

GNG2101
Design Project User and Product Manual

Submitted by:

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List of Acronyms and Glossary

Table 1. Acronyms

Acronym	Definition
UPM	User and Product Manual
BOM	Bill of Materials to build a system.

Table 2. Glossary

Term	Acronym	Definition
Acrylonitrile- Butadiene- Styrene	ABS	A material made up of thermoplastic resin.
Polyvinyl chloride	PVC	A material made up of a synthetic polymer of plastic.

1 Introduction

This User and Product Manual (UPM) provides the information necessary for volunteers of the uOttawa Free Store to effectively use the ‘collapsible clothing rack’ and for prototype documentation.

The Extendables were presented with a problem to create a collapsible but easily accessible clothing rack for the uOttawa Free Store, at the beginning of the Winter 2022 semester. The uOttawa Free Store is a store off campus where the goal is to prevent waste in order to help the world. The store allows uOttawa students to drop off items they no longer need while picking up new items free of charge (uOttawa). The clothing racks currently in use by the store were very bulky and could not be moved easily to adjust to a different layout. Most importantly, the current clothing racks were not adjustable in any capacity; therefore, the uOttawa Free Store was concerned as the store was not very accessible to students with disabilities, particularly wheelchair bound students. As the mission of the store was to provide free supplies to all uOttawa students, the store was looking for a new clothing rack that could be adjusted in height to fit the needs of a more diverse demographic of students. The store was also looking for a new clothing rack that could easily be collapsed and set-up in order for the rack to be moved to different locations around campus. Nonetheless, the uOttawa Free Store also noted that the most important details be that the final product would be durable and safe to use. The assumptions were made that the safety of the product was synonymous with the durability and stability of the rack, wherein if the rack could sustain rough handling and would be stable enough to not collapse in on itself when move, it must also be safe at the same time. The overall development of the product is available through the MakerRepo website for The Extendables linked in Appendix I.

The purpose of this document is to give the user an understanding of the background of the final prototype delivered to the uOttawa free store, as well as instructions on how to use it. Throughout this report, the problem presented by the store will be discussed in more depth and an overview will be provided in addition to the proposed solution. Instructions on getting started will be included, which will include the configuration and user considerations, instructions on how to set-up the final prototype for the rack, system organization and navigation, as well as instructions on exiting or taking apart the system. Moreover, the manual will outline a more in-depth look into the functionality of each individual subsystem and feature included in the rack along with troubleshooting and support information. Lastly, background information on the development process in the form of the product documentation will be described throughout the UPM.

For the intends of this UPM, the user is assumed to be a volunteer managing the uOttawa Free Store, though users may also include other employees at uOttawa that may handle the final prototype. While this UPM will be accessible electronically, through the use of the provided pdf format, this document ensures the security and privacy of the user. All links available throughout this document are guaranteed to be safe and will provide no connection to the user’s information.

2 Overview

The UOttawa Free Store’s main problem was the lack of an efficient functioning clothing rack. Their current clothing racks are too large, hard to move, and not accessible. The UOttawa Free Store is a very small space. Their current clothing racks take up too much space that could be used for other, more important items. Accessibility is very important to the client. Every student should feel welcome to shop at the Free Store, despite any physical impairments. For these reasons, it is important to solve this problem, and create a better functioning clothing rack.

Upon then first client meet, statements were highlighted and interpreted to determine the fundamental needs of the user. The following needs are displayed in Table 3.

Table 3. The fundamental needs of the uOttawa Free Store.

Client Statement	Interpreted Client Needs	Justifications
We would like to have racks that can be wheelchair accessible	The rack is adjustable in height	The client has expressed their extreme concern with accessibility within the free store. They want everyone to have the opportunity to shop there. Through making the clothing racks more accessible, it will allow more students to feel included. The client expressed their idea that adjustable height may grant access for the employees to change the rack height to accommodate wheelchair users. As accessibility is a major concern for the client and one of the reasons they would like to change the design, the need was ranked as 2, second only to strength out of safety reasons.
We would like to have racks that can be moved to different locations around campus.	The rack is collapsible and movable by hand	The client had expressed that mobility was an issue with their current clothes rack. The client had stated that the clothes rack needs to be exported from a building approximately a five-minute walk away and by one to two people. With a heavy clothes rack, it was not ideal to be moved for one person (safety). The client expressed that a

		collapsible design would be ideal, but if not possible, wheels would also be possible; hence why the priority is only 4.
The clothing rack needs to be able to withstand the "not-very-careful" treatment of the rack by volunteers working at the free store who are in a hurry.	The rack is durable and can withstand rough handling	The client has expressed that they want a clothing rack that can handle a lot of weight. The volunteers do not have time to be concerned about how much weight is being on it, and they have to be to take clothes on and off quickly, without worrying about the state of the rack. However, the client as also expressed the ability to, if a weight limit exists, instruct the employees to only hold a certain amount of clothing articles; hence why the priority is lower.
We would like to have racks that have an easy and intuitive set-up	The rack is easy to assemble by a maximum of two people.	The client has expressed their current racks have had issues with being set up and taken down quickly, being able to extend the bars for more use, and being able to collapse them for compact storage. Being able to meet all these needs will allow the store to feel more open and less crowded. In addition, the client expressed (as seen a couple rows later) a desire for the rack to be movable by a max of two people, so the setup may, by extension also be setup by two people. Due to the current racks still being very useful though, the priority was judged as not as important in comparison to other needs, which is why it was only assigned 6.
We would like to have racks that aren't very expensive	The rack is cheap	It was mentioned in the client meeting that the uOttawa Free store relies almost entirely on donations and thus does not have a lot of extra money to spend on an expensive clothing rack; therefore, a cheaper cost is highly necessary for the store

		to be able to implement the item into their store.
We would like to have racks that can hold a lot of weight	The rack is stable and strong enough to hold a lot of clothing	The client expressed a need for the racks to be able to hold many items. Most importantly, the racks were supposed to be stable enough to support the weight as to not pose a safety hazard; hence why the need would be categorized as the most important objective.
We would like to have racks that can be easily moved by a maximum of two people	The rack is light enough to be carried by a maximum of two people	In the meeting, it was mentioned by the client that the Free store relies primarily on the work of a few volunteers, and as such the clothing racks should not require for very many people to lift them and transport them (given their low staffing). The client, however, has also expressed how wheels could be useful for mobility in case the design is heavier, which is why the need was deemed as not as important if wheels can be used to negate any issues associated with weight.
We would like to have racks that are quick to set-up	The rack is fast to assemble	In the client meet, it was discussed that during display periods the Free store needs to be able to put their items up for display quickly, and thus the rack should be fast to disassemble and reassemble in case of a last-minute display. The client did mention that the employees usually have 30 minutes for setup, though, which is why, if enough time is allocated to setup, the need was deemed as not the most important; hence why the priority is 8.
We would like to have racks that look very polished and clean	The rack is aesthetically pleasing and simple in design	The client expressed that while aesthetics would be appreciated, they were not necessary. The client stated that while the current racks aren't "beautiful," they accomplish their task, which is what matters to the

		customer; therefore, as long as the new design isn't "hideous," they didn't see a need to prioritize aesthetics.
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This clothing rack is superior to other designs in many ways. The overall design is completely unique, and something that hasn't been seen before as seen in Figure 1. A fully collapsible and accessible rack has never been seen before, making those two key aspects that allow this clothing rack design to stand out.



Figure 1. The final prototype

The clothing rack consists of a strong base that can carry a lot of weight, perfect for placement of miscellaneous items such as books or shoes. The wooden frame can be placed onto the base through holes in the wood. When in the collapsed form, the frame can lay on top of the base. The clothes can be hung on the PVC pipes, and the height can be adjusted to three different heights. Wheels allow the base to move around with ease.

2.1 Conventions

The main action involved in the use of the clothing rack is the setting up and disassembly. This action is incredibly easy and will take less than 1 minute for each. Both require removing the frame from the base and lowering the PVC pipes out of the safety mechanism, and onto the side.

No other actions are required for the use of the final prototype.

2.2 Cautions & Warnings

The clothing rack was built to prioritize safety, although there are multiple highlighted concerns. The current safety mechanism, to lock the pipes into place is created with screw heads. It is important to ensure that they are handled with care, as it would be easy to get something caught on it, which runs the risk of potentially hurting oneself.

It is also important to ensure the locks on the wheels are always used when not being moved. If the locks are not on, the clothing rack will run the risk of possibly rolling away and hitting someone or something.

3 Getting started

3.1 Set-up Considerations

The system contains two main parts, the first being the base and wheels and the second being the frame and the clothing rack. A detailed explanation is seen in Table 4 below, and each part can be seen labelled in Figure 2.

Table 4. Description of the parts used in the clothing rack.

Part	Description
Hanging Bar	The horizontal PVC piping that is meant for hangers to hang on to display the clothing for the customers.
Support Bar	Piping that is meant to hold up the hanging bar to ensure the customers are safe when taking clothes off of the hanging bar.
Locking Mechanism	Screws that were added to ensure that the support bar wouldn't slip and cause the clothing rack to accidentally collapse.
Frame	Vertical wood pieces that hold the hanging bar and support bars in place. Will slide into the locking mechanism in the base to ensure stability.
Base	Is used to store larger objects being displayed at the free store. Used to keep the frame intact and upright.
Wheels	Wheels that lock to ensure the clothing rack can be transported around campus if necessary.

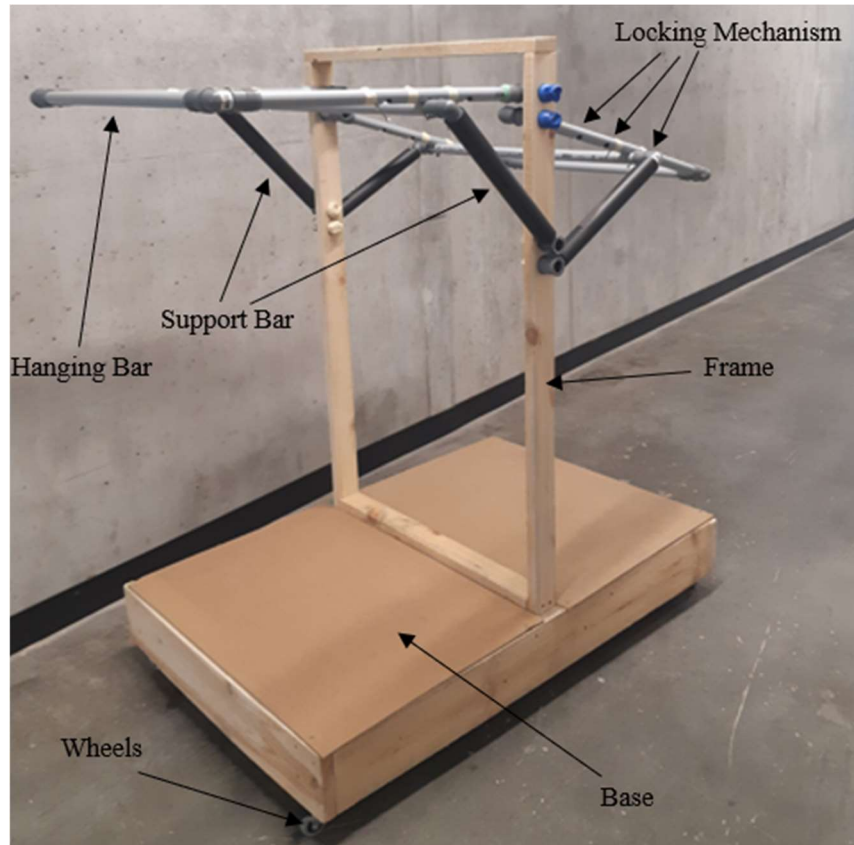


Figure 2. Clothing rack labeled with the appropriate parts.

3.2 User Access Considerations

The client from the Free Store emphasized that the clothing rack needed to be accessible for every member of the general public, including people in wheelchairs. The client expressed that they wanted the clothing rack to be low enough that a person in a wheelchair would be able to easily grab any article of clothing or objects from the clothing rack without straining themselves because they want everyone to feel included and respected. When building the final prototype, the extendables lowered the height to 54 inches, and it was decided to make the base of the clothing rack a rectangle instead of a square to ensure clothes could be easily accessed from the sides of the product. The hanging bar and support bar were built for three different height settings, allowing people in wheelchairs to grab clothes of the rods.

3.3 Accessing the System

Setting up the prototype is very simple and takes less than a minute.

1. Make sure both pieces are present, the base and the frame.



Figure 3. The base and frame of the clothing rack.

2. Place the base on the floor with the wheels touching the ground and put the frame inside the slots on both sides.
3. Lift up the hanging bar and the support bar and simply place the support bar in the groove to provide the desired height to display the clothes.



Figure 4. Frame inside the base with the bars properly setup.

4. Ensure all of the wheels are unlocked, move the clothing rack to the desired location, then flip the locking mechanism on all four wheels to the downwards position to ensure the clothing rack doesn't move.
5. Finally, place the hangers and clothes onto the hanging bar and any objects onto the base for display.

3.4 System Organization & Navigation

The collapsible clothing rack has two main pieces. The first piece contains the frame with the hanging bars and support bars. The second piece contains the base with the lockable wheels.

3.4.1 Frame

The frame contains wood planks that can slide into slots in the base of the clothing rack for stability. Higher up on the frame, there are 4 holes drilled with elbow joints secured into them to attach the hanging bars to the frame, and there are 4 other holes to attach the support bars to the frame. The hanging bars have three holes and screws drilled into them in order for the support arms to be securely attached to ensure that when in use, the clothing rack is extremely safe. The support bars rise up and fasten behind the screws into the holes and are very secure.

3.4.2 Base

The base contains a rectangular shape with boards to be used for bigger objects to be displayed on. The base contains four wheels that are screwed in on the underside that can be transported around campus and locked to ensure safety for all customers and volunteers at the free store.

3.5 Exiting the System

1. Take any objects, clothes, hangers off the clothing rack.



Figure 5. An empty clothing rack.

2. Lift the hanging bars and pull down on the support bars and gently lower them until they are completely collapsed.
3. Place one foot onto the base and pull up on the frame until it comes out of the slots in the base.
4. Place the base and the frame away in a safe place until they are needed again.



Figure 6. Fully collapsed clothing rack in storage.

4 Using the System

The following sub-sections provide detailed, step-by-step instructions on how to use the various functions or features of the collapsible clothing rack.

4.1 Wheels/Lockable Feature

The wheels are used to lock to provide stability to the collapsible clothing rack. To ensure stability through the lockable wheels, it is essential to push down on the lever to enable the locking feature on each separate wheel. To release the locking mechanism, the lever can be lifted upward. The lockable wheels provide stability to be moved across campus as well as to endure weather conditions.

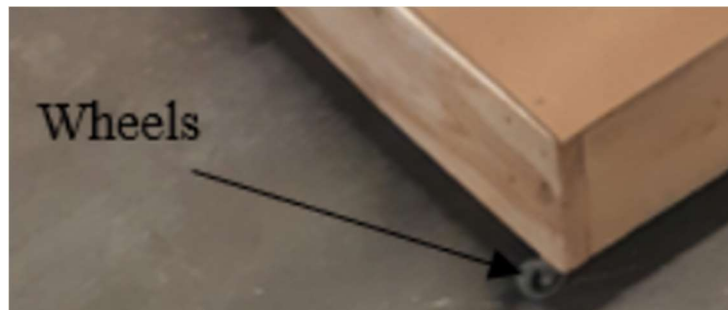


Figure 7. Lockable Wheels.

4.2 Base/Insertion Slot Located at Both Sides

The insertion slots located at both sides of the base are used to provide the collapsible aspect of the clothing rack. As seen in figure eight, the two legs of the top component get inserted into two slots below located on the base. To insert, align the top legs with the two slots and insert strongly to secure the bottom and top pieces. To remove and collapse both bottom and top pieces, slightly hold the base down with a foot and pull upwards on the frame to disconnect and collapse. This provides ease of storage for the customer.

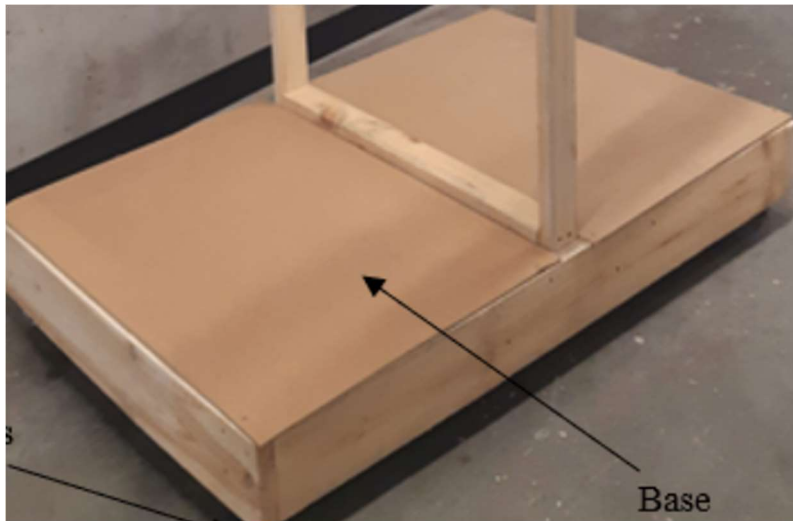


Figure 8. Base, Insertion Slots are located on both sides of the base.

4.3 Arms of Clothing Rack/Adjustable Height of Arms

The adjustability of the hanging bar or “arms” is used to adjust to various heights with varying degrees of angles to accommodate height needs. This can be done through resting the support bar against the nail/groove within the hanging bar at the desired height, this should automatically lock the hanging bar and support bar together. To release and readjust simply remove the support bar from the groove/nail within the hanging bar and readjust as the user sees fit. The purpose of the adjustable height is to accommodate people in wheelchairs to make accessibility the main priority.

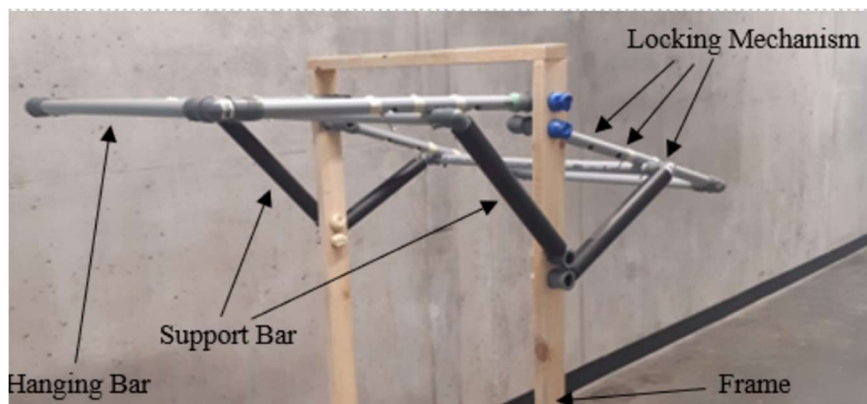


Figure 9. Hanging Bar, Adjustable height of Arm.

5 Troubleshooting & Support

5.1 Error Messages or Behaviors

In the use of the clothing rack the following problem may arise:

1. The clothing rack central beam could not easily fit in base slot – To correct this be sure to slide the top section of the rack into it's base squarely to the slots and to push assertively.
2. The supporting arm may not exactly fit in groove – To correct this one can set the supporting arm in the groove of the rack and push down firmly so that the supporting arm snaps into place
3. The clothing rack arm could begin to bend under immense weight - Avoid hanging more than 40 lbs of clothes on only one rack arm
4. The clothing rack shelf could bow or snap under immense misplaced weight – Avoid adding more than 50 pounds of weight on the middle of the shelf (at its most unsupported area). Weight bearing ability over the frame is significantly higher. Should the shelf snap proceed with repair:
 - a) Remove all material placed on shelf and replace in native conformation as much as possible
 - b) Reinforce shelf on bottom with fitting support (ie support just touches the bottom of shelf such that shelf remains horizontal)
 - c) Apply strong adhesive to area of shelf snap and allow to dry undisturbed as per adhesive manufacturer instructions.
 - d) Once dry fasten an additional board under the shelf to provide support in the middle of the shelf via fastening with screws to the base of the rack (if desired)
6. The clothing rack arm could crack at one end under concentrated strong force – Avoid pushing rack arm into frame past springback point for extended periods of time, this may result in PVC distortion and/or cracking under immense stress. Should cracking occur proceed with repair:
 - a) Remove all items from rack and collapse to a position of maximum horizontality with crack facing upward
 - b) Apply industrial grade adhesive within crack (enough to fill crack) and allow to dry according to adhesive manufacturer's instructions.

7. The upper beam could fail to slide out of the base – To pull out top rack more successfully and quickly, be sure to apply even upward force on either side of the rack while holding the base down to prevent lifting.

8. The wheels could jam if mistakenly locked – Be sure to check that wheel locks are disengaged before attempting to wheel the clothing rack base.

5.2 Special Considerations

In order to prevent breaking or malfunctioning of the rack, DO NOT do the following:

1. Throw heavy objects (above 30 pounds) onto the center of the rack shelf
2. Place objects above 50 pounds in the center of the rack shelf in a concentrated area less than 2 square feet
3. Hang heavy objects (above 40 pounds) on one rack arm alone
4. Hang off of the clothing rack
5. Aggressively push the rack into the beam past it's spring back point
6. Stand on the least supported portion of the rack's shelf

6 Product Documentation

Throughout the prototype development, several prototypes were created before the final prototype, including a mix of physical and analytical prototypes. Figure 10 was used as the design idea for the final prototype. It should be noted that the hook and rotating base attachments were discarded due to lack of time and available funds. Moreover, the weights on the bottom of the base ended up unnecessary as the base was heavy enough to lower the center of gravity.

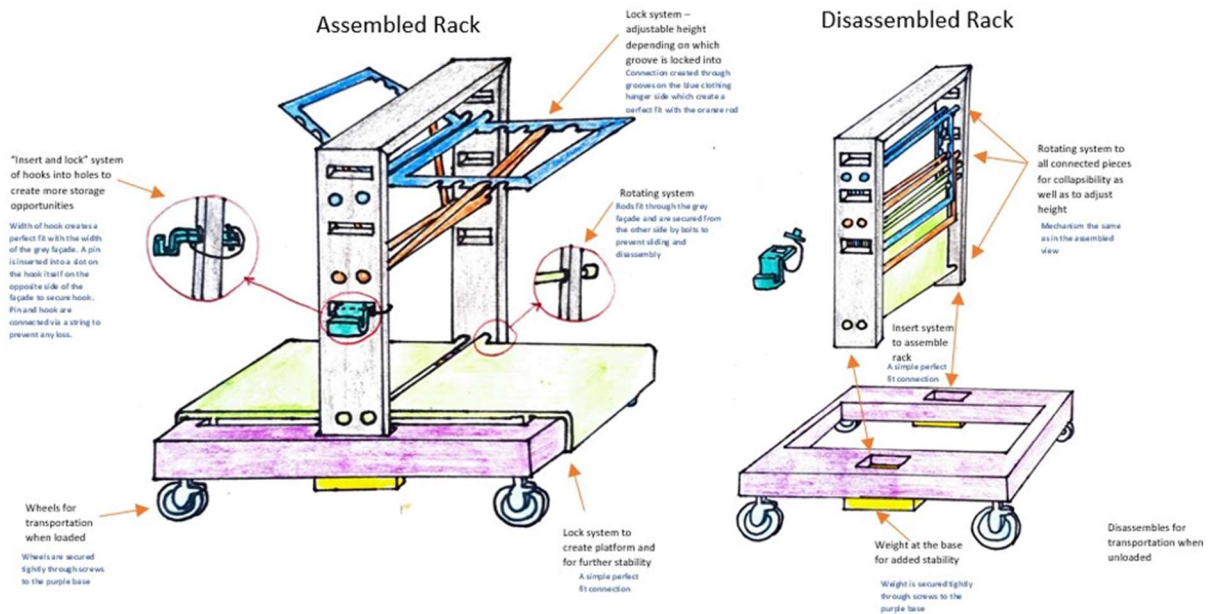


Figure 1010. Final design idea.

Throughout the design process, wood was considered for the frame and base of the clothing rack due to the materials stability and durability. It should be noted that no other material was considered, though materials like various metals could have been used if the budget had allowed it. Furthermore, base platform ended up using cardboard due to its availability in the MakerLab; however, a thin piece of wood was also considered and could also have been used. The only downside that was seen with using wood would have been the added weight of wood in comparison to the strong cardboard that was used. Again, metal could also have been used but was not considered due to budget constraints in the designing process.

For the clothing hanger subsystem, PVC was used due to its strength, durability, ability to be cleaned easily, and wear and tear resistance. Metals, such as aluminum, were also considered but were not used due to budgets constraints.

The final prototype was build as seen in the following sections. Please note that the diagrams included in the instructions are not drawn to size.

6.1 Subsystem: Base

6.1.1 BOM (Bill of Materials)

A majority of the items required for the base subsystem were acquired from home or from other free sources, such as the university MakerLab, for the development of the final prototype. A list of all the parts required to create the subsystem is included below in Table 5, along with the corresponding cost paid by The Extendables.

Table 5. BOM for the base subsystem.

Item #	Part name	Description	Link	Quantity	Unit Cost (\$)	Extended cost (\$)
1	Wooden plank	44" x 5" x 3" wood	Obtained from home	4	0.00	0.00
2	Wooden plank	19.5" x 5" x 3" wood	Obtained from home	4	0.00	0.00
3	Wooden plank	35" x 5" x 3" wood	Obtained from home	2	0.00	0.00
4	Screws	3-1/2" long screws	Obtained from home	72	0.00	0.00
5	Sandpaper	60 Grit Aluminum Oxide Sandpaper - 9" x 11"	link	1	4.99	4.99
6	Sandpaper	120 Grit Aluminum Oxide Sandpaper - 9" x 11"	link	1	4.99	4.99
7	Cardboard plank	Bigger than 45" x 35" surface area	Obtained from MakerLab	1	0.00	0.00
8	Wheels	2" Grey Thermoplastic Polyurethane Wheel Swivel	link	4	4.49	37.96

		Plate Caster, with Brake				
Total						47.94

6.1.2 Equipment list

A table of all the equipment needed to create the base subsystem is linked below in Table 6.

Table 6. Equipment list for the base subsystem.

Equipment name	Description
Cordless Screwdriver	To fasten wooden planks together.
Drill bit (1/8")	To drill a hole into the wood before the screw is added to fasten wooden planks together.
Screw attachment	To fasten screw into pre-drilled hole to fasten wooden planks together.
Handsaw	To cut carboard plank to size.

6.1.3 Instructions

1. Collect all materials and equipment listed in Table 5 and Table 6.
2. Using the handsaw, cut the carboard plank into two 22.5" x 35" pieces.
3. Align two 44" x 5" x 3" wooden plank pieces perpendicular with one another with two 19.5" x 3" x 5" wooden plank pieces in between aligning with edges as seen. The result will be a 5" x 3" x 5" hole in the middle. Repeat the process with the other two 44" x 5" x 3" and 19.5" x 3" x 5" wooden plank pieces.

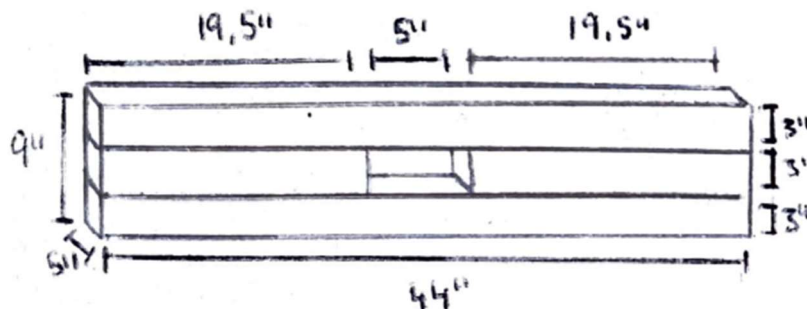


Figure 1111. Alignment of four wooden pieces.

4. Using the cordless screwdriver with the drill bit, pre-drill holes from the larger pieces into the smaller pieces. Screw the 3-1/2" long screws into the pre-drilled holes using the screw attachment with the cordless screwdriver. See below for a more detailed diagram.

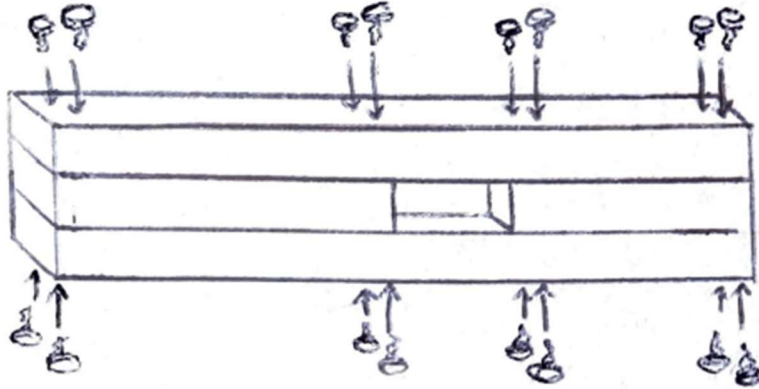


Figure 1212. Attachment of four wooden pieces.

5. Align the two 35" x 3" x 5" wooden planks perpendicular to the thicker beams previously made to create a frame as seen below.

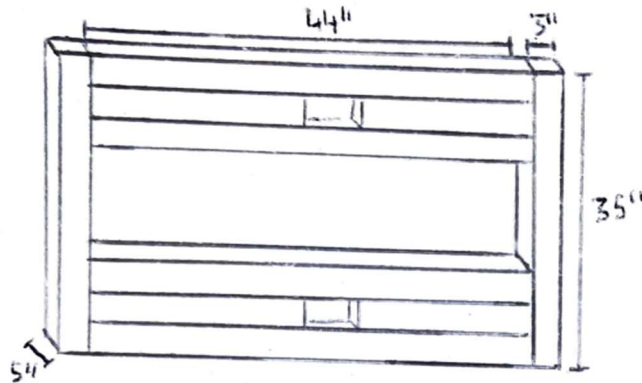


Figure 1313. Alignment of base frame.

6. Using the cordless screwdriver with the drill bit, pre-drill holes from the 35" x 3" x 5" wooden planks into the thicker beams. Screw the 3-1/2" long screws into the pre-drilled holes using the screw attachment with the cordless screwdriver. See below for a more detailed diagram.

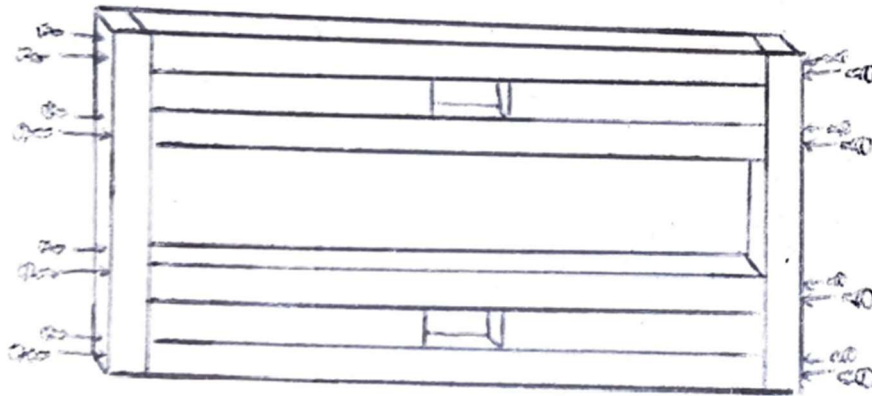


Figure 1414. Attachment of base frame.

7. Using the 60 Grit aluminum oxide sandpaper, sand down the frame. Repeat with the 120 Grit aluminum oxide sandpaper.

8. Align the cardboard planks with the corners of the frame and pre-drill holes using the cordless screwdriver and the drill bit into each of the corners of the cardboard as seen below – see the arrows.

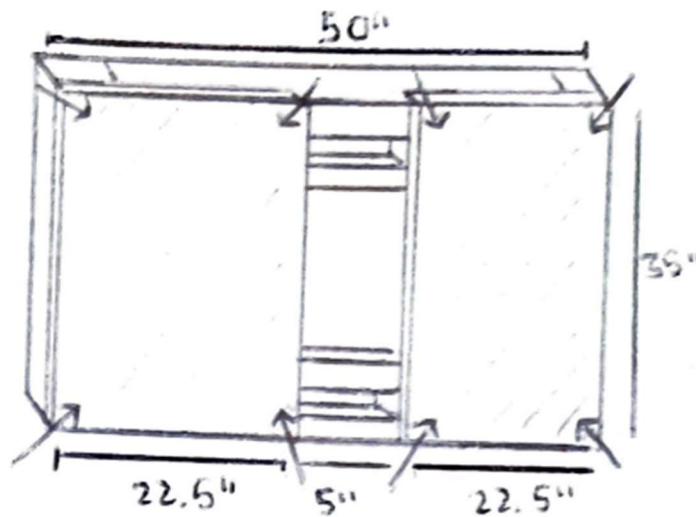


Figure 1515. Alignment and drilling of holes of cardboard and base frame.

9. Screw the 3-1/2" long screws into the pre-drilled holes using the screw attachment with the cordless screwdriver to attach the cardboard to the frame.

10. Turn the frame upside down and attach the wheels using the 3-1/2" long screws with the screw attachment into each of the four corners of the frame on the opposite side as the cardboard as seen below.

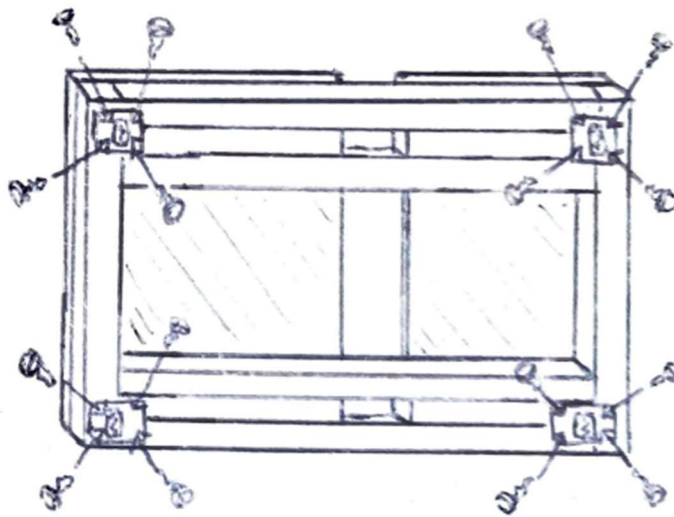


Figure 1616. Attachment of wheels to the base.

6.2 Subsystem: Frame

6.2.1 BOM (Bill of Materials)

A majority of the materials used to build the frame subsystem were collected from free sources by The Extendables, such as from home. A list of all the parts and materials used for the development of the final prototype can be seen in Table 7 along with the price paid. Please note that items 4 and 5 were reused from building the base subsystem.

Table 7. BOM for the frame subsystem.

Item #	Part name	Description	Link	Quantity	Unit Cost (\$)	Extended cost (\$)
1	Wooden plank	50.5" x 3" x 5" wood	Obtained from home	2	0.00	0.00
2	Wooden plank	29" x 3" x 5"	Obtained from home	1	0.00	0.00
3	Wooden plank	23" x 3" x 5"	Obtained from home	1	0.00	0.00
4	Screws	3-1/2" long screws	Obtained from home	8	0.00	0.00

5	Sandpaper	60 Grit Aluminum Oxide Sandpaper - 9" x 11"	link	1	4.99	4.99
6	Sandpaper	120 Grit Aluminum Oxide Sandpaper - 9" x 11"	link	1	4.99	4.99
Total						9.98

6.2.2 Equipment list

The frame subsystem was build using the equipment listen in Table 8.

Table 8. Equipment list for the frame subsystem.

Equipment name	Description
Cordless Screwdriver	To fasten wooden planks together.
Drill bit (1/8")	To drill a hole into the wood before the screw is added to fasten wooden planks together.
Screw attachment	To fasten screw into pre-drilled hole to fasten wooden planks together.
Dill bit (1 3/8")	To drill the holes into the frame for subsequent fixation of the clothing hanger subsystem.

6.2.3 Instructions

1. Collect all materials and equipment listed in Table 7 and Table 8.
2. Using the 1 3/8" drill bit with the cordless screwdriver, drill holes at 3", 7", 16" and 20" from the top, lengthwise, on each of the two 50.5" x 3" x 5" wooden plank pieces as seen.

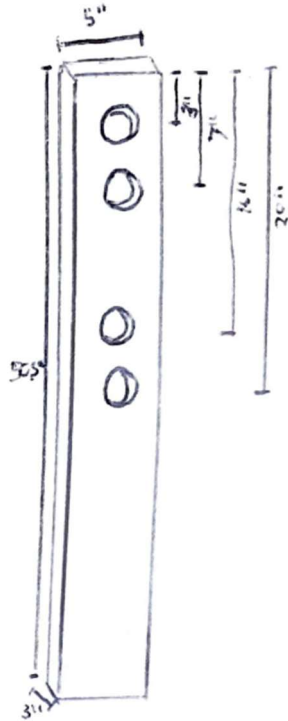


Figure 1717. Drilling holes into framework.

3. Assemble the two 50.5" x 3" x 5" wooden plank pieces parallel to each other and place the 29" x 3" x 5" wooden plank piece on top as seen below. Ensure the edges are properly aligned with one another.

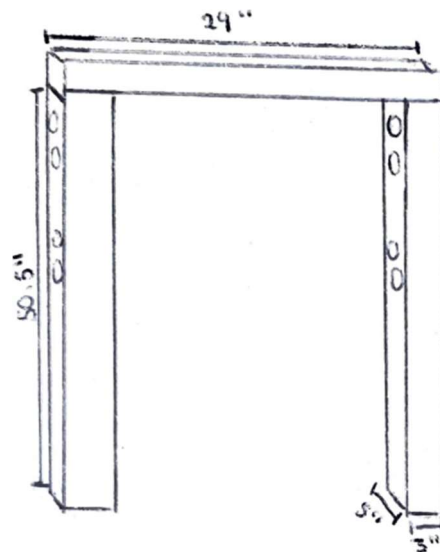


Figure 1818. Alignment of first part of frame subsystem.

4. Using the 1/8" drill bit with the cordless screwdriver, pre-drill two holes on each of the ends of the top the 29" x 3" x 5" wooden plank piece into the two 50.5" x 3" x 5" wooden plank pieces as seen below.

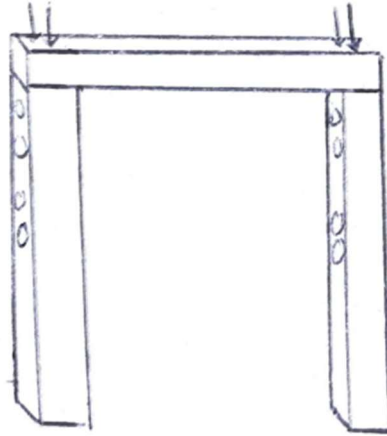


Figure 1919. Drilling holes to connect first part of frame subsystem.

5. Using the screw attachment with the cordless screwdriver, screw the 3-1/2" long screws into the pre-drilled holes.

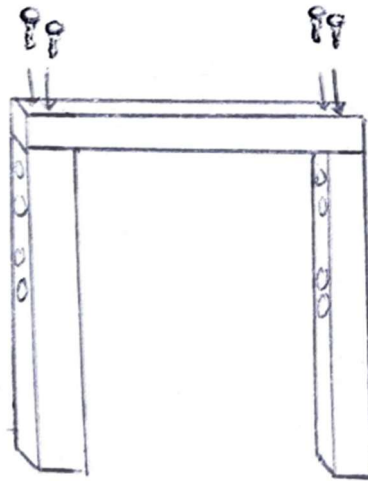


Figure 2020. Attaching screws to connect first parts of the frame subsystem.

6. Assemble the 23" x 3" x 5" wooden plank piece in between the two 50.5" x 3" x 5" wooden plank pieces 5" from the bottom as seen. Ensure the edges are aligned.

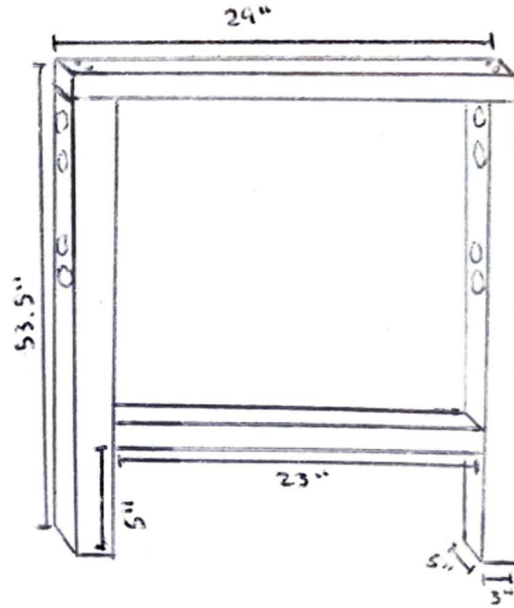


Figure 2121. Alignment of whole frame subsystem.

7. Using the 1/8" drill bit with the cordless screwdriver, pre-drill two holes on the side of each of the two 50.5" x 3" x 5" wooden plank pieces into the 23" x 3" x 5" wooden plank piece as seen below.

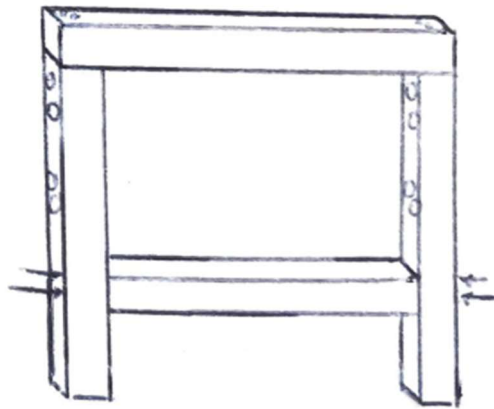


Figure 2222. Drilling holes to connect second part of the frame subsystem.

8. Using the screw attachment with the cordless screwdriver, screw the 3-1/2" long screws into the pre-drilled holes.

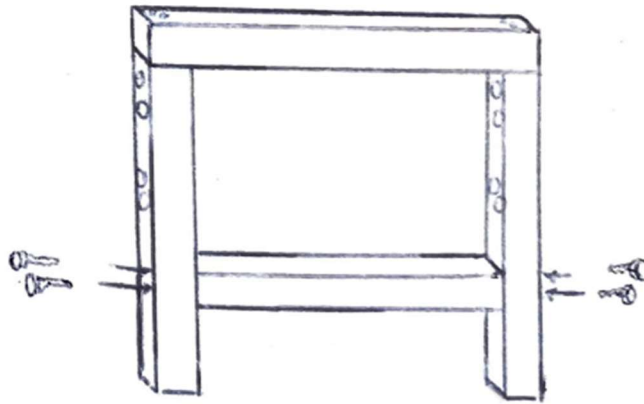


Figure 2323. Attaching screws to connect second part of the frame subsystem.

9. Using the 60 Grit aluminum oxide sandpaper, sand down the frame. Repeat with the 120 Grit aluminum oxide sandpaper. Be sure to pay attention to the holes drilled with the 1 3/8" drill bit.

6.3 Subsystem: Clothing Hanger

6.3.1 BOM (Bill of Materials)

The majority of the materials and parts were bought from Home Depot for the construction of the clothing hanger subsystem. Table 9 lists all materials used for the subsystem and the cost paid by The Extendables.

Table 9. BOM for the clothing hanger subsystem.

Item #	Part name	Description	Link	Quantity	Unit Cost (\$)	Extended cost (\$)
1	Elbow Joint	1/4" 90 Degree Poly Insert Elbow	link	8	1.49	11.92
2	Tee Joint	1-1/4" Poly Insert Tee	link	8	1.59	6.36
3	PVC pipe	Rigid PVC Bell End Conduit - 3/4" x 10'	link	2	9.49	18.98
4	ABS pipe	1-1/4" x 6' Rigid ABS pipe	Obtained from home hardware	1	9.99	9.99

5	Screws	3-1/2" long screws	Obtained from MakerLab	10	0.00	0.00
6	Masking Tape	18mm wide masking tape roll	Obtained from MakerLab	1	0.00	0.00
7	Screws	1-1/4" long screws	Obtained from home	24	0.00	0.00
8	Hot glue sticks	Clear hot glues sticks	Obtained from MakerLab	1	0.00	0.00
Total						47.25

6.3.2 Equipment list

The equipment used to build the clothing hanger subsystem can be seen listed in Table 10.

Table 10. Equipment list for the base subsystem.

Equipment name	Description
Cordless Screwdriver	To pipes and joints together.
Handsaw	To cut cardboard plank to size.
Screw attachment	To fasten screw attaching the pipes and joints using the cordless screwdriver.
Drill bit (1-1/4")	To nudge the PVC pipe for the adjusting height mechanism.
Drill Press	To use the drill press to nudge PVC pipe for the adjusting height mechanism.
Drill bit (1/8")	To drill a hole into the wood before the screw is added to fasten wooden planks together.
Hot glue gun	To glue the ends of the security screws for safety.

6.3.3 Instructions

1. Collect all materials and equipment listed in Table 9 and Table 10.
2. Using the handsaw, cut 4 27" long pieces from the PVC pipe.
3. Using the handsaw, cut 2 22" long pieces from the left-over PVC pipe.
4. Using the handsaw, cut 2 28" long pieces from the left-over PVC pipe.
5. Using the handsaw, cut 4 17" long pieces from the ABS pipe.
6. Cut one end off 2 tee joints as seen using the handsaw.

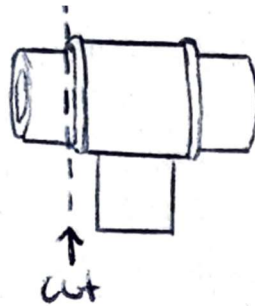


Figure 2424. Cut along tee joint.

7. Using the 1-1/4" drill bit in the drill press, cut nudges into each of the 27" long PVC pipe pieces at 6" 12" and 18" as seen below. Ensure that the cut only goes into the pipe about 1/4 of the diameter.

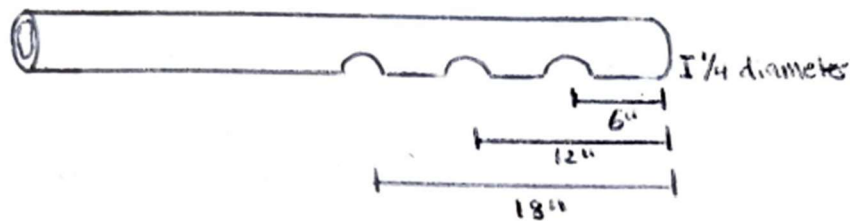


Figure 2525. Nudging into PVC pipe.

8. Connect each 27" long nudged PVC piece to an uncut tee joint on one end and an elbow joint at the other; the side closer to the nudged holes is connected to the tee joint. Connect the two 22" long PVC piece to the elbow joints of two of the nudged PVC pieces as seen below. Ensure that the whole assembly is flat and that the nudged sides are arranged parallel to one another looking up.

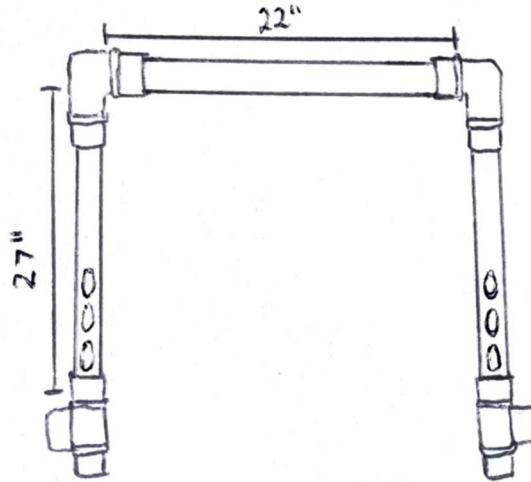


Figure 2626. Alignment of upper clothing rack hanger subsystem.

9. Using the 1/8" drill piece with the cordless screwdriver, pre-drill holes through the attachment between the PVC pipes and the tee and elbow joints accordingly as seen below. Using the screw attachment with the cordless screwdriver, drill the 1-1/4" long screws into each of the pre-drilled holes. Repeat for with assembly for two pieces.

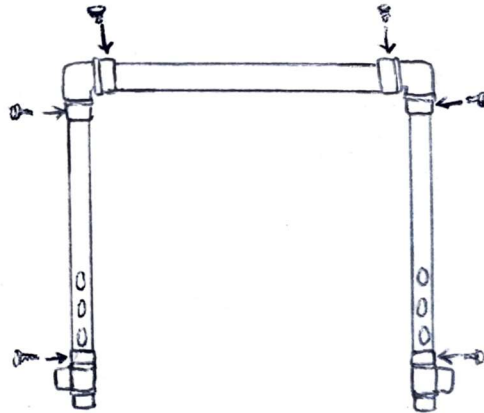


Figure 2727. Drill hole and screws along upper clothing hanger piece.

10. Insert the tee joints of each of the two resulting pieces in between the frame into the upper holes as seen. Ensure that both pieces look in opposite directions when attached and that the nudges face towards the floor. Repeat the diagram below for both sides.

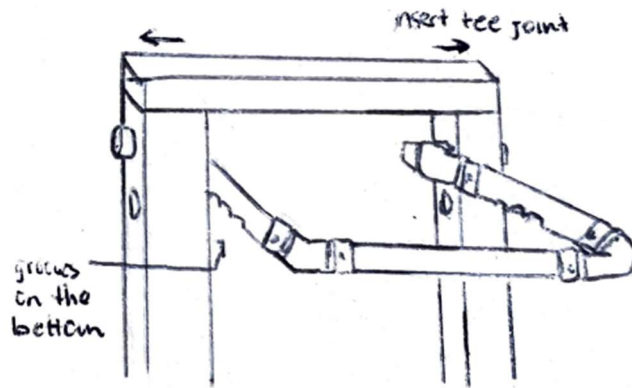


Figure 2828. Attachment of upper clothing hanger piece to the frame subsystem.

11. Wrap masking tape repeatedly onto the side of the tee joint where it goes out of the frame (outer side) until a thick layer results; essentially, the piece cannot be taken out of the ensemble anymore.

10. Connect each 17" long ABS pipes to a cut tee joint on one side and an elbow joint on the other side. Connect the two 28" long PVC pipes to the elbow joints of two of the ABS pipes as seen in the diagram below. Ensure that the whole ensemble is flat.

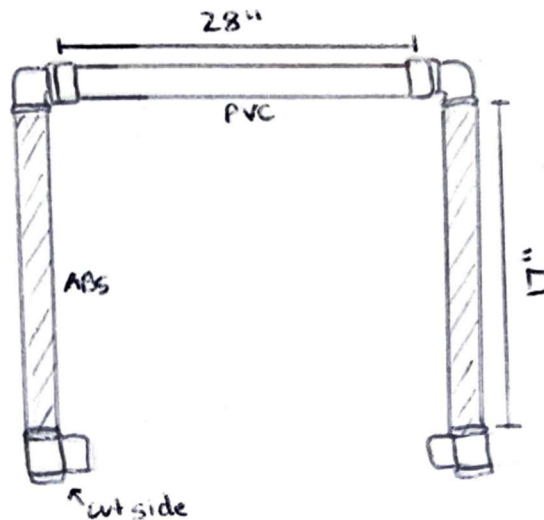


Figure 2929. Alignment of supporting arm.

11. Using the 1/8" drill piece with the cordless screwdriver, pre-drill holes through the attachment between the PVC pipes and the tee and elbow joints accordingly as seen below. Using the screw attachment with the cordless screwdriver, drill the 1-1/4" long screws into each of the pre-drilled holes.

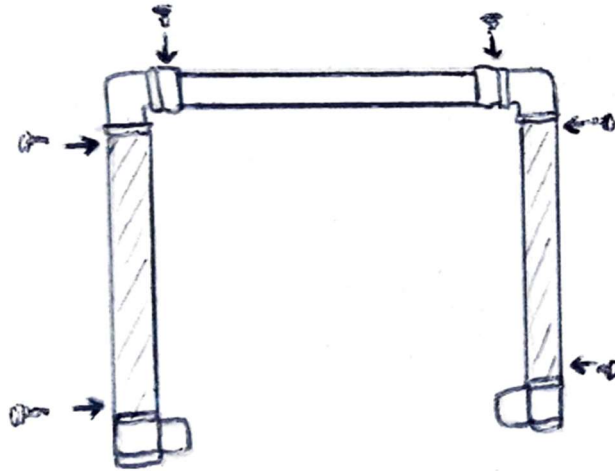


Figure 3030. Drill hole and screws along supporting arm (repeat for two pieces).

12. Insert the tee joints of each of the resulting supporting arms into the holes from the outside of the frame as seen. Ensure that both pieces look in opposite directions when attached and correspond to the upper attachment.

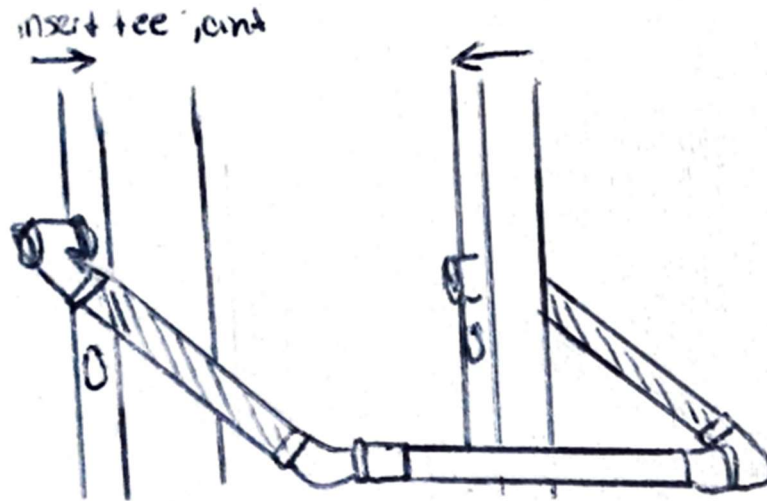


Figure 3131. Attachment of supporting arm to frame subsystem (repeat on other side).

13. Wrap masking tape repeatedly onto the side of the tee joint where it goes out of the frame (inner side) until a thick layer results; essentially, the piece cannot be taken out of the ensemble anymore.

14. Using the 1/8" drill piece with the cordless screwdriver, pre-drill angles holes about 1/4" away from each of the nudges in the PVC pipe (drill all the way through the whole pipe) and, using the screw attachment with the cordless screwdriver, drill the 3-1/2" pieces into the pre-drilled holes

until the end emerges from the upper side – angled at a 30-degree angle as seen. Note that the lower hanging rack does not require this feature for the nudge closest to the frame.

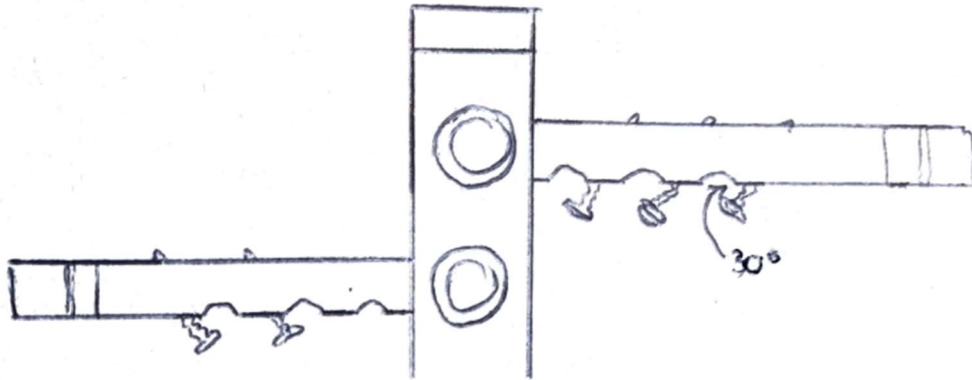


Figure 3232. Security feature to prevent clothing rack from collapsing.

16. Using the hot glue gun and hot glue sticks, hot clue the pointy end where the screws emerge onto the upper side of the arms so that it cannot hurt anyone. To further ensure no accidents, wrap each part of the arm where the hot glue is additionally with masking tape. When assembled, the clothing hanger system will look as seen below in the frame subsystem.



Figure 3333. Clothing hanger subsystem in frame subsystem assembled.

6.4 Testing & Validation

The final prototype was tested against the target specifications to ensure it performs to the uOttawa Free stores expectations. During testing, it was noted that the lower side of the clothing rack could not be assembled into the highest planned height (groove closest to the frame) due to an issue found wherein the joint of the upper support bar would interfere with the movability of the lower support bar; as a result, no safety feature was added to that position as it could not be physically reached. All tests and results can be seen recorded in Table 11.

Table 11. Final prototype test plan and results.

Target Specifications	Description of Test	Expected Results/Value	Prototype Test Results
Performance – Collapsibility	The prototype should be easily collapsible by one or two students in a short time-period.	The clothing rack should be collapsible in less than a minute by one person or two people.	The clothing rack could be collapsed by one person in 10.27 seconds. The clothing rack could be collapsed by two people in 5.80 seconds.
Performance – Set-up	The prototype should be easily assembled and set up by one or two people in a short time-period.	The clothing rack should be set-up in less than a minute by one person or two people.	The clothing rack could be assembled by one person in 11.34 seconds. The clothing rack could be assembled by two people in 8.32 seconds.
Service Life - Durability	The prototype can withstand rough handling by students, which is tested by applying sufficient force by a student from varying angles onto the frame and base when in the assembled form.	The clothing rack should be unaffected by forces exerted onto it.	The clothing rack appeared virtually unchanged after rough handling by people and applied force to the frame when assembled.

Aesthetic	The clothing rack should appear clean.	The clothing rack should look simple and easily understandable.	The clothing rack is made up of only necessary components in a simple assembly' hence appearing clean.
Performance – Working Wheels	The clothing rack should be movable in its assembled form.	The clothing rack should have working wheels that allow it to be moved by students in its assembled form.	The clothing rack had wheels attached on the base that allowed it to be moved in any direction as needed.
Safety	The clothing rack should have a safety feature to prevent it from collapsing and from moving when assembled.	The clothing rack has some feature that keeps it in place when assembled. The clothing rack has a mechanism that prevents the clothing hanger subsystem from collapsing when roughly handled.	The clothing hanger contained lockable wheels at the base that prevented it from moving its assembled form when set-up. The clothing hanger had a security feature in the form of angled nails (safely attached) beside the grooves to prevent the clothing hanger subsystem from collapsing when not properly disassembled.
Performance - storage	The clothing hanger is measured in its collapsed and assembled forms.	The clothing hanger collapses into a smaller dimension when disassembled versus when assembled.	The clothing hanger collapsed from a maximum dimension of 57.5" x 57.5" x 32.5" to a smaller dimension of 55" x 29" x 32.5".
Accessibility	The height of the clothing hanger in its assembled form was measured.	The clothing rack hanger mechanism can be adjusted to varying	The clothing rack could be adjusted on the higher side to heights 67.75", 54.5", and 46". The clothing rack could be adjusted on the lower side to

		<p>heights, some of which are reachable to wheelchair bound students.</p>	<p>heights 53.25" and 44.75". The lowest heights of each side could be easily reached by a wheelchair bound student, as seen in Figure 34. The medium heights could also be reached with a bit more straining while the highest position could not be reached by a student in a wheelchair.</p>
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Figure 3434. Proof of wheelchair accessibility.

7 Conclusions and Recommendations for Future Work

While a final prototype was developed and can be used by the uOttawa Free Store as product, The Extendables learned the following lessons.

1. Never overestimate budget for materials or tools required
2. Always budget more time than theoretically required to finish a task
3. Always make precise measurements and ensure good communication among project members about said measurements
4. Always double check every measurement made before executing an irreversible action (ex a cut or a permanent fastening)

As discussed in Section 6, the development of the final prototype was greatly restricted due to time and budget constraints. Had more time been available, the following additions would have been made and tested to improve the final prototype. These ideas can still be implemented in future work.

1. Obtain hooks that can screw into rack beam and fasten to allow for additional storage
2. If remaking prototype, allow wider central beam (as in conceptual design) to allow for rack arms to fully collapse
3. Add beam under main body of rack shelf for additional support

Having learned and reinforced these valuable lessons in the creation of the project, The Extendables have not only developed themselves as engineers, but also provided the Free Store with a fully functional and versatile product that not only fulfills but surpasses all of their needs. The Extendables had a great experience in development of this product and in the interaction with the client.

8 Bibliography

uOttawa. (n.d.). Free Store. *uOttawa*. <https://www2.uottawa.ca/campus-life/campus-sustainability/activities-initiatives/free-store>.

APPENDICES

9 APPENDIX I: Design Files

Below is Table 12 with all the relevant documents in relation to this UPM. The documents include the MakerRepo link discussed before, which includes documentation for the entire design process. Moreover, each deliverable is included that was written during the design process to outline the work done.

Table 12. Referenced Documents

Document Name	Document Location and/or URL	Issuance Date
The Extendables - MakerRepo	https://makerepo.com/LauraKarlin/ 1092.gng-2101-group-2-1- collapsible-storage-rack.	February 6, 2022
Needs, Problem Statement, Metrics, Benchmarking and Target Specifications	link	January 23, 2022
Conceptual Design and Project Plan	link	January 30, 2022
Detailed Design, Prototype 1, BOM, Peer Feedback and Team Dynamics	link	February 6, 2022
Progress Report	link	February 13, 2022
Prototype 2	link	March 6, 2022

Business Model and Economics Report	link	March 20, 2022
Final Presentation	link	April 4, 2022