a. Carelessly discarded refuse, such as wastepaper [. . .] b. A disorderly accumulation of objects"

It also appears to be the most suitable in a literature and academic context. In the Glan Net Project and its associated reports, any such undesired material object is referred as "**litter**" or "**urban litter**".

The concept refers to the ideation of a solution to the identified problem. Solution refers to the same as concept.

The design refers to the concrete application of the concept into detailed plan, functions and drawing.

The product refers to the final result of the design after manufacturing and refining processes. This is what the users obtain at the end of the processes.

The device refers to the product specifying its mechanical and electrical characteristics.

Waterways refer to any channel made of water such as rivers and canals.

Bodies of water or waterbodies: in some contexts this includes oceans. However in Glan Net context this only refers to any geographical feature containing water including canals, lakes, marinas, harbours, rivers and streams. It is the same as waterways with the addition of lakes, marinas and harbours.

2 Concept 1: Litter Isolation Device

2.1 Introduction to the Concept

This concept is the work of Taron Wright. It consists of a mesh grid net isolating litter flowing out of Storm Pipes. This then isolated litter falls onto a conveyor belt which moves it into a bin located on the side of the mechanism. The bin is then being emptied by the user once a notification is being sent.

2.2 Functional structure

Figure 2: Functional Structure

A functional structure allows an abstract view of the overall process of the concept by defining its inputs and its outputs. The functional description only specifies what the product does, it does not give any insight into how the product performs the function. In this case, the functional structure of the concept has inputs Storm Water + Energy and has outputs Filtered Water Rubbish and Signal Out. The Storm water is a material input while the Energy is energy. The material output is then separated into two outputs, filtered water and rubbish. The Energy input is expended on separating the material outputs and on producing an Signal Output.

2.3 Flowchart

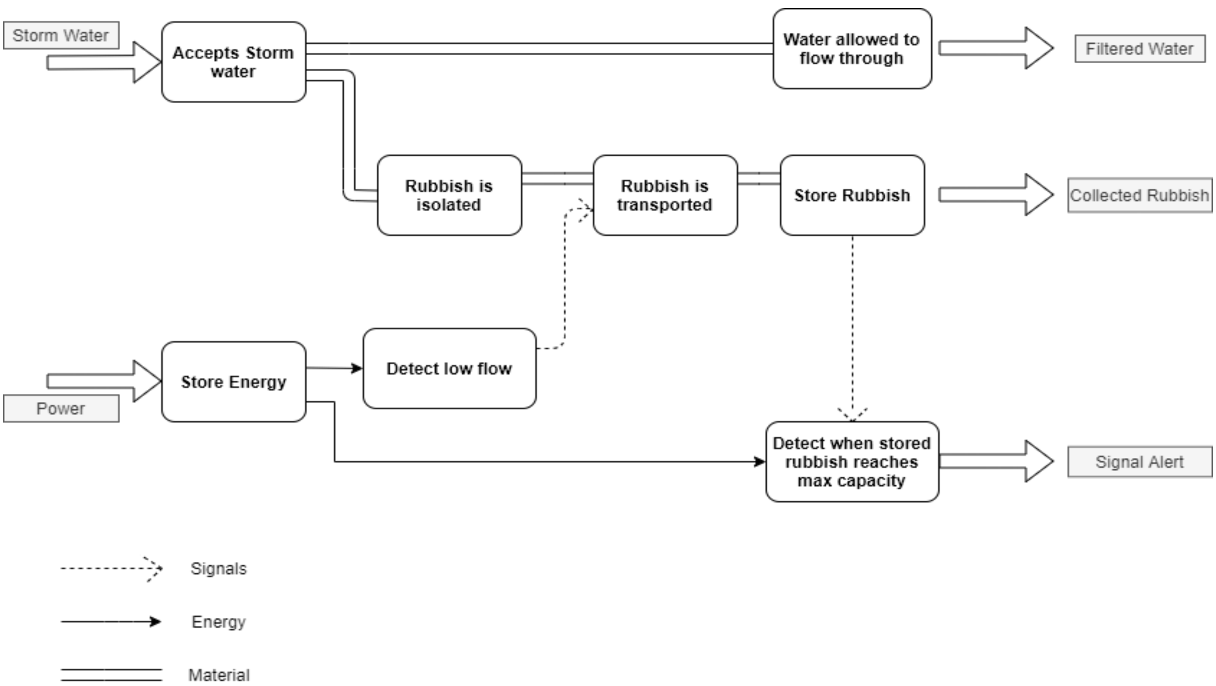

Figure 3: Flowchart

The flowchart in Figure 3 breaks down the functional structure into more complex sub-functions. The sub-functions narrow down the key functional elements of the concept without defining any single solution. The flowchart in Figure 3 has three main modes of flow which are Signals, Energy and Material. The arrows represent the direction of the flow. The sub-functions only flow if their inputs are completely satisfied, i.e. 'Rubbish is transported' will not occur until both the material flow and the signal flow reach the sub-function. These sub-functions can now be analysed to find solution principles for the concept design.

2.4 Solution Principle

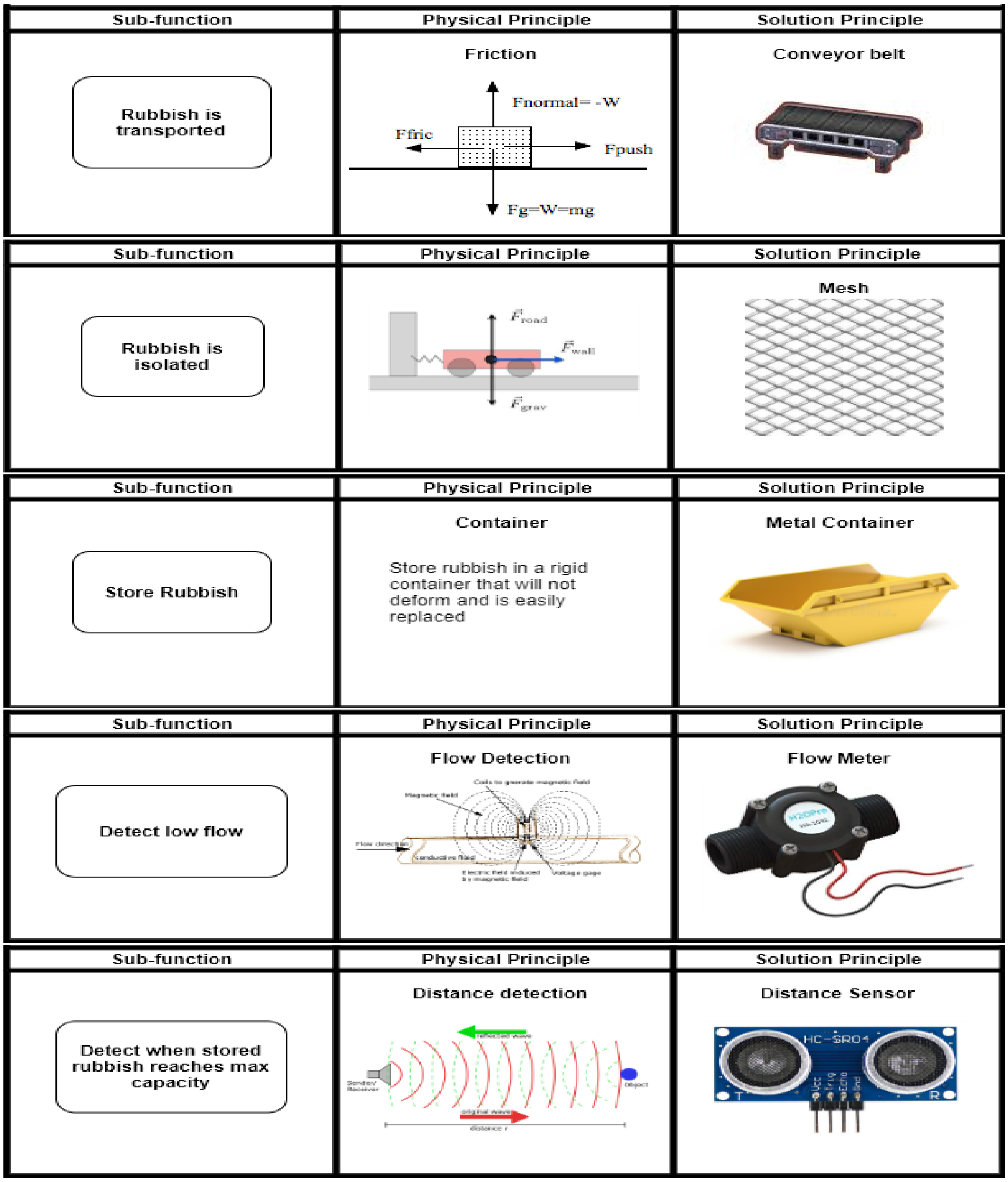

Figure 4: Solution Principle

The chart in Figure 4 shows the solution principle of each individual sub-function derived from the flowchart. The physical principles suggest the energy and forces that govern the7 sub-functions. The solution principle then embodies a possible method to achieve the sub-function. The solution principles in Figure 4 above are only one theoretical way of embodying the concept sub-functions. Other solution principles exist that could equally fulfill the sub-function criteria. As such, the solution principles generated by 1 not should be considered as a definite embodiment of the concept but rather a unique interpretation that can be improved and worked upon. However, with regards to the present solutions these can be pieced together to form one singular coherent device that will produce the outputs defined in the functional structure.

2.5 Objective Tree

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Figure 5: Objective Tree

An Objective tree is a systematic tool to generation that aids in weighting importance on various design factors. The tree moves from philosophical statements of product integrity through to how these can be achieved at an engineering level. At the top level the main attributes are identified, under which the attribute is expanded upon. There can be several branches of attributes attached, each outlining a design trait that needs addressing. Multiple alternative solutions may be on a single level. In turn these solutions are decomposed further until an engineering design solution is conceived to solve the issue.

Conclusion of the Objective Tree: The Objective Tree in Figure 5 works through the basic functional objective that are necessary for the Glan Net device. The tree above quantifies the qualitative elements of the design and highlights the design features that are most important. The most heavily weighted design consideration is 'Mechanical parts to minimize labour'. This represents how the main idea of this concept is to automate plastic collecting from pipes. This means that this aspect of the design should have the most focus. This will shape the general concept that the design needs to have a sophisticated mechanical system in place. The next most notable design elements are a 'Compact Build', 'Combat rust damage', 'Renewable Energy' and 'Cost Effective' which all have a weight of around 0.1. These features will decide the materials, size and energy source respectively of the concept design.

2.6 Concept Model

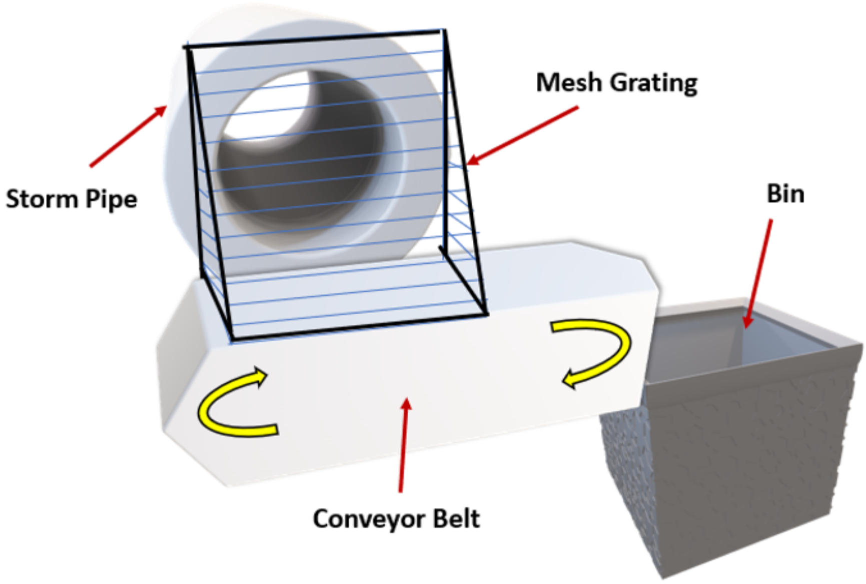


Figure 6: Model of Concept

The Model in Figure 6 shows the embodiment of the concept formed from the functional structure and the objective tree. The net isolates the rubbish flowing from the pipe. The rubbish then falls onto the conveyor belt and is transported into the bin. The conveyor belt will only work during times of low flow which is measured by a flow meter. Once the rubbish is transported to the bin the conveyor will stop moving. When the bin has reached maximum capacity a signal will be sent to the local authorities notifying them that the bin needs emptying. This concept addresses the core needs established by the functional structure of dealing with littered water through the means of Isolation, Transportation and Storing. The flow meter and the distance sensor are not visible in Figure 6 but would be positioned at the mouth of the pipe and the top of the bin respectively. Both items would need to have water-proof characteristics to ensure they are not damaged by the wet conditions.

2.7 Concept considerations

The concept model as seen in Figure 6 is just one embodiment of the solution principle. The concept has limitations that will restrict it's functionally depending on specific conditions:

1. Location - this concept will not work depending on the location of the storm pipe. This concept works for storm pipes that are close to ground level and easily accessible for emptying and replacing of the bin.

2. Power - this concept is possibly a high powered solution to isolating, transporting and storing rubbish and may require an expensive power supply.

3. Aesthetic - this concept is not very visually pleasing and may not suit highly populated areas. Not much can be done to increase the aesthetic other than attempting to blend the concept to it's environment by painting or other techniques.

4. Wildlife - this concept poses as a potential danger to wildlife that may get caught in the device or that may flock to the device because of the storing of large quantities of rubbish.

3 Concept 2: Smart Grate

Introduction of the Concept

This concept is the work of Arthur Odlum. The first concept is a device that will catch solid pollutants in a grate at the mouth of the pipe. Once this grate is filled an interlocking grate connected to an axle will transport the litter into a bin. When full a text will be sent to the user to notify them that the bin is filled and need of replacing.

The device would consist of a distance sensor, electric motor, telecommunication device, SIM800L. a bin along with a series of interlocked grates.

In Table 1, can be seen the face value criteria of the possible solution.

Objective	Functional solution
Remove pollutants from water masses	Filter water masses
Transport litter to collectable position	Mechanisms of movement
Store pollutants	Holding bin
Awareness for pollutant level	Sensor and telecommunications

Table 1: Objective table

3.1 Dimensions

The device would be situated at the mouth of the pipe, the dimensions can be altered for pipes of different heights and diameters.

3.2 Features of abstraction

Below is table 2 displaying Quantitative features against Qualitative features.

Quantitative Features	Qualitative Features
Width of 1-3m	Altering shapes and sizes
Shape: Cuboid	Sleek housing unit
Hardware: SIM800L, Arduino, Distance sensor, electric motor	External energy
Materials: Aluminum	Various components

Table 2: Quantitative vs Qualitative Features

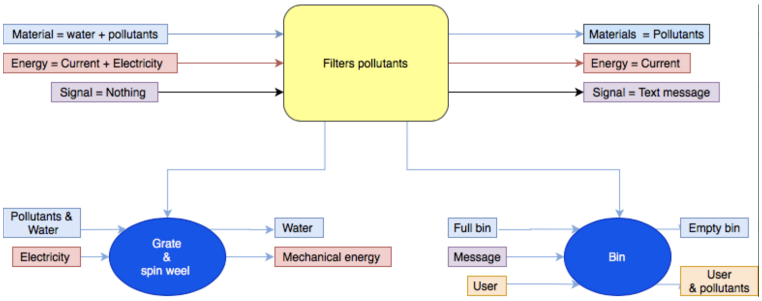


Figure 7: Functional Structure

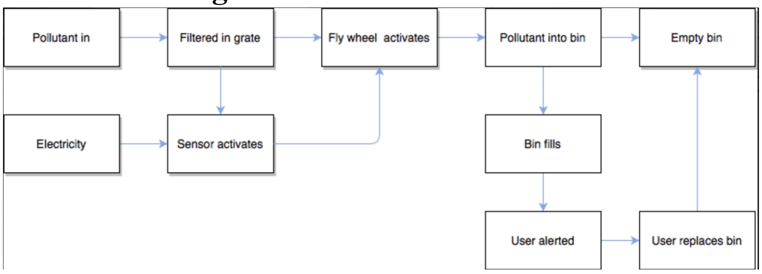


Figure 8: Functions breakdown

3.3 Pipes in Ireland

Sewers in Dublin are divided into 3 types.

1. **Foul** Takes the waste from homes and buildings.
2. **Storm** Takes rainwater from roads and pavements.
3. **Combined** Combination of both storm and foul.

In the last 5 decades, all new developments have been built with separate foul and storm. However, much of Dublin still has a large legacy of combined sewers.
Combined sewers and foul sewers do not discharge into waterways, but go to treatment plants, primarily Ringsend and are then treated. Storm sewers discharge into rivers and waterways.
At high times of rainfall, combined sewers can discharge into rivers or storm sewers.

4 Concept 3: Trap Door Net

4.1 Introduction to the Concept

This concept is the work of Aimee Goodwin. This concept aims to prevent litter flowing out from storm pipes entering waterways such as rivers or bays. When it rains, water on the street/road flows into storm drains. Storm drains are grates along side roadways. The water flows through the storm drains, under the road and through a storm pipe. Thousands of storm drains are connected to the same pipe. Storm pipes exit to rivers or waterways. During rainfall, litter on streets / roads get carried through storm drains. This potentially lets litter enter waterways and rivers.

4.2 Establishing Function Structures

To determine an optimal design it's important to clearly outline the main functions of the device. The functions keep the designer focused on the device to meet the end goals. The functions can be weighted in order to find out which functions carry the most importance. Every system has inputs and outputs, specially energy, signals and material. Machines generally have a material input such as oil for an engine which is then converted into energy and heat. Below is the function structure for our concept.

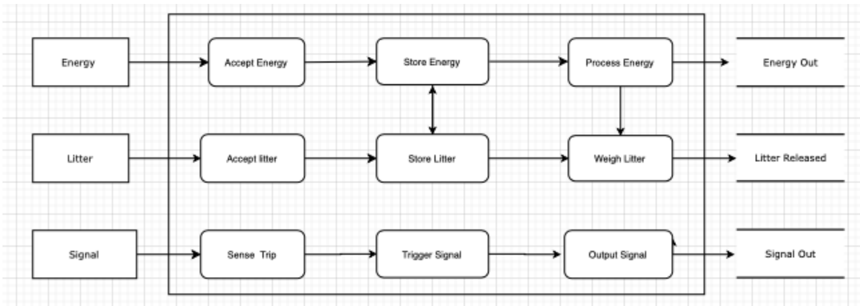


Figure 9: Most Important Functions of the System.

As shown in the diagram above there are inputs of Energy, Litter and Signal. The energy into the system is the water flowing out of the storm pipe. The litter input is the litter carried by the water that enters the net at the end of the pipe and sits upon a trap door. The signal into the system is the weight of the litter that sits on the trap door.
These mains functions can be broken down further into smaller categories and weighted in order to identify importance.

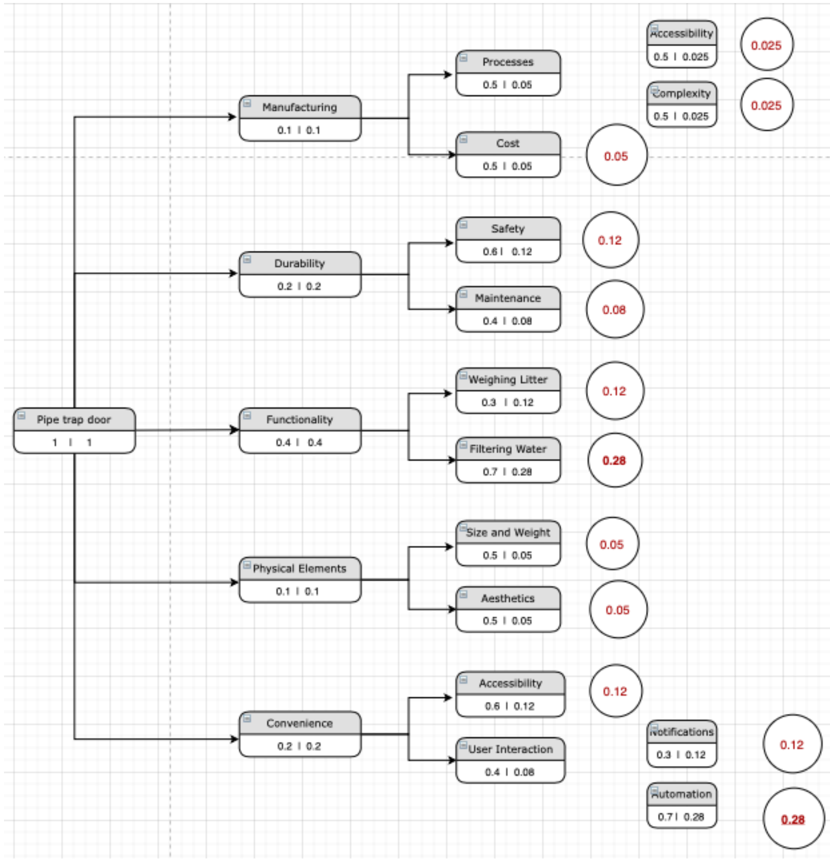


Figure 10: Weighted Functions.

The weights of each function are what in my opinion need most attention. From the diagram we can see that the convenience of automation and the functionality of filtering the water is of most importance. This result is as expected. The automation of the trap door will allow litter that has gathered get dropped into a net below. This in turn will stop litter from blocking the water exit, allow for more litter to build up and allow for a larger volume of litter to be collected.

Functionality was given the largest weight of 0.4 this is mainly due to the fact that if this concept is ineffective then there is no use for it. The functionality of filtering the water is what the concept is based around. This will prevent litter to exit the pipe into waterways which consequently will reduce the amount of litter that gets out to sea and reduce the amount of sea / public water clean up from councils. The convenience and durability is also seen to be important. Once the maximum number of rubbish drops have taken place, a notification is sent out to the authorities for collection. The collection of the rubbish from the net below the trap door should be convenient for the workers. The net and trap door that attaches onto the pipe should be durable enough to hold for extreme weather conditions. As previously mentioned, water flows into these pipes by rainwater along roads. During storms the water is violent and enters the drains and along the pipes at extreme velocities and volume. It is vital the net and trap door is durable enough to withstand these conditions as well as withstand them frequently without needing maintenance.

Manufacturing and physical elements are weighted low in comparison. A net and trap can be made of many materials that are easily accessible. The Physical aspect of the concept shouldn't be much concern either as storm pipes are generally situated in secluded locations.

4.3 Theory

The weight of the rubbish must be calculated correctly on the trap door. Once a specific weight has been met, the automated trap door will open dispensing the litter to the net underneath. The trap door will then return back to its original position.

Ideally a load cell will be used to weigh the contents on the trap door. The litter exiting the storm pipe would mostly be items carried in from storm drains on the road, eg plastic bags, food wrappers and cups. Items like these range between 4grams - 7 grams. A preset weight of 2kgs will be set on the trap door and once reached the associated circuitry would trigger a solenoid for the drop.

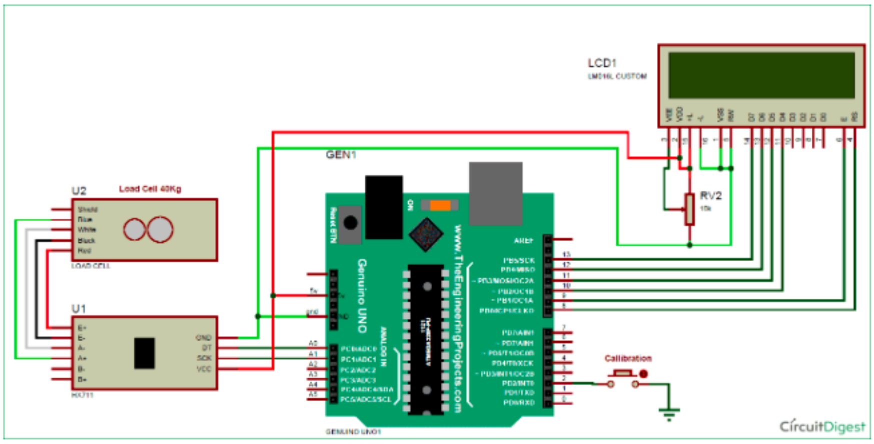


Figure 11: Load Cell and Arduino Diagram.

Due to the lightweight of the litter exiting the pipe and the constant exit of water, this might cause some issues. During extreme weather conditions the trap door might open due to the weight of the water, this would be an inaccurate representation of the amount of rubbish collected and might notify authorities to come out for collection prematurely.

Another way to trigger the trap door would be to paint the trap door a white / reflective colour, place a light source a few inches above it (an LED, or multiple LEDs), along with a reflected-light sensor (phototransistor), and trigger the trapdoor when the reflected light level drops below some threshold value.

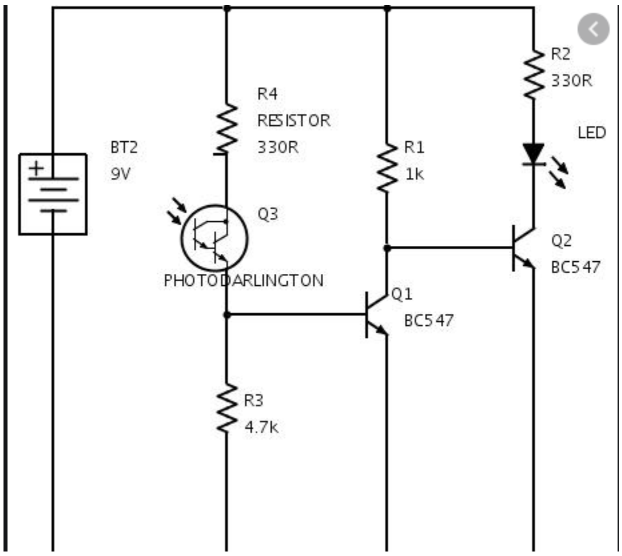


Figure 12: Phototransistor Diagram

4.4 Physical Principal

The system is quite straight forward. Water flows out from the storm drain and through the net out to the bay / river. Any litter carried by the water will get caught in the net and be left resting on a trap door. When the trap door reaches a certain weight or the reflective light off the trap door has been substantially covered, the circuit will trigger and the trap door will open. The litter on the door will be emptied into the net below and the trap door will then go back to its original position. After a certain number of times the trap door opens, a notification will be sent out to the authorities for them to collect the rubbish that has accumulated in the net below the trap door.

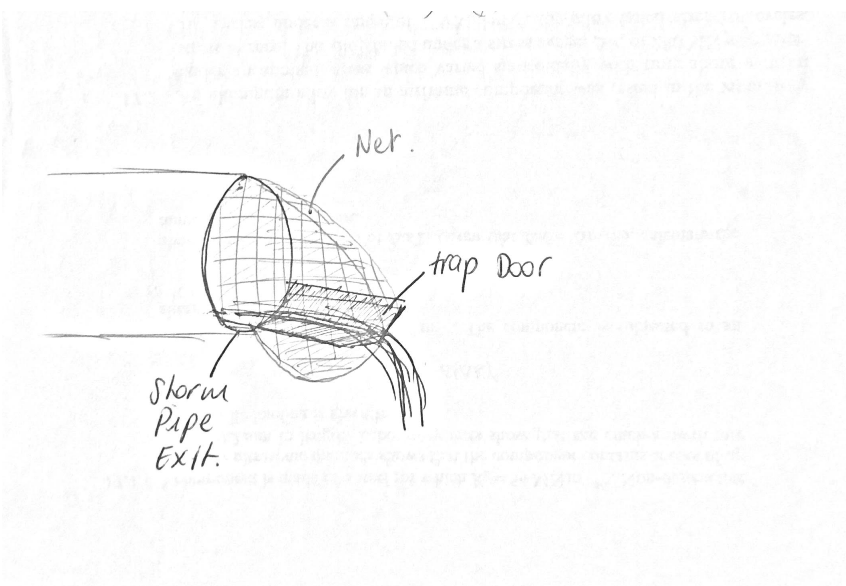


Figure 13: Sketch of Concept

5 Concept 4: Rigid Smart Net

5.1 Introduction to the Concept

This concept is the work of Yann Blake. This concept also aims to prevent litter flowing out from storm pipes entering waterways. It is a rigid smart net which collects and stores litter. Rigid, so that it can resist any abrupt or sudden high increase of the flow of water due to unsual or unexpected weather conditions leading to excess of rain or any other equivalent conditions. A Rigid net also allows to resist wind perturbations along the waterway where it is placed ; and to achieve a greater capacity of litter collected in terms of weight. Finally the rigidness allows a longer life for the device.

Smart because sensors allow the user to be informed once the net is full and requires to be emptied. The user then goes on site and activates the lifting system with a secure switch and empties the net.

The user is assume to be the organisation or people in charge of waste collection (e.g. Dublin City Council). In the same way public bins on streets are collected, such devices require no more than the same pattern of maintenance and collection planning.

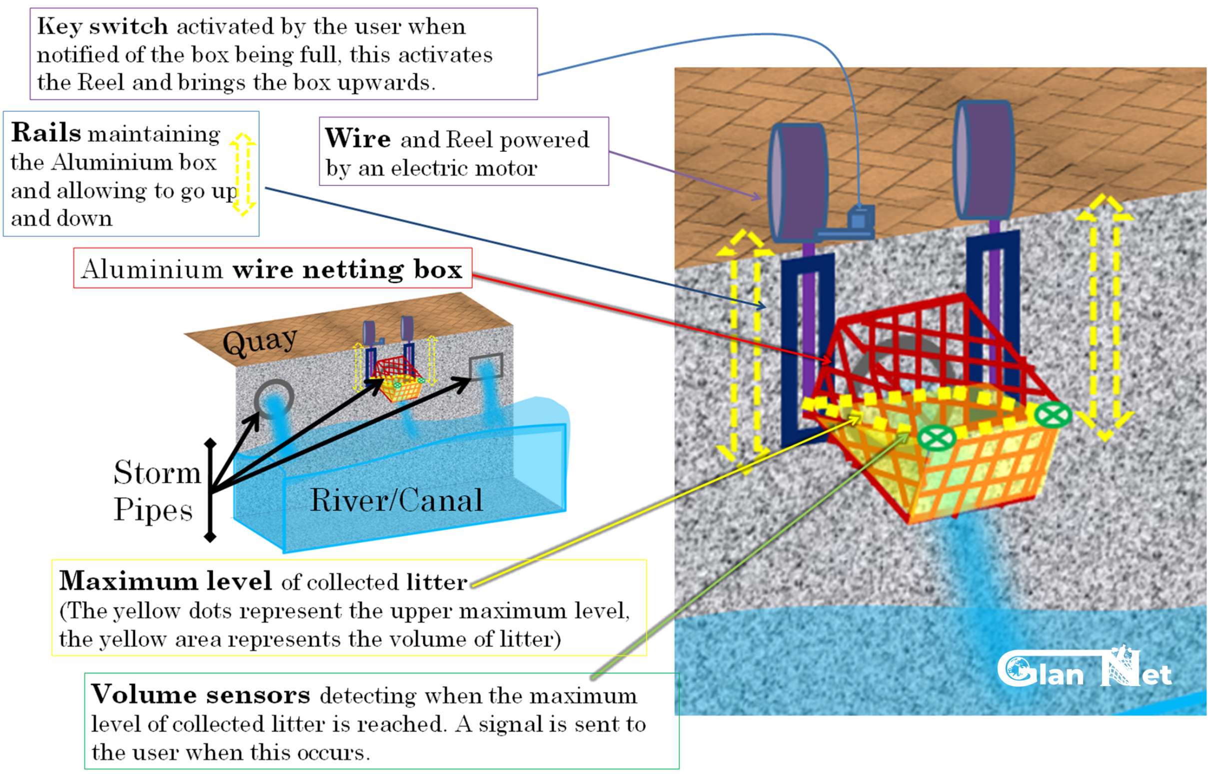


Figure 14: Main Components Description in a real environment situation.

5.2 Features of abstraction

The parallel between the quantitative and the qualitative version of a feature allows less biased insight on both the data required to the development of functional structures ; and the functions of the system meeting the requirements from the problem statement.

Qualitative Features	*Quantitative Features*
Catches the most common smallest litter	$5mm^2$ holes in the net
Adapts to all size, shapes and sorts of Storm Pipe	15 cm to 60 cm diameter/width pipes, square/rectangle cubed Net shape.
Does not block litter in its corners	Curved corners of the net
Is connected to power	Arduino Uno with bread board and lifting motor connected to power supply (solar, battery or main network)
Various components	Rails, Wires, Motorised Reel, Rigid Net, Sensors, Arduino, Arduino circuit, Wheel to rotate the Net, etc.
Creates a reponse	Sensors connected to Arduino ; Text message sent to user
Contains sensors	HC- SR04 Ultrasonic Module or IR Infrared
Is connected to the telecomm network	SIM800L connected to the user
Is able to autonomously be in motion	Motor: DC type to be determined

Figure 15: Quantitative vs Qualitative features of abstraction.

All the quantitative features are explained, justified and discussed in the following sections.

5.3 Theory

5.3.1 Water flow

The flow of water through a pipe is determined from the general fluid flow rate which is equal (=) to the area of the pipe or channel times (X) velocity of the liquid. (Q=Av) The liquid flow rate is expressed in m3/s or L/s. The area of the pipe or channel in m2 is equal to pi times r squared. In the context of a grid or a net through this cross section area, this parameter changes.

The velocity of the liquid and is regulated by standards which vary from countries and places to others. Averages are given below.

Application	Maximum Velocity *(m/s)*
General Water Service	0.9 - 2.4
Tap water (low noise)	0.5 - 0.7
Tap water	1.0 - 2.5
Cooling water	1.5 - 2.5
Suction boiler feed water	0.5 - 1.0
Discharge boiler feed water	1.5 - 2.5
Condensate	1.0 - 2.0
Process water	1.5 - 3
Pump discharge	1.5 - 3
Pump suction	0.9 - 2.4
Heating circulation	1.0 - 3.0

Table 3: Maximum Flow Velocities in Water Systems[1]

5.3.2 Size of Waste

The World Health Organization found that Tobacco waste represent a proportion of 30-40% of picked-up litter, making it the most common type of litter.[2] The same trend has been demonstrated by Ocean Conservancy with 24% of total debris of items collected from U.S. beaches and inland waterways were Cigarette butts.[3] There is a definite correlation between land pollution and its impact on rivers and then the oceans, in particular via drains.[4]

The size of a Cigarette Filter is of 20 to 30 mm long meaning a Cigarette Gutt ranges from 20 mm to the standard total size of a Cigarette 100 mm.[5] The circumference of a Cigarette ranges from 17 mm to 25 mm. Therefore in order to account for this considerable type of litter, the holes of the net for our device must be less than 5.4 mm wide (5.4 mm diameter of a 17 mm circumference). However it is important to note that this minimum concerns the slim Cigarettes which are not the most widely used sizes.[6]

Secondly, plastic bottles account for another large proportion of litter.[7] The size of the caps is from 18mm to 120mm. The most common plastic bottle size is 0.5L which usually has dimensions of 75mm diameter and 232mm height[8], while the most used soda bottle is 2L i.e. base diameter 104mm height 327mm.[9]

According to another study from International Coastal Cleanup the following top 10 types of litter comes out from their collected data : 1. Cigarette butts/cigarette filters 2. Bags/food wrappers 3. Caps, lids 4. Beverage bottles (glass) 5. Beverage cans 6. Cups, plates, forks, knives, spoons 7. Beverage bottles (plastic) 2 liters or less 8. Straws, stirrers 9. Fast food Containers 10. Cigar tips.

Bags, food wrappers as well as all the many following types of litter can have various size and dimensions, from very small for straws and stirrers to larger items.[10]

However, while it is clear that litter can be any size, the open spaces between the yarns must take into account the flow of water. In fact a net catching all Cigarette butts would surely impact the parameters of the water flow.

5.4 Functions

Functionality 0.35 | **0.35**	Filters, collects, stores litter	0.5	**0.175**
	Detects when it is full of collected litter	0.35	**0.1225**
	Adaptable to any size, shape of Storm Pipes	0.15	**0.0525**
Availability 0.1 | **0.1**	Respects standards, no patent infringement, safe for the users and surrounding environment	0.7	**0.07**
	Cost effective (the device manufacturing cost, the device price and the operation and maintenance costs)	0.3	**0.03**
User-friendly 0.35 | **0.35**	Easy to install	0.2	**0.07**
	Easy to use, user-friendly	0.05	**0.0175**
	Low maintenance	0.05	**0.0175**
	Easy to empty the collected litter from the device	0.3	**0.105**
	Accessible to be picked by the user	0.3	**0.105**
Appearance 0.05 | **0.05**	Visually aesthetic	0.4	**0.02**
	Discrete to the surrounding people/non-user of the device, security measures	0.6	**0.03**
Durabilité 0.15 | **0.15**	Low power use, environment-friendly	0.15	**0.0225**
	Materials are waterproof and resistant to various stresses	0.55	**0.0825**
	No major impact on the water flow, water evacuation	0.25	**0.0375**

Figure 16: Objective tree weighting importance of the functions of Smart Rigid Net.

5.4.1 Requirements and associated solution

Main requirements

- **Filters, collects, stores litter**. The Net pattern stops the litter against its surface. The Net forms a fully closed box so that the litter can not escape the device. The shape of the Net is orientated downwards so that the litter falls down and is kept away from the Storm Pipe mouth and Water flow.

- **Detects when it is full of collected litter**. The Sensors are placed at a level that is considered to be the maximum capacity of litter (in terms of volume) that the device can support, without blocking the Storm Pipe or damaging the the Smart Net system. A time margin in regards of the average litter rate and the time required by the user to empty the Net is comprised in the maximum level establishment. The Sensors work correctly in both air and water mediums. There are several Sensors to reduce the risk of error (probably 4). The Sensors then send a signal to the Arduino system (Arduino, board and circuit) when it detects ”full”. From the programme the Arduino sends a signal to the SIM 800L component, which informs the user through means of a text message transmitted by main telecomm network.

- **Accessible to be picked by the user**. The Rigid Net is interlocked into two rails, which are attached to the horizontal walls/sides of the waterway. The Rigid Net is able to move upwards and downwards along these rails. The Rigid Net is also attached to a doubled metal cable. The cable is connected to a motorised Reel on the top vertical floor/side of the waterway ”Quay” in Figure X. When the motorised wheel is activated by the user the Net moves up or down depending on the switch activated.

- **Materials are waterproof and resistant to various stresses**. The rigid Net, rails, and the cable are made of Stainless steel or Aluminum metal. The other components are made of weather-resistant and waster-resistant plastic material (PDCPD or PHENOLIC RESINS or POLYCARBONATE[11]). All other materials are protected/coated with the previously mentioned plastic.

- **No major impact on the water flow, water evacuation**. The Net whole size is adequate to the flow of water while still collecting the desired types of litter. The shape of the Net is such that the collected litter falls downwards and do not obstruct the Storm Pipe.

- **Respects standards, no patent infringement, safe for the users and surrounding environment** . The following requirement has been verified in previous reports, and will have further investigations if this Concept is being chosen, as the Final one.

Other requirements

- **Adaptable to any size, shape of Storm Pipes**. The mouthpiece of the Rigid Net is standard but is large enough to account the larger most common size of Storm Pipes found in Ireland’s big cities’ waterways. According to Dublin City Council the diameter/width varies from 15 cm to 60 cm.[12]

- **Easy to install**. The Rails are adaptable in length depending on the location of the Storm Pipe and are easily fixable to the walls/horizontal sides of the waterway.

- **Easy to use, user-friendly**. The Motorised Reel Lifting system includes a wheel allowing the Rigid Net to rotate towards the user and facilitate the emptying into their own waste collection equipment (e.g. a bin, a truck, etc.).
- **Low maintenance** . The Design is adapted for a use of between 5 and 10 years, with low need for maintenance every 6 to 24 months.
- **Cost effective (the device manufacturing cost, the device price and the operation and maintenance costs)**. The Design is aimed to be the most simplified while keeping the same efficiency. The choice of materials are standard costs. The maintenance cost is the same or lower than for a public bin displayed in a street.
- **Visually aesthetic**. The Design is meant to be simple and the Motorised Reel Lifting system located on the ”Quay” is the most discrete as possible. This requirement is the less important.
- **Low power use, environment-friendly**. If suitable to the costs, budget and setting, the power is Solar and comes from sunbeams. Otherwise the Arduino system and Lifting system are powered by a rechargeable long-lasting and low-consumption battery or connected directly to the main power network. The Smart Net device does not produce any pollution or interfere with wildlife and ecosystems.
- **Easy to empty the collected litter from the device**. This requirement is addressed in the previous solutions to previous requirements (i.e. Easy to use, Accessible to be emptied by the user). The motor can support and lift sufficient amount of weight.
- **Discrete to the surrounding people/non-user of the device, security measures** The activation of the Lifting system is possible by means of a secure keyswitch with two options ”up” and ”down”. The key adapted to the keyswitch is possessed by the user only. The Reel is correctly fixed to the ”Quay” to avoid any accidental or voluntary damage from surrounding people. The Reel may be considered to be hidden if possible.

5.4.2 Functional Structures

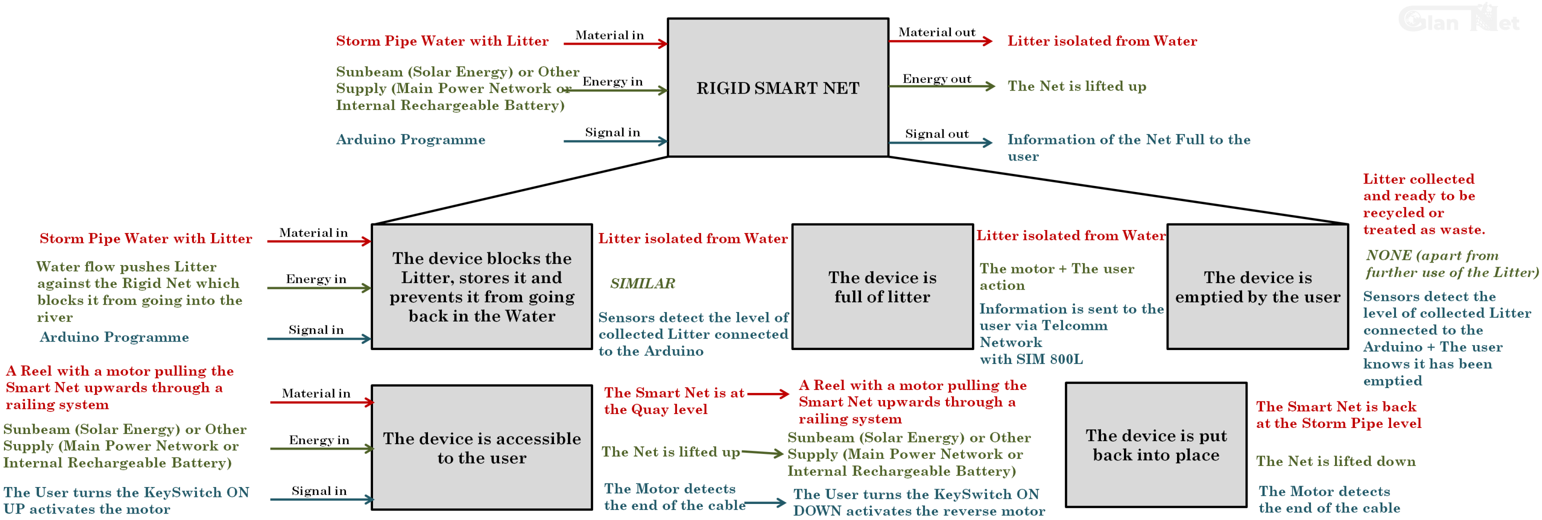


Figure 17: Functional Structures detailed

5.4.3 Overall Function

Vocabulary note

For this section, the following abbreviations will be used:

- **SRN:** ***Smart Rigid Net*** the overall Box that can be moved upwards and downards. This includes the *"physical"* sensors attached to it and the litter inside.
- **LS:** ***Lifting System*** the motorised reel lifting system which allows the motion of the Smart Rigid Net along its two rails. This includes the keyswitch, the rails, the cables and the motorised reels.
- **AS:** ***Arduino System*** the electrical and electronic circuit and components involved in the detection of the level of litter being full and the information sent to the user. This includes the Arduino, the bread board, the SIM800L, the *"electronical"* sensors, the power supply to this system.

Breakdown of Overall Function

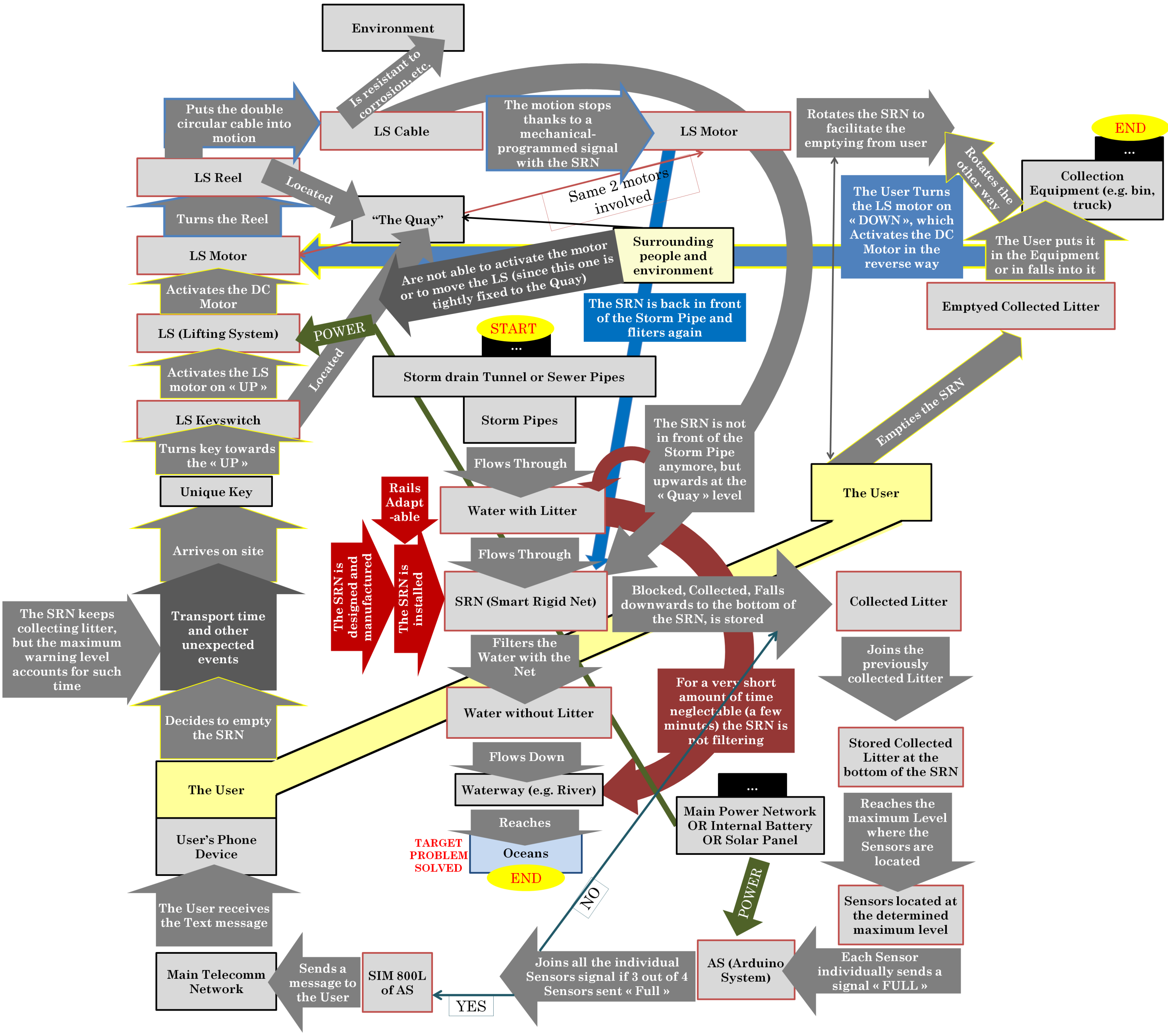


Figure 18: Full detailed breakdown of functions and components.

The diagram above in Figure 18 presents in detail every single step in the concept's functions. As this may appear difficult to read, it is suggested to start at the yellow circle "START" and follow the path of grey arrows, then once back on the SRN (Smart Rigid Net) box, follow the dark red color. It is understood now that when the SRN is lifted is does not filter anymore. Now let us focus on the LS Cable box, and follow the grey path, then the blue path: it finishes at the SRN (Smart Rigid Net) box again. It is now clear that the system works as a loop. The only two important ends for the concept is the Ocean being clean and the Litter being taken away by the User (e.g. Dublin City Council).

Note that the boxes surrounded by yellow are actions, functions or components dependent on the user. The light red boxes represent the setting up of the device, which only happens once. The darkest grey color represents the actions out of the control from the user or the concept design. Finally the black boxes mean that there is more before or after that was not relevant and wasn't represented.

5.4.4 The scope of action of the User

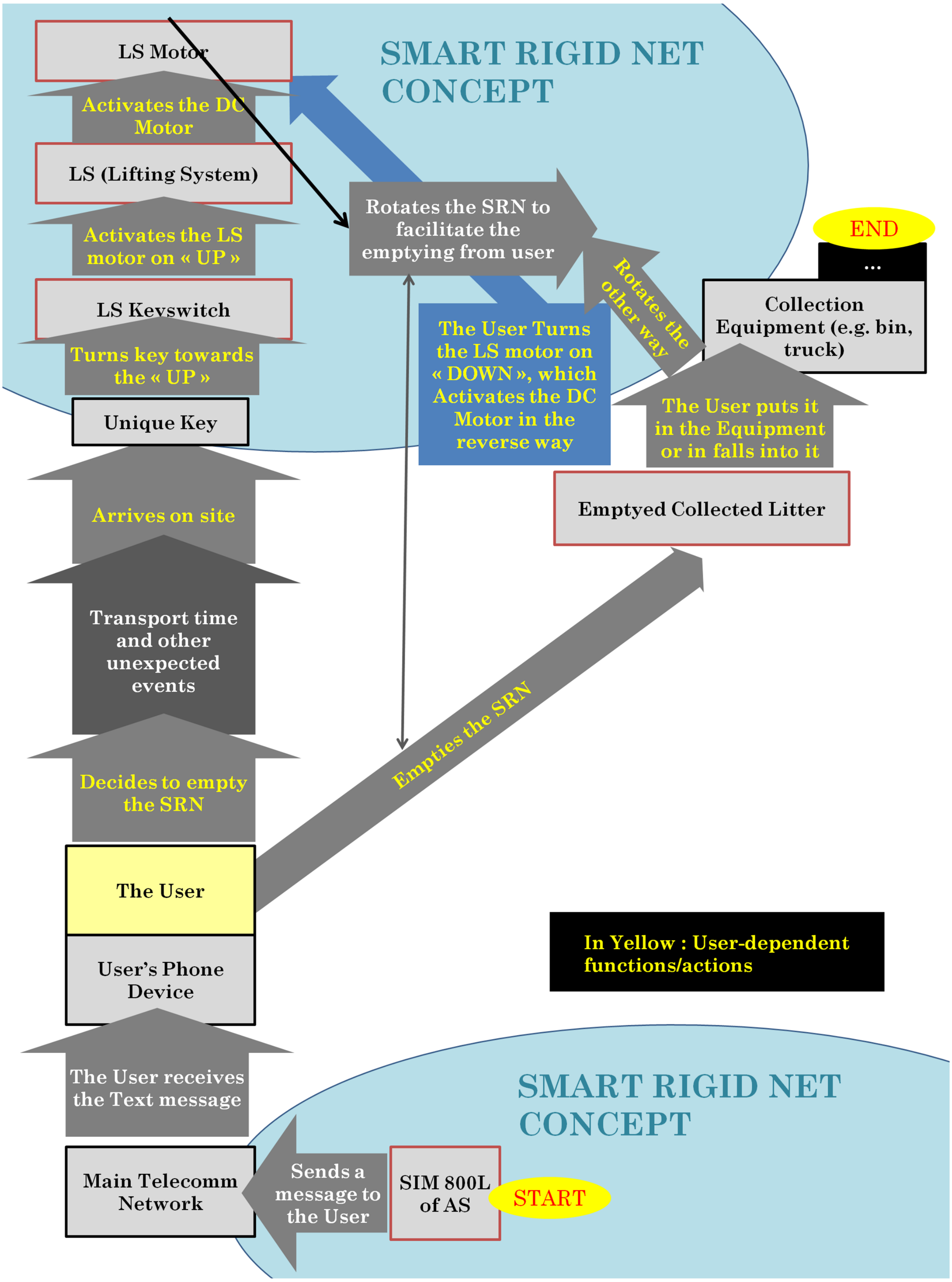


Figure 19: Scope of action of the User ; user-related and user-dependent functions.

5.5 Detailed Layout

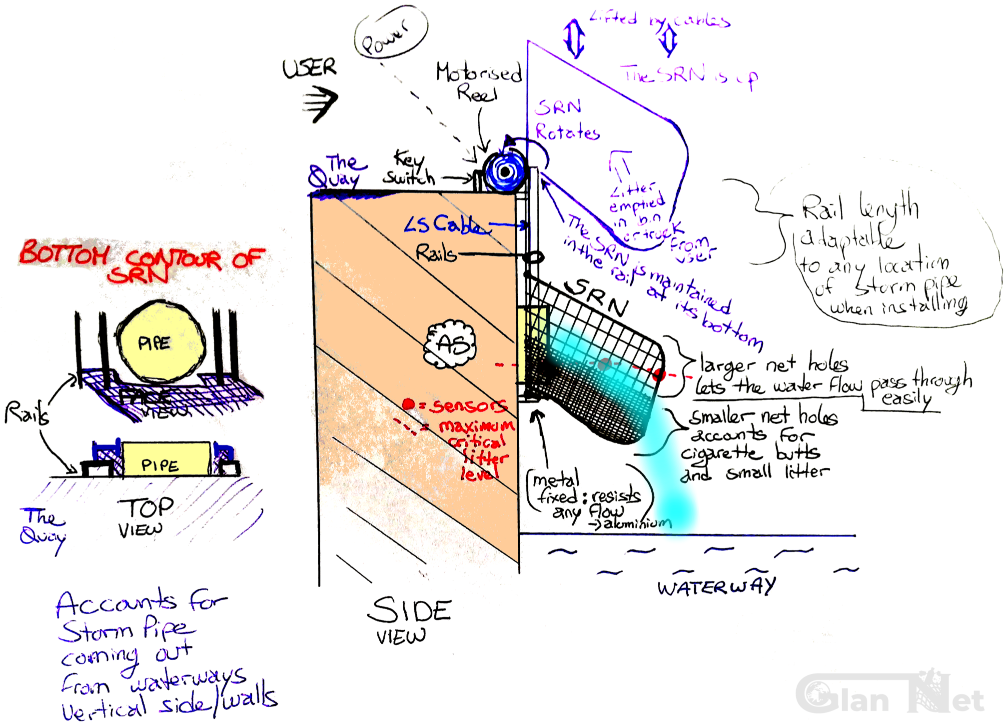


Figure 20: Detailed Layout of the Smart Rigid Net

6 Design Evaluation

6.1 Concept Selection

The four concepts that have been discussed in detail in this document will now be evaluated and compared to one another to identity the design which can best meet the needs of the product. The initial process should compare concepts on basic need statements that best describe customer needs and that best satisfy the Product Design Specification (PDS). There are many different methods and approaches for concept selection. The method chosen for this project is the Pugh Matrix method, a graphical method which utilises a matrix with columns (detailing concepts) and rows (indicating decision criteria) and sets a datum (standard) to compare concepts against. Each concept will be graded on a number of criteria ranging from Functionality to Cost to find the best concept. If a concept it better than the standard it will scored 1, if not it will be scored 0 and if it is worse it will score -1. Each score will be added together and each concept will receive a total score. This total score will give a good indication of which concept best meets the design specifications and also which concept meets the most design specifications. This information will then be considered to come up with the final concept idea to move forward with for prototype development.

Criteria	Sub-Functions	Datum	Concept 1	Concept 2	Concept 3	Concept 4
Functionality	Automation	0	1	1	1	1
	Effectiveness	0	1	1	1	1
	Adaptable	0	0	1	1	1
	Storage	0	1	0	0	-1
Durability	Materials	0	-1	-1	-1	-1
	Power	0	-1	-1	-1	-1
	Longevity	0	-1	-1	0	1
Manufacturing	Complexity	0	-1	-1	0	1
	Cost	0	0	0	-1	-1
	Size	0	-1	0	0	1
Convenience	User friendly	0	-1	-1	1	1
	Maintenance	0	1	0	0	1
	Accessibility	0	-1	0	0	1
Safety	Blockages	0	1	1	1	1
	Wildlife	0	1	1	1	1
Total		0	-1	0	3	7

Figure 21: Pugh Matrix

The Pugh Matrix in Figure 21 above compares the four concepts, that have been thoroughly explained in the document, against the datum under five criteria. The datum in this case is the current industry solution used to collect rubbish from storm pipes known as **StormX**. This datum sets the standard that needs to be significantly beat for a new solution to be considered. Immediately it is clear that Concept 1 should not be considered since it has a score of negative 1 which means it's actually worse than the current solution available. Concept 2 scored 0 which means that it is no more effective than the datum and will also not be considered. Concept 3 scored 3 which is only slightly better than the datum but not significant enough that it should be seriously considered as a solution replacement. The winner is Concept 4: Rigid Net, which scored an impressive score of 7 in the Pugh Matrix. This score demonstrates on a very basic level how much better this concept is than the current best industry solution and will be the idea that will be taken to the next stage of product development.

7 Concept Design Specifications

A design specification describes the detailed operation and attributes of a system and is used as the basis of the design concept [13]. Product design specifications are derived from the consumer needs. In the case of this project, the customer needs can be concerned as the environmental needs since the products' needs are based on the environmental issue it seeks to solve. For small scale designs, developing a clear and concise design specification is a relatively straightforward task. The product specifications should represent all the ideal features the product should incorporate to maximize it's full design potential.

7.1 Lifting System

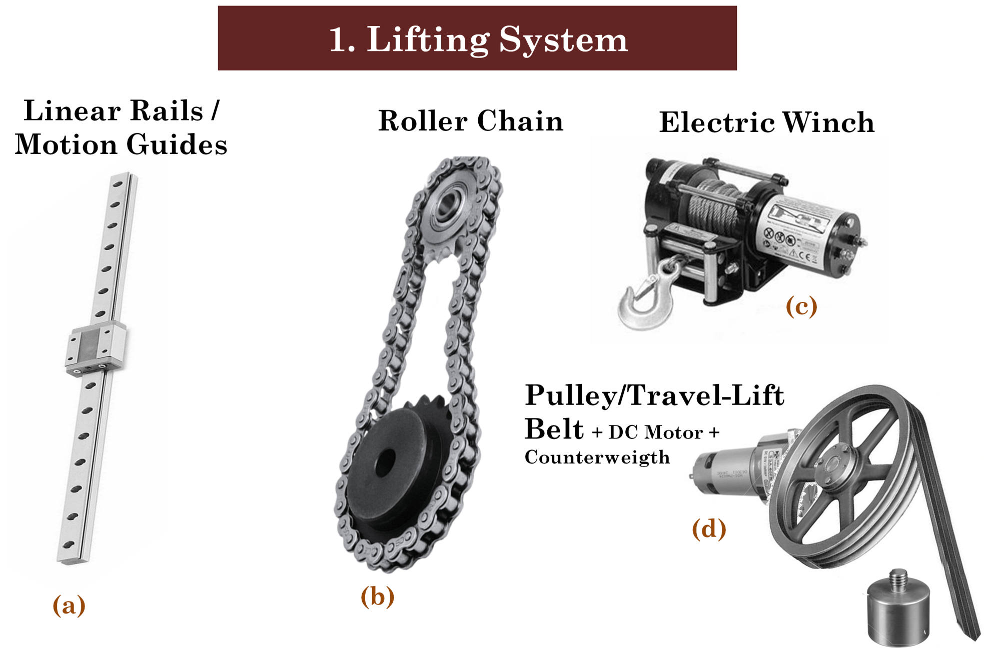


Figure 22: Lifting System Design Solutions

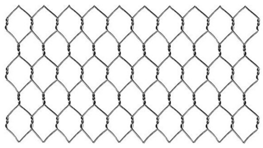
		Lifting System							
		(a)		(b)		(c)		(d)	
Characteristics	Weight	*Score (-1 ; 0 ; 1)*							
Durability	2	0	0	-2	-1	0	0	2	1
Ease of use	2	2	1	2	1	2	1	0	0
Ease of manufacturing	3	-3	-1	3	1	3	1	3	1
Reliable/Quality	2	-2	-1	-2	-1	0	0	2	1
Concept suitability	4	4	1	-4	-1	4	1	-4	-1
Cost	4	-4	-1	4	1	4	1	0	0
Total		**-3**		**1**		**13**		**3**	

Figure 23: Lifting System Selection

7.2 Rigid Net Box

2. Rigid Net Box

Chicken Wire
(a)



Aluminium Grid Mesh Panel **(b)**

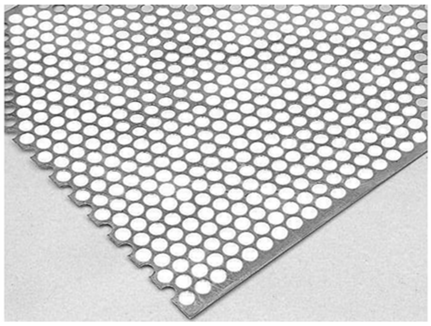


Figure 24: Rigid Net Box Design Solutions

		Rigid Net Box			
		(a)		(b)	
Characteristics	Weight	*Score (-1 ; 0 ; 1)*			
Durability (water flow resistar	2	-2	-1	2	1
Ease of use (not blocking wate:	2	2	1	-2	-1
Ease of manufacturing	3	3	1	0	0
Reliable/Quality	2	0	0	2	1
Concept suitability	4	4	1	4	1
Cost	4	4	1	-4	-1
Total		11		**2**	

Figure 25: Rigid Net Box Selection

7.3 Railing

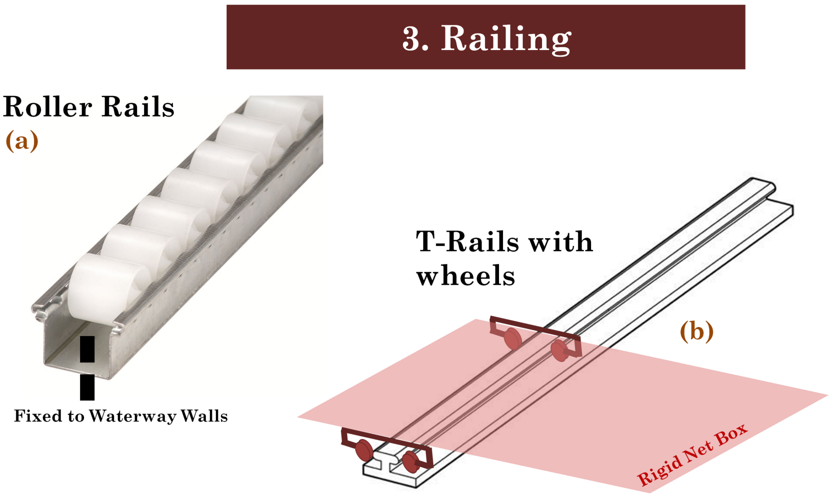


Figure 26: Railing Design Solutions

		Railing			
		(a)		(b)	
Characteristics	Weight	Score (-1 ; 0 ; 1)			
Durability	2	0	0	2	1
Litter Collection Quantity	2	0	0	2	1
Ease of manufacturing	3	3	1	-3	-1
Reliable/Quality	4	0	0	4	1
Concept suitability	4	4	1	4	1
Cost	4	4	1	-4	-1
Total		11		5	

Figure 27: Railing Selection

7.4 Litter Detection Sensors

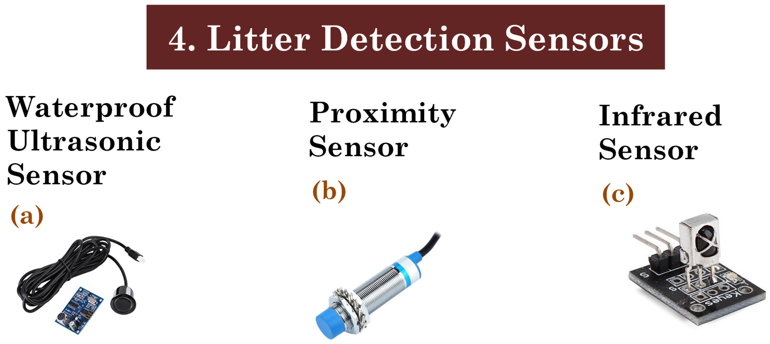


Figure 28: Litter Detection Sensors Design Solutions

		Litter Detection Sensors					
		(a)		(b)		(c)	
Characteristics	Weight	*Score (-1 ; 0 ; 1)*					
Durability	2	2	1	2	1	2	1
Ease of detection	2	2	1	2	1	0	0
Ease of manufacturing	3	3	1	3	1	0	0
Reliable/Quality	2	2	1	0	0	0	0
Concept suitability	4	4	1	4	1	4	1
Cost	4	4	1	0	0	4	1
Total		**17**		**11**		**10**	

Figure 29: Sensors Selection

7.5 Source of Energy

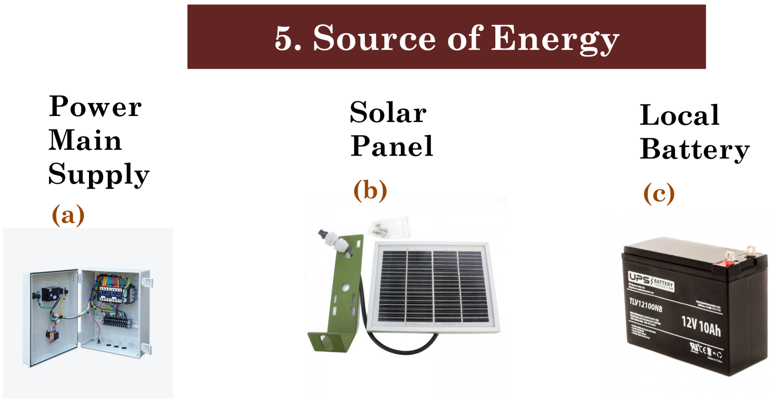


Figure 30: Source of Energy Design Solutions

		Source of Energy					
		(a)		(b)		(c)	
Characteristics	Weight	*Score (-1 ; 0 ; 1)*					
Durability	2	2	1	2	1	-2	-1
Environment Friendly	2	-2	-1	2	1	0	0
Ease of manufacturing	2	2	1	2	1	2	1
Reliable	4	4	1	-4	-1	0	0
Concept suitability	4	4	1	4	1	4	1
Cost	4	0	0	0	0	4	1
Total		**10**		**6**		**8**	

Figure 31: Source of Energy Selection

7.6 Switch of Lifting System

		Switch System			
		Key Switch		Normal Switch	
Characteristics	Weight	*Score (-1 ; 0 ; 1)*			
Durability	2	0	0	0	0
Security of Product	3	3	1	-3	-1
Ease of use (Collection)	2	2	1	2	1
Reliable	4	4	1	4	1
Concept suitability	4	4	1	4	1
Cost	2	-2	-1	0	0
Total		**11**		**7**	

Figure 32: Switch Selection

8 Paper Prototype Development

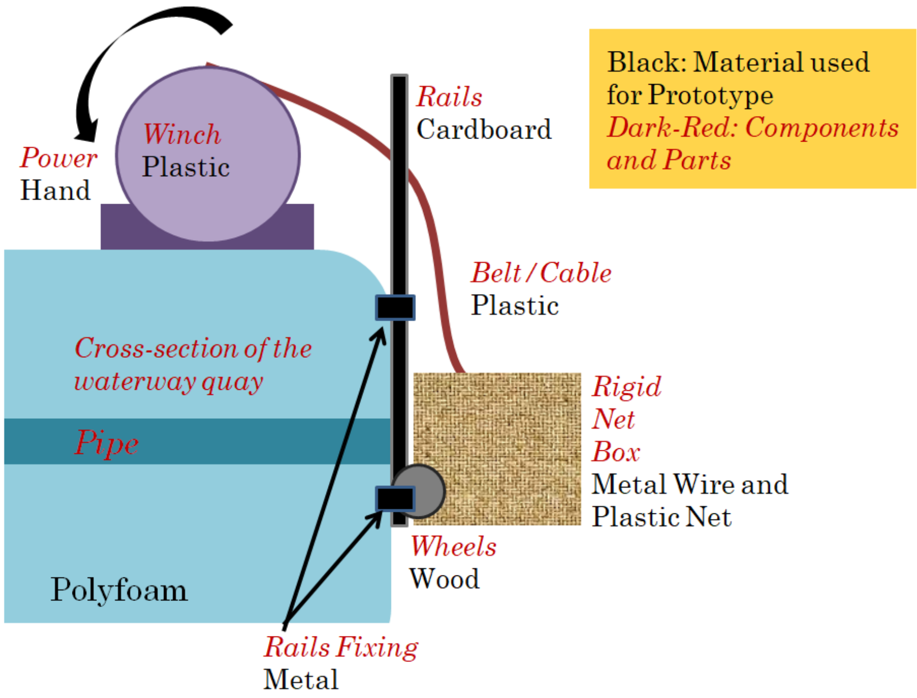


Figure 33: Prototype Plan

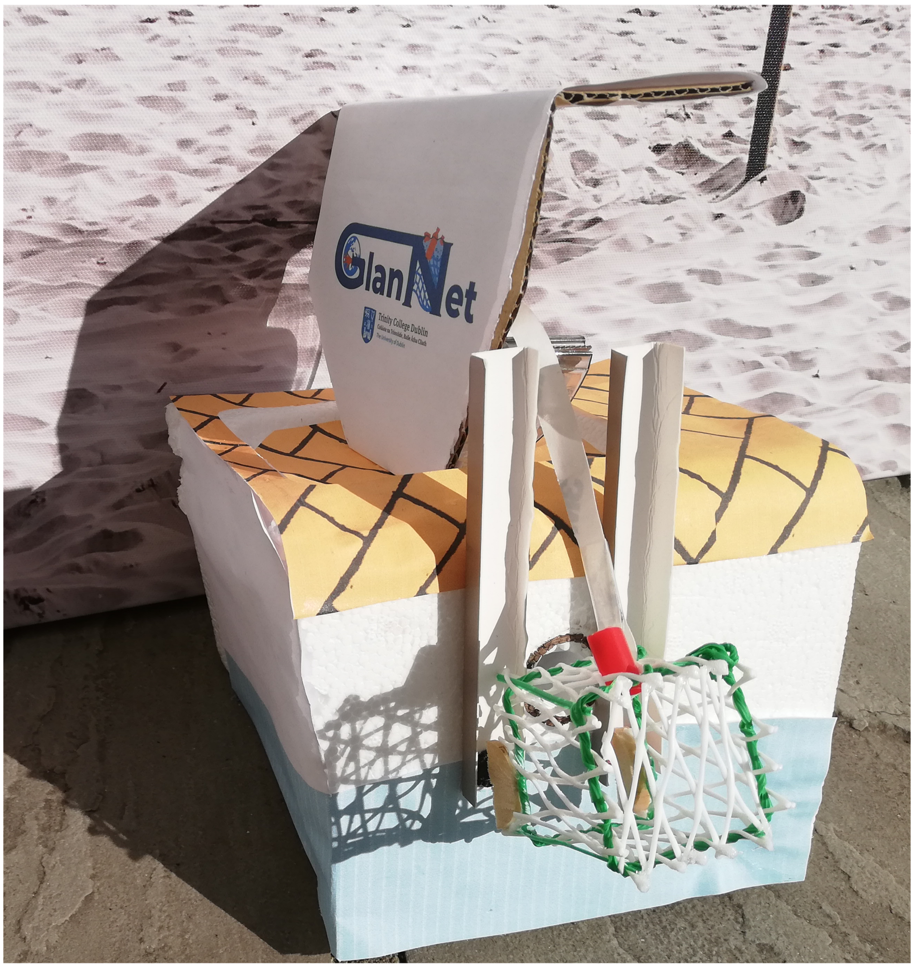


Figure 34: Paper Prototype Photography

The importance of having a guide rail above the Quay level has been shown to be necessary to bring the Rigid Net Box high enough so that the user can easily empty the collected litter. The Paper Prototype also emphasized that a simple belt or cable lifting system is very efficient as well as being very simple, that is what we should aim for: simplicity and efficiency, and not a very complex and "fancy" Design. Finally we have been able to highlight the major functions of our chosen Concept, namely, a Rigid Net Box sliding along two rails and lifted up and going down thanks to gravity.

Further prototypes are planned for in-dept evaluation of all functions and aspects of the design especially the mechanical and electrical components.

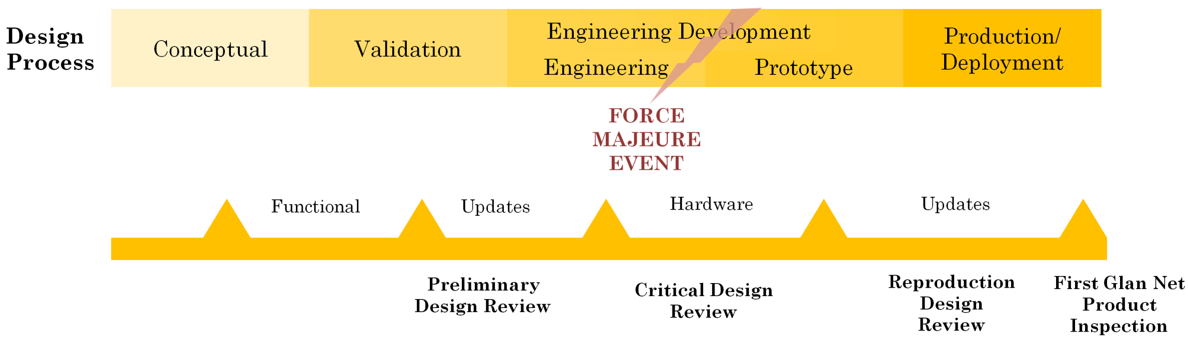


Figure 35: Evaluation and Reviews Plan

9 Discussion

This concept document is a thorough and detailed exploration of four unique concepts that each individually take new approaches to find a solution for the issue of water pollution coming from storm pipes. Each concept has their advantages and disadvantages depending on the circumstances and environment that they are applied to. The main issue with coming up with concepts stemmed from the problem of not being able to make a product that would work universally for all storm pipes. Upon extensive research and many calls to experts the team discovered that storm pipes varied too drastically in size, dimensions, locations, angles and shapes that too many variables existed to create just one universal solution. This lead to a lot of issues and delays regarding moving forward with a concept. To counter this the team based their individual concepts to specific storm pipes based in certain areas. The team understood that a universal product was just not possible based on the time, money, skills and resources available. The best the team could do was create a concept that was adaptable to different storm pipes and terrain. Based on a Pugh Matrix the solution that emerged as the best to take forward to the next step was Concept 4. The Pugh Matrix used for the purpose of this concept selection was very superficial and did not delve into specific sub-functions but rather had a broad vague overview of the concepts. Furthermore, since each concept was designed for specific environments it was difficult to get a fair comparison among all the concepts. As a result some of the concepts which scored poorly such as Concept 1 and Concept 2 might not have gotten a fair evaluation and therefore in hindsight might not have been as poor as a solution as the matrix may have suggested. Regardless, the team concluded that Concept 4 was the obvious choice to continue with as it was the superior design but simultaneously was one of the most basic. This solution targets flat non-protruding storm pipes that enter rivers, a method of pollution that not even the datum (StormX) could solve. The next step is to refine the design and begin a manufacturing plan to begin the construction of the concept.

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