AVARANA

Ashmak Moon

Project Summary

MSc Product Design Engineering
Academic Year 2021-2022
Glasgow School of Art and University of Glasgow

Executive Summary

My father and I would always go to the weekend fresh produce market on the weekend in my hometown. I have seen plenty of food go to waste even before it reaches the plate. This problem has always been lingering at the back of my mind. The biggest cause known to me were the bad roads and long distance transportation and heat damaging the produce. But why do we need to have a complex cycle comprising of mass harvesting, refrigeration, transportation, processing (if needed), and retail.

What if we were able to grow our food in the vicinity and avoid the entire complex supply chain of food. What if we could control growth parameters and grow anything in any country.

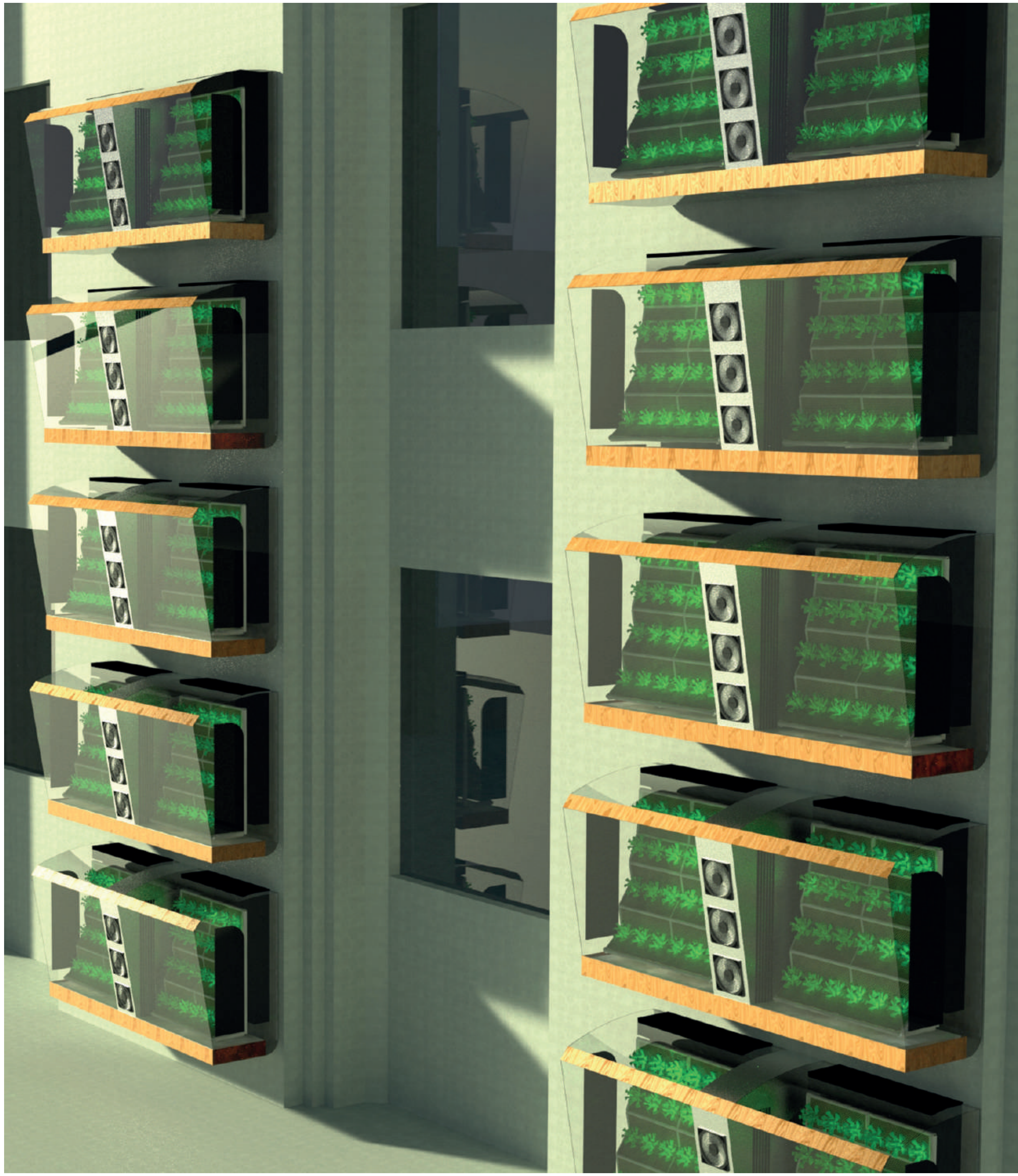
During COVID-19 pandemic, UK faced food shortages as it heavily depends on its imports, what if this could change.

In this project, my attempt is to design a modular, scalable, relaible, and robust growth pod for the urban population (ever growing) that can be placed in unused or underused urban spaces to grow food.

This will create job opportunities for the new generation of urban farmers who will be able to supply hyperlocal food with lead time as less as an hour.

With technical interventions and soilless precision agricultural ssytems in which efforts are made to keep the growing climate constant with very tight tolerances for higher yields. Here, I am planning to use a crossover of hydroponics and aquaponics to design such a pod.

As the technology becomes cheaper, the feasibility of the product increases, as of now the installation costs are high but with growing population, food demand, nutritional security, and incentives, urban farming will thrive.



Research Summary

Opportunity

Who doesn't want to eat healthy and fresh food? The conventional Agricultural industry and related supply chain has made the food less diverse, and food travels for days in refrigereated containers before it reaches us. The agricultural industry is also one of the least sustainable one, accounting to a quarter of the global carbon footprint.

So, why not grow the food in urban areas itself, taking down the requirement of refrigeration and transportation altogether. We have mostly been consuming less variety of crops and growing locally will certainly lead to diverse food. As of 2020, 83.9% of the UK's population lives in urban areas [Ref. Vertical Farming in the UK: Industry Overview – Vertical Farming Planet].

Verticle farms can reduce the water usage upto 98% compared to conventional farming which causes fertilizers runoff and water pollution.
20% of Glasgow's popoulation is unable to eat as per the diet recommended by the Scottish Government.

Crops such as Lettuce, tomatoes, cuculber, bell pepper, and herbs are imported in the UK from countries like Spain, France, Netherlands, Germany, etc., putting countries nutritional security at risk. It has anyway become more difficult to import after Brexit.

Many have started looking into alternate protein sources and foods such as bugs, caterpillars, ants, and kelp. It certainly shows the need for more fresh food.

History and Future Need

Growing food by your house is a very old practice and the cities and villages were planned based on the food availability, greatest example is that if Chinampas in the city of New Mexico (Today) which is also an example of aquaponics.
We need to go back to the same concept to make the nutrient cycle as small and efficient as possible. Today, the nutrient flow is linear causing desertification. As the population grows and the urban areas becomes densely populated, the need of urban farming will grow.
More technical interventions and research will certainly make this a sustainable activity as well.

Current Solutions

Current solutions are custom designd for every company and the personal or community products are either too small to make an impact or are really expensive. For commercial setup, the initial costs are really high.

httpsImage reference: ://growfreshgreens.co.uk/

Evogro Plant Growing System 40132-WS R

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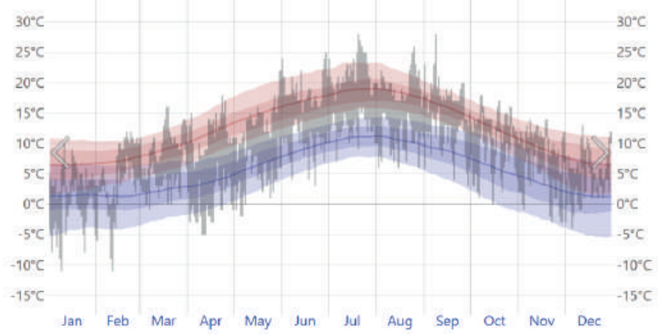
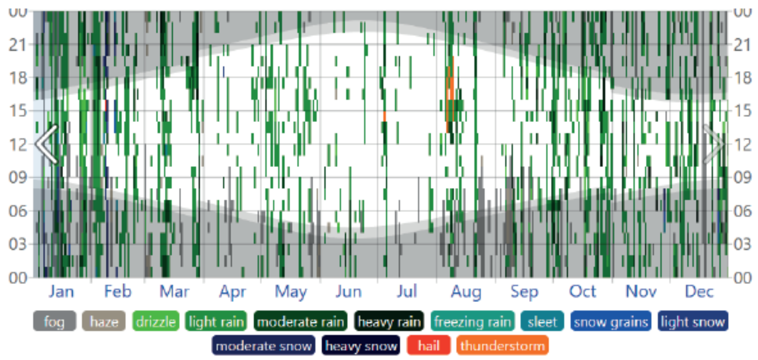
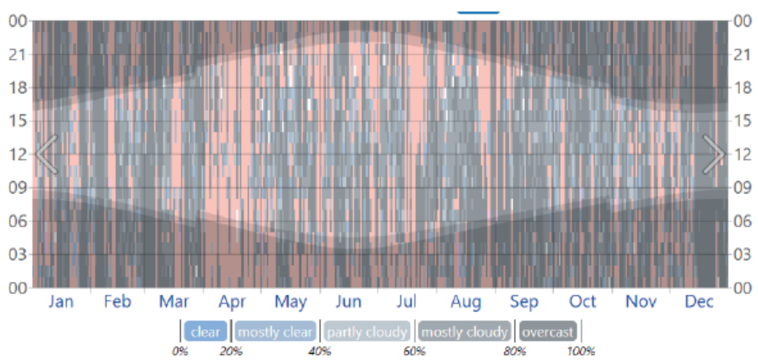
Growing in Glasgow

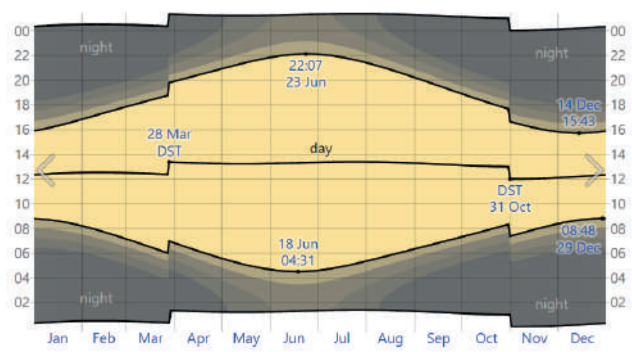
Environmental conditions and otehr points

Glasgow's weather conditions are not far from that of the Netherlands. Then why is it that Netherlands is able to export tomatoes?
Glasgow get's a lot of western Trans-Atlantic winds that carries a lot of humidity.
Glasgow's weather is erratic and many a times cloudy. Days in winters are really short.
Crop damage because of hail and frost is common and the carried experiments earlier in February failed because of frost bite.
Other parameter: Good Food Nation (Scotland) Bill and Glasgow city food plan makes Glasgow a very good product-context fit for this project.

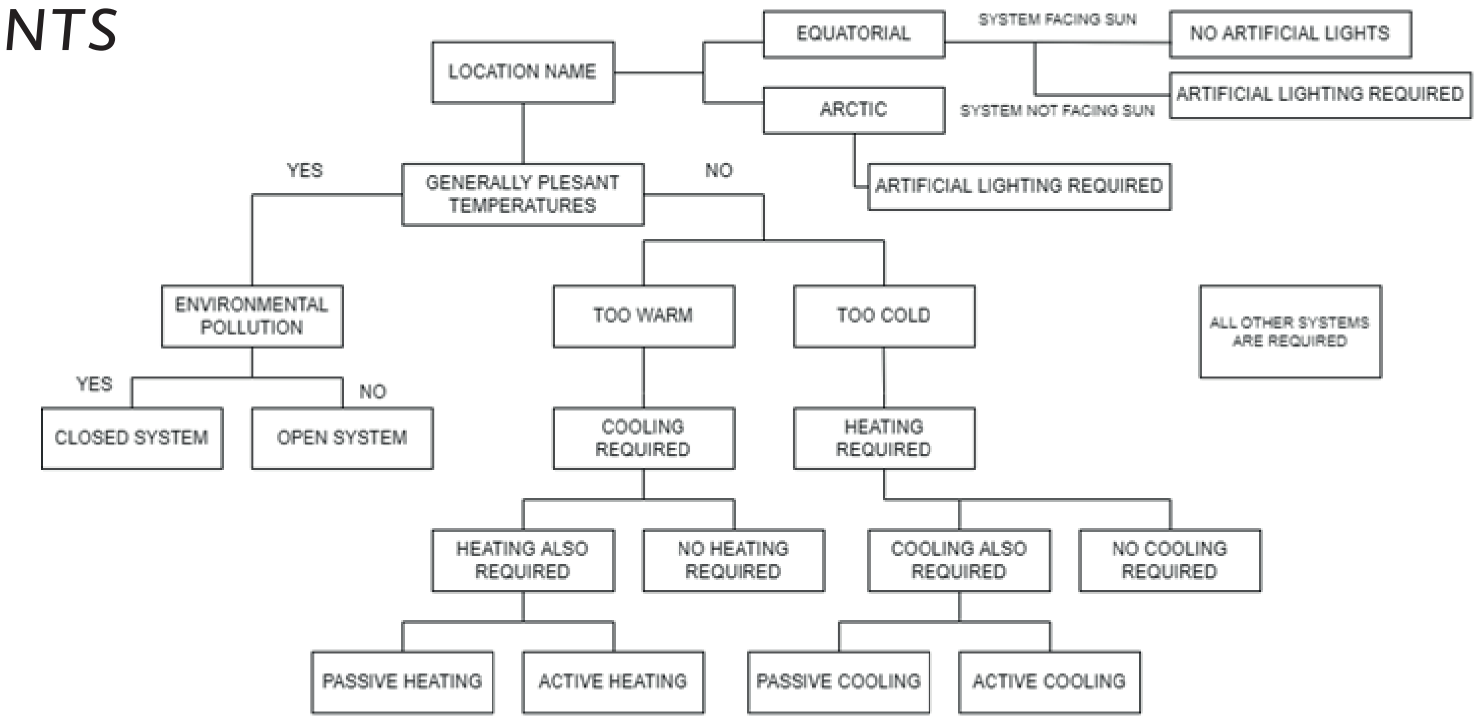








https://weatherspark.com/y/147740/Average-Weather-at-Glasgow-Airport-United-Kingdom-Year-Round



This chart is generated based on the system requirement research and considering the growing parameters. For Glasgow, the same chart is used to come to a conclusion that there is a need for:
An enclosed system with seaprate control for humidity and temperature of the root area and the leaf area.
Grow lights are needed for year long operation.
Cold as well as hot water supply is needed as the temperatures fluctuates quite significantly.
Active heating is required as the winters are cold. Even covering partly with blankets is possible (passive solution).
Because of high humidity, forced convective heating is desirable.
Because of general Zinc deficiency, zinc can be added in the nutrient mix.

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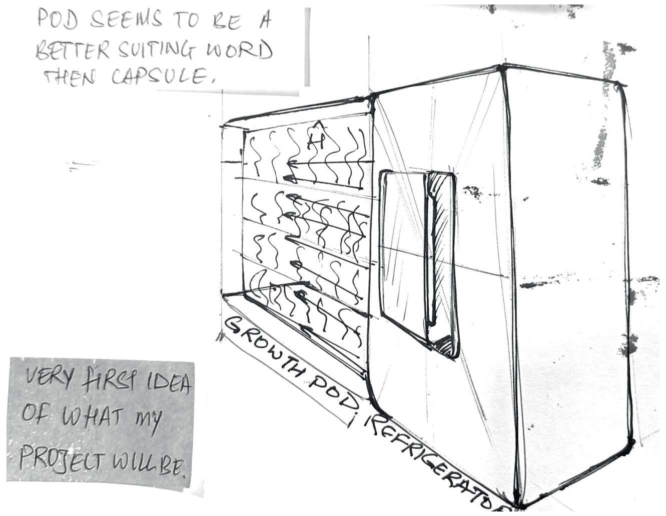
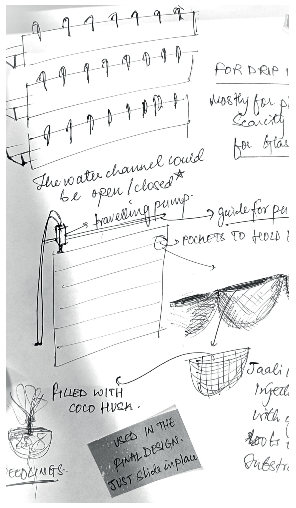
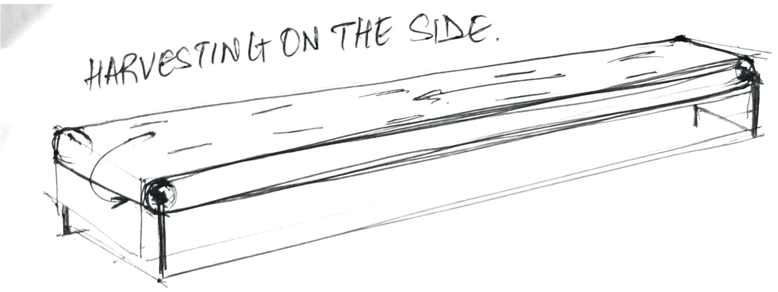
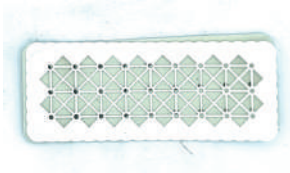
Concept generation

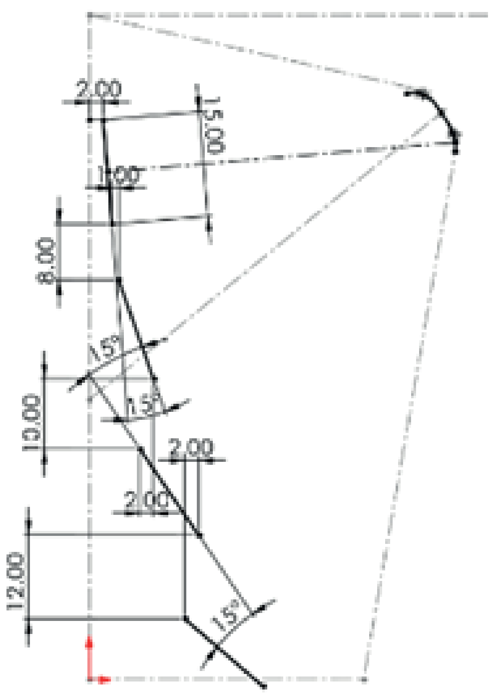
First ideas

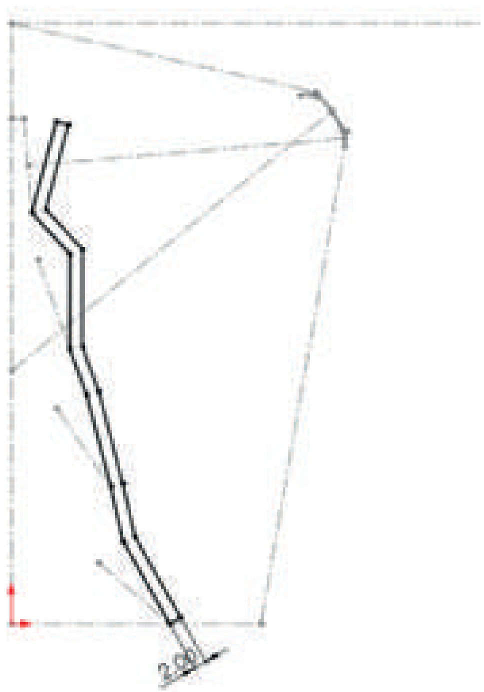






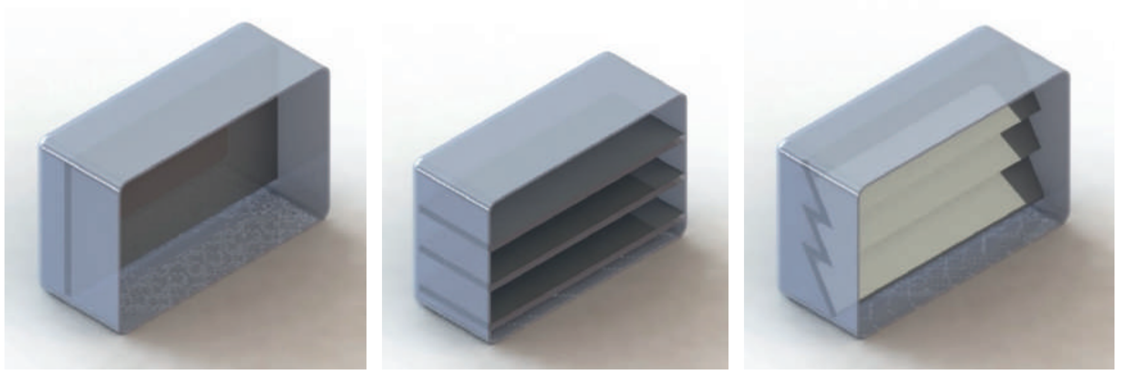


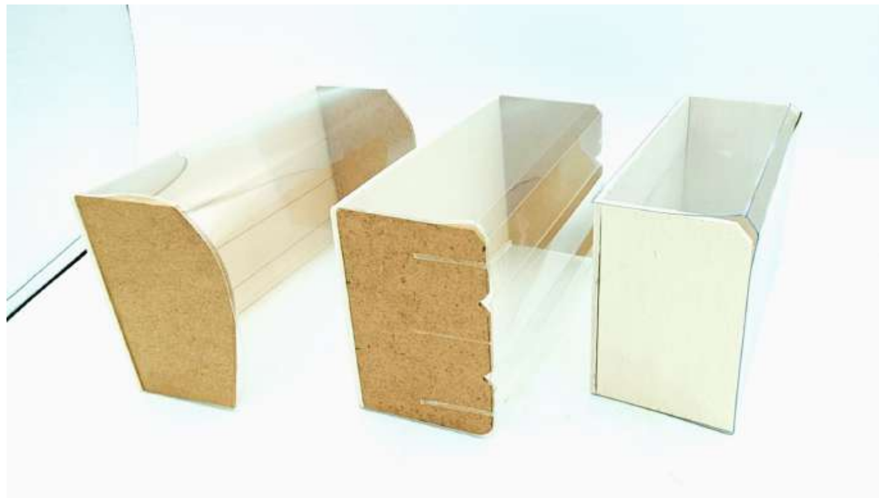


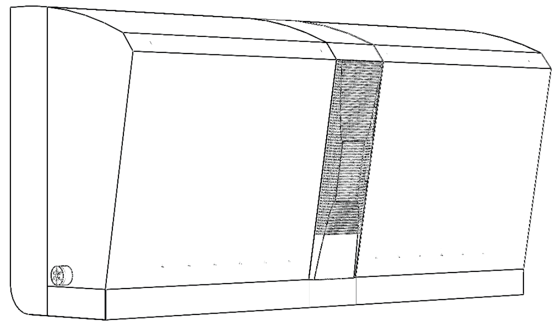


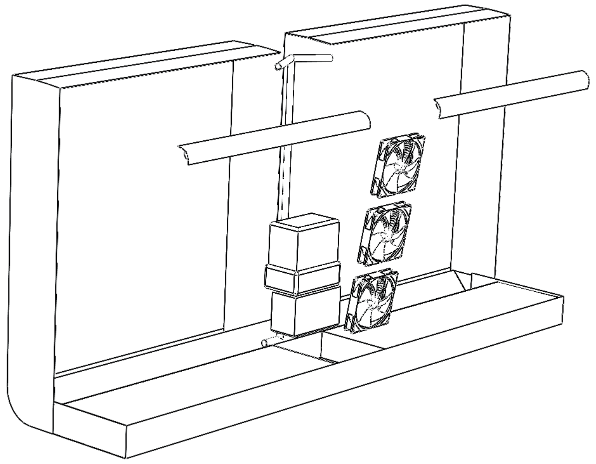
Shape optimization

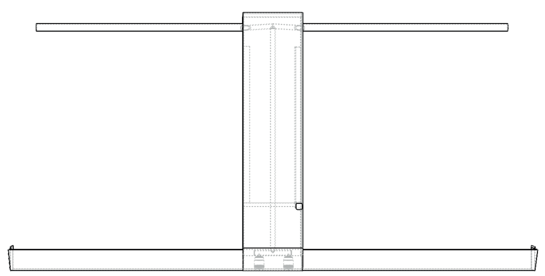
Generating options

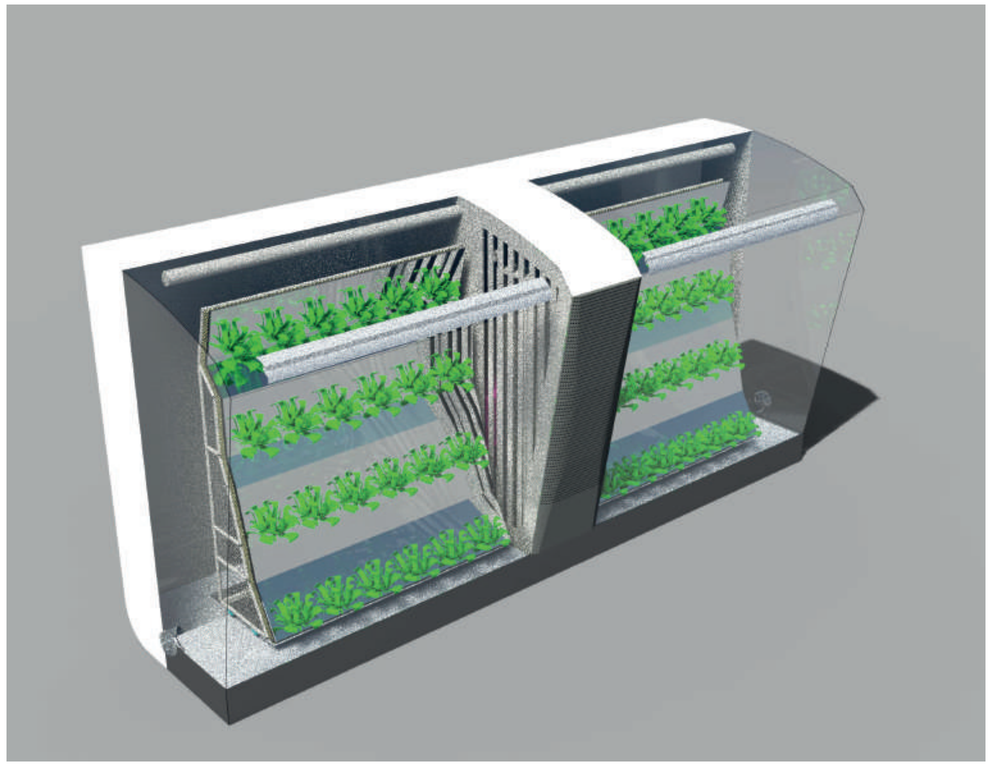












Final Outcome

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AVARANA

THE GLASGOW SCHOOL OF ART

University of Glasgow

System Requirements

Primary Requirements

Water management system: comprising of pH+ and pH- solutions, NPK, secondary, and trace element solutions. These are measured with EC sensor and pH sensor. Temperatuer control: Scottish Government favours the use of excess and surplus resources. Once such resource is the gray water drains which are warm in the winters, this water can be used in a heat exchanger to heat the pod's water input. Excess building's heat can also be used to heat up the pods. Reflector shoudl be used when it gets too sunny and warm to keep the temperautres less thn 28 degrees. Temperature sensors are hence required to measure water temperature, pod air temperature and the ambient temperature.

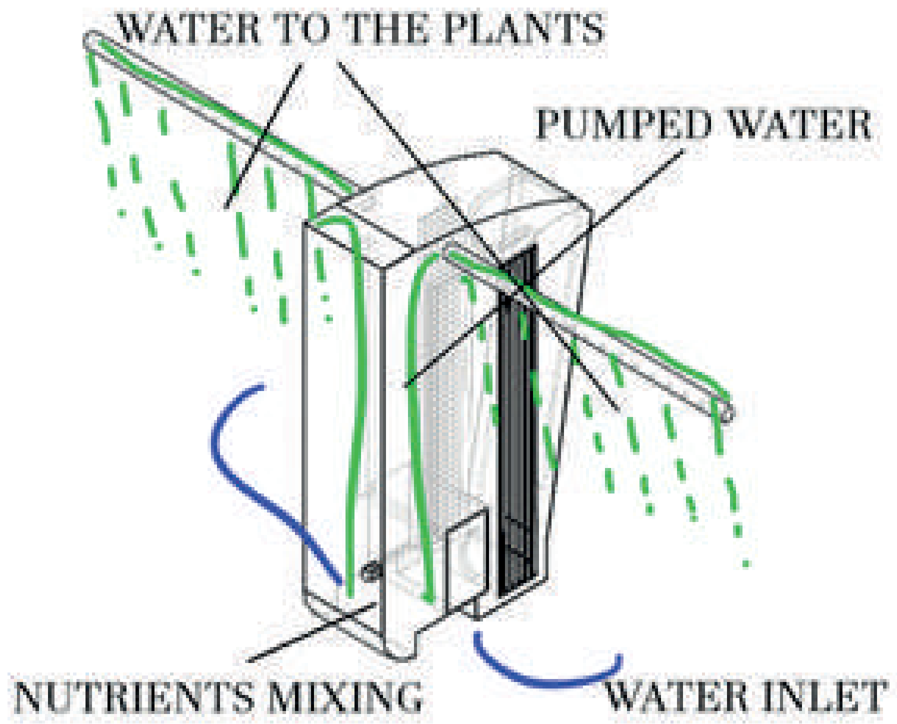
If these sources are not available, forced convective heating can be used. Similar to a hair dryer. Humidity control: Root media and leaf region requires different amount of relative humidity. The root requires about 100% elative humidity while the leafy region requires it to be about 60%. Bacterial an fungal growth can otherwise take over the leafy region in case of high humidity.

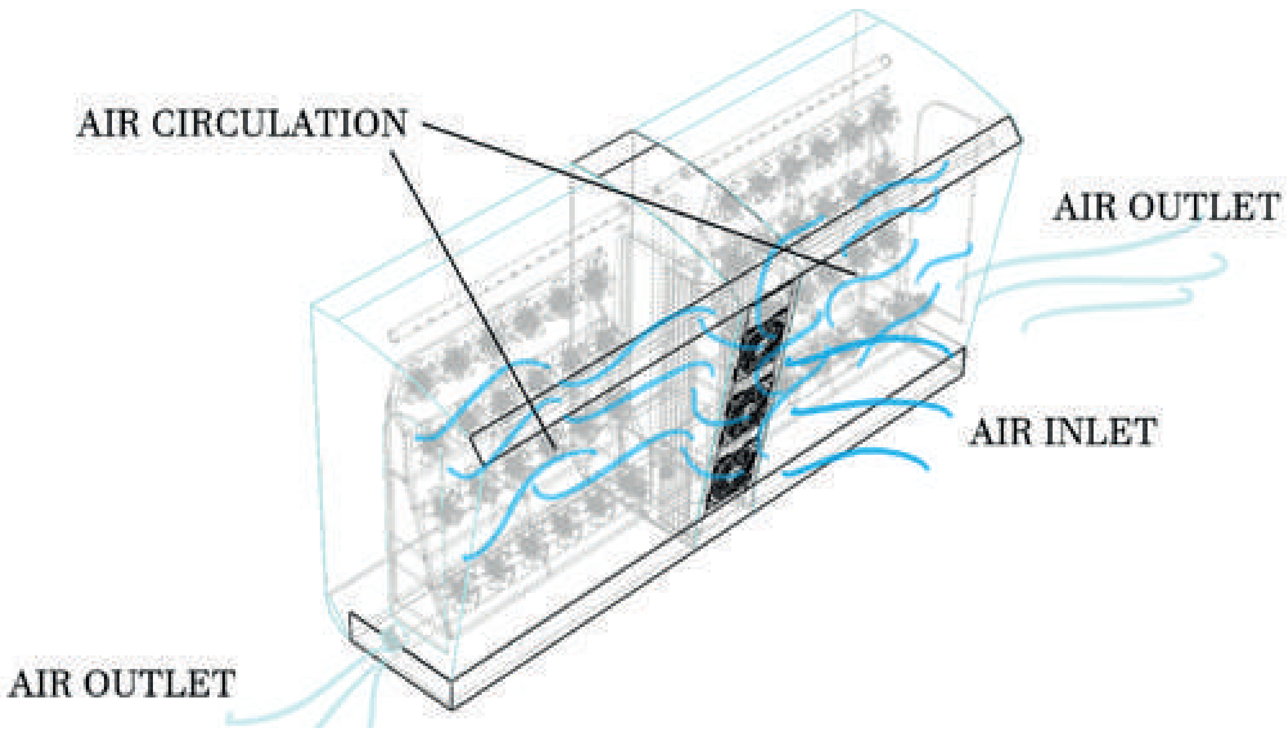
Air ventilation: Talking about bacteria and fungus, well ventilated system has less chances of infection and hydroponics is known for it.

The hydroponic technology selected is crossover of ebb and flow and aeroponics (novel system).

Lighting conditions: LED grow lights are required as the sunlight will not be present in many urban context. Considering dark and dingy allies, the LED light will be the only source of light. Reflectors can be used over nearby buildings to being in sunlight. For a densely populated urban with a lot of high-rises, this light will not be enough. The system should be able to adjust its conditions for temperature, humidity and light by itself and hence theres a need of control system that takes input from the surroundings and take the pod towards equillibrium. Electrical insulation and earthing, wire carrying tubes.

Water input and output pipes. Air exhause with another filtration unit to keep anything from coming in from the exhaust.





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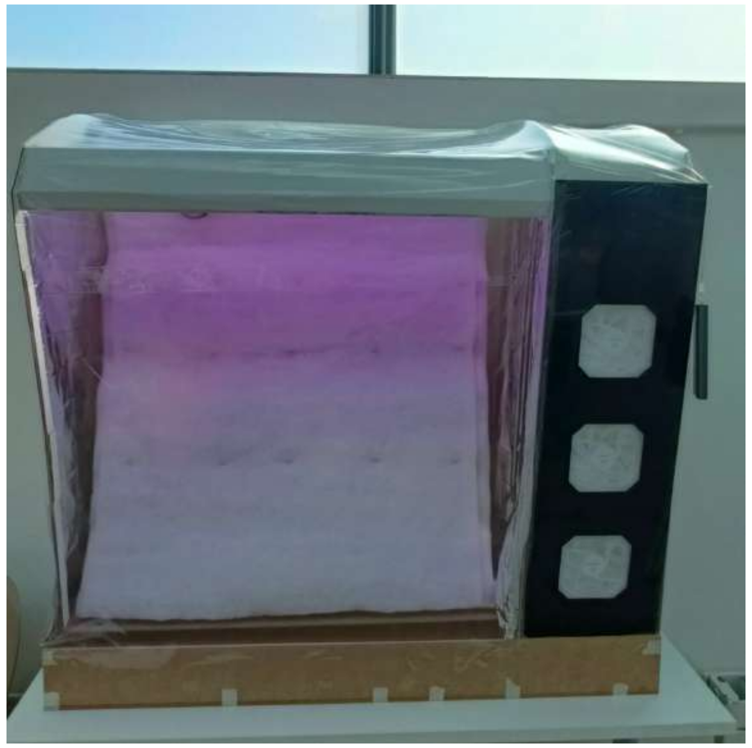
Detailed Design

Components and Functions



This prototype shows half of the total model. The electrical compartment on the right side of the image is used for controlling two halves of the capsule while only one part of the growth region is prototyped.

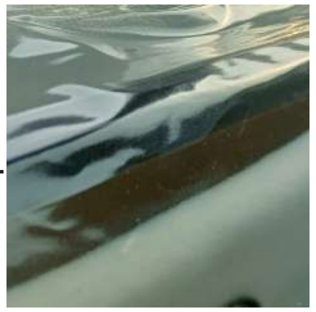
The major reason for making a 1:1 scale prototype was to study the human factors and further see the feasibility of the product in terms of its growth capacity. Many things were resolved because of the prototype such as the height of the CAD model which was bigger than the prototype, compartmentalization was realised as the prototype was being fabricated. Understandin of the material that can be used for the frame, etc. One user used the prototype to emphasize on the ease of planting and harvesting.

Grow lights:
These grow lights have a dual frequency in the color of pink and purple. This spectrum saves energy when used in the absense of the sun.

Frame:
The sliding frame supports the substrate for growing plants vertically. It slides half way out for the ease of planting and harvesting.

Substrate:
Felt, glassfiber, or cocopeat can be used as a substrate that holds the roots of the plants and also provides with nutrient mixed water.

Air ventillation:
To avoid any bacterial growth and excess moisture, the air vents brings in air. Heat element with the vents makes the air warmer when needed.



Pod body:
Highly transmittive body keeps the capsule warm when irradiated by the sun creating greenhouse effect.

Air filter:
Air filtration is required to avoid any dust from getting into the system along with any possible bacteria.

Pot:
This meshed pot holds the primary substrate the seedlings carry and makes the planting and harvesting easy.

Water circulation:
DC pump moves the water into the tray shown. The tray has evenly spaced holes dripping water on the substrate.

Door:
This opening allows the frame to slide out and plant new seedlings. Door is zipped open and close.

Perlite:
Perlite is a natural substance with very high water holding capacity. It is infused with the substrate.

Vents and mylar coating:
These openings in the vents moves the air over the leafy parts and the mylar coating reflects and improves LED efficiency.

Pot cover:
This cover is used when

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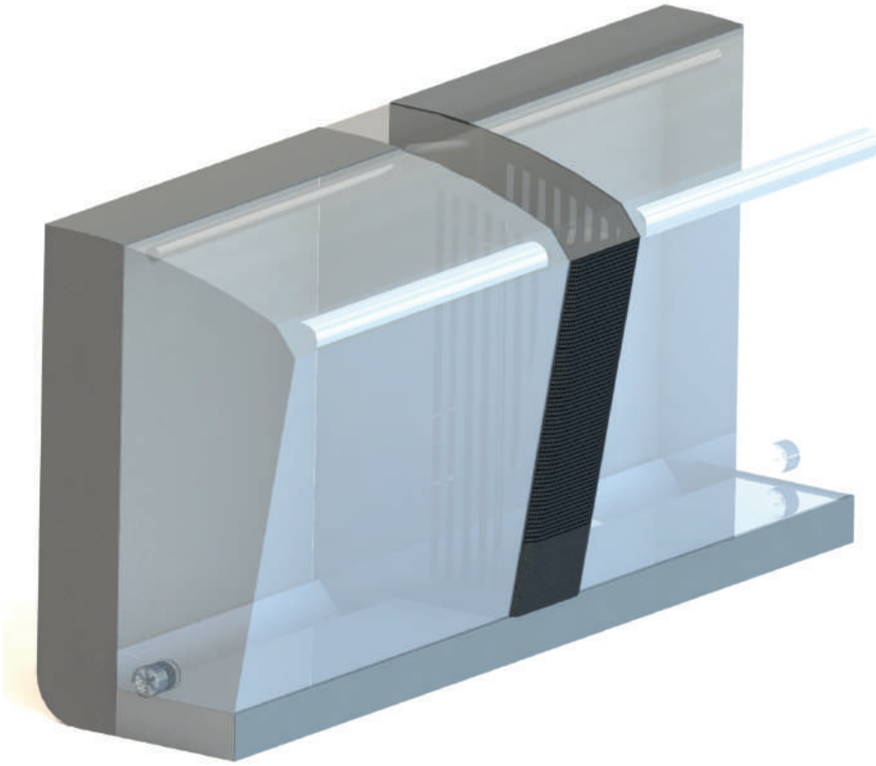
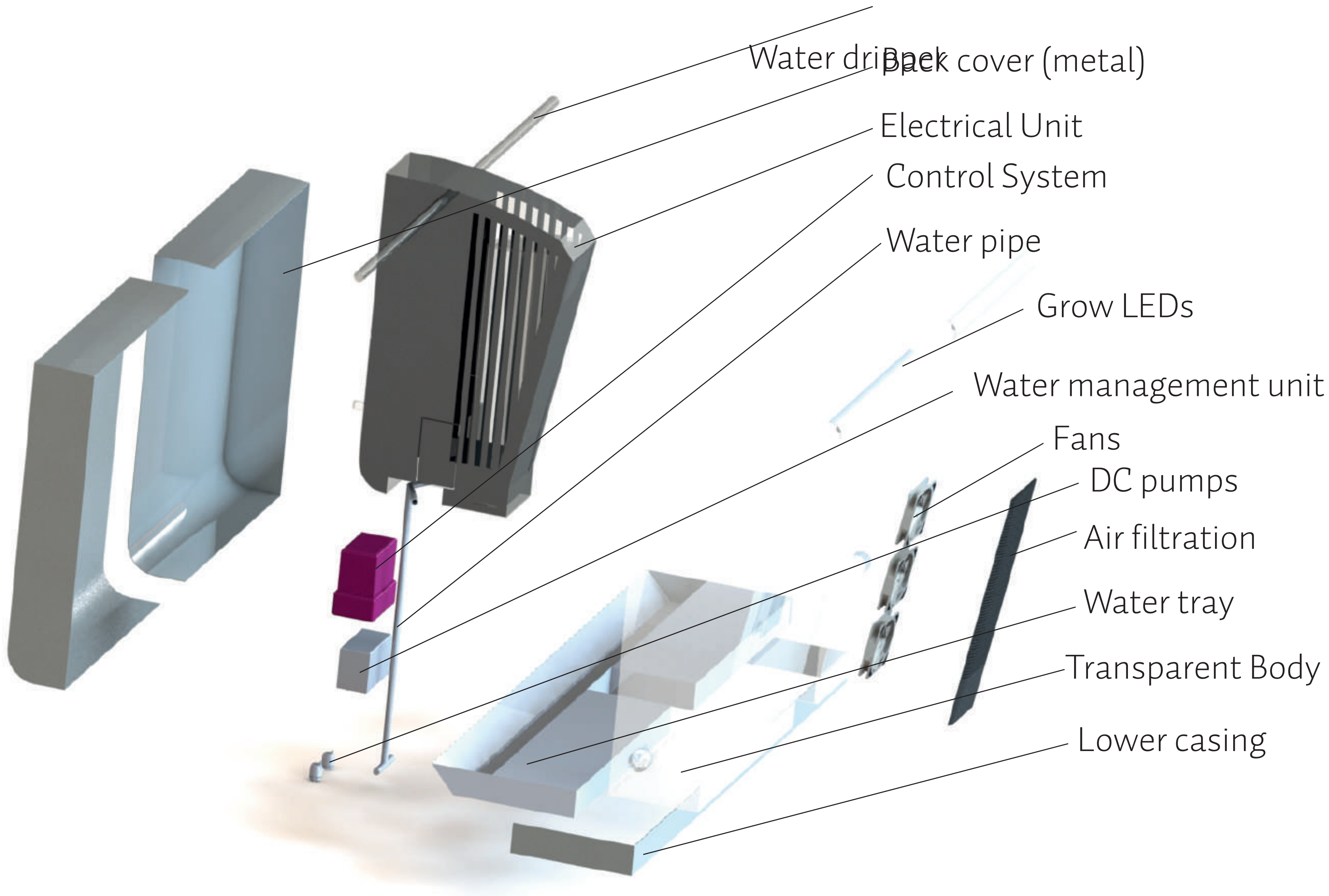
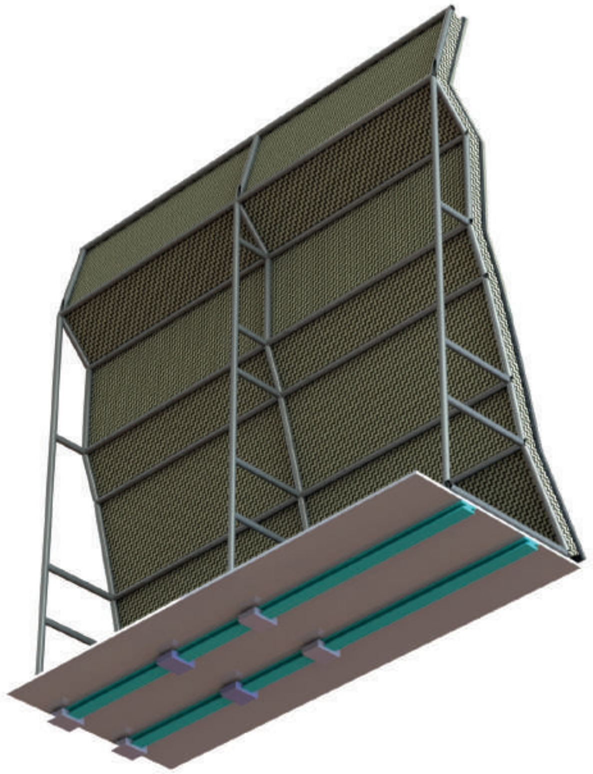
Component Placement



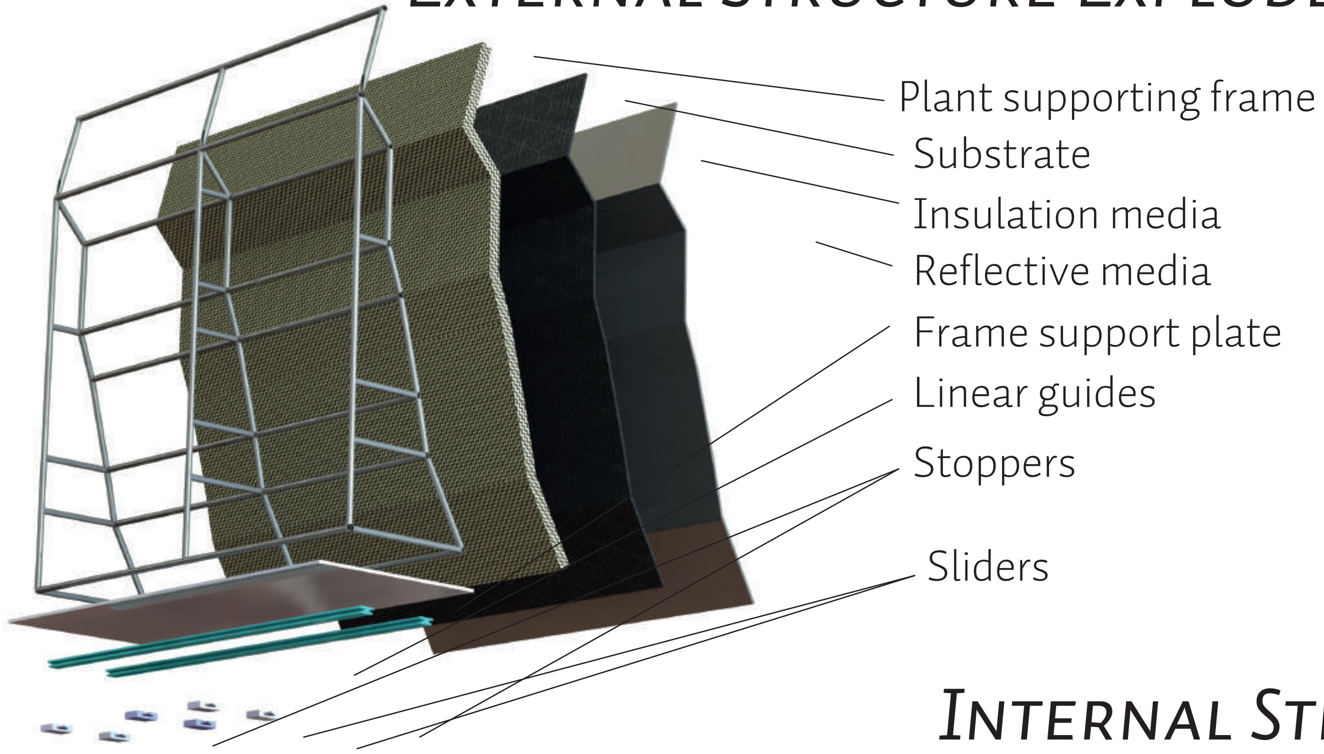
External Structure



External Structure Exploded View



Internal Structure



The internal structure slides inside the external structure sideways. The stoppers allows the internal structure to not come more than half way. The door for opening the external structure is missing in these images which will be fabric material coated with mylar on the inside. The fabric door is zip opened and closed.

Internal Structure Exploded view

Human Factors

Basic considerations:

These human factors are for the future generation of urban farmers. The current generation of urban farmers in places like Singapore have custom setups and it is generally a plane and secured environment. This however changes for Avarana.

In case of high rises mounted with these pods, the harness used by the window cleaners should be considered for using.
In case of a ladder, a person leaning towards the capsule should not fall while reaching for a plant.
Vandalism is a possibility in an urban context, hence the structure should be robust and secure as well.
Most adults should be able to harvest from the capsule hence the maximum reach after sliding the frame out should be uptill the most inside plant. Lower 5th %ile to be considered.
An urban farmer will be carrying harvest and the seedlings, either one of them on the ladder and hence the maximum weight and area of the trays to be carried should be considered.
these images shows the user sitting on a chair backwards to simulate the situation of someone hanging with a harness over a wall.
While using harness, there are other factors to consider such as wind speed and weather conditions.
Use of gloves will change the experience as well.

While harvesting and placing the plant, the holder should be properly placed in the compartment made in the substrate. The substrate is not a rigid material and hence some adjustments will have to be done while placing and harvesting. As the roots penetrate the fixed substrate, some vertical force should also be applied to detach the roots from the substrate. All this is done while the user is stretching his back. In case of a harness, a person may have to hunch down or stretch up to finish the task.

The tray slides outwards which enables the user to reach to the last plant. The frame slides half-way in this prototype but in future, the frame can slide more giving a better reach. Important point noticed here was that the frame would come in the way of harvesting and planting. The frame pushes against the body of the user if the user is too close to the wall. In case of a ladder, the frame will strike against the ladder and restrict the motion of the frame.

Further interventions are hence required to use this product in the future. For example, a moving gantry used by the window cleaners can be modified to cary all the seedlings and the harvest up and down the wall. This will also give access to the electrical unit which is in the center of the pod which is required for the maintainence. These studies also show that there should be an accessibility gap between two vertical lines of of the pods in a cluster.

The door of the pod is perpendicular to the facing direction of the user and hence the user need to twist the upper torso and open the zip. This is inconvenient while the harness is on and the user is hanging by a pulley system. The user does not have a very good control over sideways motion while hanging on the wall and active use of feet is required.

Human Factors and Persona

Further considerations:

A ladder would be placed slanted along a wall or can be against the wall. It has to be stable as both the hands are used for harvesting.

Alternate front doors can be thought of for capsule.

The trays are supposed to be hanging by the farmers waist.

The door should open such that the hands are not in the undesirable positions.

The farmer will be right next to the door-side wall.

After sliding, the planter-width should be such that the last plant can be harvested without leaning towards the capsule.

The weights carried by the farmer should be within the acceptable range for hanging around the waist while on the ladder.

Considerations:
It is easier if there's another pully taking the weight of the harvested produce and the seedlings so that multiple capsules can be harvested.
There should be a handle to pull and push the tray. If the capsule is on the right, the left hand will open the door and pull the tray out and the push it back.
The tray should only come halfway out otherwise the loads will be tipping over the tray. There should be an angle for the tray to go back by itself and lock in place and when it is pulled out, it should remain in its position and not come more outwards or slide back by itself.
Other considerations:
The wind conditions, rains, and the cold must be considered for the operation.
Proper eyewear should be used to vaoid excess exposure to grow lights of defined frrequencies.

An urban farmer germinates the seeds in a propagator.

The propagator is kept highly humid and dark in the beginning and later snlight is let in.

The seeds are ready into seedlings.

These seedlings are carried to the pod site.

The current crop is harvested by opening the pod.

The harvest is collected in a harvest tray.

The seedlings are placed in a substrate slot.

The pod is secured and the farmer leaves.

Cleaning the pod:

The farmer clears the current crop.

The water is infused with hydrogen peroxide and kept empty.

After a couple of days, the farmer visits again to empty out the water.

The capsule is flushed with clean water to remove residual hydrogen peroxide.

The farmer likes organic food ans so, instead of using industrial hydroponics nutirent mix, the farmer used nettle and cumphery tea to fill the nutrient cartridge.

The farmer visits the pod and replaces the empty nutrient cartridge which is the part of water management system.

Acknowledgement and Disclaimer:

All resources for the images are mentioned at the bottom of that side. All other resources are in the following links. A compilation of all resources is in the form of a padlet pdf.

All design aspects for this product are not considered and the product is nothing but a hypothesis.

Trials and testing in the field is needed for conforming any results and hence this report is kept as vague as possible.

Yes, the technology exist today to make the product, so technical feasibility exist but context is also as important.

This product is certainly not meant for places with perfect environmental conditions to grow food.

Precision agriculture in my project is not supposed to replace the conventional agriculture but aid it and give the nature some time to heal by reducing the burden on it.

This report should not be used to make the actual pod as the project remains incomplete. The nature of this device is based on vast research and 2-3 months are not enough for finishing this task.

I would like to thank Stuart Bailey and Hugh Piezy to guide me through this journey. A special mention to Dr. Stuart Grey for not only guiding but keeping me motivated throughout. He did say I would burnout and I did. I tried to do justice by the design process and the engineering process associated with this product design so I will strongly recommend to go through the hand written notes and ideas. Scaning is made easier through the sticky notes.

Lastly, I would like to thank my parents and my sister for their unconditional love and suport.

The project is incomplete, but my journey at GSA feels complete. ;P