Date: 10/20/2016
Team Name: Delicious 3.14
Section: 151-S

Testing Protocols and Risk Analysis: Delicious 3.14

1.1. Problem Definition:

An estimated 7.4% of the United States population lives in areas with little to no access to conventional supermarkets. The prevalence of these food deserts in urban Denver, Colorado forces many low income families of four or more people to rely on fringe foods such as mini marts and gas stations. What is an in-home, affordable solution for these families to supplement their diets with fresh, healthy, and nutritious food that would be well accepted and utilized throughout the Denver
community.

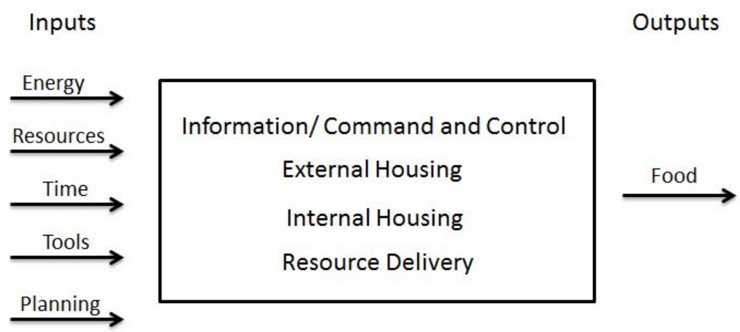

Figure 2: Systems Diagram

1.2. Systems:

Figure 1: Systems Diagram

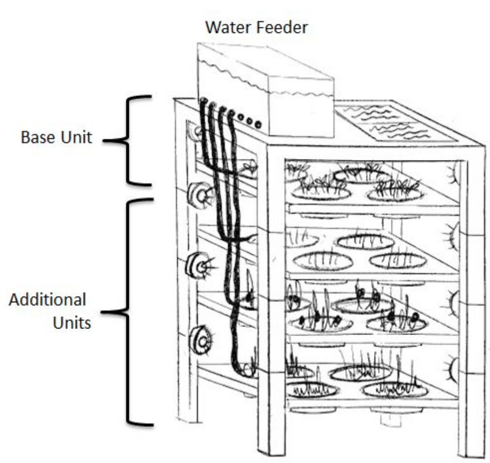

Figure 2: First Design Plan of the Food System

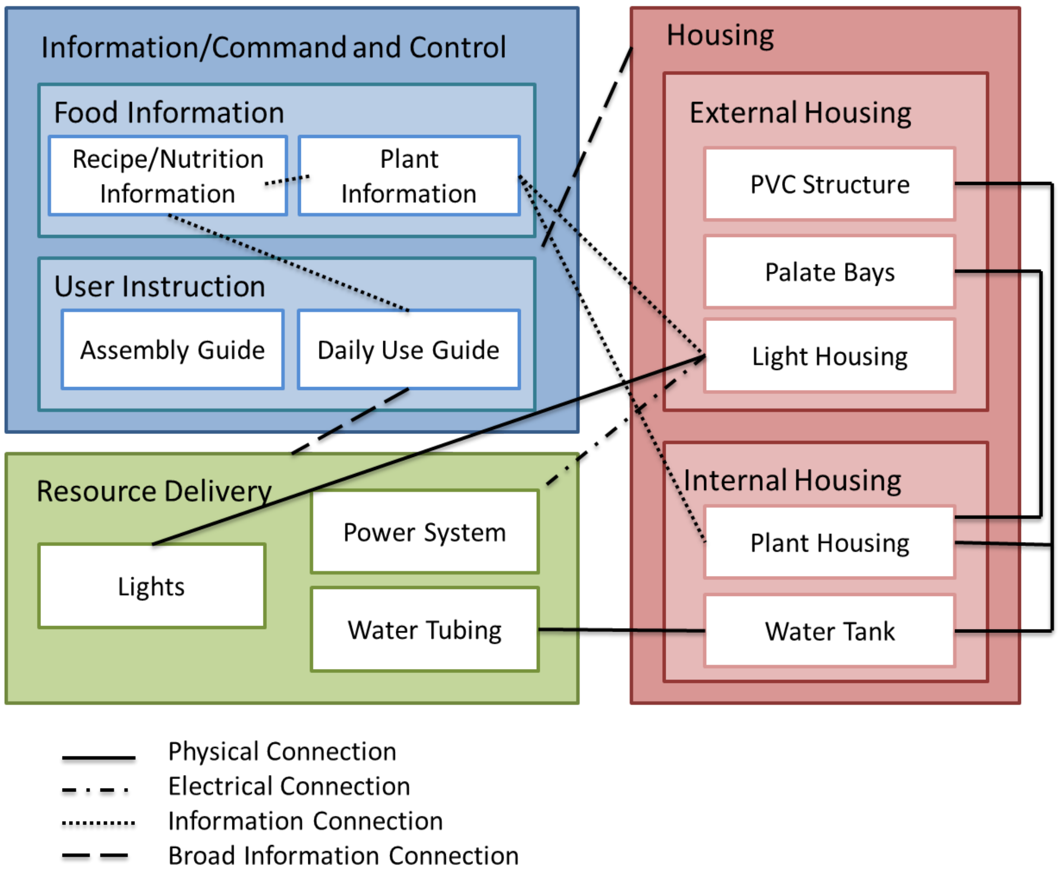

Figure 3: Systems Breakdown

1.2.1. <u>Description of System:</u>

Our looks like prototype will model the food system shown, in its earliest iteration, in figure 2. This food system is in the form of a modular in-home gardening system. The system will be sold as a base unit and then additional units, in order to make the system affordable for low income families. The system will include everything needed to begin an in home garden, including seeds, soil, pots, a lighting system, a gravity fed drip watering system, and the modular units. Helpful instruction guides and gardening guides will also be provided to the use. The system will house many types of plants and be very user friendly and customizable for the consumer. All of these components can be viewed in figure two, the original design plan for the food system and its subsystems.

1.2.2 <u>Subsystems</u>**:**

1.2.2.1. Information/CC: Food Information (Research Validation Plan)

This subsystem involves giving information to the user about different plants that can be used, a nutritional guide, and different recipes that can be used with the plants that are grown. All of the information will come in a booklet that will come with the system. This will allow for easy access to this information that will benefit the user's health and maximize the potential of the system. This will be the main resource for information for users for planting and cooking.

- Garden Guide
    - Recipe Book- Healthy, nutritious, and simple recipes that can be cooked with the fruits and vegetables from the system.
    - Nutritional Guide- A brief yet informative graphic/list that includes all of the necessary daily nutrition for a human, along with some healthy living tips.
    - Plant Information- A plant-by-plant based guide that includes the information necessary to grow the plant to its full potential. This includes amount of water, soil, space, when to harvest, how deep to plant, etc.)

1.2.2.2. Information/CC: User Instruction

This subsystem involves conveying the information to assemble the final product and daily use of the technical aspects of the product to the recipient. This will require interfacing and communicating with the other subsystems to understand how to operate their specific system. The user instruction is the communication to the product user of all of the parts of the product. This will be introduced as the assembly guide and daily use pamphlet page.

- Assembly Guide - pamphlet that outlines steps for assembly
- Daily Use Instructions - One page document outline of how to use the product

Major Tasks/Functions:

- Step-by-step assembly instructions
- Combined parts list
- Outline of system requirements
- Safety labels
- Solidworks graphics of the product
- Daily use guide

Components to Test:

- Effectiveness of communication of assembly step-by-step
- Effectiveness of communication of daily use guide
- Satisfaction of questions answered after reading information guide

These are the components that will determine whether the user instruction subsystem is successful in completing its goals. Effective communication of the product is the overall goal.

1.2.2.3. External Housing

This subsystem encompasses the external structural portions of the food system. The entire system needs a support structure to contain it all; this is where the external housing comes into play. The external housing must interact very closely with all of the other subsystems. The external housing is closely related to the internal housing subsystem, as they are directly connected physically. The external housing must also connect with the resource delivery subsystem, both through physical and electrical connections. This subsystem must also interact with the information/ command and control subsystem, as informing users how to build the product and use the external housing is important for the success of the system. The external housing subsystem including the:

- PVC Structure- The main structure of the system which supports the palate bays, lighting, all of the internal housing, and resource delivery systems.
- Palate Bays- The structure that supports the plant housing
- Lighting Housing- The structure that supports the lights of the system.

The External housing subsystem includes many major tasks and functions including:

- Provide sturdy support for the other components of the system.
- Provide for a stackable/ modular system
- Be easily assembled by the user
- Hold the cables/wires needed for other portions of the system
- Provide ample housing for lighting
- Be as aesthetically pleasing as possible

Components to Test/Validate:

- Structural integrity and stackability of the PVC structure- is it a sturdy, easily stackable structure?
- Weight load limit of the palate bays -how much weight can the bays hold?
- Safety of the light housing - how safe is the light housing?

The technology involved in the external housing has to do mainly with the structural integrity of the system. The design of the PVC structure and palate bays will have considerable effect on the end product. Therefore, the technology and planning involved in this subsystem are integral to the development of the product. There is also technology involved in the light housing and its connection to the power system. This comes in the form of an electrical connection and wiring.

1.2.2.4. Internal Housing

This subsystem involves what the plants will grow in (housing) and where the water needed will be held. This subsystem essentially covers the housing of all the materials that go into the actual growing of the plants. This system is vital in the success of the project as the soil and water is what makes plants grow. Without a good system for supplying the water and soil, the project would not be able to serve its purpose to be a sustainable in home system that produces fresh and nutritious food. This subsystem works very close with the external housing subsystem and the resource delivery subsystem. This subsystem must be compatible with the external housing that holds everything in an organized way. Internal housing must also be compatible with how the water will be transferred to the plants (resource delivery).

- Plant Housing - The “pots” that will be holding the plants and soil. The pots will be rectangular pots in order to grow more plants in the available space and to more easily fit onto the external structure..
- Water Housing - The structure that will hold the water for the plants and distribute the water to the sections of plants. This section is designed to sit on top of the external structure and will have a drip system provided by the resource delivery subsystem.
- Soil - The soil that will hold the roots of the plants. The soil will be a light soil with light fertilizers to avoid irritant hazards. Further tests/research will be in place to find an efficient soil.

Major task/Functions:

- To house the actual plants
- To hold the materials (soil, water) needed to grow plants within the system
- To allow the plants to grow efficiently
- To organize the plants within the palettes
- Allow easy accessibility to harvest the plants (being able to pick up individual plants from the palettes)
- Interchangeable plant pots

Critical Components/testing/research:

- The water housing - How much and how efficient can the water housing hold water. Testing for leaks, how big of a container that would be most efficient (finding the balance between limited refills and the aesthetic size of the housing on top of the unit), and how often the tank has to be cleaned (for the guide)
- Plant housing - How many plants can fit in the pot in the smallest amount of space (most efficient use of space). Research how much space the most common plants that will be grown actually need to grow efficiently.
- The Soil - Which types of soil grow the plants most effectively while being affordable, long lasting, and safe to the touch. Testing and research will be done on how fast the plant grows in the soil and how long that soil lasts all while keeping cost in consideration.

1.2.2.5. Resource Delivery

This subsystem is integral for the functionality of our system. It is the method in which the plants will receive all the necessary resources for successful growth. It consists of lighting, water delivery, and power. In order for the lighting to work power must be supplied to the system. This power system with interface closely with external housing in order to maintain cosmetic appearance. Lighting will also interface with external housing as the light bulb sockets will attach to the housing. In order to maximize plant growth research will be conducted to determine the optimum bulb type to grow plants indoors. Lastly, the water delivery component will allow for the plants to receive the necessary amount of water through a gravity-fed drip system.

- Lighting- Lights that provide optimum wavelengths of light for plants
  - Utilizes light bulb sockets, light bulbs, power cable
- Water Delivery- Provides plants with appropriate amount of water
  - Utilizes drip system hose and nozzles
- Power System- Deliver power to components that require it
  - Utilizes power cable

Major Task/functions accomplished by subsystem:

- Provide resources to plants
- Provide power to necessary components
- Interface with external and internal housing

Critical Components/testing

- Water drip speed in order minimize user work and maximize self-sustainability. Test a system that can alter water drip speed to account of varying plant water requirements.
- Power levels in order to minimize risk in power system and determine power requirements of system
- Lightbulb type in order to confirm research and test the effectiveness of the light bulb in growing plants

1.3. Testing Protocols/Research Validation

1.3.1. <u>Research Validation: Information</u>

1.3.1.1. There are many questions that must be asked during the design, iteration, and testing of our food system. These questions include:

- What are the plants that will yield the most nutrition?
- What are the fastest growing plants that yield nutrition?
- What plants will grow within a confined space?
- What are the essential nutrients that a human needs daily?
- What are some simple recipes?
- What are some nutritional recipes?
- What are some recipes that do not require expensive ingredients?

1.3.1.2. How To Answer: Extensive research online and in the library (for both plant types and recipes). Using feedback from a focus group to decide on the nutritional guide that will be used.

1.3.1.3. Research Plan: Start in the library, and look for books about growing plants, human nutrition, and recipes, respectively. Gather some general information about plants and human nutrition. This includes the types of plants that make the most sense to be in the system (easiest to grow, easiest to cook with, best harvest, etc.). Get some ideas about recipes, like how long they take, the simplest ingredients, provide the most nutrition, etc. Go online and compile lists of plants to use, different nutritional charts, and different recipes. Compile this information and format into an easy to use/read booklet.

1.3.2. <u>Testing Protocol A: User Instruction // Command and Control</u>

1.3.2.1. Hypothesis:

The step-by-step assembly guide will effectively communicate to the product user stakeholder how to correctly and completely assemble the product. The guide will also answer all questions and/or concerns related to use, requirements and safety of the product.

1.3.2.2. Test Plan / Procedure:

The test plan for the testing the user instruction is divided into multiple sections:

- Communication of assembly step-by-step
    - Have the prototype step-by-step guide prepared
    - Have prototypes of subsystem parts disassembled and prepared to be assembled
    - Give testing participant consent form with aim and goals of test
    - Give them time to assemble the product using the guide and parts
        - Record video of their work, track the time it takes for them to assemble the product, and take qualitative observations of their work
    - After completion, give them a participant assessment form to collect qualitative data of their experience
    - Debrief them on how their information will be used
    - Conduct this procedure three times
    - Analyze data to improve prototype
- Effectiveness of communication of daily use guide
    - In a separate testing period, have the product fully assembled
    - Give testing participant consent form with aim and goals of test
    - Give participant time to follow the daily use guide for the product
        - Record video of their work, track the time it takes them, and take qualitative observations of their work
    - After completion, give them a participant assessment form to collect qualitative data of their experience
    - Debrief them on how their information will be used
    - Conduct this procedure three times
    - Analyze data to improve prototype
- Satisfaction of questions answered after reading information guide
    - After the daily use guide prototype test, give the participant a separate participant assessment form specifically related to remaining questions or concerns they may have after reading the information guide
    - Analyze data to improve prototype

1.3.2.3. Equipment/Materials:

- Completed prototypes of the step-by-step assembly guide and daily use guide
- Complete prototypes for each subsystem, disassembled into parts
- Video recorder
- Stop watch
- Observation notebook
- Testing forms for participants: consent form and participant assessment form

1.3.2.4. Phases of Testing:

Testing of the user instruction will take place later in the prototype design phase, as the testing can only be done when there are semi-completed prototypes for the other subsystems available. Prototypes of the step-by-step assembly guide and daily use guide, should however be designed continuously through the process. During testing of the user instruction subsystem, participants may be selected for availability, although participants within target population for final product would also be beneficial. After initial testing, prototype may be improved then retested using the same procedure and different testing participants.

1.3.3. Testing Protocol B: External Housing

1.3.3.1. Hypothesis:

The external housing will provide a safe and sturdy structure to house the rest of the food system components. It will be easily stackable and assembled by the user. It will be able to house the recommended plants and soil without issue. The lighting housing will provide a safe, water tight housing for the lighting connections.

1.3.3.2. Test Plan:

The test plan for the testing the external housing is divided into multiple sections:

- PVC Structure:
    - Put on protective clothing, equipment
    - Acquire multiple heavy blocks of known weight to use during testing.
    - Assemble the PVC base units and additional units according to the assembly instructions provided.
    - Place one heavy block onto various sections of the external structure.
    - If the structure remains stable, add an additional block to the system.
    - Continue adding blocks to the system until obvious signs of failure are present.
    - DO NOT add additional blocks once the structure begins to fail. This may cause unintended risks and should be avoided at all costs.
    - Using a scale, record the weight load limit of the system and qualitative data about the strengths and weaknesses of the system.
    - Iterate the design of the external housing
    - Test the subsystem again, using the same process.

    - Continue this iterative process until the weight load is a desirable weight- greater than the expected weight load of the entire system.
- PVC Stackability:
    - Assemble the PVC base unit according to the assembly instructions provided.
    - Assemble a PVC additional unit according to the assembly instructions.
    - Add the additional unit to the base unit, timing how long the process takes.
    - Record quantitative and qualitative data about the ease of stackability
    - Iterate the design of the external housing
    - Test the subsystem again, using the same process.
    - Continue this iterative process until the stackability is desireable.
- Lighting Housing
    - Inspect lighting housing for any non- watertight components
    - While no electronics are in the system, spray the external portion of the system with water to check for leaks
    - Record qualitative data for watertightness
    - Iterate the design of the external housing
    - Test the subsystem again, using the same process.
    - Continue this iterative process until the lighting housing is as watertight as possible.

1.3.3.3. Equipment/Materials:

- PVC Structure- base unit and additional unit(s)
- Lighting housing
- Cinder Blocks (or other heavy blocks)
- Scale
- Safety equipment- hard hat, closed toed shoes, etc.
- Stopwatch
- Spray bottle
- Video Recorder (if mentor cannot observe in person)

1.3.3.4. Phases of Testing:

Phase 1:

The first phase of testing the external structure is to perform tests on the housing before other subsystems are integrated into it. It must be a functional system on its own before other systems may be added to it. To do this, the PVC Structure Test, Stackability Test and Light Housing Test may be performed. This early testing will be informal; no quantitative data will be taken. Later, as other subsystems are introduced, the testing will become more formal. In Phase One, the Structure Test will be completed without the palate bays, as their design is closely integrated with the internal housing subsystem. The Stackability test may be completed in its entirety and the Light Housing Test may be completed without electronic components of the resource delivery subsystem. Approximate dimensions of the system will be determined in this phase of testing as well as general design plans. Overall, this phase of testing is approximated to take a week's time.

Phase 2:

The second phase of testing the external structure will begin to see interfaces with other subsystems. This round of testing will include the palate bays involved in the external housing, as details in the internal housing subsystem will have been narrowed down by this point. The PVC Structure Test will be re run in order to gauge the weight load limit of the palate bays are iterate the system as needed. Also, the Light Housing Test and Stackability Test will be re done with primitive versions of the lighting system, wiring system, and watering system of the prototype. This phase of the testing process will be more formal than the last. Quantitative data for the weight load limit of the palate bays will be collected as well as a weight load limit of the entire system. The interfaces of the external housing with other subsystems will begin to be solidified in this phase. This portion of testing is approximated to take a week's time.

Phase 3:

This last phase of external housing testing will bring the external housing together with the other subsystems. In this phase, all tests will be performed again, with formal reflections written and submitted to the mentor. The Structure Test will conclude that the structure has ample support and stability for all of the other subsystems, especially the internal housing and resource delivery. The Stackability test will ensure that the system is still easily stackable with all of the other subsystems attached to it. The Light Housing test will prove that the lighting housing is safe and watertight so that the light system may run safely as part of the resource delivery subsystem. This portion of testing and iteration is estimated to take two weeks to complete.

1.3.4. <u>Testing Protocol C: Internal Housing</u>

1.3.4.1. Hypothesis:

The internal housing contributes to one of the most important features of this product which is growing the plants. The internal housing provides a housing that can be easily interchangeable with other housings that hold the soil which allows the plants to grow. It also provides the housing for the water needed by the plants.

Success within this subsystem looks like plants growing enough to produce fruits/veggies and no leaks in the water housing.

1.3.4.2. Test Plan:

- Testing the water housing
  - Gather materials
  - Construct water housing with clear plexiglass

    - Connect the sides with a solvent proof glue
    - Place water inside the container
    - Check to see if there are any leaks present
    - Fix the leaks as they occur
    - Repeat steps until a leak proof housing results

1.3.4.3. Equipment/Materials:

- Water housing
    - Saw/cutting utensil
    - Sheet of plexiglass
    - Solvent proof glue
    - Water
    - Straight edge
    - Ruler
    - Bucket

1.3.4.4. Phases of Testing:

Phase 1:

The testing of the water housing is simple and only requires a couple early stage tests. It will take a day's work. Once a dimension of a water housing is found through considering aesthetic and capacity reasons along other subsystems, a prototype will be made. The prototype will go through a series of testings to find all leaks and eliminate them. Once a proper prototype is found, it will be configured to fit on top of the external housing. This stage will also take a day's work to find an appropriate spot on top of the structure and to properly secure the housing on top of the structure. The last part of this phase is to configure the water drip tubes on the water housing. This part of this phase will take multiple days of testing.

Phase 2:

The testing of the actual subsystem with the others will take roughly two weeks and longer. This stage involves placing the completed internal housing subsystem in with the other subsystems and testing to see if the subsystems are compatible with each other. Due to expected difficulties in putting the project together, the timeline for testing is projected to be longer in order to fit in more time for adaptations.

1.3.4.5 Research

- Depth of seed
    - How deep should the seed be planted?
    - This question should be answered relatively accurate. Many plants have different root systems which calls for different depth placements.
    - This question can be researched on gardening forums, results from others gardens, and the root systems of the plants.
- Research on plant distance
    - How far apart should the plant seeds be put away from each other?

    - Due to time constraints, research on 6 or more types of popular seeds will be completed on how far they should be placed from each other. This part is needed for the information delivery subsystem.
    - This question can be researched on gardening forums, results from others gardens, and the root systems of the plants.
- Water tube placement
    - Should water be delivered straight to soil of above the soil?
    - This question can be researched on gardening forums, results from others gardens, and on informational site or journals that look at how plants absorb their water.
- Type of soil
    - What kind of soil/fertilizers help the plant grow faster, lasts long, and is cost efficient?
    - This question can be researched on gardening forums, results from others gardens, and the science of fertilizers and plant nutrients from academic journals and informational websites.

1.3.5. <u>Testing Protocol D: Resource Delivery</u>

1.3.5.1. Hypothesis: Deliver resources necessary for plant survival, water and light, to internal housing of plants while interfacing compatible with external housing. Provide power to components that require it.

1.3.5.2. Test Plan:

The following list outlines the general testing protocol used to test the resource delivery subsystem.

- Water testing:
    - Fill tank with water (constant for each trial)
    - Open valves to drip hoses (variable amounts?)
    - Time how long it takes for tank to empty
    - Record amount of water collected in each container if testing more than one hose
    - Repeat for variable hose lengths and shapes
- Power testing
    - Set up lamps
    - Measure power output by standard wall socket
    - Plug in lamps
    - Determine if lamps short out or do not have enough power

1.3.5.3.Equipment/Materials:

The following list outlines the equipment/material necessary for testing

- Water tank
- Drip system hose, nozzles
- Volumetric containers
- Lamp sockets

- Light bulbs
- Plants w/ pots
- Power cable
- Voltmeter

1.3.5.4 Phases of Testing:

The following list outlines the various testing phases during the design process

- Basic functionality testing- 1 week
  - Determine that basics of subsystem are functional
    - Water travels through hose, lights turn on, power is being supplied
- Functionality Testing- 1-2 weeks
  - Determine that required resources are being supplied
    - Necessary amounts of water, lighting schedule, power levels, sustainability
- Iteration testing- throughout process
  - Test changes to subsystem to determine if they improve the system

1.4. Safety Plan: Risk Identification and Mitigation Plan

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1.4.1 Risks:

1. Structure falling onto tester
   While testing the external housing of the system, one risk could be the structure tipping during testing or crumbling on top of a tester. Especially during the testing process, when heavy blocks are being added to various parts of the structure, tipping could be a real concern.
2. Water leakage/damage
   This system contains a gravity fed water system, which has the potential to leak from the water housing or through the tubing. This water leakage could cause water damage to the testing facility or to the rest of the system.
3. Shock/electrocution (due to water + electricity, touching powered cable)
   This system contains both a water system and electrical components. When mixing water and electricity, shock and electrocution are valid concerns.
4. Fertilizer contact
   The accidental consumption, spillage, or storage of fertilizer during testing could cause health concerns for the tester.
5. Power surge/lighting fire
   This system contains connections to a power system as well as a wiring system for the lights. With these electronic components, power surges and lighting fires are possible
6. Minor injury during assembly
   Within assembly and testing, the threat of minor injury (cuts, scrapes, splinters) is present. This is a risk we will attempt to mitigate.
7. Self-esteem injury during assembly

If our model is too complicated to build or understand, long term self esteem injury could be acquired.

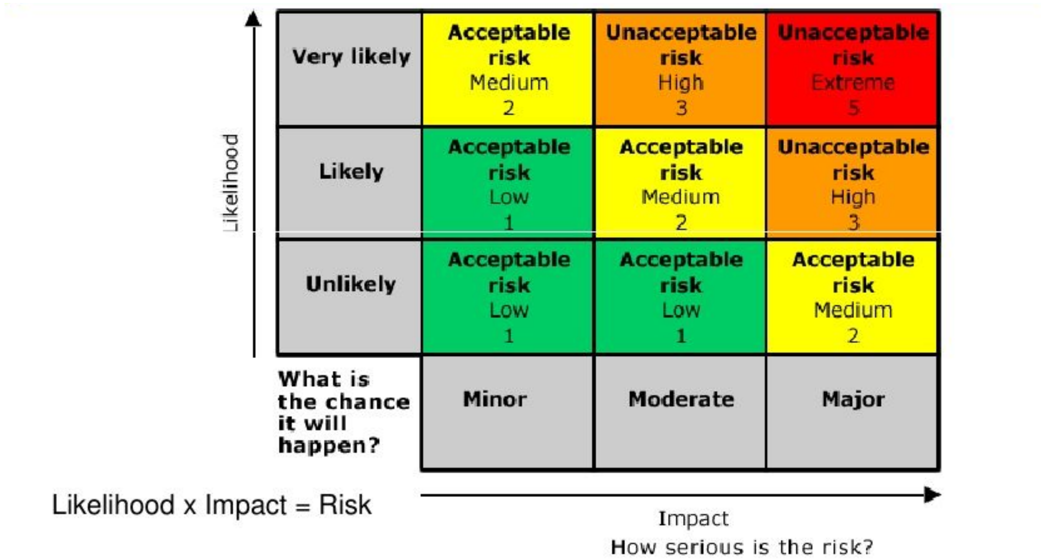

Figure 4: Risk Matrix

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Table 1: Risk Register on Testing

Risk	**Likelihood**	**Impact**	**Magnitude**	**Mitigation Plan**
1-Structure Falling	Unlikely	Moderate	Low	To avoid the risk of the entire structure falling onto the tester, we will take many precautions. First we will be careful not to tip structure past its tipping point when testing with blocks. We will also stand clear of structure when weight is being added. Also, protective clothing such as hardhats and closed toed shoes will be worn at all times when testing structural integrity.
2- Water Leakage	Likely	Minor	Low	To avoid risks due to water leakage, we will ensure all hoses are connected properly during assembly. We will also have rags available to clean up any spills that occur during testing. Last, tests will be performed on watertight surfaces to avoid water damage to the testing facility.
3- Shock/ electrocution	Unlikely	Major	Medium	In order to avoid shocks and electrocution due to testing, we will fabricate the system to avoid water and electrical combinations at all costs. Also, we will clean up all water spills

				immediately, turn off power when not in use, and be very conscious of the potential risk. We will also wear closed-toed shoes, long pant, and protective equipment when testing the electrical components of the system.
4- Fertilizer Contact	Likely	Minor	Low	To mitigate the risks involved with fertilizer, we will be sure to to wash hands thoroughly after contact with fertilizer.Also, we will discourage consumption of the fertilizer, use only light fertilizers, and be cautious in where fertilizer is stored.
5- Power Surge/ Lighting Fire	Unlikely	Major	Medium	To reduce risks that may cause a power surge or lighting fire, we will monitor power level and use approved power cable. Research will be conducted before executing any power systems or lighting systems. We will also have access to fire suppression methods (fire extinguisher, water buckets) available if needed. Protective clothing will also be worn at all times during testing to mitigate this risk.
6- Minor injury during assembly	Likely	Minor	Low	In order to reduce risk of minor injury during assembly and testing, we will take precaution to assemble the system properly and according to the instructions. Also, fabrication of sharp edges within the system will be avoided. We will also have a first aid kit on hand in case any of these minor injuries occur.
7- Self-esteem injury during assembly	Unlikely	Minor	Low	In order to reduce injury to self esteem during the assembly process, we will be impartial when observing testing of participant demonstrating use of step-by-step instructions.

1.5. Plan for Stakeholder Feedback

1.5.1. <u>Demonstrations for Mentor</u>

Our team will provide a spreadsheet or other document outlining research findings and testing results. Videos of testing can be provided to the mentor if requested. A participant reflection and rating form will be completed by individual testers to collect quantitative information on the prototype. If the prototype rating is not satisfactory, more iterations to improve the product will be completed.

1.5.2. Plan for Interviewing Stakeholder

Table 2: Communication Plan for Stakeholder Feedback

Stakeholder/Type	Name, Contact Info	Due Date	Person(s) Responsible
User (low-income family member)	Contact manager at local food bank	11/14/2016	Chase
Distributor (Retailers of the product)	Contact manager at a retailer (Home Depot, Walmart, etc.)	11/21/2016	Franco
Manufacturer Expert (professor?)	Contact professors specialized in manufacturing	11/21/2016	Caleb
Sustainability Expert	Contact at the National Renewable Energy Laboratory	11/7/2016	Kristin
Informed Party	Food Bank Worker	11/21/2016	Alex
Proxy Stakeholder (End User)	Epic students	10/27/2016	Everyone