Innovative Soft Wash System

Senior Design Proposal submitted to the
Department of Mechanical and Materials Engineering
College of Engineering and Applied Science
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in fulfillment of the
requirements for the degree of

Bachelor of Science
in Mechanical Engineering Technology

by
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Table of Contents

Problem Statement

Current soft wash systems on the market come with an exceedingly high price tag, little versatility, and poor mobility. Most soft wash systems are geared towards commercial use but the ones for the average homeowner are not ideal for a new user from a usability and cost standpoint.

Research

Background of the Problem

Soft wash systems have been around for quite some time now and the performance of them varies depending on the system that you desire to use. With all soft wash systems for the average homeowners to purchase, they all tend to use the same method of mixing the chemicals, which is in the form of batch mixing. Batch mixing may get the job done, but the user could have a more productive system with increased efficiency. (4)

Batch mixing is one of the most common ways of preparing chemicals to conduct a soft wash on a residential property. This type of mixing chemical uses calculated ratios dependent on the strength that you are looking to get out of the wash. With batch mixing you are pre-mixing your water, Sodium Hypochlorite, and a surfactant which is also known as soap. The use of this method is fine if you know the exact mixture you are looking to get, but that is almost always not going to be the case. You may need a stronger mix, or you may even need a lighter mix if you are working with a sensitive mixture. Either way, if you are batch mixing you cannot change that mixture without completing wasting the mix that you have already prepared. (11)

The magnitude of the problem is that homeowners need to precisely measure out each of their chemicals and water ratios. If the ratios are not correct then you are stuck with a batch that you cannot use and are wasting time, chemical, and money. From a safety standpoint with a proportioner you can be in constant control of the amount of SH you are putting onto the surface that you are cleaning and will not risk damaging anything, but if your mix is too hot with a batch mix set you can run the risk of damage to your property. An example of this would be if you are cleaning a surface near a pool. You would not want your mix to be as hot to protect the water and if you had a proportioner you could lower the mix for that area, instead of mixing a brand-new batch. (11)

If the user of the system had a way to control the exact amount of chemical to be input for the specific cleaning being done it could not only cut down on cost, but also improve the effectiveness of the system itself. The standard batch mixing system can be extremely costly and still not produce the desired output. The focus of this design and problem will be to decrease the cost, improve effectiveness, improve efficiency output, control the chemical input, and satisfy the customer.

Applicable Standards

The standards that will put restrictions on our design will be as follows, AWWA B300-2018 and 29 CFR 1910.1200 (6). The standard AWWA B300-2018 states that the chemical when not mixed into a solution must be stored in a cool and dry area for no more than 9 months (10). Also, it states that upon receiving a hypochlorite it must first be diluted before its arrival for individual use. As for the standard of 29 CFR 1910.1200 it states to be cautious when handling the hypochlorite chemicals and to wear gloves and immediately rinse or remove any clothing that the chemical might have encountered (10). The user also must wear the PPE of safety glasses and long pants/shirts when handling the hypochlorite solution. Once the chlorite is mixed within its given solution though it becomes even more diluted and is less of a hazard (6). With the two standards being stated above in the design process we will have to ensure that there is an easy chemical deposit point so that the user is at the least amount of harm as possible. The flow of the chemical solution will also have to be sealed without any leaks present to eliminate the corroding of equipment or harm to the user. There will also need to be airtight storage containers for the chemicals to be placed in to ensure they are stored properly without any other issues arising.

State of the Art

We split the design of the overall project into 3 major parts, the frame, plumbing, and the drivetrain. My part of the project is the drivetrain. We will cover a variety of several types of current designs beyond that of just a soft wash system. To perform the tasks at hand while doing it efficiently, multiple products will have to be combined. To begin we will have to look at a basic current soft wash system for the everyday user, a basic portable frame, a schematic of the plumbing will be analyzed, and a drive train will be implemented as well.

NorthStar Soft Wash and Disinfectant System with 4.0 GPM Bleach Pump (4)

Northern Tool + Equipment company has designed a basic soft wash system for the typical homeowner. The system is compact and sits on a small rolling cart to be transported to desired locations. This system has one mixing tank that holds all of the chemicals at once with the measurements having to be decided before the soft wash process begins and once mixed there is no removing a chemical only adding more. The system once the chemicals are added runs off a 12V pump that pushes the mixture through a hose and out of the nozzle tip to then remove mold, dirt, grim, and disinfect the area being sprayed. The spraying system is mechanized by a pump for the chemical mixture, but the mobility of the system is manual requiring the user to lift the small handle on the cart which fully loaded weighs around 120 lbs and move the system to their desired location.

With the above system my teammate and I will work together on a frame design. To add onto the frame, I will be specializing in the designing of the drivetrain to transport the system to desired locations with ease and to decrease the ergonomic concerns when purchasing our design. The task is to fully have a self-propelled chassis that allows the user to move their system with little physical force required.

Frames

Southeast Soft Wash Trailer Build (2)

Southeast company builds a soft wash framing system that is completely contained on a towable trailer. This system is built to hold a commercial size soft wash system with the size of the trailer being 6’ x 12’. This trailer will hold all aspects of your system but has many downfalls when it comes to portability and the everyday household user. This trailer is highly priced with the cost of a dual axle trailer and custom-built framing it comes out to $27,000.00 but this also includes the price of the entire soft wash system as well. The next aspect is the size, this system is exceptionally large, and it requires a vehicle with a hitch to be able to tow the system to its location and then the system is not easily movable while in use. This system is targeting commercial use and is not very suitable for the average homeowner.

Southeast Mini Soft Wash Skid (2)

Southeast manufactures another type of soft wash support system called the mini skid. This system allows for enough space to contain all the needed equipment on a smaller scale using a 48” x 40” skid. With this system it is designed to either be placed in the bed of a truck or remain stationary in one position with a long hose designed to reach wherever the user needs to go. This system still has a high price tag for the average user coming in at $7,000.00. With this being said the system still targets commercial use due to it being a larger soft wash system and the mobility of it is still lacking requiring a truck or a pallet jack to be able to be moved from one destination to the next.

NorthStar Soft Wash and Disinfectant System with 4.0 GPM Bleach Pump Cart (4)

As discussed above NorthStar manufactures a soft wash system that is all contained on a small steel cart with the dimensions of 47” x 20” x 25”. This system is much smaller than the two frames discussed above and holds less with only a 13-gallon holding tank. This smaller design though makes the system much lighter and a lot more user friendly when it comes to mobility. The user will lift the handle and be able to drag the chassis anywhere they desire without having to use the aid of another system to assist. This system size also brings down the price significantly coming in at $550.00, which targets the everyday user. This system size is ideal for the average user, the only issue is the limit to the batch mixing system and once all the solution is added to the tank the system becomes quite heavy, meaning it can be difficult to transport.

Drive Train

Honda 21 in. 3-in-1 Variable Speed Gas Walk Behind Self-Propelled Lawn Mower with Auto Choke (5)

Honda manufactures a walk behind lawnmower that operates with a self-propelled system that allows the user to use little effort while moving the mower. This drive train is a rear-wheel drive system that uses a transmission connected to a throttle to control the speed at which the mower is propelled at. This transmission is connected to the gasoline motor for power and runs off the oil and gas supplied to the 4-stroke engine. This drive train puts out 8.2 ft.-lbs. of torque which means it can easily propel the small residential

mower. Although this system is adequate it is quite expensive with the mower itself running $550.00 and the transmission is not functionable without the motor of the mower meaning the drivetrain needs the mower engine to operate. This system is also larger when working with a limited amount of space.

Traxxas Sledge 6S 4WD Brushless RTR Monster Truck w/6S LiPo & Dual Charger Combo (3)

RC is known for their fast pace remote control cars, and they are well built when it comes to the drivetrain and powering it. When looking at the Traxxas Sledge this car can hit speeds up to 70 MPH being powered by a high output servo motor and 3s Lipo batteries. The servo motor is paired with an electrical transmission that controls the speeds at which the car operates. The transmission is then connected to the wheels through a set of pinion gears and steel axles. This system produces high outputs but is also only driving a small compact RC car that weighs 12.74 lbs without batteries. To follow the car frame and wheels itself are not the bulk price of the system but the controls and drive train make up the majority of the cost and this car comes in at $1,040.00 which is a high price for a typical user.

X7 Max Folding Electric Scooter (1)

TurboAnt manufactures residential scooters for everyday travel. This scooter is used by people to get from one point to another and can travel up to 20 MPH and hold 275lbs. This system has a unique drive train where the motor is directly placed inside the front wheel to propel the frame and rider of the scooter forward. This motor is then connected to a throttle control to allow the user to see the digital output of their desired speed. This motor is then powered by a high impact 36V DC battery that can hold a charge of 10 Ah and up to 32 miles. The downfall to this system though is that the battery charge time requires 6 hours to reach a full charge. It also is on a higher price range due to its unique features of being built directly into the tire and frame itself with it running around $600.00.

End User

The focus of interest will be on those who are impacted by this problem are homeowners. Many of whom may think they need a new roof, new siding, or even a new driveway. All of these can be expensive to replace but can also be rejuvenated by using a soft wash system to get rid of algicides and other forms of natural occurrences that can affect the curb appeal of your home. Many people do not realize the harm of taking a high pressure, pressure washer to the side of their home can severely damage and even go against your roof or siding warranty.
Many of the companies that provide these services charge large amounts of money to come out and do the services of soft washing for you. With an innovative design, homeowners can take the problem into their own hands and be able to complete the service themselves each year for a fraction of the price it would cost to have a company come out.

Summary of Research

An efficient mobile residential soft wash system does not exist on the market. A system that allows the user to avoid batch mixing and mix the correct amount of chemicals while keeping the solutions separate from one another until they are dispersed can not only be more beneficial in cleaning the surfaces being sprayed but it can also save time and money by not mixing the solutions until necessary. This system also needs to allow the user to have easy mobility, being ergonomically friendly to prevent any excessive force needing to be used in the transport of the user's system to wash their desired objects. This soft wash system needs to be lightweight and be transportable under its own power source so that the residential user only has to steer the system to its destination point. While making the soft wash system more efficient, compact, and user friendly for a homeowner the system also needs to be kept at a reasonable price point by using the most durable efficient products, but also only using the necessary specs on motors and frames to ensure affordability of the designed product.

Quality Function Deployment

Based on a survey conducted on the 15th of September 2022 at the University of Cincinnati, we collected data from students and residents of greater Cincinnati. From the data, opinions about

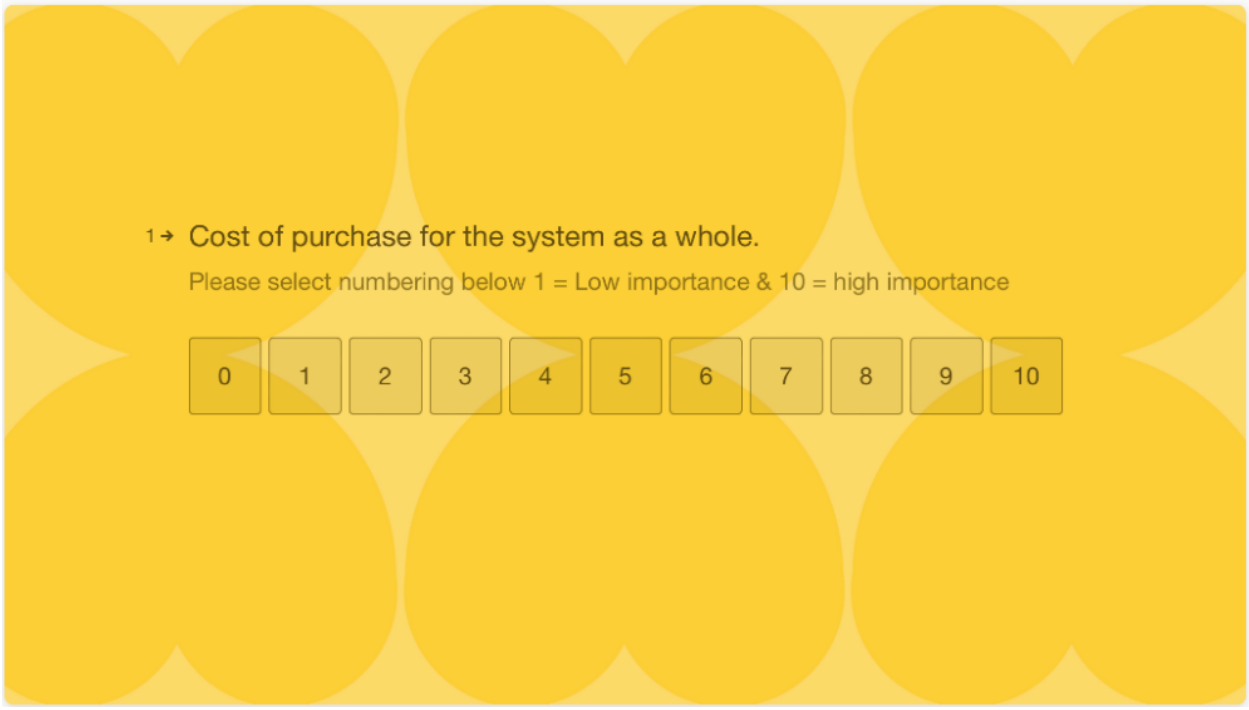
cost, ability to operate, transportability were gathered. Based on the surveys collected, which a sample has been included below, project objectives have been created.

Survey Sample

Innovative Soft Wash System

Hello, my name is Daniel Hagen, a fifth year Mechanical Engineering Technology student at the University of Cincinnati. My project partner and I are conducting research to learn more about the public's opinion on residential soft washing. We are working on designing an innovative soft wash system that will allow homeowners to clean their own houses without the need to contract an outside company. Please answer the following survey questions to help guide this project to completion.

Answer 1 to 10 in order of importance; 1 meaning least important and 10 meaning highest importance. This survey had a sample of 30 responses.



2 → Efficiency of the system.

Please select numbering below 1 = Low importance & 10 = high importance

0	1	2	3	4	5	6	7	8	9	10

3 → User safety to ensure no possible injuries occur during operation.

Please select numbering below 1 = Low importance & 10 = high importance

0	1	2	3	4	5	6	7	8	9	10

4 → Chemical combination and flow control of solutions.

Please select numbering below 1 = Low importance & 10 = high importance

0	1	2	3	4	5	6	7	8	9	10

5 → System is easily operated.

Please select numbering below 1 = Low importance & 10 = high importance

0	1	2	3	4	5	6	7	8	9	10

6 → Mixing and holding of solutions is easy and accessible.

Please select numbering below 1 = Low importance & 10 = high importance

0	1	2	3	4	5	6	7	8	9	10

7 → System is easily transported around with little effort.

Please select numbering below 1 = Low importance & 10 = high importance

0	1	2	3	4	5	6	7	8	9	10

8 → Overall size and weight of the entire system.

Please select numbering below 1 = Low importance & 10 = high importance

0	1	2	3	4	5	6	7	8	9	10

9 → Tell us how you feel about the current residential soft wash systems on the Market in general.

Please select numbering below 1 = Very Unsatisfied & 10 = Very Satisfied

0	1	2	3	4	5	6	7	8	9	10

10 → Cost to purchase soft wash systems.

Please select numbering below 1 = Very Unsatisfied & 10 = Very Satisfied

0	1	2	3	4	5	6	7	8	9	10

11 → Efficiency of available systems.

Please select numbering below 1 = Very Unsatisfied & 10 = Very Satisfied

0	1	2	3	4	5	6	7	8	9	10

12 → User safety during operation.

Please select numbering below 1 = Very Unsatisfied & 10 = Very Satisfied

0	1	2	3	4	5	6	7	8	9	10

13 → Chemical mixing and flow control of system during use.

Please select numbering below 1 = Very Unsatisfied & 10 = Very Satisfied

0	1	2	3	4	5	6	7	8	9	10

14 → Easy operating system for all users beginner to expert.

Please select numbering below 1 = Very Unsatisfied & 10 = Very Satisfied

0	1	2	3	4	5	6	7	8	9	10

15 → Mixing process and holding tanks are easy to use and accessible.

Please select numbering below 1 = Very Unsatisfied & 10 = Very Satisfied

0	1	2	3	4	5	6	7	8	9	10

16 → System is easily transported with little effort.

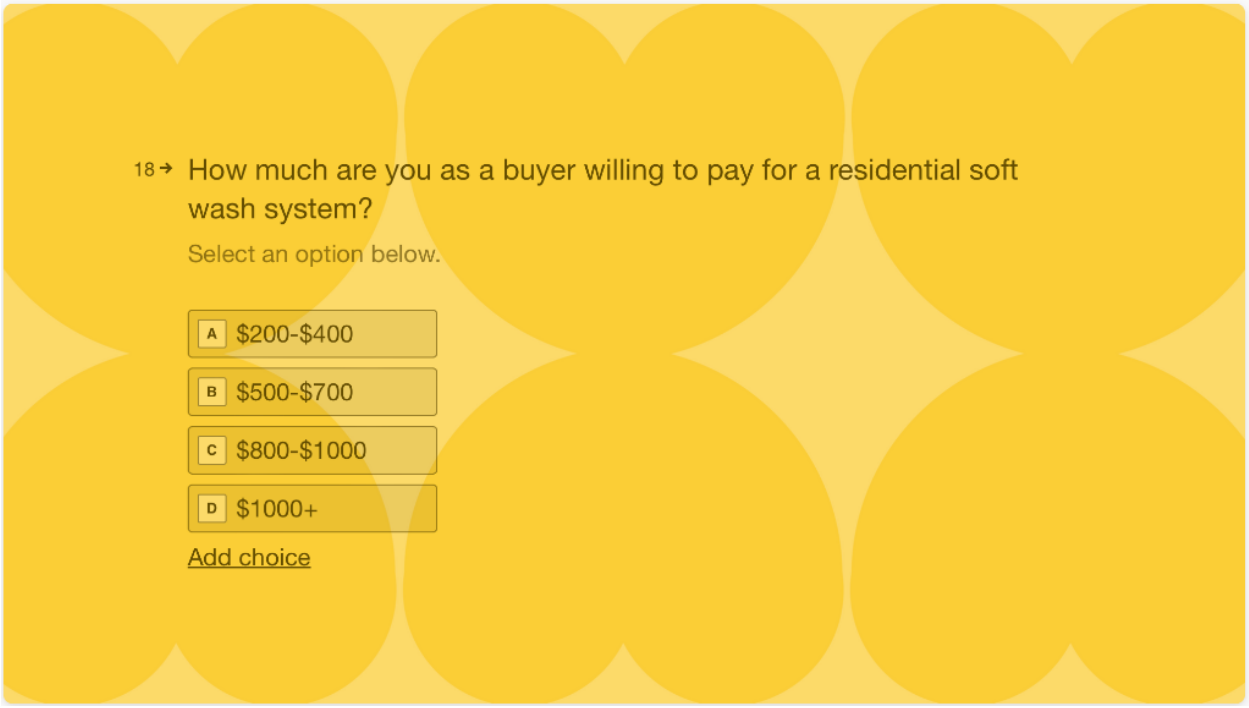
Please select numbering below 1 = Very Unsatisfied & 10 = Very Satisfied

0	1	2	3	4	5	6	7	8	9	10

17 → Size and weight of the system.

Please select numbering below 1 = Very Unsatisfied & 10 = Very Satisfied

0	1	2	3	4	5	6	7	8	9	10



Customer Features

Ease of Solution Mixing

Ease of Operation

User Safety

Cost

Efficiency

Ease of Access for Supplies

Transportability

Size/Weight

Engineering Characteristics

Frame Material Selection

Plumbing Material Selection

Type of Pump

Drivetrain Motor

Solution Holding Tanks

Material Joining

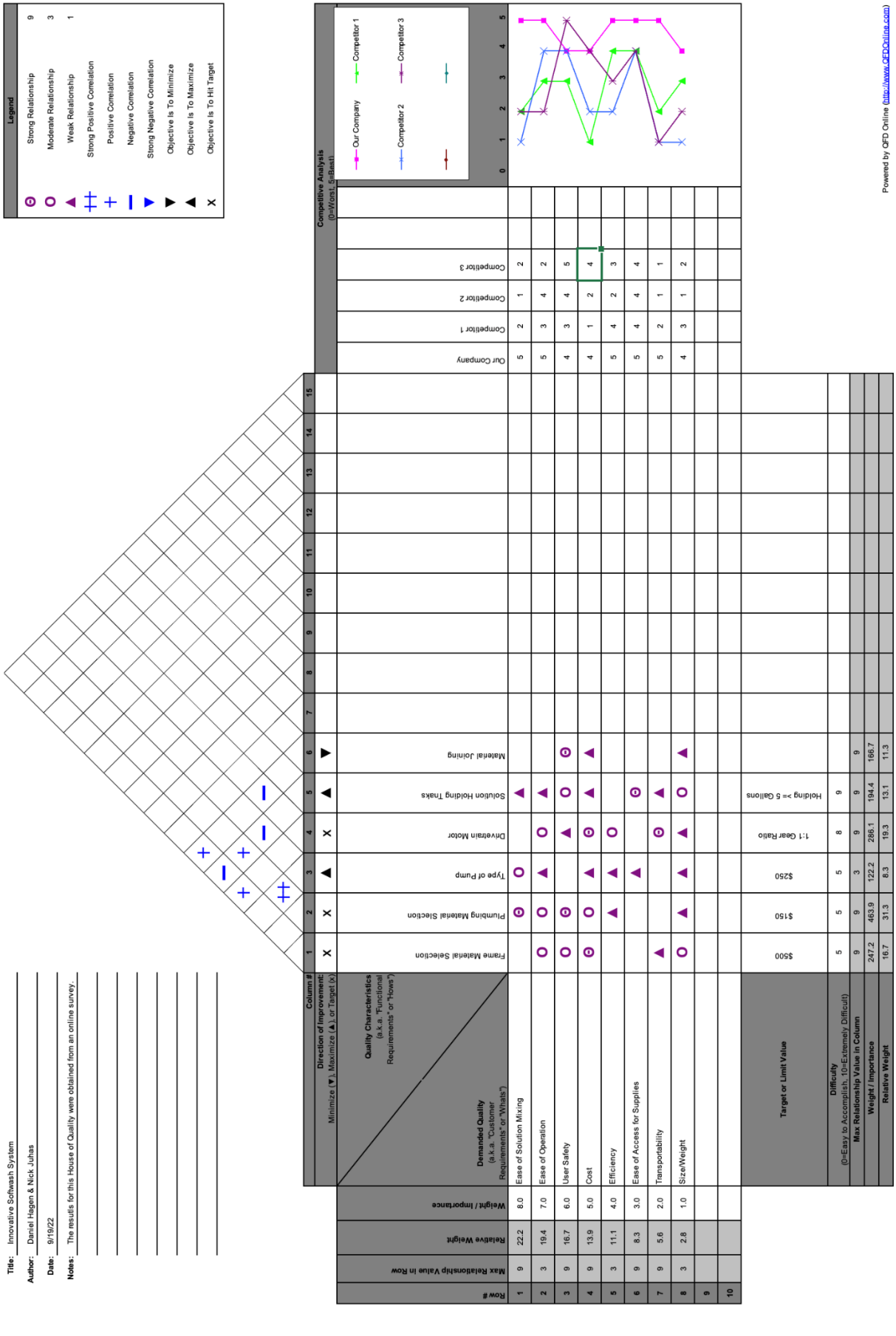
House of Quality

Title: Innovative Softwash System

Author: Daniel Hagen & Nick Juhas

Date: 9/19/22

Notes: The results for this House of Quality were obtained from an online survey.



Product Objectives

Ease of Solution Mixing (22.2%)

We will use basic plumping for the manifold that will allow the user to control the solution that they are mixing.

Ease of Operation (19.4%)

We will ensure that new users will be able to operate easily and use basic switches for controls and ball valves for flow control.

User Safety (16.7%)

All welds will be grinded to ensure no sharp edges exist. All fittings will be sealed properly to ensure that no chemicals leak onto the user. All tanks will also be sealed with a safety lock.

Cost (13.9%)

We will attempt to use scrap steel to construct the frame. We will minimize the use of PVC angles and T's and use as many straight pipes as we can. We will repurpose plastic tanks.

Efficiency (11.1%)

We will ensure that the user has a manifold that will control the flow of solution that they are creating.

Ease of Access for Supplies (8.3%)

The user will have easy access to repair any plumbing that goes bad as well as to replace chemical in their tanks as needed.

Transportability (5.6%)

A 1:1 gear ratio will be used with a high output motor and throttle control system to ensure the user has ease of mobility under self-propelled power. This overall drivetrain will be able to push the system around with the user exerting little effort.

Size/Weight (2.8%)

We will use lightweight steel to ensure that the frame is sturdy but not too heavy.

Design Concepts

Frames

Concept 1:

This concept is a larger design that has a frame built as a trailer foundation. It has two axles with the back axle being fixed and the front axle being attached to a swingable tongue that rotates about a bearing. The tires are pneumatic rubber tires that measure 10 inches in diameter. These tires are meant to hold a heavier load and be pulled over a rougher terrain. This trailer is heavier and more durable, but requires more of a force to pull when it comes to the mobility. The trailer has a larger base though which allows for more space for solution holding tanks and soft wash motor design.

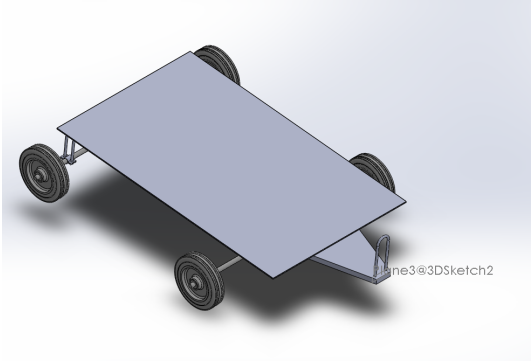


Figure (1)

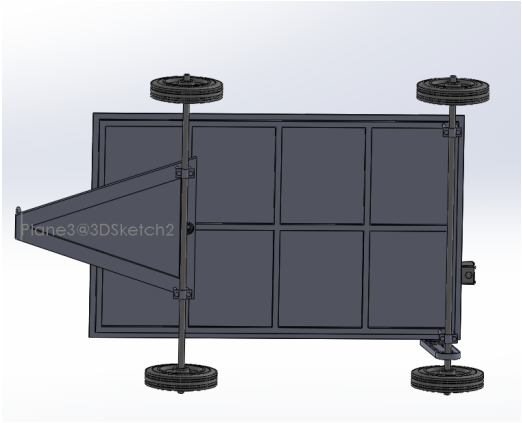


Figure (2)

Concept 2:

This concept design is built as a smaller compact material cart that allows for better mobility, but cuts down on the space available for solution holding tanks and the manifold/soft wash system to occupy. This system uses 8-inch hard rubber wheels in the rear and hard plastic 3-inch wheels in the front that are both supported by swivel mounts and break locks to unsure the cart does not move or roll when it is at rest. The cart also has a handle at ergo height for the average user that allows for a push able function that slowly moves under its own power. The only down fall is that the cart can be difficult to make sharp or quick turns with the two-wheel base in the front.

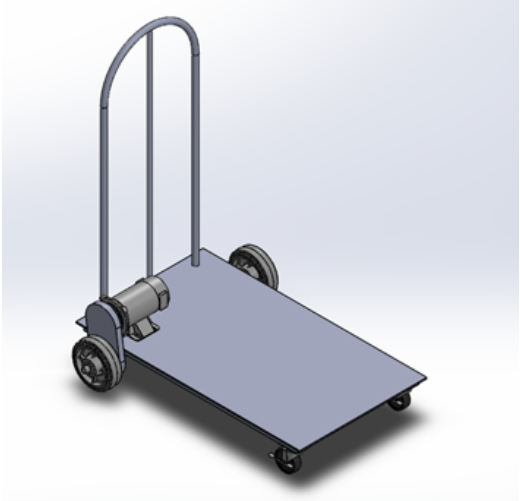


Figure (3)

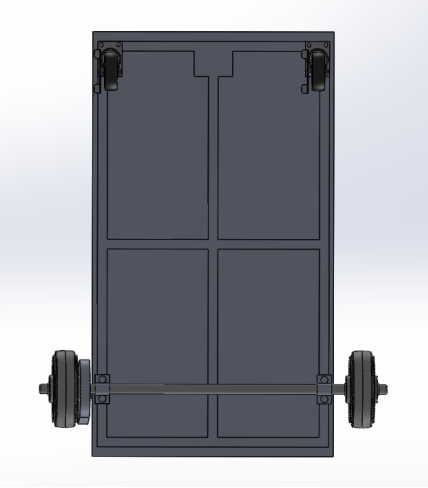


Figure (4)

Concept 3:

This concept once again utilizes the function ability of a smaller material cart. Unliked concept 2 this cart has a once 3-inch swivel wheel in the front supported by a base with the break functionality. This swivel base then interacts with a bearing that is attached to the handle to allow for easy and quick turning. The back wheels are 8-inch hard rubber wheels and are fixed to a rotating axle that will be used to drive the system. This system although has a smaller area for design functions the movability is maximized and has a light weight frame that still can support the needed materials and motors for our system.

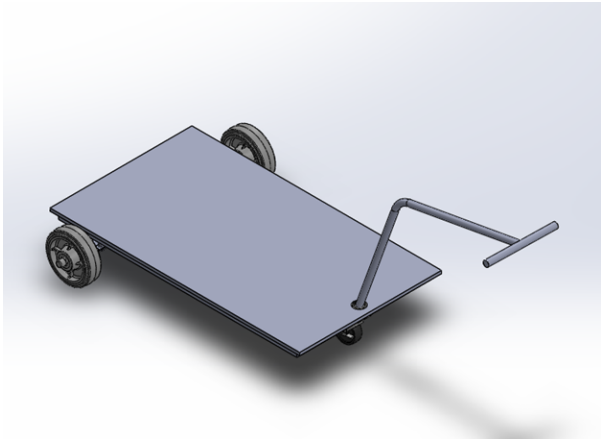


Figure (5)

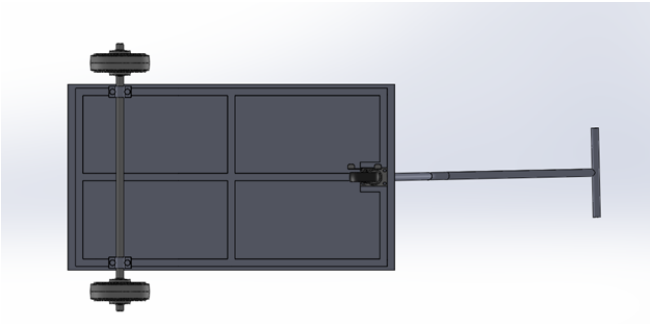


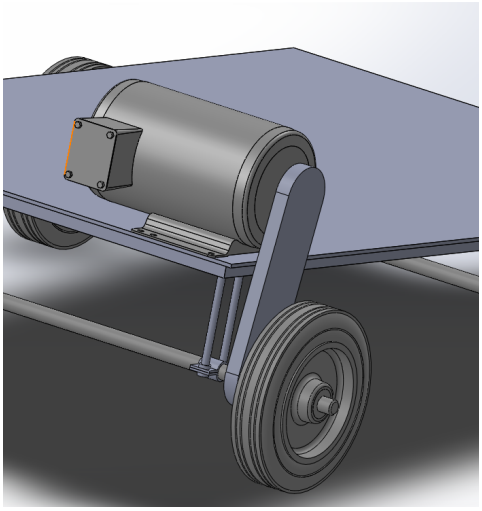
Figure (6)

Drive Trains

Concept 1/Frame 1:

This drive train design is paired with frame 1. The motor that is used has the output capacity of 10 hp gasoline motor with the gas being contained inside the motor assembly. This larger motor

is needed due to a bulkier and larger trailer style frame. With the large motor it is connected using a gear drive and chain to turn the axle directly. The chain is made out of steel to withstand a large load applied when it comes to propelling the system forward. This system will have a small throttle control that is wired in and placed by the motor itself. The throttle will allow the user to select at what speed they want the trailer to propel forward at. This is a rear axle drive system and for safety a plate guard is in place to cover the gears and chain to prevent any injuries.



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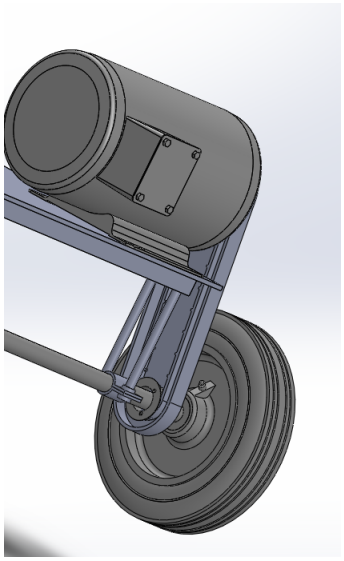
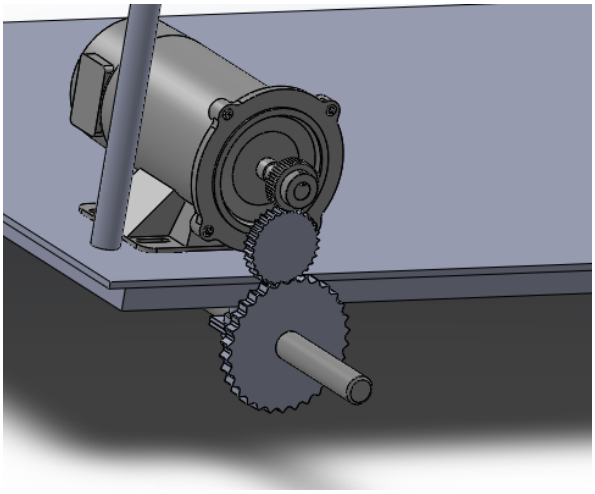


Figure (8)

Concept 2/Frame2:

Design 2 is paired with frame to which uses a much smaller DC motor that is rated for 2 HP. This system has a smaller motor assembly due to a lighter frame and smaller concept. This motor is attached to the axle by using 3 gears. The gears are then turned to rotate the gear that is directly connected to the axle propelling the system forward. Once again, a throttle system will be applied to control the speed and start/stop of the motor. This motor is run off of a small 12V battery that allows for compact power usage and also electrical capability.



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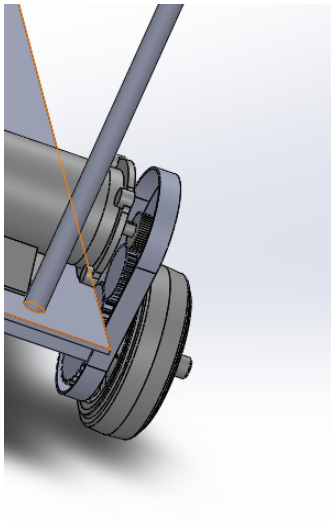
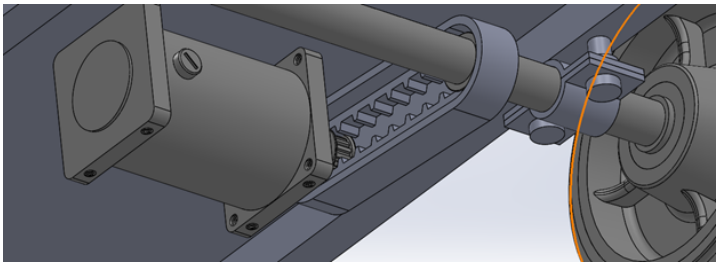


Figure (10)

Concept 3/Frame 3:

The final design is paired with frame 3. This system is driven by a high capacity 24V motor that has a driving capacity of 4 HP. This system has a larger motor, but a smaller and lighter compact frame. This will allow the system to operate almost completely on its own power. The system is attached directly to the rear axle using a drive belt. This drive belt is driven by the motor in return rotating the wheels to propel the system. This system is also controlled by a throttle system that allows for adjustment in speed which will be placed on the handle to allow the user easy access to change the speed as needed. This option also is mounted on the bottom side of the frame which conserves space and allows for the drive train to be hidden and out of sight to also increase safety and prevent injury.



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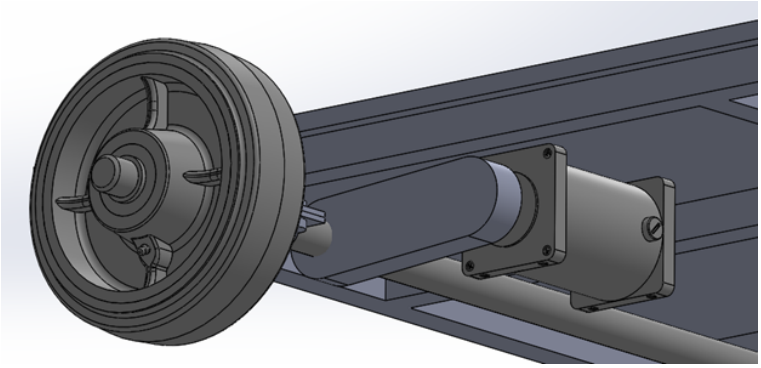


Figure (12)

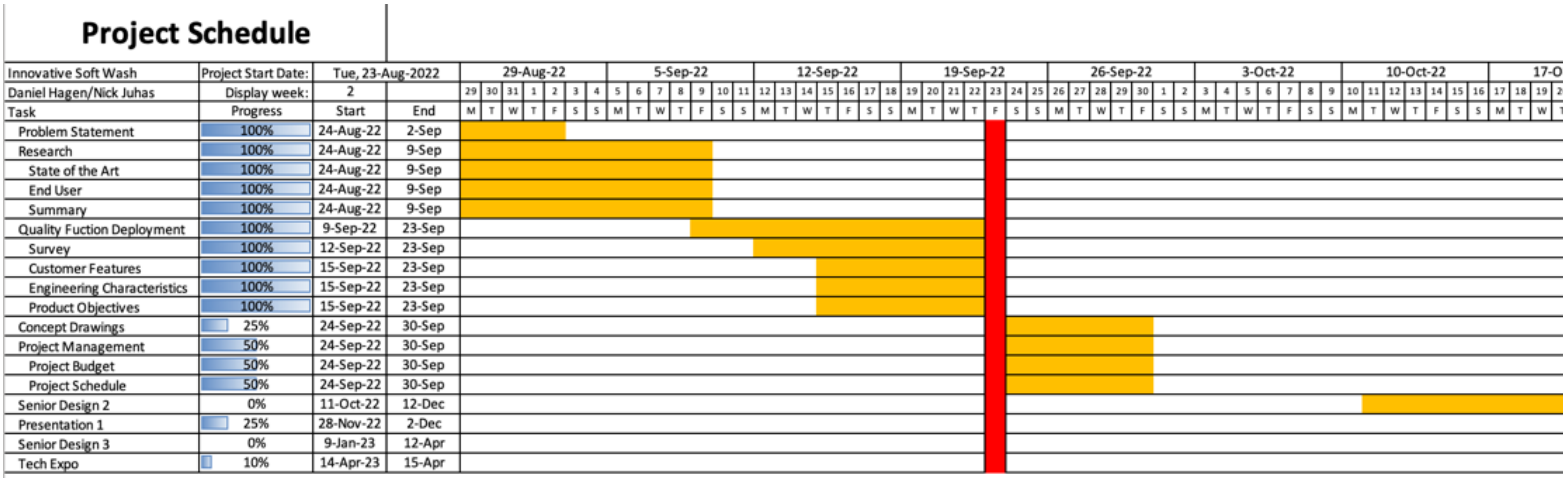
Project Budget

The below project budget is subjected to change slightly as the prices of steel and materials varying day to day in today's market. Overall, this is a rough estimate on what our budget will breakdown to when the full design and assembly of the product will be created.

Manufactured Items	Purchased Items		
Frame	24V Motor	$ 100.00	
Manifold	24"x44"x1/8" Steel Plate	$ 700.00	Varies depending on market
Drive Train	1" PVC Tubing	$ 10.00	Varies depending on market
Tank Bracket	5-gallon tanks	$ 20.00	
	Gears	$ 100.00	
	10 gallon tank	$ 50.00	
	Drive Belt	$ 25.00	
	Wheels	$ 80.00	
	Axles	$ 70.00	
	12V Deep Cycle Battery	$ 110.00	
	12V regular battery	$ 100.00	
	Ball Valves	$ 225.00	
	12V Pump	$ 200.00	
	Steering Bearing	$ 60.00	
	PVC Tees	$ 10.00	Varies depending on market
	PVC 90-degree elbows	$ 10.00	Varies depending on market
	Controls	$ 50.00	
	Rachet Straps	$ 30.00	
	Total	$1,950.00	

Project Schedule

The schedule below is based on given dates that are subjected to change. These dates are preset and could have fluctuation depending on the future of senior design 2 and 3 along with the presentation and tech expo dates. Overall, this is the highlighted areas on what we have accomplished and what is to be accomplished the rest of the year.



Product Design Changes

During this process of designing and building our project from the ground up there were a lot of things that had to be taken into consideration. One of the biggest concerns was always keeping the price of the entire design to a minimum. The price played a huge role in almost all of our design changes to keep the product in a price range that was affordable to the average consumer. The design changes will be discussed in further detail below.

Frame Design Change:

The biggest price point was the design and fabrication of our cart that would essentially hold and contain the entire system. With the constant rising and fluctuation of steel prices we decided to go with a prefabricated cart that we then could make modifications to fit our overall needs. This change would consist of eliminating the purchasing of a large steel plate and other elements such as individual axles, wheel assemblies, and handle fabrication. By using a prefabricated product, we were able to cut or frame/cart cost from $800 to $200 which is a huge savings when it comes to the final design of the system. Instead of the frame being complete solid steel the cart now utilized steel cross wiring as the base with support beams in the shape of a 2ft by 4ft rectangle. To ensure that the contents of the cart would have a solid base to rest upon a solid chemical resistant polypropylene plastic 2ft by 4ft plate was placed on top of the steel wiring and bolted down to allow for a solid base for the holding tanks, pump, batteries, and motor to be attached to. This not only cut down on the overall cost, but it also cut down on the overall weight which allowed for the drivetrain to propel the system with a lot more ease. This frame also came with complete axle, wheel, and wall assemblies that we were able to modify to benefit our design. The only downfall was that we had to change the front design from being a single swivel wheel to a two-wheel axle due to the swivel wheel being extremely high in cost and then custom bearing had to be made to support the one-wheel drive system in the front which would almost cost the entire budget of the project to just create a custom swivel wheel. By going to a two-wheel axle though in the front it also gave the cart more stability even though the turning radius would not be as sharp with a two-wheel turning system.

Drivetrain Design Change:

To follow with the axles the design change of the drivetrain was made as well. At first, we planned to use a belt drive due to creating a better connection from the axle to the motor. Once we began investigating this further though we ran into the issue of driving up the cost a lot higher than our budge could handle again. With the usage of a belt drive the belt costs are high and being able to find the correct glue that would hold under the subjected pressure that the belt would be subjected to was extremely difficult and costly. With this being said we then could not cut the belt to a desired length to provide proper tensioning on the motor sprocket. The next concern with the belt as well was the sprockets to match up with a toothed belt were high in cost as well running around $35 for the proper sprocket versus the standard bike sprocket with a cost of $8. Finally, the last concern with the belt was that with the through axle we used by drilling out the axle supports in the prefabricated frame. This axle was a cold rolled rod that was cut to length and was connected to the wheel to drive the system. Knowing this we decided to go with a standard bike chain and standard sprockets cutting the overall connection of the drive train cost from $200 to $40 which is another large cost savings. The bike sprockets were welded to the 24V DC motor and the cold rolled steel axle to then allow for use to remove the needed chain links to provide proper tensioning to the system to eliminate as much slipping of the driving chain as possible and the standard metal chain was rated for much higher of a tension force that it would be subjected to meaning that the potential for a fracture in the chain was very low unlike the potential for a fracture in a belt was extremely high. All of this consideration is why we decided to change our design and go with a chain drive.

Product Testing

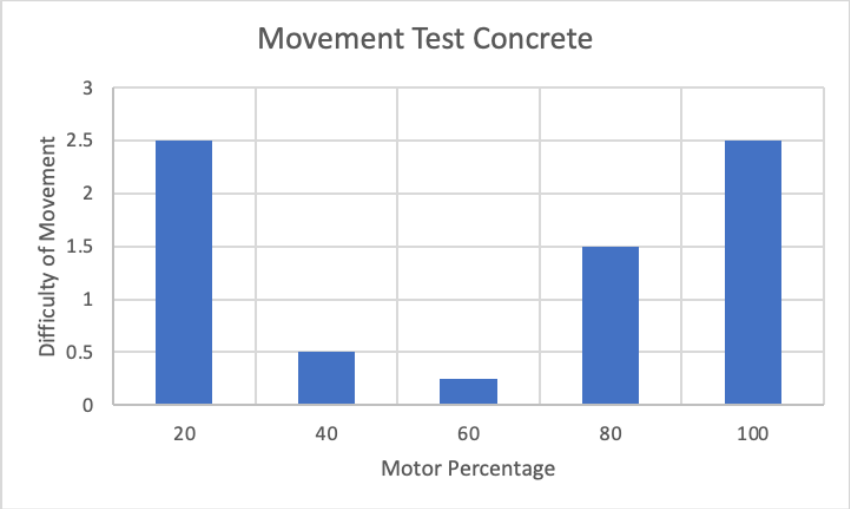
When it came to testing our design and see how well it performed after it had been fully assembled there were two can concepts that we needed to focus the testing around. The two concepts that the testing was focused on was how well the soft wash part of the system would clean a dirty surface that had been out in the weather and elements for years, along with how well the drivetrain portion of the design would move the system forward or backwards.

Drivetrain Testing:

To test the drivetrain section of our project we focused the testing on how much the operator would have to pull the cart to make the cart move to the desired location. When testing this the 24V DC motor was able to be incremented in increments of 10% up to 100% power. When testing this we placed the cart on concrete, grass, gravel, and uneven surfaces. When testing the cart on the varying surfaces we then were able to rate the difficulty on moving the entire cart on a scale of 1 to 5 with 1 being an easy movement and 5 being a difficult movement. When running the test, we were able to come to the results that operating the motor between 40% and 60% power which can be seen below in the figures below provided the best overall results. These results were the best overall due to the system being propelled slowly at a typical walking pace of an operator. If the motor power was less than 40% the cart would not propel itself forward and would require the operator to pull with excessive force to move the cart in the direction that it needed to go. If the speed of the motor was above the 60% threshold, then the cart would either be propelled too fast, subjected to spinning the tires and losing traction, or the potential of the chain drive coming off due to the sprockets rotating at too high of a speed. With all of this being taken into consideration the overall best results were between the 40% and 60% range for the motor speed due to the operator would have to apply little to know pulling force to move the cart to the desired location, the motor speed would not cause traction slipping or loss due to the axle spinning at a slower rate, and finally the chain/sprocket connection was not subjected to high speeds so that the chain did not slip or have any concerns in that area.

Movement Test Concrete					
Motor %	20	40	60	80	100
Difficulty of Movement	2.5	0.5	0.25	1.5	2.5
1 Easy - 5 Hard					

(Figure 13)

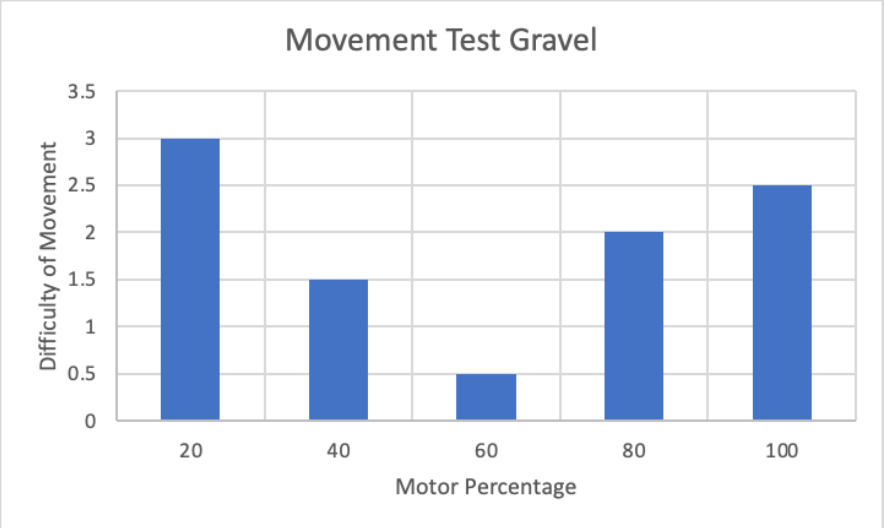


(Figure 14)

(Figure15)

Movement Test Gravel					
Motor %	20	40	60	80	100
Difficulty of Movement	3	1.5	0.5	1.5	2.5
1 Easy - 5 Hard					

(Figure 16)

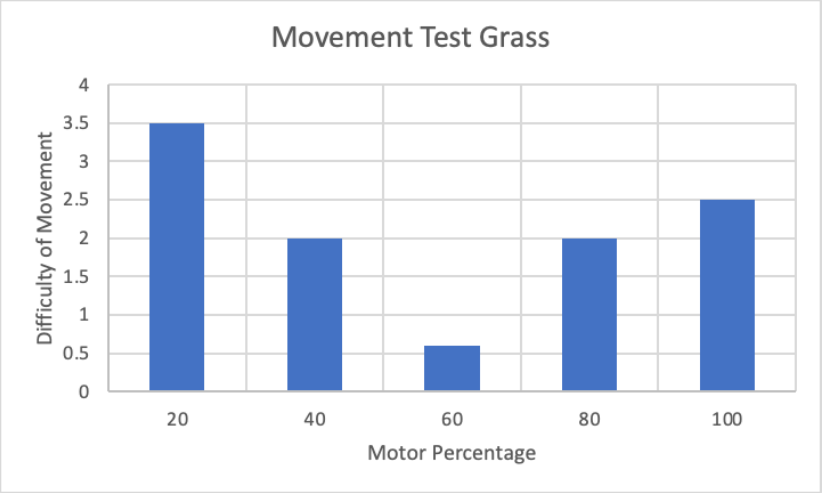


(Figure 17)

(Figure 18)

Movement Test Grass					
Motor %	20	40	60	80	100
Difficulty of Movement	3.5	2	0.6	2	2.5
1 Easy - 5 Hard					

(Figure 19)

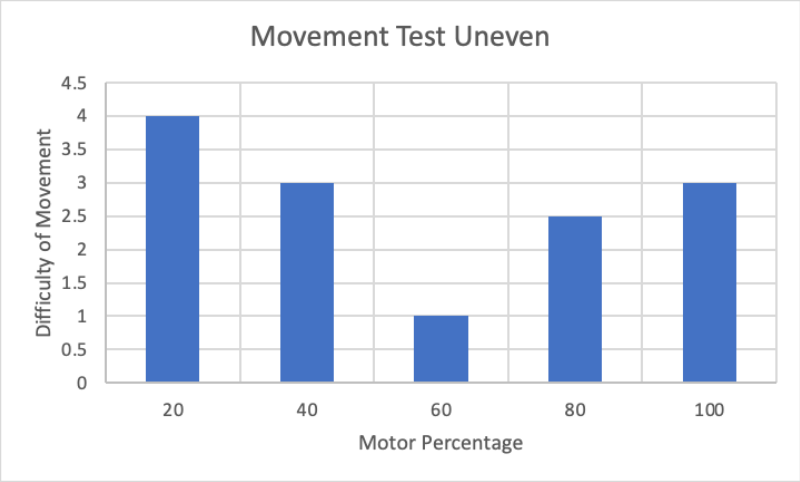


(Figure 20)

(Figure 21)

Movement Test Uneven					
Motor %	20	40	60	80	100
Difficulty of Movement	4	3	1	2.5	3
1 Easy - 5 Hard					

(Figure 22)



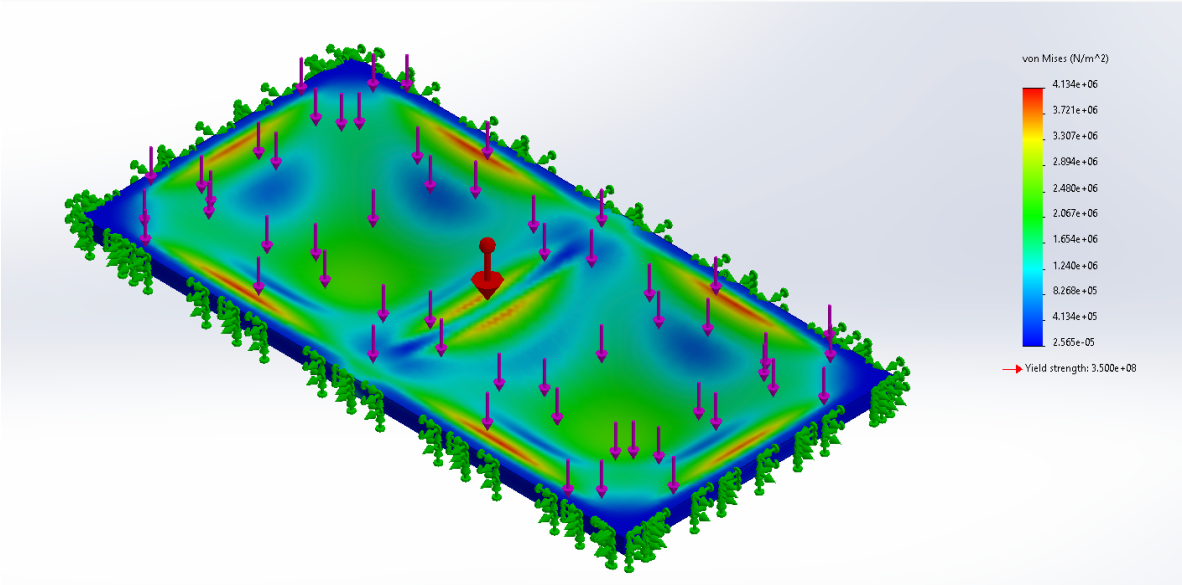
(Figure 23)

(Figure 24)

Frame Testing:

During this process the only frame test that was performed was a FEA analysis on the overall frame in itself. This was based off when the cart is fully loaded the weight from the liquids and batteries would be around 250 lbs. The cart showed that it would hold well over that weight meaning that our components would be safe to rest on top of and be carried using the cart design. Once we assembled everything and fully loaded the cart, we put a 500 lb load in it for 8 hours and the cart showed no signs of deformation and failure in any of its components (axles, wheels, bearings, base plate, etc.). As a whole this proves our FEA analysis to be correct and that the user

does not have to worry regarding any frame failures due to weight of the components placed on top of the system.



(Figure 25)

Overall Recommendations/Changes

Throughout any engineering process or design after the first overall prototype is fully built and assembled there are always changes or improvements that can be made to the system as a whole. No design process is ever perfect the initial time that it is created. During this design process of creating our innovative soft wash system there are a lot of things that went right and worked out to benefit the system as a whole and there were many things that also could have been approved on for future design revisions. The sections to follow will cover the main recommendations and changes that we would pursue in the future if we were to revise our design for a manufacturing stand point.

Frame Recommendations:

During the design process of the frame/cart some design changes were made to allow for cost savings. As a whole the design of the cart in the end worked out great for our system to carrying and enclose all of the components. A few changes that would potentially be considered in the

future would be the overall size of the cart and the axle types of the cart. The overall size for potential manufacturing of our product we would like to cut down on the length by a foot and go from a 2ft by 4ft frame to a 2ft by 3ft frame. This would allow for easier shipping of the product and be able to contain a lot of components in a smaller space which also allows for potential savings again using less material for a smaller and more compact design. This could be done due to the point that we have extra room for more storage that is available on the cart which that extra room could be minimized and make the system easier to store and transport. Next, we would, change the rear axle design by adding bearings into the axle versus a sleeve that allows the drive axle to rotate. By adding bearings, it would allow for a more smooth and free spinning axle to drive the system and not produce any friction. The sleeves that are currently in place can cause a buildup of friction putting extra resistance on the motor that is not needed if the sleeves are not thoroughly greased. Also, by adding the bearings it would eliminate not only the friction but also having to apply a lubricant or grease to the axle to ensure that it is constantly free spinning.

Drive Train Recommendations:

Looking into the aspect of the drive train as mentioned in the design change section of the paper we had to change the drive system from a pulley to a chain drive due to issues with potential pulley fracture and slipping on the system. Also, by changing to a chain driven system we were able to have cost savings as well. With this all being said we could change a few things about the system in itself though we would use a higher-grade steel for the sprocket and also increase the sprocket size on the axle, then a proper chain tensioner would be used as well. The reasoning to use a higher-grade steel sprocket and increase the sprocket size is to decrease the potential in deformation due to welding the sprocket to the axle and increase chain tensioning. The decrease in deformation would be less in a larger size and higher-grade steel sprocket because the teeth are farther away from the heating zone along with it would take a greater amount of heat to cause a deformation in a higher-grade steel. A larger sprocket would also cause more contact for the chain and be less likely to slip or miss a tooth as the motor drives the system forwards or backwards. To follow the more contact of the chain on a larger sprocket if we had a proper tensioning tool, we could tension the chain and ensure that both sides of the system had proper tensioning of the chain on the sprockets to prevent any slipping. Currently with the chain

tensioned using a basic tensioner and the smaller sprockets at high speeds the chain tends to slip periodically and even has the potential of coming off of the drive system. So, by doing the recommended steps we could eliminate this issue in future design revisions.

Conclusion

Through this entire year and process of designing and creating a new system a lot was learned from aspects of design to how we individually process things to find a solution to an issue that arises. Being able to investigate, calculate, and design a product from the ground up was a huge impact and truly an enjoyment during my senior year that allowed me to understand what I really want to pursue when moving on from college. The design process and calculations were the aspect of the project that was the most challenging for me, but as for the research and development aspect I truly enjoyed and thrived in that element of the project. This was able to show me that I would prefer to be on the actual manufacturing and troubleshooting side of a business versus the design side. Overall, our project and design turned out the way we projected it to even though there were some unexpected issues and design changes we were able to create a fully developed product that met all of our requirements and expectations. As a group we were also able to sit down and analyze what areas we would have done differently and what areas we believed we succeeded in. This project allowed us to grow as seniors and greatly benefitted us as we move from the college atmosphere into the vast world of engineering!

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