UBC Social Ecological Economic Development Studies (SEEDS)

Community Service Learning (CSL) Project

Portable Shelving Units

Student Report

UBC Farm Work Flow CSL Project

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EXECUTIVE SUMMARY

UBC Farm provides fresh, organic produce for customers within the community and for weekly markets during the growing season. Due to budget and time constraints, several inefficiencies in cleaning and storing produce have remained unaddressed. A six-man UBC CSL Team was requested to analyze efficiency and work flow at UBC Farm's Harvest Hut, where produce is cleaned and packed. The team observed the process of cleaning and packing produce, as well as cleaning and storage of the large containers used to store produce.

Due to the small workspace in and around the Harvest Hut, the team determined construction of two portable shelving units would allow for easy packing and displaying of produce, as well as a simple means of organizing empty or full containers. The designs would need to account for the height of the farm workers and the amount of produce harvested every week. In addition, the shelving units need to provide effective vertical storage without compromising the Harvest Hut's limited floor space, and double as a place to dry the empty containers after washing. .The shelving units were designed such that each unit could support 270 lb of produce and provide 36 ft^3 of storage space for produce, while only occupying 105 ft^3 of volume and 17 ft^2 of floor space.

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ACKNOWLEDGEMENTS

The UBC CSL Work Flow Team would like to thank UBC Farms Academic Coordinator Andrew Rushmere for his patience and input during the design process, as well as Dr. Susan Nesbit and Mr. Kaveh Movazaffi for their support and guidance for this project. We also wish to extend thanks to the rest of the UBC Farm organization for the interest, support, and access provided during our analysis of the Harvest Hut and other work areas.

LIST OF TABLES

1.0 INTRODUCTION

This report details a portable shelving unit project proposed to Mr. Andrew Rushmere, Academic Coordinator at the UBC Farm. In order to improve organization and efficiency at the farm's Harvest Hut, Mr. Rushmere has a group of second-year Civil Engineering students from the University of British Columbia's Community Service Learning (CSL) program to design and construct a system of portable shelving units to assist in organization and display of produce.

The design team consists of Nathan Baugh, Greg Emslie, Jordaan Gudsson, Mike de Hart, Leo Hu, and Terrence Tang. This report details the background of UBC Farm and describes the design team's goals, objectives, roles, and decision making process. A detailed project design and construction schedule for the shelving units is also outlined in this report.

2.0 BACKGROUND OF UBC FARM AND SHELVING PROJECT

UBC Farm is 60 acre organic farm located at the southern end of the University of British Columbia's Vancouver campus (UBC Farm, 2010). It provides an area for students and other members of the community to learn about the relationship between agriculture and sustainability. UBC Farm also provides certified organic produce to local consumers and retailers (UBC Farm, 2010). Each week during the harvesting season, volunteers pack 30 containers for sale within in the community. The organization expects this number to rapidly expand in the near future.

2.1 Work Flow

When harvest season comes, the volunteers at of the UBC Farm pack a variety of vegetables into large Tupperware containers, or “totes”. Packing the vegetables into containers organizes the vegetables for sale to local vendors. Due to the farm’s high produce volume, the volunteers are continuously packing large quantities of containers on small and unstable tables. The lack of adequate packing and storage space leaves the work area untidy, disorganized, and difficult to work in.

2.2 Vision

As a means of improving efficiency and organization on site, the UBC Farm organization presented several areas of the workspace that they felt needed improvement. The organization made clear they needed to improve: produce cleaning methods; drainage of the workspace, organization and storage of packed containers, and shelter of the workspace from weather. After consultation with the CSL team, UBC Farm has requested shelving structures that will utilize the Harvest Hut’s vast vertical space without compromising its limited floor space. The shelving units will allow easy, more efficient packing, and reduce clutter around the Harvest Hut.

3.0 SCOPE OF THE PROJECT

Every week during its harvesting period, UBC Farm runs a delivery system to various customers in the community. With more than 40 orders of produce to pack each week, the farm volunteers are limited to a particularly small space inside the Harvest Hut. Currently, the packing and organization of produce-filled containers is done on foldable tables inside the Harvest Hut. The foldable tables can only accommodate four containers at a time, and must be set up and taken down every packing period due to space constraints within the Harvest Hut. The portable shelving units will improve the system of packing these containers every week by allowing the volunteers to pack multiple containers in an organized way, without compromising floor space. This project demonstrates the application of structural design to help with work flow in a community organization.

3.1 Goals

The goal of this project is to learn the nature of project design and management while giving back to the community. Members of the team learned how to take on individual roles and responsibilities, how to communicate with a client, how to document their work, how to problem solve, and how to design and build from an idea. The challenge of the project is to construct a shelving unit for the UBC Farm workers that would improve work flow by organizing containers and produce more efficiently. This would permit workers to pack orders for their customers with greater speed and less chance of mishaps.

3.2 Objectives

The shelving unit was designed in term one in the CIVL 201 course (See section 7.0

Detailed Design). Many meeting were held between the team and the client to assess the problems and to discuss the final build solution. The actual construction build will take place during term two in the CIVL 202 course and will span over three days. The shelving unit will be built at the UBC Farm and will be constructed according to the detailed design description over the three day schedule (please see section 8 for the schedule build).

3.3 Constraints

Several constraints were presented to the team before and during the design process.

3.3.1 Non-Negotiable Constraints

Use of treated lumber in the design is not permitted. To preserve lumber, it is treated with chemicals to prevent organic decay (Whittemore, 2010). Exposing these chemicals to produce disqualifies it from organic certification and creates risk to human health. As a certified organic farm, UBC Farm does not allow treated lumber on site.

3.3.2 Negotiable Constraints

The project is subject to 4 Major negotiable constraints:

- *Size and Capacity of Shelves:* The number of containers the shelving units would be able to hold was dependant on budget and material restrictions. The client requested the shelves be able to store anywhere between 15 and 30 containers, each. The 15.5” x 24” x 9” size of the containers determined the length of the shelving unit, base on how many containers each shelf was able to hold.

- *Materials:* With the exception of treated lumber, the construction materials for the shelving units are negotiable. Regular lumber, PVC piping, steel, and Electrical Metallic Tubing (EMT) conduit were all compared and considered based on their environmental impact, strength, corrosive properties, and total cost. The need to support several containers, each weighing 15 lb when full, limited material options.
- *Time:* The timeframe of construction is flexible. Unforeseen circumstances may arise and could slightly extend the length of construction
- *Budget:* The initial budget of $300 may be insufficient due to material costs and the number of shelving units the client requested. Additional funds (up to $500) may be requested.

4.0 THE THREE CONCEPTUAL DESIGNS

The project consisted of three major conceptual designs that were proposed to the client. Each design varied in terms of produce capacity, manoeuvrability, structure size, and stability. Some factors for construction of the initial designs were: height, length, width, and stability.

4.1 Design One

The Design One is a vertical model with four parallel vertical supports and six horizontal bars supporting the containers on each level. This structure is very compact in its width, and structurally simplistic to build. It takes advantage of the abundant vertical space in the Harvest Hut, without compromising the limited floor space. The goal of this design was to minimize required materials and costs while allowing for a maximum capacity of 21 totes per shelf. However, this compaction and simplicity came at a cost of stability and packing efficiently. While it takes up the least amount of space, a high centre of gravity compromises the design's stability during transport, and having the containers sit flat on the shelves makes them difficult to efficiently fill with produce (see Appendix A, Figure 1).

4.2 Design Two

The Design Two is a wider model of the First Design with five horizontal levels for containers, three levels on one side and two levels on the other side. This design also has six vertical support poles, and a sloping top (see Appendix A, Figure 2). . This double-sided shelf allows for containers to be stored on each side for a maximum capacity of 35 containers. The design's main objective is to maximize capacity, stability, and packing efficiency. While this design has a large capacity and is relatively simple to build, it also occupies a large area in the Harvest Hut, and is very difficult to move if the unit is full of produce. The client's value of floor space made this design not viable,

4.3 Design Three

The Design Three is a hybrid of the first two designs; it consists of six vertical supports and three horizontal racks that hold a total of 18 containers. Four of the six vertical supports are slightly angled to widen the base and increase structural stability. This shelf incorporates some of the space-saving characteristics of Design One, and at the same time, maintains the strength and rigidity of the second design (see Appendix A Figure 3). Mr. Rushmere and the team agree that this design provides enough storage without occupying too much space, as well as being easy to transport around the site. It was agreed that Design Three should proceed to construction, with two units being built for the Harvest Hut.

5.0 DESCRIPTION OF DECISION MAKING

Many difficult decisions need to be made to ensure a successful CSL project. A democratic method was installed to determine the team's decisions. Examples of major team decisions are: the designations of responsibilities; the agreement on designs and materials; and planning the building process. Decisions regarding the designs are discussed intelligently with the client, with both parties making their concerns understood. Through extensive research and collaborative thinking with the client and within the team, both parties came to the best possible decision for the project design. By using a democratic method with making decision, every team member, and the client, got a fair stake in determining the result. This ensured equality and fairness within the team and between the team and client. This technique also expedites the judgments made by the team, as any conflict could be decided by a quick team vote after thorough explanation of the issues, to ensure complete understanding. A vote is taken while asking every member's opinion about a specific option; a group member will state which option he prefers and the reason behind their decision. This process is sometimes stalled by split decisions within the group, but after group discussions a proper course of action is usually decided. A democratic system is the best way to ensure the best interests of the project.

The first major decision was to delegate specific positions to different members of the group. Each member informed the team of their specific strengths and weaknesses. Based on this information, the team organized itself to provide the best possible fit for everyone, in order to make the strongest team possible. This also provided the client a well functioning team to work with in order to solve their work flow issues. The second major decision was to determine the overall best design for the project. Three main designs were considered. The team and with the client discussed the pros and cons of each particular design option. Ultimately, the final decision for this design was decided by the client, based on input and information provided by the team. The next major decision was to determine the materials needed to build the final design. The positive and negative attributes were weighed against each other using the Multi Criteria Decision Model (MCDM). The team's MCDM for this project is shown in Table 1 below.

Table 1: Design MCDM

Decision-Maker	CSL Workflow Team		
	Design One	**Design Two**	**Design Three**
Criterion 1	Cost	Cost	Cost
Crit. Indicator (include units)	Dollars $	Dollars $	Dollars $
Crit. 1 Indicator Value	10	1	8
Normalized or Subjective:	Normalized	Normalized	Normalized
Weighting Factor	5	5	5
Total	50	5	40
Criterion 2	Compactiveness	Compactiveness	Compactiveness
Crit. Indicator (include units)	# Totes / m^2	# Totes / m^2	# Totes / m^2
Crit. 2 Indicator Value	7	10	6
Normalized or Subjective:	Subjective	Subjective	Subjective
Weighting Factor	3	3	3
Total	21	30	18
Criterion 3	Stability	Stability	Stability
Crit. Indicator (include units)	C of G / Base Area	C of G / Base Area	C of G / Base Area
Crit. 3 Indicator Value	1	10	9
Normalized or Subjective:	Subjective	Subjective	Subjective
Weighting Factor	2	2	2
Total	2	20	18
Site Totals	73	55	76

Selection Rationale

Criterion 1:	The cost was determined by the total length of pipe need to construct the structure. The material for each design were constant, therefore the length was the only factor. This project has a confined budget and therefore the cost was a major factor.
Criterion 2:	The compactiveness was simply how many totes were held by the structure within a defined base area. The compactivness determined the overall efficenticy of the design
Criterion 3:	The stabiliy of the structure was determined by design. The center of gravity (C of G) and the base area. Saftey of the workers was the main concern for this section.

These criteria, combined with the cost of the material, were used to determine the most suitable shelving design. Finally, the last major decision was to decide on a method on how to build the design. A method utilizing the man-hours between all group members to achieve the maximum efficiency was ultimately chosen. A flowchart shows the major components of the decision making process used (see Appendix A, Figure 4).

6.0 FINAL CHOICE AND RATIONALE

After a few modifications, Design Three was our final choice for construction. The design was chosen based on its capacity, stability, and manoeuvrability. The client also raised concerns about the designs being too high for some of the workers. Design Three was based on the positive aspects of Designs One and Two, and with effort made to improve on the detriments of the first two designs.

The client selected Design Three due to its stability, and manoeuvrability. The wide base and low center of gravity provided enough stability for movement around the Harvest Hut and supporting a large capacity of produce, while not impeding on the relatively small available space in the Harvest Hut. The client also liked the design for the angled shelves, which allows for volunteers to pack the produce easily. While it does not have an ideal capacity, each unit can still hold 18 containers. The client requested two shelving units in order to make up for the deficiency in capacity of one unit.

Design Three is superior to the other designs in most areas. Design Two provides the highest container capacity but takes up too large of an area, and is not as manoeuvrable as Design Three. Design One provides the most simplistic construction and takes up the least amount of space in the Harvest Hut, but is not as stable as Design Three.

7.0 DETAILED DESIGN

The chosen design, Design Three, is an upright shelving unit with a rectangular base and top (see Appendix A, Figure 5). The design has trapezoidal sides which lower the centre of gravity (see Appendix A, Figure 6). The design has 6 sturdy wheels attached to the base for easy mobility and support of each unit's weight when stocked with produce-filled containers. The design allows for storage of up to 18 containers, holding three vertically stacked rows of 6 containers (see Appendix A, Figure 7 and Figure 8). There is a 9 in. clearance between containers to allow produce to be placed in containers easily. The design accounts for an average container weight of 15 lb, or a total storage weight of 270 lb.

7.1 Materials

The following materials were decided upon for construction of the shelving units:

- EMT conduit piping
    - 1 in. diameter pipes through main structure
    - ½ in diameter pipes for internal, horizontal supporting racks.
- PVC piping
    - 1 ½ diameter pipes in front of the shelving unit to hold containers in place
- Traditional PVC pipe fittings
    - Used for all joints
- Industrial adhesive
    - Used to cement all fittings to the various pipes
- 6 heavy duty wheels

7.2. Calculations and Dimensions

The size of the design is 98.5-in. by 25 in. by 74 in. Each row of shelving is tilted at a 28° angle from the horizontal to allow for easy packing into the containers. The trapezoidal size shapes have an angle of 5° from the rear vertical bars to lower the unit's centre of gravity. The vertical distance of ?? in. between each tote allows for easy access to each individual container.

Each front pipe, which extends off the structure and holds the containers in place, has a diameter of 1/2 in. Each horizontal pipe, which supports the underside of the containers and is located within the structure, has a diameter of ¾ in. The vertical support pipes all have a diameter of 1 in. The various pipe lengths are listed in Table 2 below.

Table 2: Required EMT Conduit pipe length

Type of Pipe (various diameter)	**1 ½ inch diameter**	**½ inch diameter**	**1 inch diameter**
Length of the lateral faces (twice the result)	6.3+5.3+5 = *16.6"*	None	2(3+3+64.1)+22+25+70=*257.2"*
Length of the front face	3(98.5) = *295.5"*	6(98.5)=*591"*	2(98.5)=*197"*
Length of the back face	None	None	2(98.5)+70=267"
Total Length	*328"*	*591"*	*978"*

7.3. Estimated Cost

The project's budget accounts for the cost of EMT conduit piping and the heavy duty wheels. Prices are listed in Tables 3, 4, and 5 below.

Table 3: Estimated cost of EMT conduit piping

Components 1	½ inch diameter pipe	½ inch diameter pipe	1.0 inch diameter pipe
Total Length of Each Type of Pipes (ft)	328.7” 591”		978.4”
Pipe Material	PVC EMT		EMT
Cost of Material ($/in)	0.086 0.042		0.10
Total Cost of Each Type of Pipes ($)	28.27	24.82	97.84
Total Cost			***$150.93***

Table 4: Estimated cost of wheels

Components	Type	Cost of Each	Number of Each	Total Cost
Wheel	3” Swivel Rubber	$9.00	6	***$54.00***

Table 5: Total estimated budget

Component Costs	[$]
Pipes 150.93	
Wheels 54.00	
Total	***$204.93***

7.4 Stress on Unit

In order to ensure the containers stay on the shelving unit, and the unit can support the entire weight when filled to capacity (see Appendix B). At maximum capacity, it was found that the horizontal support bars experience weights of 72.2 lb, 7.24 lb, and 42.3 lb respectively. Initial observations show that EMT conduit can easily support the weight of an adult human without bending, so these results safely fall within range.

8.0 LIST OF ACTIVITIES AND SCHEDULE

This section describes the process and time frame of our project. The outline of our schedule is separated into two parts: design and planning, and the structural build of the project.

8.1 Design and Planning

All the design and planning is done in the first semester in the course CIVL 201. This is when we meet as a group and get to know each other before planning the project. Our first task was to introduce ourselves to the client, Mr.Rushmere, who then showed us around the farm and the Harvest Hut. He pointed out all the imperfections of the working area and the team obtained a list of problems with the packing area's work flow. The team held meetings to discuss which problem would be most beneficial to solve within our constraints and we confirmed with Mr. Rushmere that the team would design a shelving unit to help solve their packing and storage issues.

Once approved, the team made three conceptual designs for the work flow portable shelving unit. The conceptual designs were based on the size and weight of the containers, the size of the working area, and the characteristics of the volunteer workers who will be working with the units. The team presented the designs to Mr. Rushmere, and through discussion, both parties have agreed the best solution is to build two shelves based on Design Three. From here, a detailed design was developed during team meetings, outlining material considerations, joining of the materials, and stresses on the components of the shelving units. Lastly, the team developed this formal report to outline the entire process. The entire schedule of activities is listed in Table 6 on the next page.

Table 6: Schedule of activities

Date	Personnel Present	Activity
September 30, 2010	Group	• Group introduction • Discussed project • Exchanged contact information
October 6, 2010	Group and Mentor, Kaveh Movazzafi	• Introductions to mentor • Assigned roles • Visited the farm and met Andrew Rushmere (Client) on Oct 1
October 7, 2010	Group	• Discussed design ideas for problems noted by Andrew
October 13, 2010	Terrence, Kaveh (Mentor Meeting)	• Outlined the process and dates for the project
October 15, 2010	Group	• Visited farm to analyze workflow
October 23, 2010	Group	• Drafted ideas for each problem • Set up google document for formal report
October 28, 2010	Group, Andrew Rushmere	• -Agreed upon building a shelving unit for workflow • Sent three conceptual designs to Andrew
October 29, 2010	Group	• Visited farm to measure out working area, sizes of totes and the weight of full totes
November 2, 2010	Group	• Discussed Project design
November 3, 2010	Terrence, Kaveh (Mentor Meeting)	• Discussed sustainability in our designs
November 9, 2010	Group	• Discussed project • Split up responsibilities for writing the different parts of the report • Began writing formal report

November 16, 2010	Group, Andrew Rushmere	• Discussed final build design • -Andrew has approved of design three as our build • -Discussed materials for build
November 17, 2010	Terrence, Kaveh (Mentor Meeting)	• Last mentor meeting, discussed the end of the design and planning phase
November 18, 2010	Group	• Discussed all the different sections of the report and organized all ideas
November 19-21, 2010	Group	• Planning of the final design • Write up and final edits of the formal report
November 22, 2010	Group	• Submission of team's report
November 24, 2010	*Group, Kaveh (group Meeting)*	• *Final group meeting, wrap up of CIVL 201 and the planning and design phase for the group*
December 2, 2010	*Group, CIVL 201 Panel*	• *Presentation for our project*

*italics note future events

8.2 Structural Build

The building of our finalized design will take place in second term, in the course CIVL 202. Materials are gathered and organized beforehand, and with permission from Mr.Rushmere and the UBC Farm organization, the supplies will be stored on site in the Harvest Hut. The two shelving units are to be built on the farm over the course of three days.

8.2.1 Three-Day Build

The three day build is preliminarily scheduled in Table 7 on the next page.

Table 7: Outline of Three-Day Build

Day 1	• Gather supplies and tools and set up build space at UBC Farm Harvest Hut • Cut out required lengths of pipe to make the bases of the shelving units • Assemble and glue together the base of the shelving units • Screw wheels to the two bases
Day 2	• Cut out required lengths of pipe for the vertical supports and horizontal racks • Bend the vertical supports to required angles • Assemble and glue together the horizontal racks to the vertical supports • Fit the whole midsection (consisting of the vertical supports and horizontal racks) to the bases and adhere with glue • Cut out pipe for the top section of the shelving units • Fit and glue together the top pieces of the shelving units
Day 3	• Attach and glue the top pieces onto the midsection of the shelving units to complete the structures • Attach display racks to the front of the shelves • Paint the shelves to seal metal and extend shelf life

9.0 ROLES AND RESPONSIBILITES

The UBC Farm organization, as well as the CSL team and its members, had a variety of different responsibilities during the design process. All parties will also have various roles throughout the construction phase, as well.

9.1 The Organization

In the first semester, UBC Farm Academic Coordinator Andrew Rushmere provided the team with a detailed description of the project's scope. He provided the team with information on the facility's use and floor plan, and gave the team multiple tours of the workspace where the shelving units would be located. Mr. Rushmere is the team's contact with UBC Farm for the design and build.

In the second semester, Mr. Rushmere will provide the team access to the Farm and the harvest hut during the build process. Mr. Rushmere will remain in contact with the team during the 3 day build, and will be able to provide feedback and ensure the safety and productivity of the volunteer staff will not be compromised during the build.

9.2 The Team

In the first semester, the team is responsible for researching UBC Farm and the scope of the project. After analysis of the project, the team is to provide project deliverables in a professional manner. The team is also responsible for informing UBC Farm, Dr. Susan Nesbit, and a panel of judges of any issues or concerns regarding the project in order to have the construction process approved.

9.3 Team Members

Upon organizing the group in the first semester, official group contacts were assigned within the team. Greg Emslie became the team's contact with UBC Farm, Terrence

Tang was the team's contact with the group mentor, and Mike de Hart was the group's contact with Dr. Susan Nesbit. Leo Hu was responsible of drafting a 3D representation of the selected design using Google SketchUp, and Jordaan Gudsson kept digital file documentation of the design process. All group members took part in the design of three options to present to the client, which were developed during weekly group meetings organized by Terrence Tang.

In the second semester, the team will implement its design proposal. All team members will take part in the construction process. Terrence will continue to keep in contact with the group mentor, and Greg Emslie will continue email correspondence with Mr. Rushmere as needed. Greg will inform Mr. Rushmere of any difficulties with construction or access to the harvest hut during the three day build. The responsibilities of each team member during the three day build are outlined in Table 8 below

.

Table 8: Group responsibilities during construction

Task	Team Members Responsible
Gathering tools and materials	Greg Emslie
Measuring length of EMT conduit for cutting	Leo Hu Terrence Tang Jordaan Gudsson
Assembling segments	Terrence Tang Jordaan Gudsson
Cementing sections together with industrial adhesive	Nathan Baugh
Attaching wheels to base	Nathan Baugh

10.0 RISK ASSESSMENT

This project involves risks for both team members and for future users of the shelving units. Firstly, no team member has a detailed knowledge of structural engineering. Thus, while careful thought and effort are put into planning the shelving units, there is the possibility of the containers falling off of the shelves. Calculations have been done to the best of the team's abilities and care will be taken during the construction process to ensure maximum strength of the shelving units. This will reduce the likelihood of injury from falling containers.

Secondly, during the build, there are numerous risks for team members. To reduce the risk of injury associated with using hand tools, instruction will be given by knowledgeable team members to members with less hands-on experience. This will ensure that tools are used properly, efficiently, and in a manner that reduces the potential for injury.

Thirdly, not all team members have experience with construction procedures and construction safety. This inexperience could lead to increased risks for all team members. As a result, on the first day of the build, the team will hold a meeting to review the construction process and to introduce safety measures, such as a supervision system, and protective clothing and eyewear. This will ensure that all team members have protection and the same understanding of safety guidelines, allowing for a safe and efficient three day build.

In addition to the risks introduced above, it is possible that further risks will be discovered as the build progresses because construction processes do not always go as initially planned. Should changes in the construction phase introduce new risks, the team intends to research and develop new plans to reduce the risk and ensure safety on site.

11.0 RELFECTION QUESTIONS

Looking back through the design process raises many questions on how improvements could be made with regards to communication and project design. The discussion and reflection of these questions will work to improve the team's communication and make the build process simpler and more efficient. These questions include:

- How could communication within the team improve?
- Was the contact with the client handled in a professional manner?
- Was there room for improvement in the design process?
- Did the team manage time and tasks properly?
- Were individual responsibilities divided up fairly?
- Was the chosen design the best possible choice for this project?
- Could the design have been improved if drastic changes were made?
- Was communication with the professor and team mentor adequate?
- Are the materials strong enough to endure the maximum load of the full containers?
- Does the design make best use of the budget?
- Do the joints fit and adhere together securely enough?
- Is the shelving unit of appropriate height for all farm volunteers to use?
- Has the group learned the hands-on skills to safely and appropriately construct the shelving unit?
- If something were to go wrong during construction, would their be adequate budget to fix the issue?
- Are there enough materials for the project?
- Has the build been completed within the three day schedule, if not what was necessary to complete it?

12.0 CONCLUSION

This report outlines a working model of our project and the projected outcome. The detailed design and build schedule might be subject to change in term two, during the construction phase of the team project. Those affected by the success of this project are the team members designing and building the shelf, the UBC SEEDS Farm Initiative using the structures, and the people organizing both the CIVL 201 and 202 courses.

Overall, Design Three was chosen as the best solution to the client's concerns about work flow at UBC Farm. The advantages of Design Three are its stability, manoeuvrability, and capacity of alterations during the design and build processes.

These factors ensure: the safety of volunteers while using the shelves; the client flexibility in the location of the shelving units; and the team the ability to meet the client's needs most effectively. The design process that led to this decision involved: initial meetings with the client to determine the scope of the project; team meetings to plan and draw conceptual designs, decide on a final design; and make other decisions regarding the final design. As the design was finalized, a build plan was determined and where risks were analyzed to ensure efficiency and safety during next semester's build.

The construction of Design Three will enable UBC Farm volunteers to pack produce orders for clients in a more efficient and organized manner. This will allow the farm to become more cost effective and improve time usage of its staff. The UBC Farm Work Flow CSL team has recommended Design Three as a means of work flow improvement and as a model for future considerations for storage and transportation of produce.

13.0 REFERENCES

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APPENDIX A: ILLUSTRATIONS

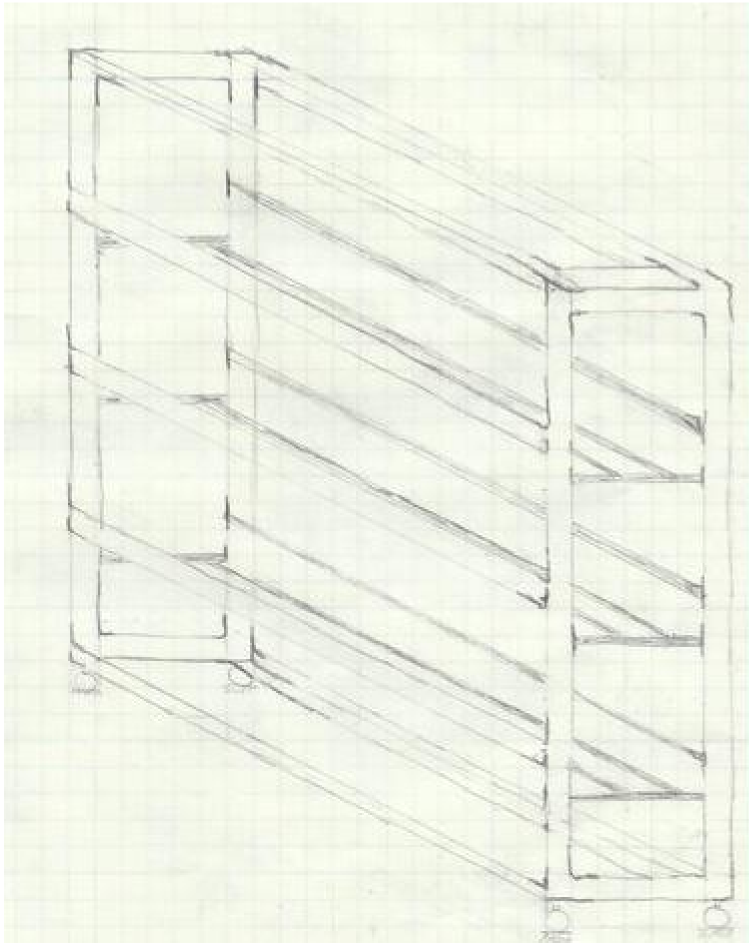


Figure 1: Design One

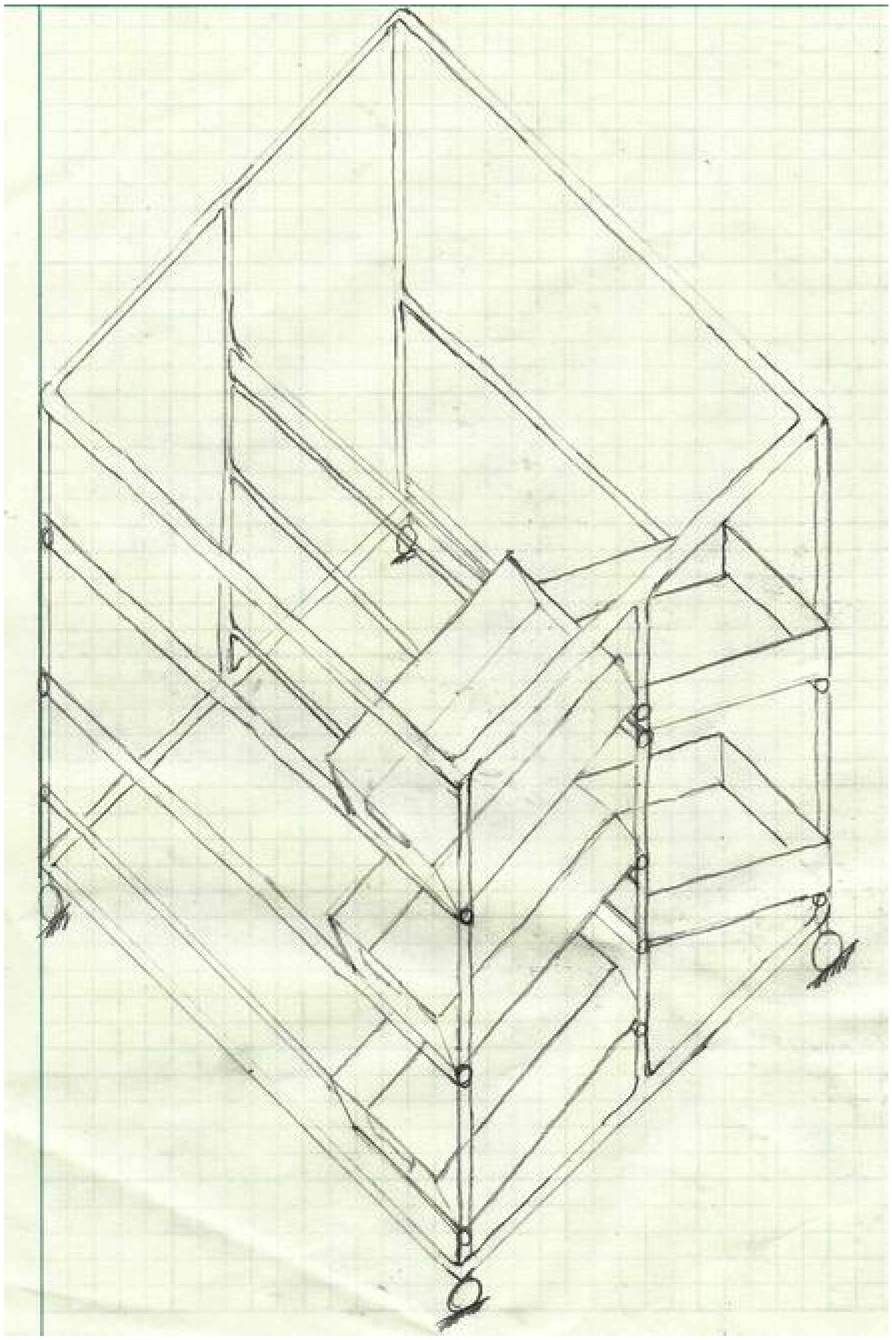


Figure 2: Design Two

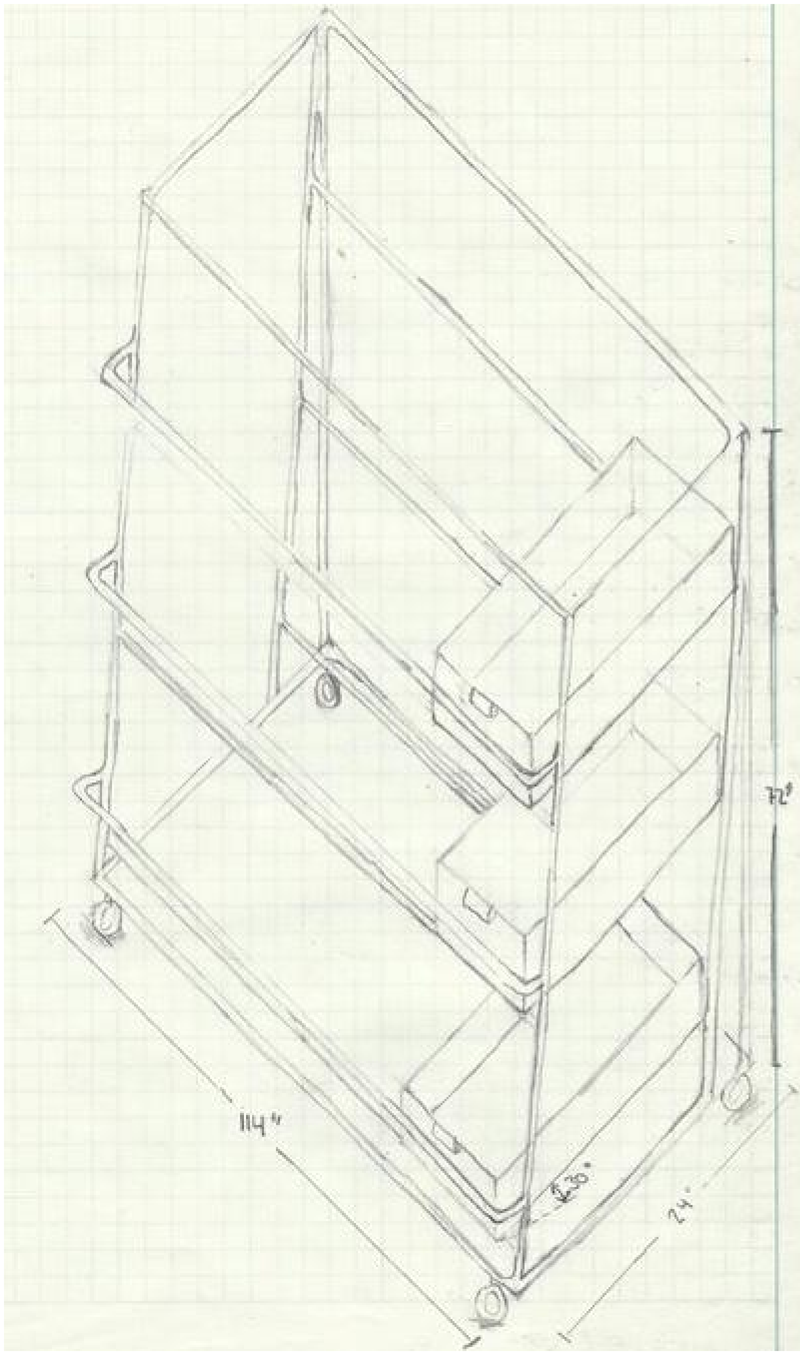


Figure 3: Design Three

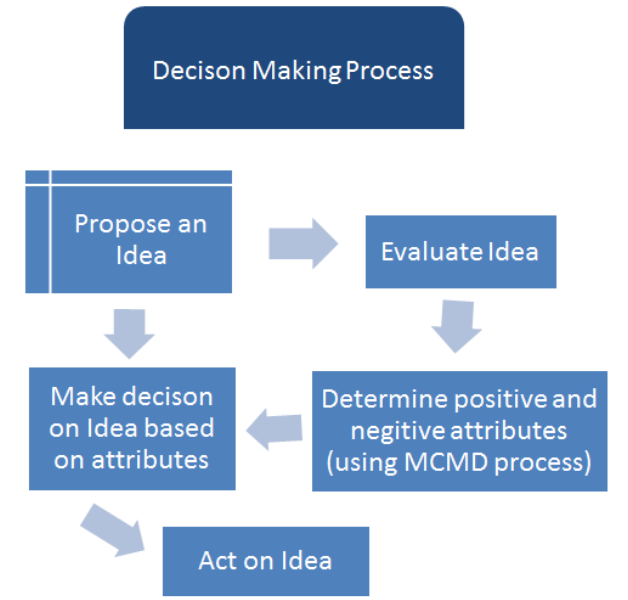


Figure 4: Decision Making Flowchart

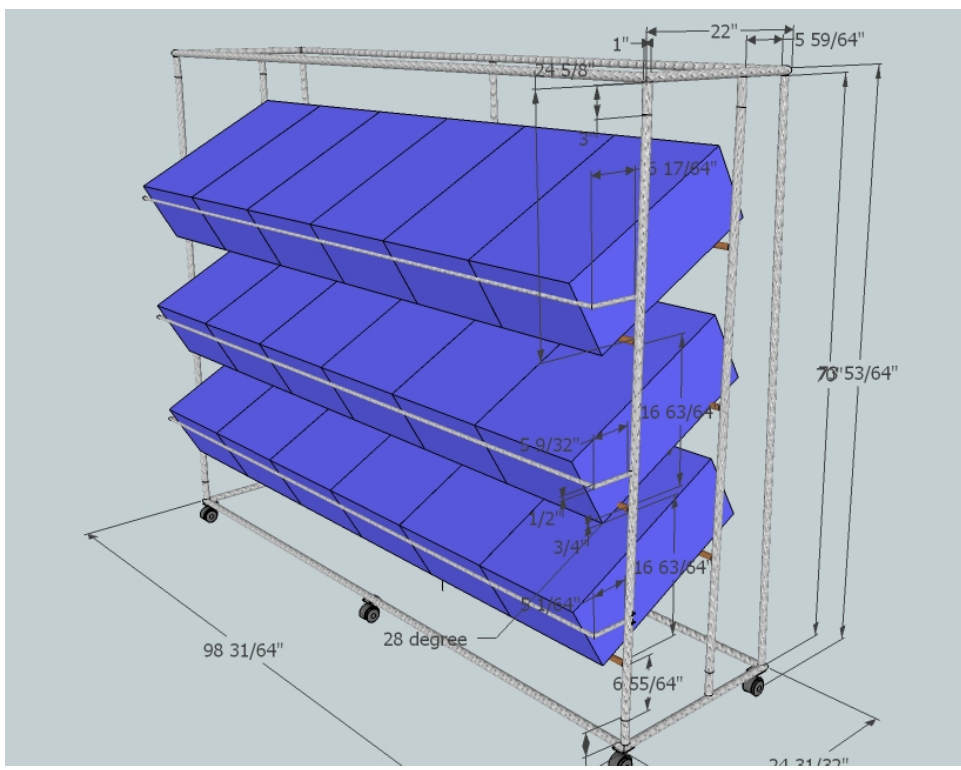


Figure 5: 3D Google SketchUp View of Final Design

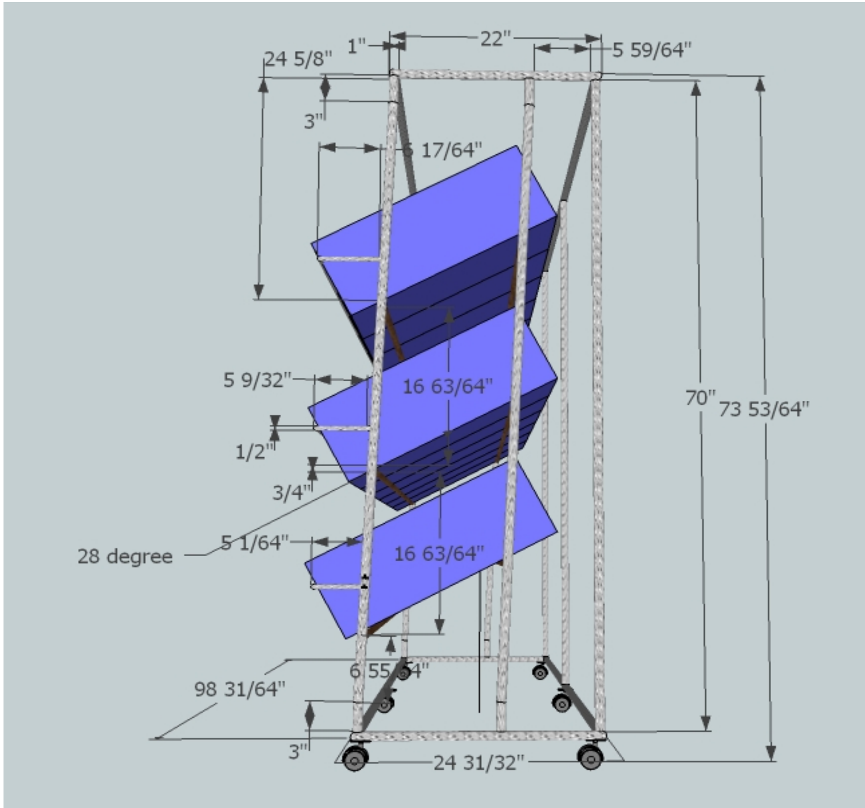


Figure 6: Side View of Final Design

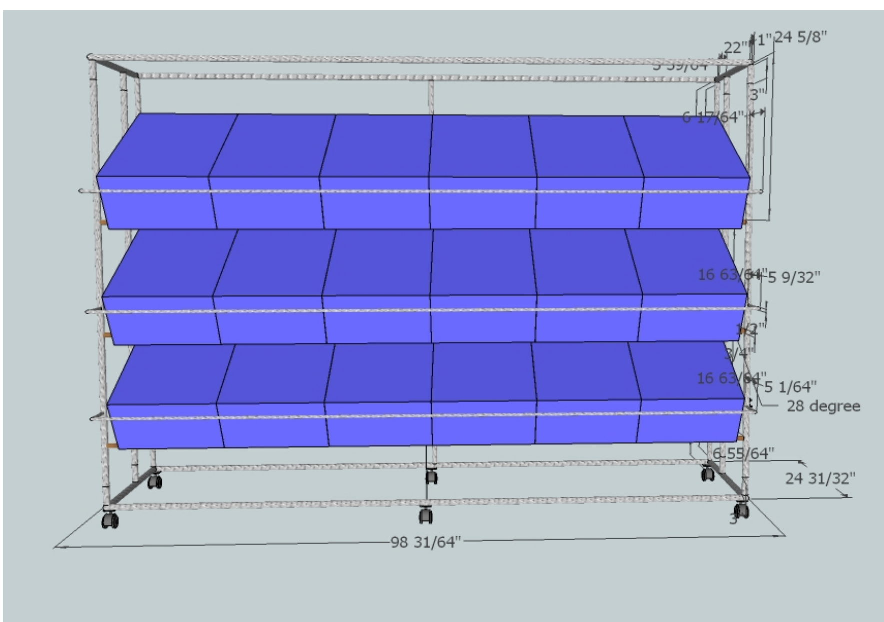


Figure 7: Front View of Final Design

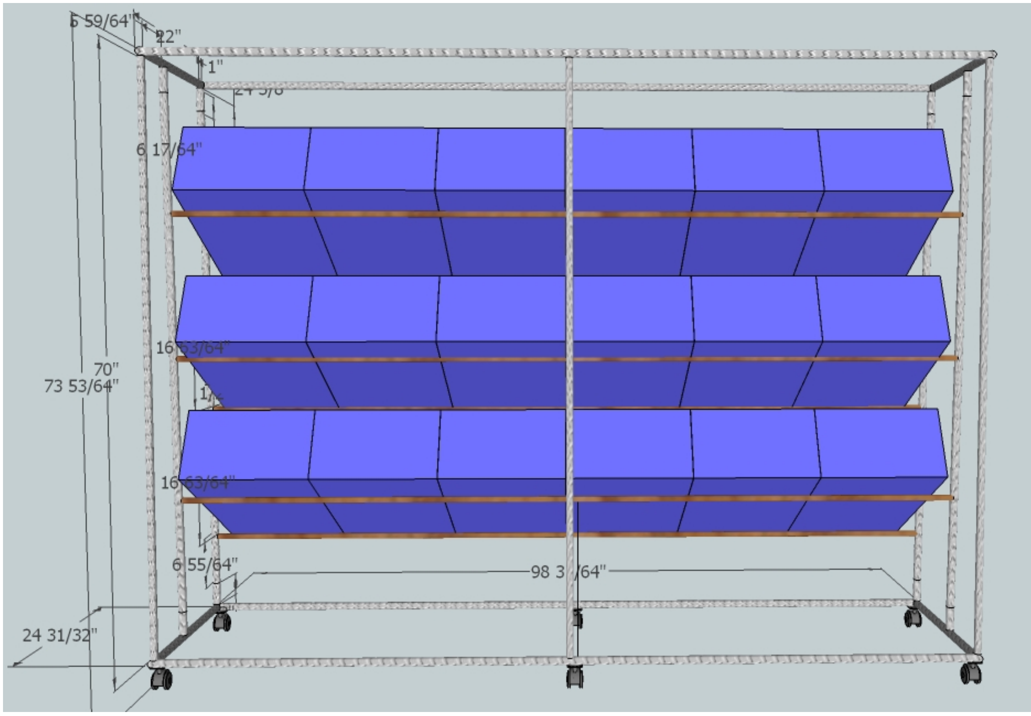


Figure 8: Back View of Final Design

APPENDIX B: STRESS CALCULATIONS

One tote = 15lb

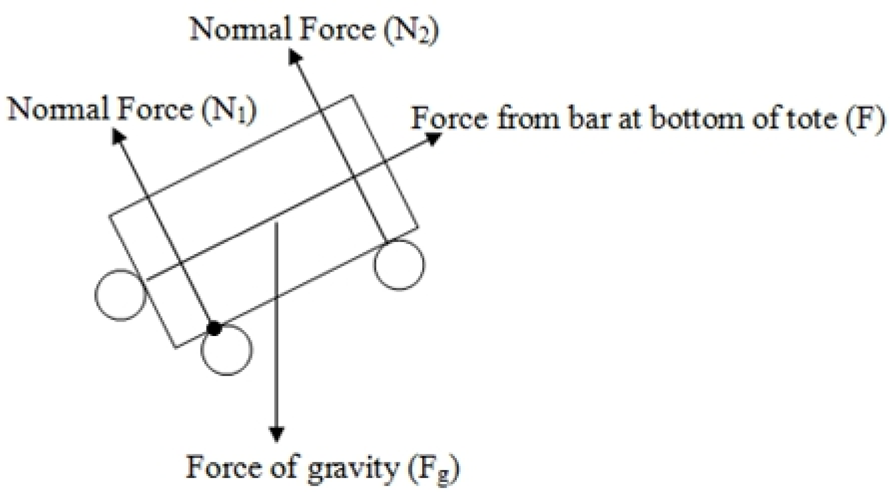
Sum of forces = 0 (Equilibrium: containers stay on rack)

Angle of totes = 28°

Black dot = point A

Length between bottom two bars = 1.34 ft (L_1)

Length between bottom of tote and bar at the end of the tote = 0.5 ft (L_2)



Sum of forces in vertical direction:

$$N_1 + N_2 - F_g \cos(28) = 0$$

Sum of forces in horizontal direction 0:

$$F - F_g \sin(28) = 0$$

Sum of moments taken about point A:

$$FL_2 + (F_g sin(28)L_1)/2 - F_g cos(28)L_2 - N_2L_1 = 0$$

Solving equations 1, 2 and 3 for N_1, N_2 and F gives:

$$(N_1, N_2, F) = (12.04 lb, 1.21 lb, 7.04 lb)$$

The force on the bars is equal to these three forces because the totes are not moving.

If there are six totes on each level then the total force on each horizontal bar is

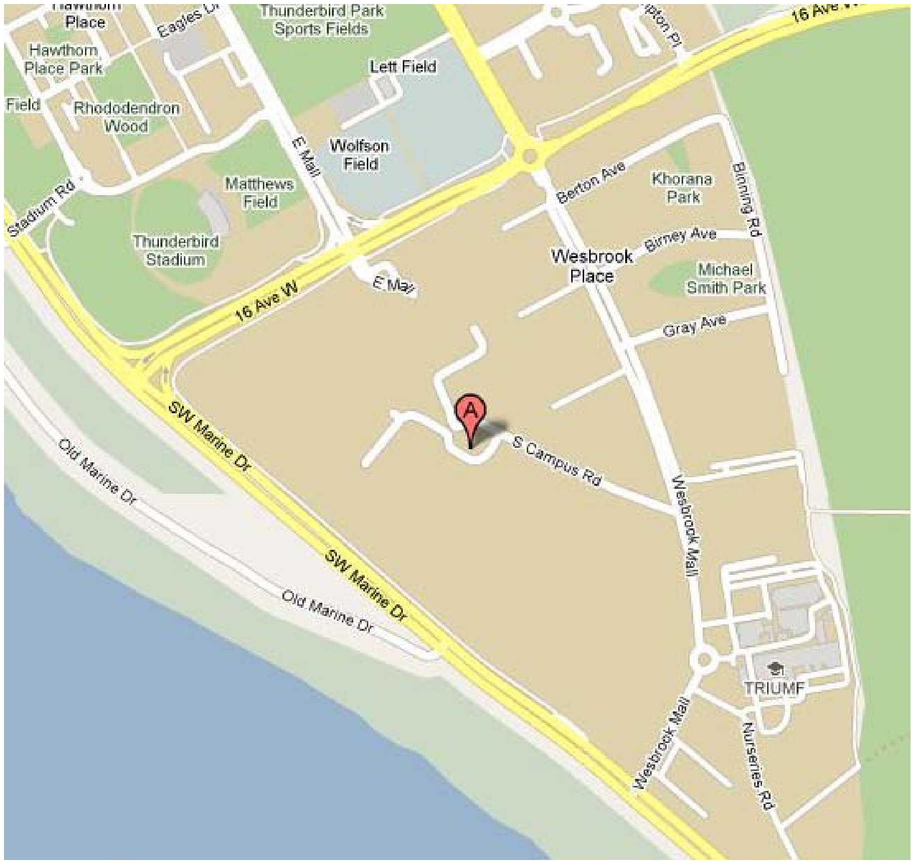
$$\boxed{(6N_1, 6N_2, 6F) = (72.21 lb, 7.24 lb, 42.25 lb)}$$

APPENDIX C: CONTACT INFORMATION

Name	Role	Contact Information
Susan Nesbit	• Civil 201 Professor • Provided the outline of the project • Offered any help or answered any questions regarding the project	Email: [redacted] Tel[redacted] Location: CEME - Room 2013
Kaveh Movazaffi	• Team Mentor • Kept in touch with the team leader and ensured our progress • Offered any necessary help in regards to our project	Email[redacted]
Andrew Rushmere	• Academic Coordinator • Introduced us to the site of the project • Sent feedback on our designs • Provided us with any required information for our project design	Email: [redacted]
Brenda Sawada	• UBC SEEDS Manager • Provided an outline for our UBC SEEDS project • Offered any help in regards to our project • Offered sustainable material suggestions • Acquired our permission to post our project onto the UBC SEEDS site	Email: [redacted] Tel: [redacted]

UBC Farm

6182 South Campus Road (Southern end of UBC's Vancouver Campus)



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