# Project Deliverable J:
# Final Design Report

## GNG 1103 - Engineering Design

**Winter 2018**
**Faculty of Engineering**
**University of Ottawa**

**Professor:** Sawsan Abdul-Majid


**Team Number:** ProjC 4
**Team Members:**
Forgie, Matthew
Kanopoulos, Jonathan
Kuang, Spike
Pham, Duc Duy
Rashid, Fatima


**Due Date:** April 16th, 2018

# Abstract

From the start of the semester, we were faced with a problem as a class and then required to team up with our classmates to face this problem proposed to us by our elementary school clients. This problem was to design a better hydroponics system for our clients than the models they have used in the past. This required a considerable amount of research of their current models, problems the clients faced in utilising their model, as well as looking into different methods of implementing hydroponics designs.

Each member of our team set out to find and create their own take on how to solve this problem of developing a hydroponics system through research then sketching out either a full model or possible conceptual systems to be utilised within the model. Once each member was done with these ideas, we convened as a group to discuss the merits and flaws of each design and if they should be used or not. In the end we decided we liked the upright folding model of hydroponics system best.

After this final design was chosen we got together as a group to develop the first of 3 prototypes. This model was a miniature mockup of our design which we made from layered cardboard to show to our clients, while describing our concept.

After the development of this prototype, we moved on to the second prototype where we designed one of the critical systems for our hydroponics system. This prototype consisted of a the water system for our model which was tested. After this the rest of the project was created and displayed to the judges at design day.

# Table of Contents

# List of Figures

# List of Tables

# Introduction

Over the course of 3 months, a number of prototypes were developed and after thorough consideration, the team have successfully put together a hydroponic system that would address most of the crucial problems that the clients were facing. The key aspects that make our model stands out are mobility and portability.

# Needs Identification

During the session, our clients listed out a few problems that they were having with their current model. Regarding the plant row, the system has trouble draining properly, leaving behind some amount of residual water, which can be unhealthy for the plants in the long run.

Moving on to our clients current water distribution system, it requires the user of the system to refill the 75L reserve, which involves many trips back and forth with buckets to fill the reserve. Thus, making the process time-consuming and inefficient. Another problem faced by our clients is the fact that when the reserve is running low on water, there is nothing in the project that is there to alert the users of this situation. The system also leaks substantially when used by the user.

Another set of problems faced by the user are the current dimensions of the system. Due to the current dimensions of the system, it inhibits use of the system by younger and disabled students. This is due to the system being too tall. The dimensions also make the system unwieldy to move around where they need it to go. Its height also stops the students from taking the system in the elevator. This is a problem as mobility from classroom to classroom is key. In the system's current state, it is very difficult to move from place to place by the students who are utilising the system due to its unwieldy size, poor wheels on the bottom, and the lack of a proper place for students to maneuver the system from.

Finally, our clients also want to integrate automatic watering and lighting systems, where they would be toggled on and off at a specific time period. These are needed when human interaction is not available, especially on holidays.

# Problem Statement

After meeting with our clients, a number of current problems and criteria were laid out regarding our client's current hydroponics system. We as a team will be tackling these problems, so that in the future when designing our prototypes we will have a clear understanding of what is needed and expected from our clients - a reliable and cost-efficient solution for their hydroponics vegetation production systems.

# Conceptual Designs

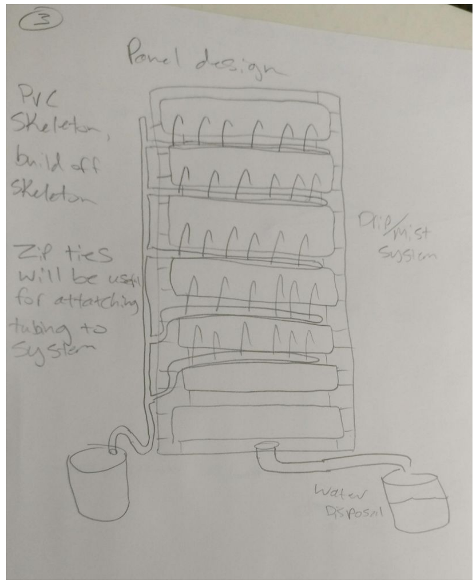


*Figure 1.* Conceptual Design 1

Very tall design that would efficiently maximize space while using a fairly high volume of plants. This design uses a series of small tubes to transport water to the plants and has drippers above each plant holder. External reservoir making it easier to fill and add nutrients. No system to drain/reuse water after going through system. Planned to be held with zip ties which may be problematic.

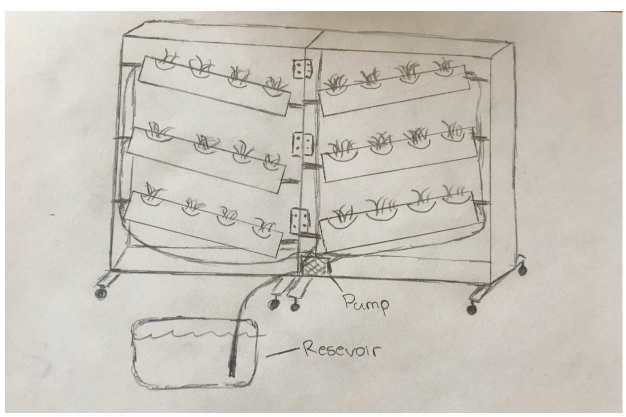


*Figure 2.* Conceptual Design 2

Design include an external reservoir for easy fill and transportation. Rather than drippers, this design brings water to each row and flows through the roots of the plants. Made up of two halves and connected by hinges so it can be folded and easily transported or stored. Light wood frame that is relatively short for younger children to reach but wide to maximize space.

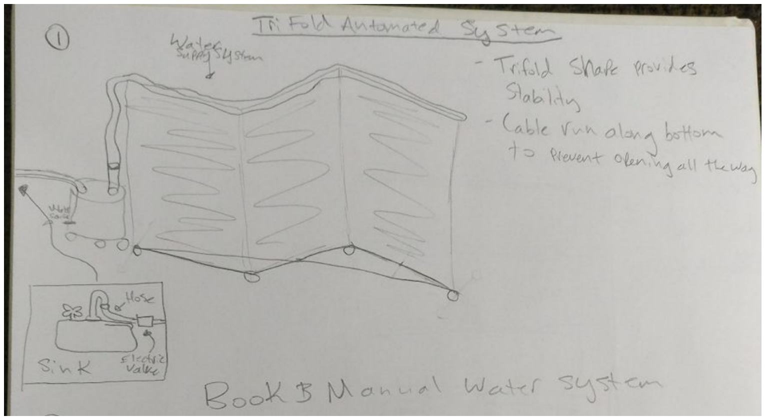


*Figure 3.* Conceptual Design 3

Tri-fold design that would maximize space while opened but compact while folded. Able to be folded and rolled into an elevator easily by small children. Does not include large reservoir but rather a small one that connects to a tap/sink to have continuous flow which would fix the problem of constant refilling.

# Design Criteria

- Functional requirements
  - Able to hold around 20 plants.
  - Drain water properly.
  - Must be placed on wheels for easy moving.
  - Stability: wheels must be locked when not moving.
  - Fail-safe when water is leaking.
  - Notification to change water.
- Non-functional requirements
  - Aesthetics
  - Product life (years)
  - Corrosion-proof
  - Safety: minimal pinch point
  - Reliability
- Constraints
  - Weight (lbs): must be light enough for the students to move/carry.
  - Cost ($): must be below $100; can go above a bit but it must be very convincing.
  - Size ($L \times W \times H\ ft$): when stored, must be small enough to fit inside the elevator; when deployed, must be manageable for younger/disabled students.
  - Operating conditions: wet, humid, dirt.

# Target Specifications

- Around 4-6ft tall
- Column for holding plants 4-5ft long
- Lights on timer 12 hours (on/off)
- 50-75 liter reservoir
- Entire system should be under 150lbs
- Must plant at least 20 plants
- If backup reservoir include at least hold 25L of water

# Benchmarking

*Figure 4.*

This design shows a good way to distribute the water between all the plants in a cost effective way. Problems include that the bucket could fill up with water and it would be difficult for young children to move. Also it would be difficult for the children to move the things that the plants go in. The materials used are similar to our current idea but this design may be too heavy and difficult to transport in elevator.

*Figure 5.*

Idea for designing plants to be plated in this layout would be good because it secures plants in a secure position that could be easily transported. Although the picture looks like this design could take up a lot of space in a room and watering all the plants may be difficult to implement.

*Figure 6.*

The layout in this design would be good because it is compact enough to fit in a small space in the room and could be put on wheels and moved with little force. It is also small enough to fit in an elevator and as long as the height is not overly tall it would work well with children working on it.

# Risks and Contingency Plan

| No. | Risk | Contingency Plan |
|---|---|---|
| 1 | Getting over the budget | Try to find other cheaper materials (on Kijiji, second-hand stores, ebay, etc.) |
| 2 | Pump break down | Always use surge protected outlets with the pump, ensure the pump is not overworked. If broken, attempt repairs. |
| 3 | Water leakage | Leak management through the use of silicon caulking and/or duct tape. |
| 4 | Power Outages | In the event of a power outage, the system will proceed to drain and return to an off state, when the power is returned to the system, it will begin once more. |
| 5 | Water & Electricity | Wiring and electronics will all be wrapped and waterproofed through the usage of heat shrink, and electrical tape. |

| | | |
|---|---|---|
| 6 | Pests & Diseases | With extra funds left over, netting or tarps can be placed over the system so the use of pesticides is not needed. |
| 7 | System Failure Threats | With system failure, it will be possible to remove electricity from the pump. This will cause an emergency stop. |
| 8 | Broken PVC | In the case of one of the PVC pipes cracking/snapping/etc… the system can be partially dismantled and replaced for additional cost |
| 9 | Lack of materials | The group members would split the costs 5 ways to reduce the price of the needed parts. |
| 10 | Water contamination | We will have to ensure the system remains clean and not contaminated. If contaminated, we will flush the system with water. |

# Estimated Bill of Materials

| No. | Components and Materials | Costs |
|---|---|---|
| 1 | PVC pipe (30 ft) | $18.62 |
| 2 | Wood frame (2 by 4, 30ft) | $28.92 |
| 3 | Tubing (20 ft) | $13.54 |
| 4 | Screws | $7.67 |
| 5 | Hinges (2) | $6.20 |
| 6 | Pump | $15.25 |
| 7 | Reservoir | $10 |
| | **Total** | $100.02 |

# Prototype I

Whatever the project is intended to be produced, creating a prototype is crucial to the design process. As we have discussed in class, a prototype is a representation of part or all of a design concept with the purpose of learning something useful. For this particular project, we need to verify whether the design is plausible or not and check for any necessary modification. In other words, by testing the prototype, we would gain better understandings of any possible problem. In addition, by showing the design model to the clients, we would be able to gather valuable feedbacks and potentially improve the design based on the comments.

## Test Objectives Description

The objective is to determine if the client likes the overall idea for the design of the hydroponic system. It is to see if there are certain components of our design is what the client is looking for or if adjustments/ redesign need to be made. We need to collect feedback on each component of the system (placement, reservoir, pump, size, portability, ease of use, etc.).


*Figure 7.* Model is fully opened

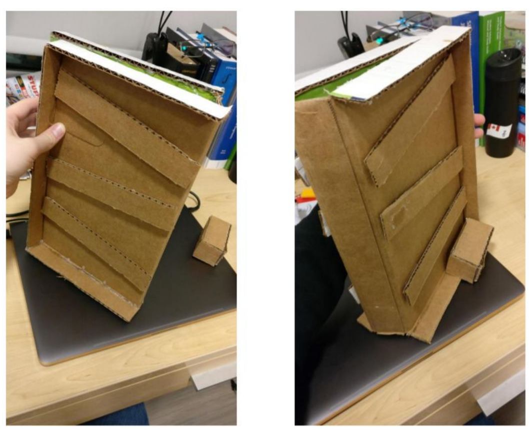

*Figure 8.* Model is folded together

We were learning how we can improve on our design. More specifically, any problems with the watering system and how we were getting water to each of the plants. We were determining if the overall layout of the system successfully met the clients needs and what areas needed to be carefully reconsidered.

The team came up with the design as shown in Figure 7 and Figure 8. In both figures, the pop-out slides represent the tubings of the system while both the pump (the smaller box) and the reservoir (the white box) remain separated. In addition, the system is designed like a book and both it and the reservoir would be placed on wheels for ease of transportation. The tubings are placed at an angle so that the water would flow down easily with gravity. Essentially, there would be a pipe running up in the middle of the system, providing water and nutrition for all of the plants.

The one type of result that we could get is the client is satisfied with every part of the system and we can easily start working on the second prototype. Another result is that the client does not like a certain component of our design. The worst result is that the client does not approve of any part of the design. Fortunately, after the meeting, we found that the clients were interested in our design. However, they did mention that the size of the reservoir was important; the one they had then could hold upto 75 liters. So it would be better if our reservoir could hold at least that amount, if not more.

## Details

The type of prototype which we designed is a "Mockup". This is as it displays the prototype and what it will look like, however it lacks nearly all functionality of the actual final product. This type was decided upon due to the complexity of systems required in making a working hydroponics system, as well as time requirements and cost limitations.

Out prototype is a small miniature utilised through the cutting, gluing and stacking of cut out cardboard. To recreate this model to be used for testing, you would be able to cut out, and design another copy of the prototype

The dimensions of this prototype will be measured out to allow for proper rendering of the full project when completed.

The reactions and input of our clients will be recorded so that the next prototype model can be fixed and improved, with un-liked aspects being removed or improved on.

This prototype will be comprised primarily of cardboard and hot glue. The costs will be negligible, using recycled cardboard, and hot glue from the makerspace.

The construction of this model will have to be completed, ie… cutting, slicing, gluing of cardboard, and the painting of the model itself.

# Prototype II

The second prototype is made to validate our hydroponics system, but this time, the design is closer to the final product. While the first prototype is more of a small scale model, the second prototype will represent parts of the actual system, including, but not limited to: the water piping, the frame, the water pump.

## Test Objectives Description

The objective of this next test is to determine if the water pump system works well with our design. We want to find out if the water pressure is sufficient and if the splitter works properly. Since from the last prototype we learned that our design is sufficient we can now get more specific with the subsystems.

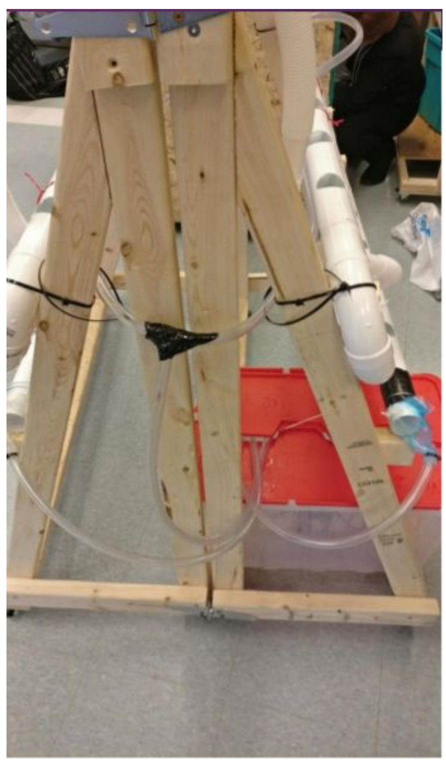

*Figure 9.* The T-connection between the water pipes

If the pump can efficiently deliver water the proper distance that we need. We also would like to know if the splitter will work or if a second pump is needed in order to get water to both sides of the system. From the last deliverable we learned that the clients liked our design and believed that it could meet their needs.

One possible result that is the one we are hoping for is that the single water pump delivers enough water through the tubes and the splitter works properly without leaking. Another result is that the pump does not have sufficient flow through the tubes and not enough water would get up to the plants. Also, the splitter for the tubes may not work or even leak.

These results may tell us that our current system works well and that nothing needs to be changed. We may also need to find a new splitter or maybe buy smaller tubes to increase the flow. Our last option which is not desirable is that a second pump must be bought.

The criteria for success is that the pump can run for 30-60 minutes without leaking while still delivering enough water through the splitter and out the tubes. Criteria for failure is that the pump/tubes leak at some point or the pump is unable to flow enough water out the tubes.

## Details

This prototype is a working model, it is focused. The focus is on the water circulation system for our hydroponics system. It was decided that without this system working properly, the rest of the model would be pointless, this is why it was chosen to be designed.

For the building of this prototype, you would need 20 feet of clear half inch diameter tubing, 2 brass T-splitters to split the tubing, and a water pump. Cut the tubing into a 4½ foot length, as well as 2 smaller 3 feet sections. Connect the 4½ foot section to the pump and the T-splitter, and connect the 2, 3 foot tubes to either side of the T-splitter. Fully submerge the pump under water and plug it in.

We are measuring the water pump and its ability to pump water 4 feet high, as well as provide water to the system.

The pumps ability to pump water to the required height of 4 feet, while pumping a great enough volume, as well as doing it with minimal leakage of water to the surrounding areas.

A 20 foot, clear, half-inch tubing, a water pump, 2 T-Splitters. Approximate estimated cost $40.

Assembly of these pieces will be required, the lengths of tubing must be cut properly and attached in the required layout.

# Prototype III

The purpose of this final test is to validate our actual hydroponics system in a real environment, where the system is expected to operate properly. The test will again check for the followings: water leakage, maximum weight tolerance, hinges endurance  etc. Since this is the last test that we will perform on the prototype, it is crucial that all the flaws are ironed out and addressed accordingly.

## Test Objectives Description

One of the test objectives is to verify that the overall size of the size of the frame will sufficiently work with the amount of plants we are planning to use and the use that this design is intended for. Another objective is to find out if the wood frame is sturdy enough to hold the intended weight of the system. A third objective is to figure out final details of the system such as the placement of the wheels, hinges, and tubing for water.

*Figure 10.* Model is fully opened

*Figure 11*. Model is folded together

Through this prototype, we are learning if the size of the frame needs to be smaller in order to increase mobility of the system and be able to fit in the elevator. Another thing that is being learned is if our basic triangular is sturdy enough to hold everything intended in the system with the amount of support it has. We are also learning exactly where the best placement of the wheels, tubing and hinges.

Some results are the frame is too big or too small. Another result that is optimal is that the frame is about the right size so that the pipes for the plants is sufficient and it can easily be moved around in an elevator. Some other results are that frame is not strong enough to hold everything needed for this design. Hopefully the result is that the frame is strong enough to hold everything we need.

From these results we will decide if the frame needs to be made smaller or if the size is not sufficient and needs to built bigger. It will also determine if additional support (if any) needs to be added and at what points in order to increase the sturdiness and durability of our frame. We are also going to use this test to determine where the wheels, tubing and hinges need to placed in order to increase the functionality of the system.

The criteria for failure is that the frame cannot hold the full weight of the pipe system to hold the plants or if the frame is difficult to move around and fit in an elevator. The criteria for success is that the frame hold the entire weight of all parts needed and is can be easily pushed around with little force.

## Details

This prototype is a fully functioning model, a working representation of the final product for our customers.

Moving up to this point, a number of tests have been completed on the system to ensure the quality of our designed project, and to safeguard against failures of the project's systems. We have let each system run individually to allow for any flaws in these systems to come forth. We tested the water delivery system, then the strength of the wooden structure, then the strength of the wheels on the model, as well as the water reservoir, and the PVC plant holding system.

Now that the project has been completed no real information is being measured anymore other than if the system faces any complications or problems.

The proper function of our model is being observed, and it will be recorded and marked by judges at the design day event.

The materials required were all purchased and in the end, incurred a fee of $217. The $100 provided by the school will be removed from the project's cost, and the rest will be split between the 5 group members of our group.

# Conclusion and Recommendations

After completing this project, we have learned many things and gained a great deal of knowledge and information on the topics of engineering design. We learned about utilising data which we gained from our customers and about how to effectively draft an idea as a team. From this we were able to design a working hydroponics product which was better and more improved than their previous models. In the future, we would change a few things when developing our system. First of all, we would utilise better, more concrete blueprints for our model, keeping better track of the individual system parts along the way. This would help with cost minimization, which our group struggled with somewhat. Another thing that we would look to in the future is how we could implement the netting system into our model to hold the individual plants, as well as the implementation of an automated LED lighting system.