Hozhoni Cleaning Crew Device

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Project Group #34

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DISCLAIMER

Contents

1 BACKGROUND

1.1 Introduction

The Hozhoni Foundation works to increase the quality of life and the independence for those with disabilities. The Hozhoni foundation provides residential care and services that enhance the quality of life, self-sufficiency, dignity and self-respect of the individuals they serve [1]. Hozhoni currently has a work program that allows those with disabilities the ability to hold a job and serve the community in which they live. This current work program allows individuals to be a part of a cleaning crew at the Hozhoni foundation. However, some crew members had challenges maneuvering with the cleaning supplies that are needed to complete the assigned tasks. Hozhoni has contacted our team to construct a device that can aid those with disabilities to safely and efficiently transport the necessary supplies around their work space. The lap table design created is adaptable to different style of wheelchairs as well as being able to use by those not in wheelchairs.

1.2 Project Description

The cleaning crew at the Hozhoni foundation had trouble carrying cleaning supplies around the facility*.* The main concern for Hozhoni is to create a system that allows wheelchair users to efficiently carry and organize the necessary supplies. The users also include individuals with mental disabilities and employees who cannot lift heavy loads. The system(s) should be lightweight and detachable from the user's wheelchair*.* The system also accommodates individuals that are not in a wheelchair. Our team's goal was to create a system that can be manufactured by someone at home and can accommodate as many users as possible.

1.3 Original System

Currently there is no system that fulfills the customer's requirements given by the Hozhoni foundation. It is ideal that the system utilizes slightly modified parts.

2 REQUIREMENTS

2.1 Customer Requirements (CRs)

Safety: The system ensures that those in wheelchairs or other physically challenged individuals are safely and efficiently carrying the cleaning supplies around. The device ensures that the users are protected from any cause of danger, risk, or even injury.

Adaptability: The system is able to adjust or change to work more effectively in various wheelchair models, either motor or manual adaptations.

Light Weight: The device is designed for individuals who cannot lift heavy weights, it must weigh less than 10lbs and must be detachable from the user's wheelchair.

Portability: The device is easy to carry and relocated due to versatility of its design. This feature will help the physically challenged individuals carry the cleaning supplies around without any difficulties.

Ease of Building: The system is simple to manufacture to any individual at home

Simple Construction: The Hozhoni system is to be simple and accommodates as many users as possible. The system is required to utilize slightly modified parts.

Modular: The system easily stores into compact areas.

Low Cost: The cost of the device must be kept as low as possible, this will ensure that anyone can purchase the materials required.

Life Span: The system must last more than 5 years with little to no upkeep.

Tooling Required: The device is able to be easily replicated by any persons, limiting the use use of special tooling. This will help other users to benefit from this device without much cost of resource or expenses.

2.2 Engineering Requirements

The engineering requirements was created to allow the team to translate the customer needs into actual values. **Table 1** shows the engineering requirements for this project as well as their respective target values and tolerances. Most of the engineering requirements were focused around the size and weight of the device due to the device having to be constrained in a small area. The width of the device is based off the width of the seat, this is to ensure that all final designs are suitable to fit within the wheelchair's dimensions. The target for the weight of the device is 7lbs and has a tolerance of 2lbs. All of the engineering requirements are lower than their targeted values, with the exception of the lifespan. **Table 2** shows a more in-depth look into the relationship between the engineering and customer requirements for the device.

Table 1: Engineering Requirements

Engineering Requirement	**Target**	**Actual**	**Pass/Fail**
Weight of device	7 lbs	4.85lb	Pass
Size(width)	10 in	6.18in	Fail
Size (Length)	15 in	16.125in	Pass
Cost (cFinal Device)	$200	$80.85	Pass
Storage Size	$0.52ft^3$	$0.28ft^3$	Pass
Lifespan	5 years	N/A	N/A
Weight Capacity	15 lbs	<15lb	Pass

2.2 House of Quality (HoQ)

Table 2: Device's Customer & Engineering Requirements

House of Quality (HoQ)

Customer Requirement	**Weight**	**Engineering Requirement**	Light Wheight Material	Mode of transport Source	Tow Attachments	Pushability	Organizational System	Wheelchair Atacchment	
Safety	10		x	x	x	x	x	x	
Adaptability	10				x			x	
Light Weight	9		x	x		x			
Portability	8			x		x		x	
Ease of Building	7		x						
Simple Construction	6		x						
Modular	9			x	x		x	x	
Low Cost	6		x	x					
Life Span	5								
Tooling Required	5								
Absolute Technical Importance (ATI)									
Relative Technical Importance (RTI)									
Target(s), with Tolerance(s)									
[add or remove T/T rows, as necessary]									
Testing Procedure (TP#)									
Design Link (DL#)									

Approval (print name, sign, and date):

Team member 1: Amber Juare 9/29/16

Team member 2: [illegible] 9/29/16

Team member 3: [illegible] 9/29/16

Team member 4: [illegible] 9/29/16

Team member 5: [illegible] 9/29/16

Team member 6: ______

Client Approval:

Testing Procedures:

The following details the testing procedures our team chose to evaluate the final device to their respective ER's.

Weight

The weight of the device was tested by placing the box and belt on a bathroom scale. The scale was already owned by a team member.

Size (width)

A tape measurer was used, that was already owned by team members, on the outside width of the device is measured to verify that it does not exceed the width of the wheelchair seat.

Size (length)

Using the same tape measurer, the team measured the length of the device to ensure it did not exceed the length of the upper thigh, or the side length of the wheelchair.

Storage Size

This test was conducted by placing various objects of different sizes into the device, this will allow our team to determine if the device has sufficient space to store items.

Weight Capacity

The device was loaded to 10 lbs above the weight capacity target to determine if the device can withstand an unexpected additional load.

Lifespan

The device was attached and detached from the wheelchair multiple times as well as being loaded and unloaded. This allowed us to determine if the device will fatigue easily.

Design Links:

Design Link Weight: The weight of the device was chosen to be 7 lbs so when the device was fully loaded it would not exceed 20lb. This was set because users have troubles carrying heavy loads, above 20lbs.

Design Link Width: The design is limited to width of the wheelchair which is 16 in.

Design Link Length: The finals design(s) are restricted to the length of the thigh, approximately 6in.

Design Link Cost(Final device): The cost of the final device is not constrained by anything, however low cost is desired.

Design Link Storage size: The device is required to have ample room for all supplies required by the user.

Design Link Life Span: The device needs to last at least 5 years before having to be replaced/rebuilt.

Design Link Weight Capacity: The device must be able to support the weight of the supplies(approximately 10-15lbs).

3 Existing Designs

3.1 Design Research

The design research process was an informative way to explore the current assistive devices on the market. The focus was on wheelchair accessories and assistive devices such as carts. Three main designs that meet our criteria were the movable pouch, Winnie Cart, and the ActiveCare scooter trailer. The following will analyze the three designs and their subsystems.

3.2 System Level

3.2.1 Existing Design #1: Movable Pouch

Figure 1 shows the schematic for the movable pouch, this device attaches to the back of the wheel cheer and can swivel forward to allow the user easy access to the supplies [2]. In lieu of a pouch, a section tub would be used in order for the user to organize the supplies.

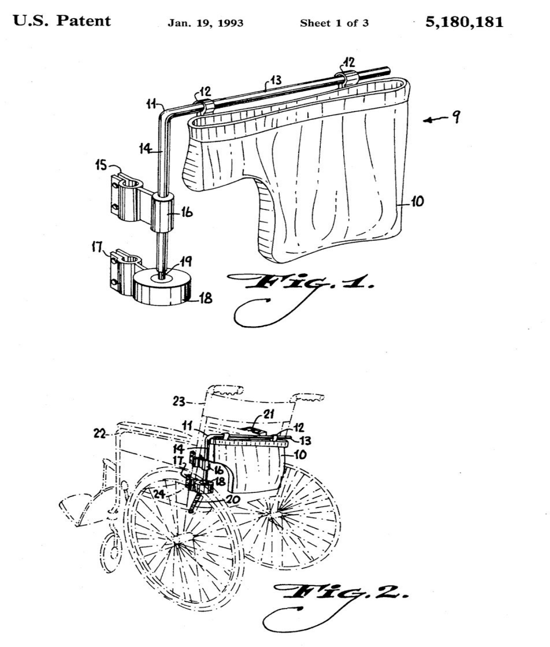


Figure 1: Movable Pouch Schematic

3.2.2 Existing Design #2: Winnie Wagon

The Winnie Wagon, shown in **figure 2**, is designed for senior citizens that have difficulties carrying large loads or many items at once [3]. The design is a tall cart that can be collapsed to allow simple storage. The winnie wagon concept will work best to accommodate those who do not use wheelchairs and will allow undemanding mobility of multiple items. It is also ideal for transporting tall items such as a mop or broomstick.

Figure 2: Winnie Wagon

3.2.3 Existing Design #3: ActiveCare power scooter Trailer

Figure 3 shows the ActiveCare scooter trailer, this device attaches behind the wheelchair and acts as mobile storage device. The trailer can be detached and folds up to store in small places. A cover is also included to ensure that the items do not spill out when traveling over bumps or up ramps [4]. The scooter trailer is ideal for transporting mop buckets with ease. However, it would not be easily accessible to those in the wheelchair and would need to modified in a way that the user can gain access to the supplies with minimal effort.

Figure 3: ActiveCare Scooter Trailer

3.3 Subsystem Level

Three main subsystems, or requirements that need to be kept in consideration are how much storage space is allotted to each design, the mobility, and the actual size of of the device. Looking at how each design relates to each subsystem will give our team a better idea of what design we want to go with and modify.

3.3.1 Subsystem #1: Storage Space

An ideal storage volume would be approximately 1-2 cubic foot. The storage space should not be too large to avoid making moving around difficult.

3.3.1.1 Existing Design #1: Movable Pouch

The movable pouch patent does not state a volume, however the storage space appears to be insufficient for larger items such as spray bottles.

3.3.1.2 Existing Design #2: Winnie Wagon

The Winnie Wagon has a volume of approximately 2.2 cubic feet, which is ideal for our team's design limitation [3]. The height of the Winnie wagon, about 2 feet, would help to transport taller items such as mops and brooms.

3.3.1.3 Existing Design #3: ActiveCare Scooter Trailer

The ActiveCare scooter trailer has a volume of about 8 cubic feet, which would be slightly too tall for the design specifications.

3.3.2 Subsystem #2: Mobility

The system would allow the user to transport the supplies with ease. The device would be able to be transported with little to no effort involved. The ability to turn corners or change directions easily would also be considered.

3.3.2.1 Existing Design #1: Movable Pouch

The movable pouch is the most mobile of the existing designs. The pouch takes up minimal space and does not have to be transported across the ground.

3.3.2.2 Existing Design #2: Winnie Wagon

The Winnie Wagon has excellent mobility. Moving around corners or changing directions could pose some difficulties due to size specifications, however would prove overall to maneuver well.

3.3.2.3 Existing Design #3: ActiveCare Scooter Trailer

The ActiveCare scooter trail has good maneuverability and can be transported with ease. Going around tight corners could pose a problem when attached to a wheelchair.

3.3.3 Subsystem #3: Size

The system needs to be stored in a closet, dimensions unknown, when not in use. All of the existing designs currently examined have ideal storage qualities.

3.3.3.1 Existing Design #1: Movable Pouch

The movable pouch can be easily stacked on top of each other, if a tub was to be used multiple tubs would have the ability to be stacked within each other.

3.3.3.2 Existing Design #2: Winnie Wagon

The Winnie Wagon is collapsible and would allow for convenient storage.

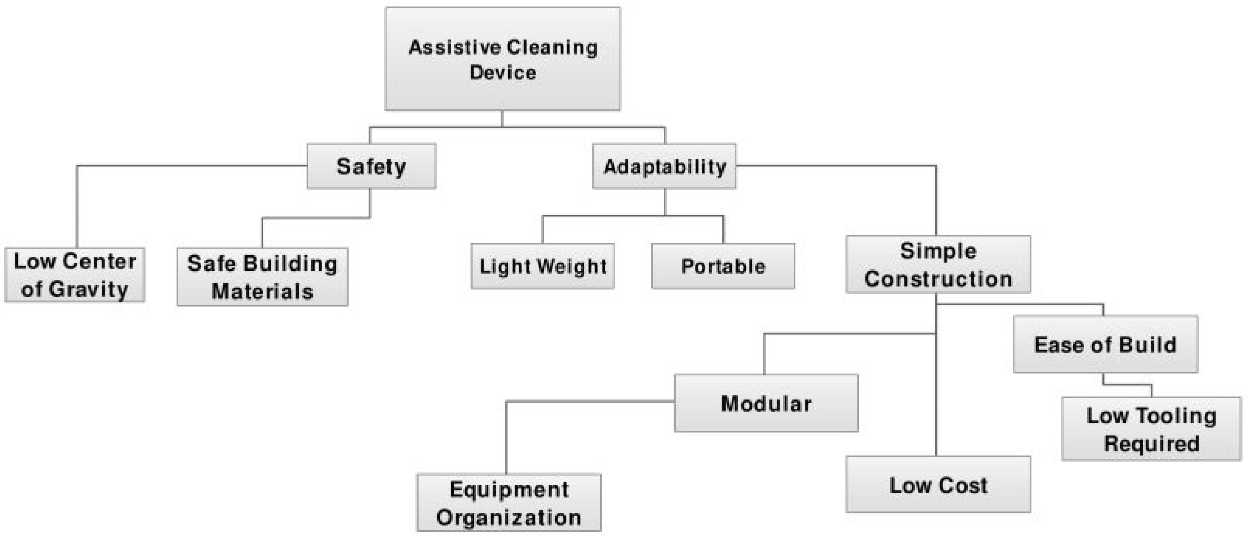
3.3.3.3 Existing Design #3: ActiveCare Scooter Trailer

The scooter trailer folds u into itself to be more compact and allows for convenient storage.

3.4 Functional Decomposition Diagram

Below, **Table 3** depicts the important functions this project must accomplish through the use of a Functional Decomposition Diagram. This diagram is important because it is used to facilitate the understanding and management of large and/or complex processes and can be used to help solve problems. Its main purpose is to take something complicated and simplify it. The individual elements of the process and their hierarchical relationship to each other are commonly displayed in this diagram.

Table 3: Functional Decomposition Diagram



4 Designs Considered

The following sections contain the team's top 10 design choices including the team's one "crazy" idea. This "crazy" idea was generated to help spark some creativity during the brainstorming session.

4.1 Design #1: Water Tank

This design will allow the user to fill a water tank, that will be attached to the back of the wheelchair, and drips water as the user travels. A mop will trail behind the water drip component to wipe up the subsequent area. This design will address the desire to have a more efficient way of mopping. However, this idea does not include a way to carry the other supplies needed to perform further duties. In regards to the subsystems, the water tank does have sufficient space, but no room is reserved for extra supplies. The water tank is mobile but can cause maneuverability issues. The volume of the water tank would be approximately 1-2 gallons. The size of the tank would not be a problem.

4.2 Design #2: Storage Down Under

For this design a storage unit will be installed under the wheelchair. To access the supplies, the user would need to slide out the storage container, which would be done from the front, the under storage would not create a mobility issue. The size of the storage compartment would be fairly short in order to prevent the unit from dragging on the ground. Storing taller items, such as spray bottles, could pose an issue. Tall item would have to lie down on their side, which may can cause leaking to occur.

4.3 Design #3: Arm Side Pouch

Figure 4 below shows the arm side pouch concept. There will be a sleeve on each side of the arm rest. The sleeve will contain a series of pouches for the user to store their cleaning items in. This design may cause a restriction on the wheels, if the sleeves were altered so that they contour with the wheel's curvature instead, then there would be no mobility issues. The pouches are very thin, about a few inches thick, and would only be about 12 in long. The size of the sleeves are ideal, however the storage size is smaller. Since pouches are being used, adequate room should be allowed so that the user can easily store and take the items out.

Figure 4: Sketch of Side Pouch

4.4 Design #4: Front Wheel

The front wheel design is a stand alone support table, which rests on a single wheel. The user can then place the needed supplies on top of the platform. The tabletop will be in front of the user to allow for easier access, refer to **Figure 5**. The size of the system is relatively larger than the other concepts, as it does not collapse into a more compact state. The storage size is not really applicable to this design although the user would be able to place all needed supplies on the tabletop. The front wheel may impair the wheelchairs turning radius, overall, the concept should not affect the wheelchair’s mobility.

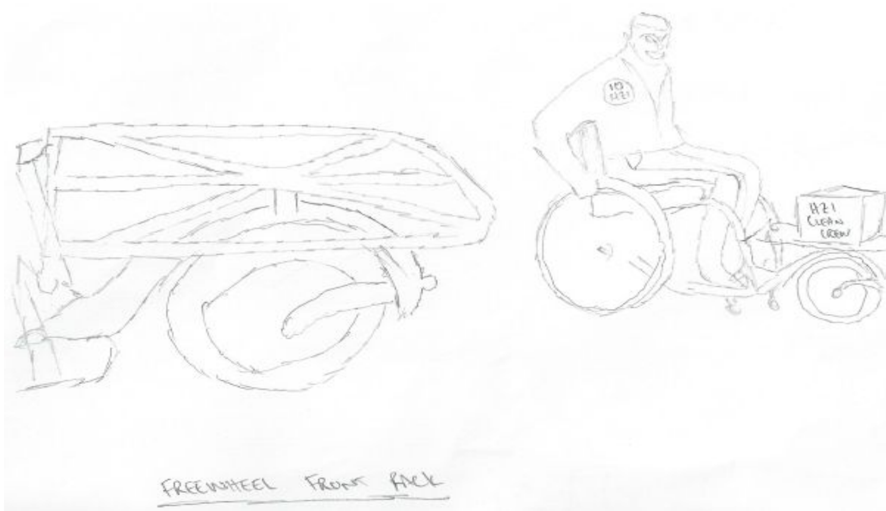


Figure 5: Front Freewheel Sketch

4.5 Design #5: Cleaning Vest

The cleaning vest was one of the team’s bio-inspired ideas. The inspiration came from a kangaroo's pouch which is used to carry their offspring. Just like a kangaroo, the user will put the vest on and place their supplies in the pouch. The vest would be the size of the user's torso and have about 3 different sized extruding pouches, see **Figure 6.** The vest would not have an effect on mobility of the wheelchair, bending down to reach low places can cause challenges. The vest would not have much storage space for larger items such as the paper towel rolls.

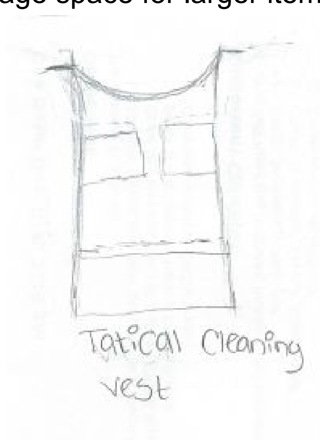


Figure 6: Cleaning Vest for Attachables Sketch

4.6 Design #6: Lap Table

The lap table design is the most simple of the team's design and contains all essentials, the concept can be seen in **Figure 7** below. The tabletop system has a curved bottom to create a better form to the user's legs. Velcro or a high friction material would be used to keep the unit in place to the user lap. The size of the device would be the width of the chair and be the length of their lap. There would be sufficient storage space for all items. The lap table will only limit the user's ability to reach lower areas.

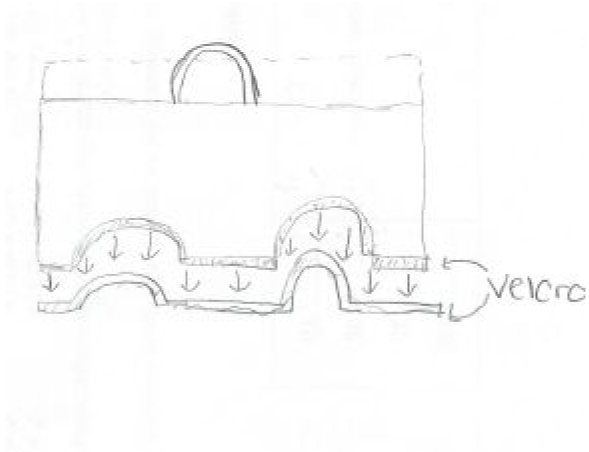


Figure 7: Lap Attachment Sketch

4.7 Design #7: Banana Leaf Over Head Canopy

Our teams second bio-inspired idea is the banana leaf concept. The banana leaf creates an awning and hangs down inspiring our team to create a canopy style design. This design, shown in **Figure 8**, hangs over the user and has a series of hooks and pouches to hang and store items. The canopy would be rather tall so it would have to be designed for the lowest height clearance at the facility. The height may also cause a balance issue if the top becomes loaded too much. Mobility would not be an issue as long as the canopy is short enough to clear hallway doors. Storage space can be adequate if enough hooks and pouches are placed.

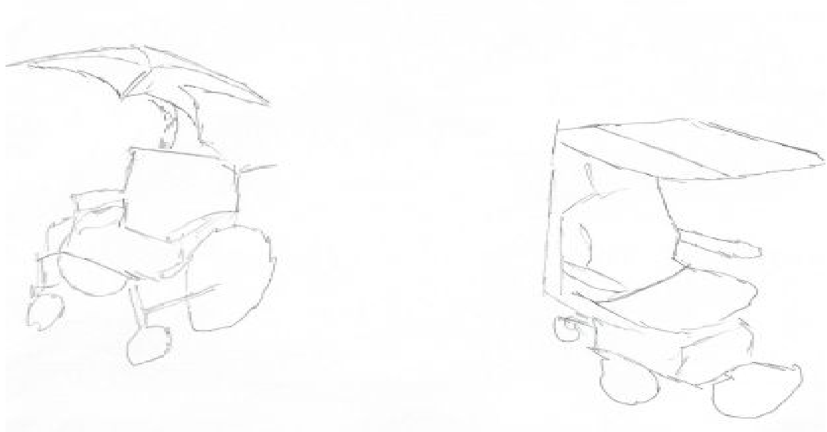


Figure 8: Bio-design Banana Leaf Canopy Sketch

4.8 Design #8: Street Sweeper

This design creates more efficient way of sweeping the grounds. Two round brushes will be installed under the wheelchair. The street sweeper design does not have any storage space for supplies. Mobility will not be hindered with the street sweeper design. The brushes would be large and slightly bulky for storage in small spaces.

4.9 Design #9: Whipple

The whipple design is a variation of the street sweeper design. The brushes will be installed in front of the wheelchair instead of behind it acting as a push broom. The whipple will have no storage space and will be too large to store in compact areas. The whipple would have the same mobility as the street sweeper.

4.10 Design #10: Duel Mop

In this device we would have special mops to clean the floor. The device would have two mops connected together to be held by the user. These dual mops would have a flexible angle and a sideways swing while maneuvering around, this design does not cause challenges when turning corners or changing directions. This design has multiple uses to clean in front of the wheelchair or on the sides. These mops are easily detachable in order for the user to can dust and mop various surfaces. This concept holds a tank containing 1 gallon of water connected to the end of the mops handle allowing cleaning solution to feed through to the mop’s head. The storage size is not a concern in this design because the user won't store any other supplies. The mop’s device will be more mobile than a storage device. It will allow the user to transport the device around and it will be light enough to carry.

4.11 Design #11: The Drone

The drone idea is the team’s “crazy” idea. This design will have an independant drone, operated by the user, that carries the supplies for the user remotely. **Figure 9** below shows how the concept will work. The drone would be very mobile if controlled correctly. The drone itself would not have storage space. The size of the drone would also be small and compact enough for storage.

Figure 9: “Crazy” inspired Drone-concept sketch

5 Design Selected

5.1 Rationale for Design Selection

The 10 designs described in section 4 were evaluated further using a pugh chart (Table A1) to narrow the options down to three concepts. The pugh chart uses a datum, reference design, as a baseline to evaluate the other concepts. The lap table was designated the datum because it was the most simplistic design that embodied all customer requirements. The criteria that was used to evaluate each design were lightweight, adaptability, portability, ease of building, modular, attach and detachability. Table A1 located in the appendix shows our teams pugh chart results. Designs 3, 5, and 6 were determined to be the team's top three concepts. After the three concepts were placed into a decision matrix, the criteria remained constant but each criteria received a weighting. The three designs were scaled from 1-10 with 10 being the design that is most like the criteria and 1 being least like the criteria. **Table 4** below displays the result of the decision matrix. The arm side pouch was concluded to be the ideal design for this project. However, the customer chose the lap table design over the arm side pouch.

Table 4: Decision Matrix

Criteria	Weight	Design 1 (The vest)	Design 2 (Lap Table)	Design 3 (Wheel Chair Arm Side)
Adaptability	19%	7	5	7
Light Weight	20%	5	5	10
Portability	20%	9	5	6
Modular	10%	4	2	4
Attach/ Detach ability	18%	6	5	7
Cost	13%	3	5	5
Total	100%	34	27	39

5.2 Design Description

The lap table design, Figure 10, was analyzed using oak plywood and ABS plastic. This analysis included a weight, cost, and stress analysis of both materials, see Appendix. Oak wood had the lowest weight, cost, and stress on the bottom surface. This result resulted in our team choosing to use a wood material over plastic. The dimensions used are (6 x 16 x 6) in, this changed slightly from the analysis as the length and width were changed to better suit the user. A thickness of 0.5 in was used in the solidworks and analysis. The engineering drawings can be found in the appendix as well as the bill of materials for the solidworks design. The design will have an inside volume of 0.25ft^3 and a weight of 5lbs, which leaves the storage space smaller than anticipated.

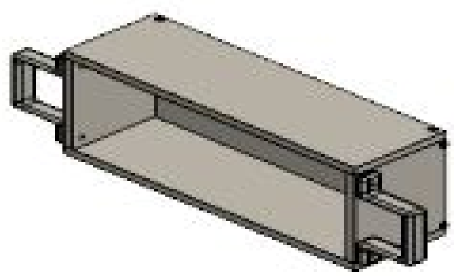


Figure 10: Lap Table design

6 Proposed Design

The first step was to complete a cardboard prototype that displayed the storage size available and the overall feel the device will have. Next, plywood will be purchased from a local hardware store as well as a box of screws. A power drill will also need to be purchased to drill the screws. The bill of materials can be seen in **Table 5**. Most supplies can be purchased through Home Depot other materials will be purchased from JoAnns', or another craft store. Another approach would be to construct the design using ABS plastic. This would require a 3-D printer. Both designs would be approximately the same price with wood being the slightly cheaper option. Using plastic would also be a disadvantage for the client due to the fact that their facility does not having access to a 3-D printer.

The belt that will be used to secure the box to the user, will be made of flexible metal. The metal should be flexible enough to bend into shape, but also stiff enough to support the box. The original designed called for an elastic belt but was quickly replaced by the metal option. The metal belt allowed for easier customer use as well as manufacturing.

Table 5: Bill of Materials Final Design

Material	Cost	Material	Cost
1-Wood X2	12$	5-Velcro	12$
2- Screw X13	6.50$	6-Elastic Belt	6$
3-Handle X2	8$	7-Divider	6.50$
4-Saw	20$	8-Sanding	6$

7 Implementation

The proposed design shifted slightly, these changes included using an aluminum belt in place of the elastic belt and using dovetail joints. The dovetails joints were included to enhance the durability of the box. The aluminum belt replaced the elastic belt to allow for easier placement of the blt on the user.

7.1 Manufacturing

Team 34 designed the laptop table to be as simple to build as possible. All materials can, and were purchased at a local hardware and craft store. The bill of materials and manufacturing process for the belt and the box are detailed below.

Belt

The belt that attaches to the user was originally designed using elastic material, where the belt would wrap around under the chair and velcro at the ends. Team 34 decided to use Aluminum sheet metal to construct an easier system to use belt. The ends of the current belt slide under the user's leg and is kept secure by their legs. Using flexible sheet metal allows the user to easily pull apart the ends and slide them under their legs. The users weight keep the belt secured in place while the box will be secured to the belt by velcro. Table 6 lists the materials and quantities needed to construct the belt.

Table 6: Bill of Materials (Belt)

Aluminum sheet metal (width 6in)	2.5 ft	$6.49 (25ft roll) [Home Depot]
Fabric	0.5 yrd	$2.49/ yrd [JoAnn's]
Thread	1 spool(Using only about 2.5ft)	$2.49 [JoAnn's]
Velcro	2 ft	$6 [JoAnn's]

Procedure:

1) Cut 2.5 ft of aluminum sheet metal with metal shears
2) File the cut end to remove sharp edges
3) Measure out 16in for the center section, this will be the section the box rests on
4) Bend, from center, the ends until an oval shape is obtained. Allow a radius of curvature of about 3-4 in.
5) Place metal piece over fabric, face down, and wrap fabric around metal piece. Make sure fabric is taught
6) Glue fabric together and use clamps to hold the fabric secure while glue dries
7) Using "peel n stick" velcro (2 x 16in) strips, apply velcro to top center section

Laptop Table Device

The Laptop Table device was originally designed to be assembled with flat seamed joints that allowed for an ease of construction that satisfied the customer requirement for ease off assembly and manufacturing. With further analysis and testing, an alternative joint method for structural integrity of the device has been created. As opposed to the flat joint or butt joint method of construction, a “Dovetail” joint proved to be most effective for structural longevity and durability. With assistance from an authorized manufacturing facility, with dimension of the Laptop Table device provided, components can then be produced prior to arrival to user and construction can be simply completed by the consumer. Table 7 below lists the materials required for assembly of the Laptop Table device.

Table 7: Bill of Materials (Laptop Table Device)

Side wall components	(2)- 6” x 6” Panels	$1.15/in^2 [Home Depot]
Undersurface base component	(1)- 6” x 16” Panel	$1.15/in^2 [Home Depot]
Front & Rear wall components	(2)- 6” x 16” Panels	$1.15/in^2 [Home Depot]
Exterior Waterproof Adhesive	3 ounces / device	$1.25 [Home Depot]

Procedure:

1) Account for all required materials
2) Apply adhesive to entire surfaces that have the “Dovetail” treatment
3) Ensure adhesive is evenly coating all surfaces that will make contact with each other
4) Begin assembly starting with the Undersurface base component fitting the sides together accordingly

7.2 Design of Experiment (DOE)

Storage space was chosen as the testing parameter as a result of wanting to maximize the internal area. Four different shaped boxes were analyzed to determine which shaped box would have the maximum amount of storage space. The shapes analyzed were: triangular, oval, rectangle, and trapezoidal. The thickness (0.5in) and dimensions were held constant for the analysis. These dimensions include using a max length of 16in and a max height of 6in. Table 8 below tabulates the interior area for each shape.

Table 8: Interior Area for Each Shape

Triangular	48in^2
Oval	88.27in^2
Rectangle	96in^2
Trapezoidal	90in^2

The rectangular shaped Laptop Table device had the largest interior area while the triangular shape had the lowest. The results of the analysis, combined with the easy manufacturability confirmed the team's decisions to use a rectangular shaped box.

8 Testing

After completing all the manufacturing for the system Team 34 tested the weight of the device, weight capacity, and ensuring that sudden motions

References

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Appendix

Table A1: Pugh Chart Results

	1	2	3	4	5	6	7	8	9	10
Adaptability	-	-	+	-	+	D	-	-	-	-
Light Weight	-	+	+	-	-	A	-	-	-	-
Portability	-	+	+	-	+	T	-	-	-	-
Ease of Building	+	-	+	-	+	U	-	+	-	-
Modular	+	+	+	+	+	M	-	-	-	-
Attach/ Detach ability	-	-	+	-	+		-	-	-	+
Σ +	2	3	6	1	5		0	1	0	1
Σ -	4	3	0	5	1		6	5	6	5

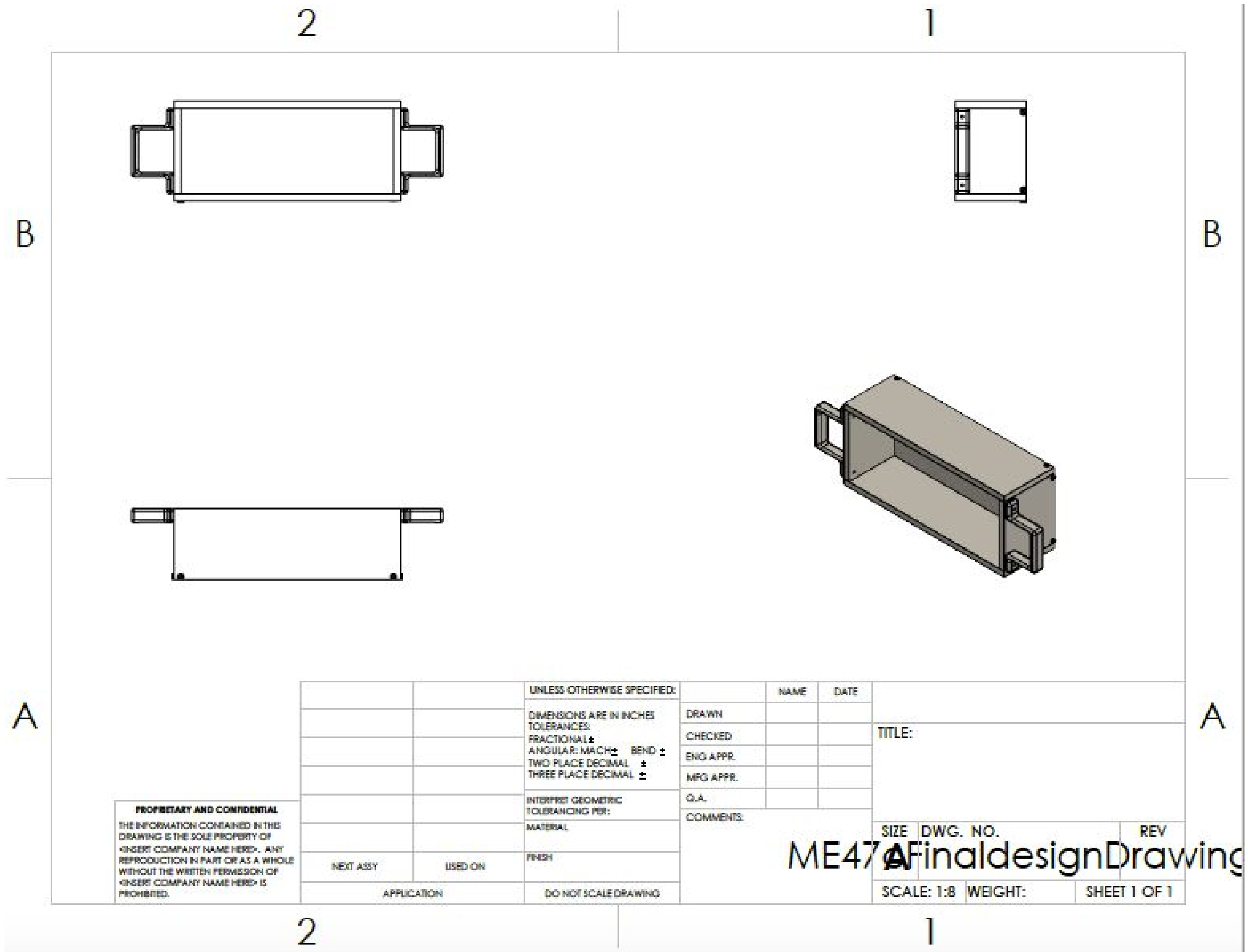


Figure A2: Lap Table drawing

Lap Table Analysis:

Weight:

Equation 1 below was used to determine the weight, in lb_m, of the device.

$$W_{device} = \rho * V_{device} \quad (1)$$

Where,

ρ= density of material (lb/ft^3)

V_{device} = Volume (ft^3)

The volume of the device was determined by using equation 2:

$$V_{device} = V_{whole} - V_{inner} \quad (2)$$

V_{inner} was calculated using a thickness of 0.5in this made the dimensions (16in x 9in x 5.5in) for the inner cavity.

<u>Wood</u>:

V_{device} = 0.132 ft^3

ρ = 45lb/ft^3 [1]

W_{wood} = 5.94 lb

<u>ABS plastic</u>:

V_{device}= 0.132 ft^3

ρ= S.G. * ρ_{water} = (1.08)*(62.3lb/ft^3) = 67.28lb/ft^3 [2]

$W_{plastic}$= 8.76 lb

<u>Loaded Weight</u>:

Weight of supplies: 10-15lb

W_{wood}(loaded) = 15-20lb

$W_{plastic}$(loaded) = 18-23lb

Cost:

The cost of the device was approximated by looking at websites like Home Depot, JoAnn’s, and Velcro.

Wood:

Table 1 below tabulates all the required materials and their respective prices to build the lab table device using wood.

Table 1: Bill of materials for wood

Material	Quantity	Price	Location
1 oak panel (0.5in x 24in x 48in)	1	$15.00	Home Depot.com
Velcro (5ft long, 3/4in wide)	1	$2.89	Velcro.com
wood screws ($0.04 per screw)	6	$0.24	Home Depot.com
1 yard felt fabric	1	$3.99	JoAnns.com
		Total: $22.12	

ABS Plastic:

Table 2 below displays the required materials and their cost to build the lap table design with ABS plastic.

Table 2: Bill of materials plastic:

Material	Quantity	Price	Location
1 sheet ABS Plastic (24in x 48in)	1	$42.12	Onlinemetals.com
Velcro (5ft long, 3/4in wide)	1	$2.89	Velcro.com
1 yard felt fabric	1	$3.99	JoAnns.com
		Total: $49.00	

Stress:

Equation 3 is used to determine the loaded stress, σ, on the base of the device. Table 3 displays an approximate stress based of the loaded weights calculated previously.

$$\sigma = \frac{F_{loaded}}{A_b} \quad (3)$$

Where,

F_{loaded} = Loaded weight (lbf)

A_b= Area of the base (in^2)

F_{loaded} was determined by equation 4.

$$F_{loaded} = W_{loaded} * g \quad (4)$$

Where,

W_{loaded}= mass of the device when loaded (lb)

g= acceleration due to gravity (ft/s^2)

Table 3: Stress for wood and plastic designs

Material	**Stress (psi)**
Wood	3.4
Plastic	4.3

Individual Analysis

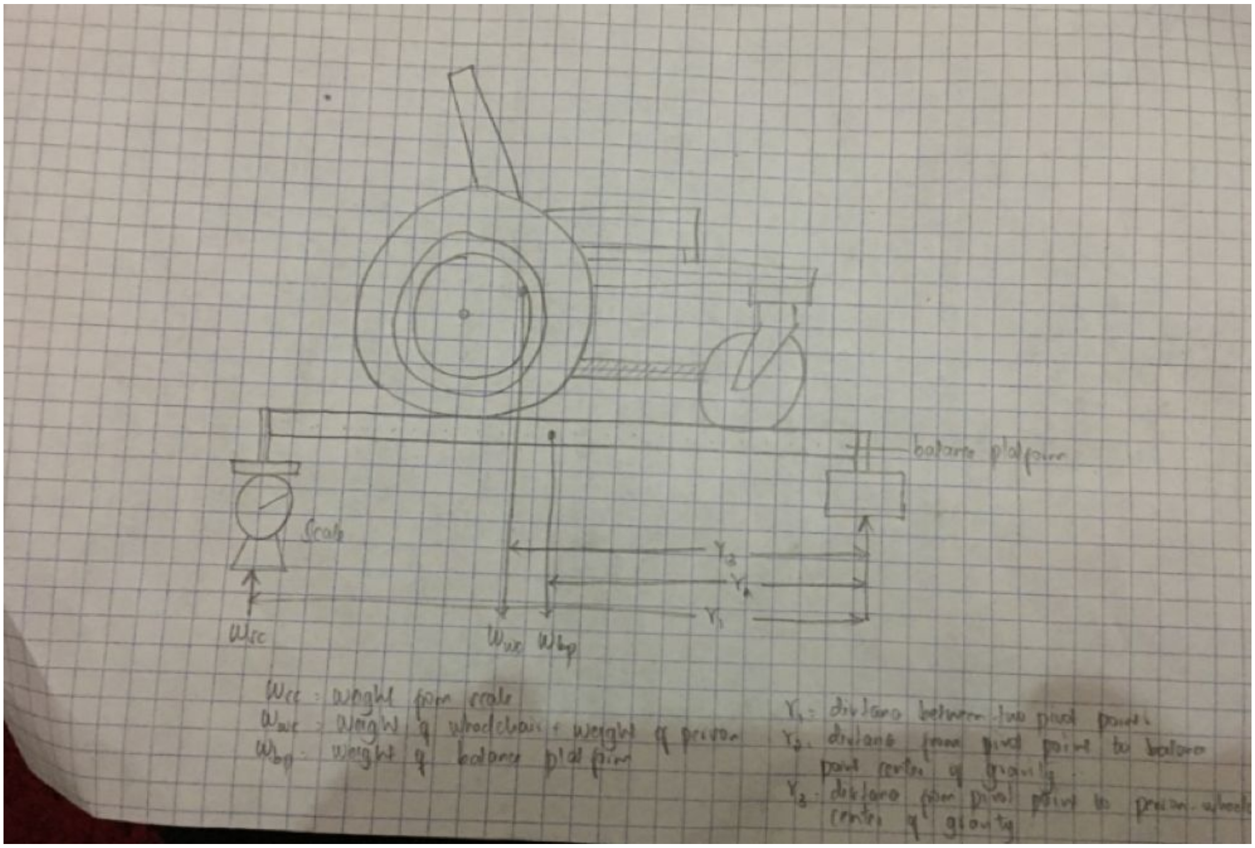
WHEELCHAIR DESIGN

Wheelchair ergonomics are an important factor when it comes to design. A wheelchair must be easy to propel, comfortable and easily modified in order to cater to individual users. There are several factors that must be considered while designing a wheelchair the most important being the center of gravity of the wheelchair. This is especially important when a storage compartment is designed as part of the wheelchair. The storage compartment can be located in two places one being on the seat as a backpack the other being below the seat. The mechanics of the storage compartment must be considered during the design.

The wheelchair designed for as shown in sketch provided contains a storage compartment located below the seat. This means that the weight of the wheelchair, the weight of the patient and the weight of the storage compartment must be incorporated into the overall design. The center of gravity is a vital aspect of wheelchair design. The center of gravity should be easily adjustable and this can be done by ensuring the axles of the rear wheels are easily movable. This ensures that the patient can adjust the center of gravity when needed in order to ensure minimal effort for propulsion. Center of gravity is also important as angle of tipping can be easily determined. The center of gravity should be located as close to the rear axle as possible in order to ensure maximum stability.

The center of gravity varies from patient to patient due to differences in weight. A wheelchair must therefore be able to accommodate different patients of different weights and limb lengths. The center of gravity should therefore be adjustable so as to increase performance of the wheelchair. This can be done by adjusting the rear wheel axles of loosening certain wheelchair frame parts towards the center of the wheelchair. The wheelchair must therefore have an adjustable axle plate or it must have a dynamic axle bar.

In order to determine the center of gravity of the wheelchair several factors must be considered being the weight of the user and the weight of the wheelchair. The weight of the storage compartment must also be factored in. Consider the design shown below:



The wheelchair must be placed on a balance platform of a predetermined weight and balanced out with a scale this will aid in determining the center of gravity using static moments.
To determine the center of gravity the following must be taken into consideration:
R_1= distance between the two pivot points = 1.5m
R_2=distance between pivot point to balance point center of gravity =0.6m
R_3= distance from pivot point to person wheelchair center of gravity = 0.75m
The following weights must also be considered
W_{sc}= weight of scale= 100N
W_{ws}= weight of wheelchair + weight of person +weight of storage compartment = 766N
W_{bp}= weight of balance platform = 100N
Using static moments:
Where R_{rw}= distance from rear wheel axle to the patient/wheelchair center of gravity
R_{rw} = distance from pivot point to rear wheel axle = 1.25m
For a patient with a weight of 500N the center of gravity is located 14cm from the rear wheel axle. This is close enough to ensure stability of the user and minimize probability of tipping. The center of gravity would change with the weight of the user and therefor the position of the rear wheel axle should be easily adjustable. The center of gravity aids in making valid and quantitative measures in making wheelchairs more efficient and stable.

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Analytical Tasks Assignment

By:
Calvin Schnorbus
Project Group: 34
Hozhoni Cleaning Crew

Fabric Strength Analysis

Instructor: David Trevas
ME-476C (1167-9464) (Fall 2016 M16) 005

Submitted towards partial fulfillment of the requirements for
MECHANICAL ENGINEERING DESIGN I
November 18, 2016

Department of Mechanical Engineering
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BACKGROUND

As the Hozhoni team speaks with clients and employees of the nonprofit, a task to create a device that aides in the process of regular cleaning duties become evident. The main issue that has come to the capstone team's attention is the challenges that maneuvering around a complex in a wheelchair while carrying all of your supplies can have. The task required to aide the client in their work is to create a device that allows the employees with disabilities to better perform their job without struggling to hold their equipment [1].
With the great amounts of individuals who have disabilities, the device that will be created can not only aide those employees working with the Hozhoni Foundation here in Flagstaff, Arizona. This device will have the potential to assist many others across the nation who are wheelchair bound or have difficulty carrying many items at one time.

OVERVIEW

This analytical analysis will work to evaluate the strength of material for the "Side Pouch Supply Holder" as seen in **Figure 1.** This analysis will focus on multiple factors that will help establish which fabric material will be most suitable for the application intended. The first variable that will help determine a viable material would be the durability of fibers. Durability testing evaluates fibers or fabrics under conditions that are assumed to measure its permanence by virtue of the power of the material to resist stress or force. The procedures typically subject the material to stress of some kind, and measures the amount of force at which a material fails. These procedures focus on the physical-mechanical aspects of materials. Results reflect the amount of force the material experienced at failure [2]. Durability testing is often used to determine whether the material is acceptable to the user and the intended application. Most common factors are measures of strength and abrasion resistance.

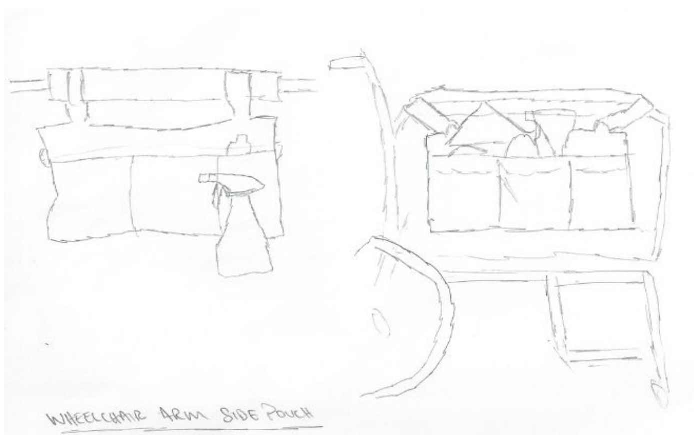


Figure 1 - Side Pouch Supply Holder

The next variable that will be analysed is the safety of the material in question. Measuring a material's reaction to conditions of use provides information that can be used to predict product performance. Safety addresses the physical risks to which the user of a product is exposed [3]. For the majority of fabric materials, the major safety issue is flammability.

METHODS

In order to effectively measure the durability of a fabric, the factor must be broken up into two variables to be dimensioned. The first factor of the durability of a fabric in question would be the tensile strength of the material. A biaxial woven fabric can be treated as an assembly of two systems of essentially string perpendicularly interlaced with each other in a two-dimensional lattice. Therefore, fabric strength is the resultant of the line strength taking into account the interactions between the two line systems.
To being with tensile strength of the material, it is important to identify the assumptions that will govern the analysis. First, the tensile strength distribution of the individual strings is of Weibull form. The dimensions are of elongation of material as force is applied axially. The next assumption is that any variations in the materials pattern or individual strands that make up the fabric will be neglected. The final assumption is that the parameters of a fabric are negligible. This means that the interactions between each individual string in a fabric under tension will not affect the form of the strength distribution function of the entire system.

According to the above assumption of the Weibull distribution function of yarn tensile strength, for a single yarn with length l_y , the probability of its breaking load being σ_y can be described by a two-parameter Weibull function:

$$F(\sigma_y) = 1 - \exp[-l_y \alpha_y \sigma_y^{\beta}] \qquad (1)$$

The mean or the expected value of the yarn breaking load, σ_y can then be calculated as:

$$\overline{\sigma_y} = (l_y \alpha_y)^{-(1/\beta_y)} \Gamma\left(1 + \frac{1}{\beta_y}\right) \qquad (2)$$

Where α_y is the Weibull scale parameter, and β_y is the shape parameter of the yarn. The shape parameter is an indicator of the variation in yarn breaking loads. A higher β_y value corresponds to a lower variation, and when $\beta_y \rightarrow \infty$, the variation would approach zero and the string breaking load would be independent of its length.

The next factor that established the fabrics durability is the abrasion resistance during operation. Abrasion resistance is the ability of a fabric to resist surface wear caused by flat rubbing contact with another material. There are two different test methods commonly used by the textile industry to assess abrasion resistance: Wyzenbeek and Martindale.
The Wyzenbeek testing process requires samples of the test fabric to be pulled taut in a frame and held stationary [4]. Individual test specimens cut from the warp and weft directions are then rubbed back and forth using an approved standard cotton duck fabric as the abradant. The end point is reached when two yarn breaks occur or when appreciable wear is reached.
Abrasion results are one of several means of comparing fabrics for a particular application. However, it is important to note that the results of multiple abrasion tests on the same fabric sample can vary by as much as 25,000 +/- Wyzenbeek double rubs, units to which this procedure uses to determine durability.

The final factor being analysed is the safety variability pertaining to flammability of a product. Flammability is evaluated by a procedure know as a 45 Degree test and also a Vertical Flammability test. The 45 degree test is used to distinguish explosively flammable textile materials from others, whereas the Vertical test is a more stringent test for assessment of clothing [5]. This analysis will only focus on the 45 Degree test.

The two factors that are measured using this test are the ease of ignition (how fast the sample catches on fire) and the flame spread time (the time it takes for the flame to spread a certain distance).

This test works through the mounting of samples in a frame and held in a special apparatus at an angle of 45º. A standardized flame is applied to the surface near the lower end for specified amount of time. The flame travels up the length of the fabric to a trigger string, which drops a weight to stop the timer when burned through. The time required for the flame travel the length of the fabric and break the trigger string is recorded, as well as the fabric's physical reaction(s) at the ignition point.

The results of this test are determined through the calculation of the arithmetic mean flame-spread time of the six (or twelve) specimens. The time of flame spread is the average time for all the specimens of that sample material tested. The conclusion of the data and the time of the flame spread determined the "Class Rating" of the material which is determined by the Consumer Product Safety Commission. Each class is rated for a certain application and determined where a material can be used.

CONCLUSION

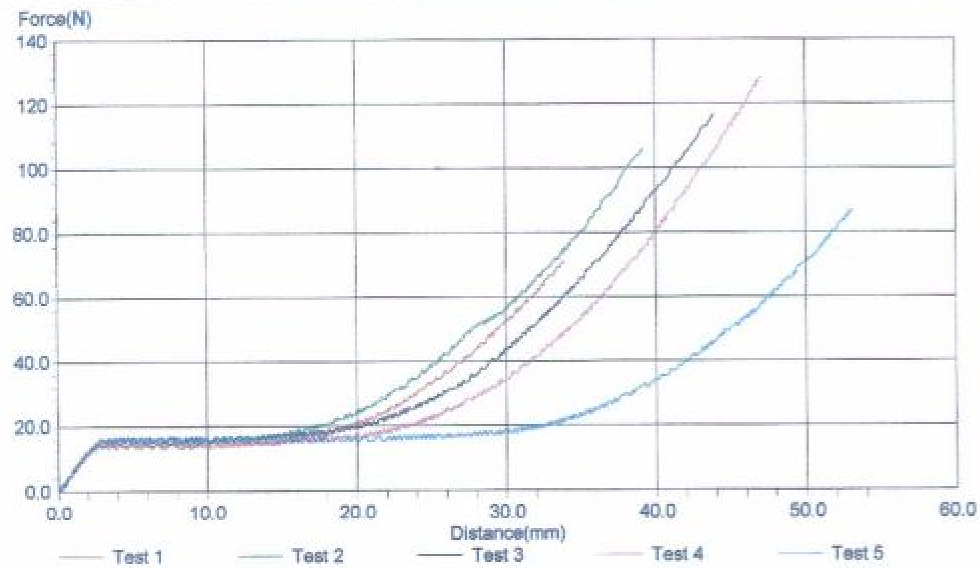
Overall, in order to determine a fabric that will be viable for the application of an assistive device for the Hozhoni, the factors that were analysed will be used to choose the best option.
So far, the material that shows the best outcome when evaluating different materials is the synthetic nylon based vinyl produced with knitted polyester scrim for good tear resistance and better flexibility.

Tearing Strength of Fabrics
Tongue Method ASTM D 2261

Ref 1 : Celtics
Ref 2 : Tear
Ref 3 : warp

Test Name : Tearing Strength of Fabric
Test Type : Tear
Test Date : 11/23/04
Width : 75.000 mm
Thickness : 0.002 mm

Test No.	ASTM D2261 Part 10.2 Tear Strength (N)	ASTM D2261 Part 10.3 Tear Strength (N)	ASTM D2261 Part 10.4 Tear Strength (N)	Load @ Peak (N)	Average Load (N)
1		25.101	17.610	71.490	43.830
2		35.748	21.030	106.340	66.446
3		37.098	21.695	117.610	74.419
4		37.333	19.185	129.970	80.999
5		27.171	19.280	87.700	54.091
Min		25.101	17.610	71.490	43.830
Mean		32.490	19.760	102.622	63.957
Max		37.333	21.695	129.970	80.999
S.D.		5.878	1.623	23.336	15.071
C. of V.		18.090	8.215	22.740	23.564
L.C.L.		25.192	17.744	73.647	45.244
U.C.L.		39.788	21.776	131.597	82.670



The H
erculite #10 Black Industrial Vinyl is the best fit for the application of a side pouch cleaning device due to many variable. This special material is used in the industry because it shows many versatile characteristics. This fabric has a high temperature control, is mildew resistant, UV ray resistant, flame resistant, has a high tear resistance, abrasion resistance, and finally is a waterproof material. Having all of these materials makes it a great material for ponchos, Tents, uniforms, backpacks, Personal Protective Equipment (PPE), cords, ropes, and cables, straps and bedsheets & mattress fabrics, hats, gloves, and belts [6].

Using this material for the Side Pouch Supply Holder will pass all of the tests our team expects this device will see. With its high resistance to wear and abrasion there are no doubts that this material will be durable enough for the application in question. Listed in Appendix A are the strength test outcomes of this material from the manufacturer.

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Individual analysis performed

Student's Name: Fahad Alaenezi

Date: 18th November 2016

Professor's Name: D. Willy, D. Trevas, AND S. Oman

Team number and name: Team #34, Hozhoni Cleaning

Section information: Section #5

Subject: ME 476C

ANALYSIS OF A CLEANING CREW DEVICE (Dual Mops)

Introduction:

Disability is a big issue that affects most people on our planet. We all know or have someone with one disability or another. Some are born that way; some are involved in accidents; so on, and even a lot of war veterans find themselves disabled. Not only is it necessary to enable disabled people to live their lives as normal as possible, it is also very much possible. With design, simple chores that have been impossible or difficult for disabled persons can be made very easy. This project seeks to simplify the cleaning chores for persons that have to use wheelchairs due to disability. It seeks to come up with mops that are easy to use while on a wheelchair. It is stable on its own, handheld and with attachments to the chair that enable water tank to be applied during use.

This project has two mops that are connected to be held by the user to clean the floor. These dual mops have flexible angles and sideways swing while maneuvering around. This design does not cause challenges while turning corners or changing directions. The concept uses a lot of frictional analysis to enable find means to easily control the device. The device also depends on human power for drive; and operates through the application of pressure. For this purpose, pressure analysis will be involved in the project safety. The Hozhoni Company ensures that those in wheelchairs or other physically challenged individuals are safely and efficiently carrying the cleaning supplies around. The device makes sure that the users are protected from any cause of danger, risk, or even injury.

The adaptability of the Dual Mops device is able to adjust or change to work more effectively in various wheelchair models, either motor or manual adaptations, and the light weight is used because the Dual Mops device is targeting those individuals who cannot lift heavy weight, it weighs less than average and is detachable from the wheelchair's user. The device is also portable which makes it easy to carry and get relocated due to the versatility of its design. This feature helps the physically challenged individuals carry the cleaning supplies around without any difficulties. The Dual Mops device is easy to build and construct and therefore, it can be to any individual at home thus accommodating as many users as possible. The system utilizes slightly modified parts; thus, making it ascertainable .Its (Dual Mops) system is subdivided into small parts, which can be independently created as well as used in different applications. In terms of cost, the device is relatively cheap for efficiency and effectiveness; the Dual Mops system is cheaper than the current cleaning supplies organizational program. This makes it tangible for disabled employees and foundations to own it. Finally, the life span of the Dual Mops device is long, as its parts can be modified to suit the needs and requirements of the users.

Equations will be used in the project:

Friction Force:

$FF = \mu \cdot FN$ - If the object is not moving, you are dealing with static friction and it can have any value from zero up to $\mu_s F_N$.
- If the object is sliding, then you are dealing with kinetic friction and it will be constant and equal to $\mu_K F_N$.

Torque:

$\tau = F \cdot L \cdot \sin\theta$ - Where θ is the angle between F and L; unit: Nm.

Work:

$W = F \cdot D \cdot \cos\theta$ - Where D is the distance moved and θ is the angle between F and the direction of motion, unit: J.

Efficiency = $Work_{out} / Energy_{in}$

Mechanical Advantage = force out / force in M.A. = F_{out} / F_{in}

Center of Mass – point masses on a line

$x_{cm} = \Sigma(mx) / M_{total}$

Mechanical Energy:

$PE_{Grav} = P = m \cdot g \cdot h$

$KE_{Linear} = K = \frac{1}{2} \cdot m \cdot v^2$

Newton's Second Law and Rotational Inertia:

τ = torque = $I \cdot \alpha$

I = moment of inertia = $m \cdot r^2$ (for a point mass)

Friction:

- Coefficient = $(0 < \mu < 1)$
  $F_f = F_N$

Net Force (F_{net}):

- Flat plane: $F_{net} = F_a - F_f = F_a - \mu mg$
- Inclined plane: $F_{net} = F_{\parallel} - F_f = mg\sin\theta = \mu mg\cos\theta$

Pressure:

- P =
- P = F/A (= mg/A when using a gravity or weight mode

Physical modeling

Material:

Polyurethane, density is 20-lbs.-per-cubic foot, when dry.

The weight when wet is calculated as follows:

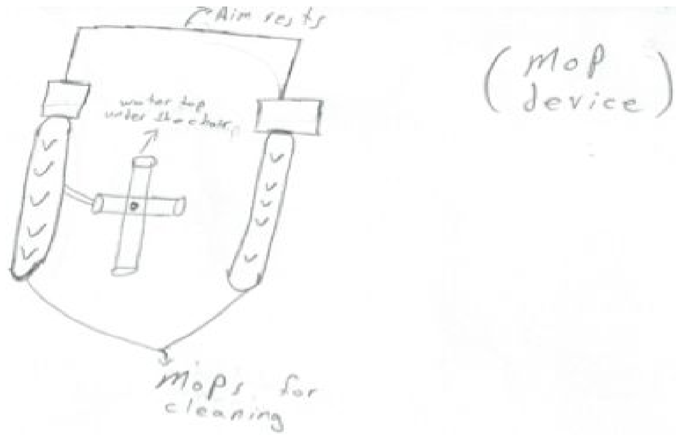
Maximum increase in amount of water by mass is 3% of the total mass. So maximum density is

Maximum mass:

7 lb. this is the mass when the mops are wet.

Dimensions:

Consists of two roughly cuboid mops each of weight 3.5 lb. the maximum volume should therefore be
The mop experiences very little, if any change in volume while wet or dry. So this volume will be taken as the volume of the dry mop during design.



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[2] Augusta *Forces & Friction - Formula Sheet* retrieved from http://www.augusta.k12.va.us/cms/lib01/VA01000173/Centricity/Domain/396/Forces_and_Friction_Formulas.pdf.

To: David Willy, David Trevas, and Sarah Oman
From: Hussain Ali Alwateeb
Subject: Analytical Tasks Assignment.
Date: 11/18/2016

Project brief

The project is about designing a wheel chair which will help a disable person in floor cleaning operation. The user will use this chair to clean different kind of surfaces, which could be accessible by wheel chair.

Concerned Problem

As the brush is going to be placed under the legs of the user, and user will perform moping by moving its chair from place to place. The major concern of this problem is the frictional force which could cause serious difficulty or require extra force to move the chair/brush and hence could be inconvenient for the user.

In this project we tried to analyze this problem by examining the force required to move a mop on several surfaces.

Some facts and figures:

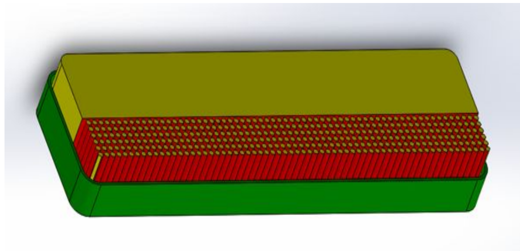
Mop:

There are several moping materials and technologies, some are suitable for rough surfaces, other for plane surface, some are efficient than others and some are cheaper in cost. A complete data on the comparison is available on internet.

Microfiber

In the discussion of best moping material, the newly introduced microfiber material is best choice because it gives better surface cleaning with least friction.

Proposed Design:
The designed proposed in this project is simple microfiber mop, with nylon brush. Nylon brush will clean the insertions and dips in the floor while the microfiber will give it a final cleaning.



Design requirements:
The basic and main requirement of the assembly is that it should have a mop/brush under it, to which user will push against the floor. The mop will be pushed using a lever mechanism.

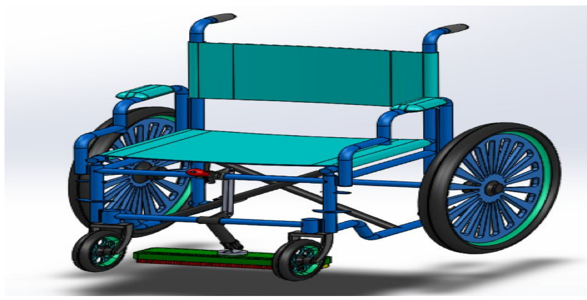
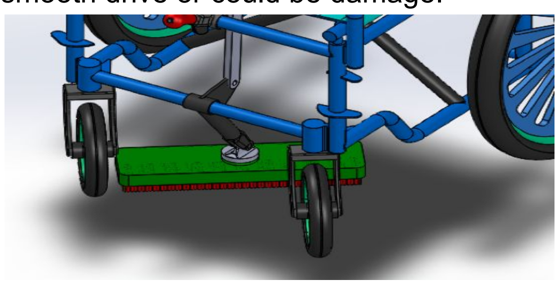


Figure 3: Wheelchair assembly
There are some design considerations which are to be considered for easy drive of chair. The brush/mop under the chair should have a universal joint so that it could keep its self-aligned with the floor and steering direction during turning. Otherwise the brush could cause problem in smooth drive or could be damage.



Friction analysis:
Whenever a body is pushed against a surface perpendicularly, it suffers from a frictional force during dragging on that surface. This frictional force is due to the natural physical phenomena. The magnitude of this frictional force is dependent on the coefficient of friction between the two materials and the perpendicular push force.
For this design, frictional values between the mop and different floors are to be considered along with the suitable force, with which mop will be pushed.

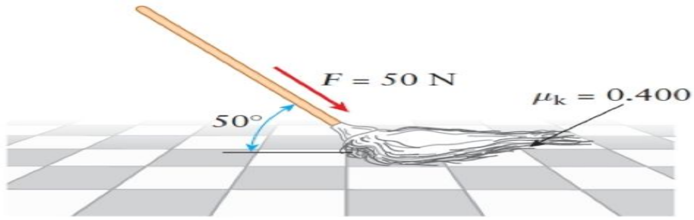


Figure 4: statics of moping operation

For this values are taken from an online source www.engineeringtoolbox.com. The following table shows these values. The suitable friction value could be leather fiber-cast iron which is 0.31. this values reaches upto 0.45 in case of asphalt road.

Table 1: coefficient of friction for different materials

Materials and Material Combinations		Static Frictional Coefficient - μ_s -	
		Clean and Dry Surfaces	Lubricated and Greasy Surfaces
Ice	Steel	0.03	
Iron	Iron	1.0	0.15 - 0.20
Lead	Cast Iron	0.43[1)]	
Leather	Oak	0.61, 052[1]	
Leather	Metal	0.4	0.2
Leather	Wood	0.3 - 0.4	
Leather	Clean Metal	0.6	
Leather fiber	Cast iron	0.31	
Leather fiber	Aluminum	0.30	
Magnesium	Magnesium	0.6	0.08
Masonry	Brick	0.6 - 0.7	
Nickel	Nickel	0.7 - 1.1, 0.53[1)]	0.28, 0.12[1)]
Nickel	Mild Steel	0.64[1)]	0.178[1)]

Force calculation:
the force required to drag the mop along with the wheel chair is dependent on the vertical push by lever and the coefficient of friction. The moment in the lever pivot will raise a force at the end of the lever. The vertical component of this force will raise the frictional force btween the floor and the mop.

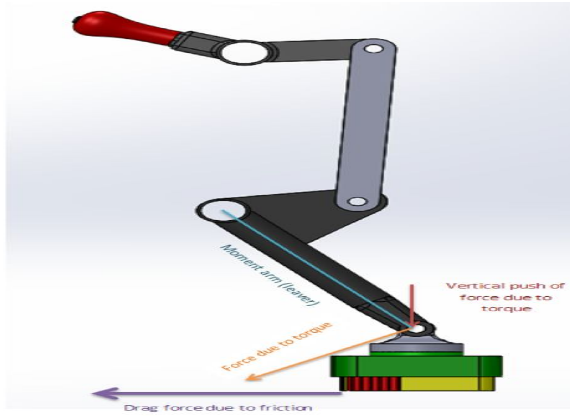
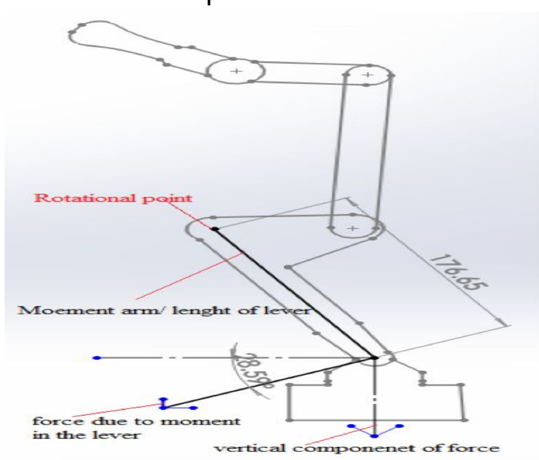


Figure 5: various forces on the mop

Geometrical analysis:
As per requirement, specified in the literature, there should be at least a vertical push of 30N i.e. the vertical component of the force due to the rotation of lever should be 30N.



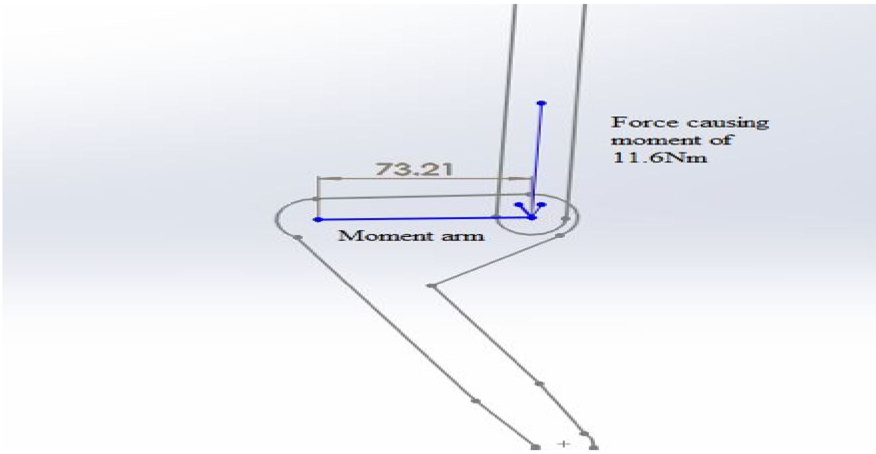
As the vertical component of this force should be 30N. the force itself would be;

$$F = \frac{30}{Sin\ 28} = 66N$$

And hence the moment causing this force should be

$$M = 66 \times 0.176m = 11.6Nm$$

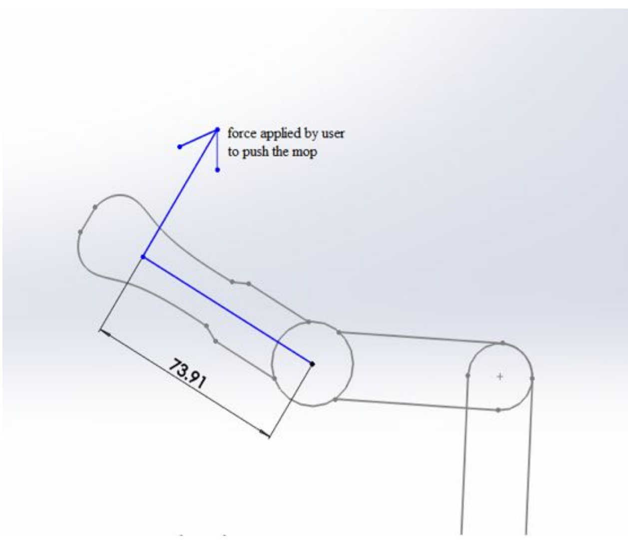
This moment is being produced by the force being applied on the adjacent link of length of 73mm. the force is transmitted by a transmitting link.



$$Force\ causign\ moment = \frac{11.6Nm}{.073m} = 159N$$

Now this downward force of 159N must be the result of a moment at the pivot one.

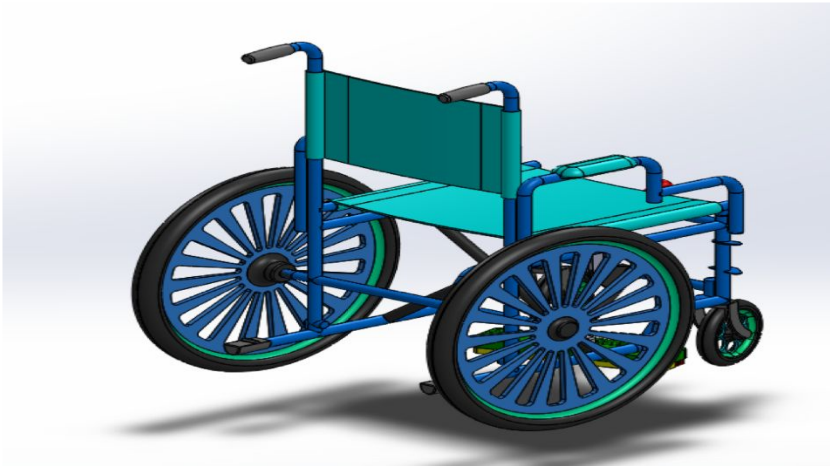
$$M = F \times r = 159 \times 0.07 = 11.13Nm$$



Now at the end of the mechanism, the user pulls up the lever to push down the mop. This force could be found as:

$$F = \frac{11.13Nm}{0.073m} = 160N$$

Assembly design:



Design of Mop pushing lever
Below is the CAD assembly of the mop model. The read knob is the lever to be pulled by the user and this will push down the vertical lever. The vertical lever further push the 2nd lever downward and hence the brush will be pushed down.

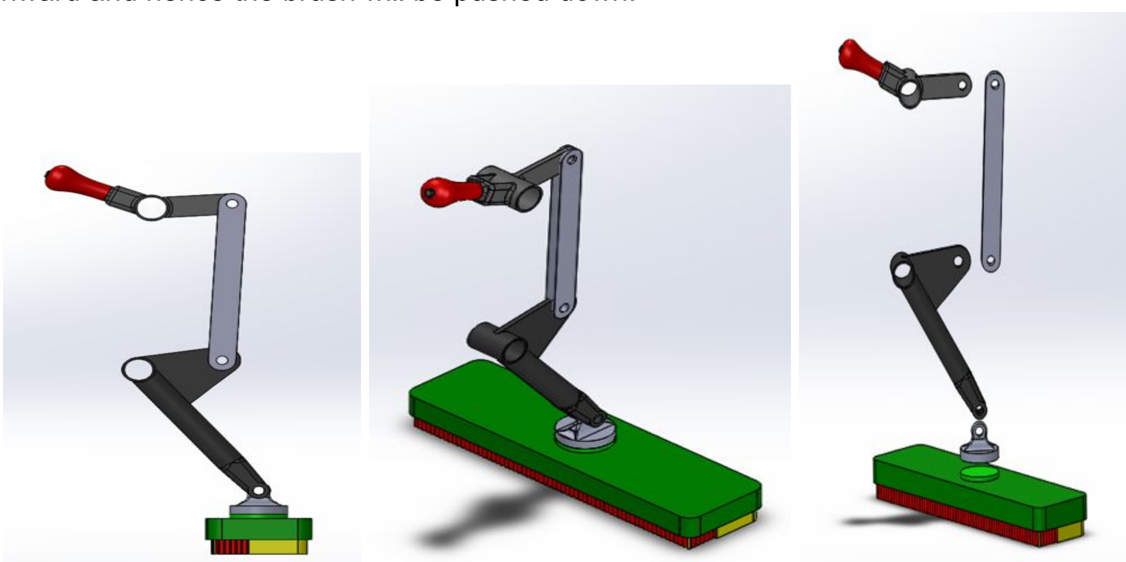


Figure 6: mop assembly

The lever will be locked by the saw-teeth counting mechanism and the pin will lock the level at its position.

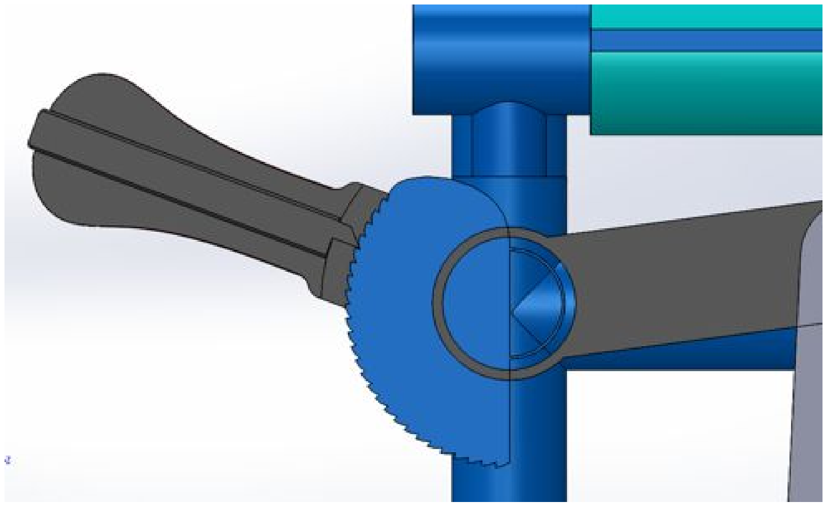


Figure 7: Locking Mechanism for lever

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