Powered Utility Cart

Senior Design Proposal submitted to the
Department of Mechanical and Materials Engineering
College of Engineering and Applied Science
University of Cincinnati

in partial fulfillment of the
requirements for the degree of

Bachelor of Science

in Mechanical Engineering Technology

by

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Problem Statement

In today's large volume industries time is money. Opportunity is frequently lost to waiting for personnel, supplies, and or a critical item. There are many automated solutions that assist the handling of products to save time, but these solutions often have large up-front investments and require initial integration into the facility layout and design. Many facilities operate 24 hours a day and 7 days a week; the labor's shifts are usually 8 or 12 hours. The fast pace and hours working bring fatigue to many workers. This creates a sluggish performance of tasks, increasing time and wasting money.

We are proposing an assistive drive system that will retrofit to many standard utility carts. This will decrease fatigue of pushing these carts, which are heavily used in large scale facilities. Decreasing lost time and improving the moral of tired workers are just a couple of the potential benefits of the proposed solution. Safety measures are to be included in the final deliverable conforming to OSHA regulations. This will decrease injury and absenteeism among staff due to fatigue of operating carts that are heavily loaded. Funding is to come from sponsorship and personal backing.

Research

Background of the Problem

In today's manufacturing and logistics industries, there is little to no room for otherwise preventable downtime. Every minute that passes, millions of dollars in products are manufactured, assembled, received, and/or shipped in facilities across the globe. Products that are either distributed or manufactured are dependant on quick turn-around times to meet goals and deadlines specified by company and customer demand. A high-efficiency operation of any maintenance staff, trade, or service staff is critical for optimum performance of a facility. The costs of maintenance, estimated to be between 15 and 40 percent of production costs (Dunn, 1987) (Löfsten, H. 1999), and the trend toward automation has forced managers to pay more attention to maintenance. Managers have figured out (Sheu and Krajewski, 1994) (Löfsten, H. 1999), that maintenance, with its high cost and low efficiency, is one of the last cost-saving frontiers in management. Due to the high costs of unplanned production downtime, managers and maintenance crews always must be trained to think that downtime is lost time. Traditionally, there are two primary approaches. The objective of preventive maintenance is to reduce the probability of failure in the time period after maintenance has been applied. Another is corrective maintenance, which strives to reduce the severity of equipment failures once they occur. In general, in order to maintain the probability of a specific performance level, two types of policies have been proposed (Corder, 1976) (Löfsten, H. 1999).

Manufacturing facilities & distribution centers may be different in their specific purpose. Every building is unique and operates in a variety of different ways. However, they are similar in one very striking way; pure scale. Due to the size of these facilities personnel can average walking 10-15 miles every single day during a shift. Ergonomically, this is straining on employees. Increasing efforts to find innovative solutions that can minimize the physical burden within a single shift. These efforts are targeted to decrease doctor visits, medical expenses on the company's behalf and or downtime to absenteeism. We are addressing this issue for a few reasons. One of which being to address ergonomic concerns generated in facilities nationwide. It is not only a concern for those who do push these carts around daily, but also for facility management. If this does not get addressed, companies can stand to pay millions of dollars each year to expensive surgeries and worker compensation for a problem that could have been addressed sooner.

There are currently turnkey solutions that end users have at their disposal. Many are automated solution carts, however, they can be extremely expensive. Current market options that have been explored also do not offer a retrofittable solution that can attach to the bottom of existing carts. Due to heavy capital burden, end users can be hesitant to buy these carts because they have to invest a considerable more amount of capital to purchase powered utility carts. End users that are looking to incorporate powered utility carts also have to address the replacement of existing non-powered carts. This is why we would like to offer to the market a retrofittable solution that can attach to existing carts at a considerably lower cost than buying the full turnkey solutions that are available today to end users.

State of the Art

One of the most (in-use) products on the market today is similar to the *Rubbermaid Commercial Heavy Duty 2 Shelf Utility Cart.* This cart features a semi-sturdy plastic design that can support up to 500 lbs. The cart rolls on 5" castors. This cart can be used in any application but it primarily used in large scale facilities for maintenance. This cart is nonpowered and does not support any addable or retrofittable solutions in the market today.

Another example of (in-use) products on the market today do offer driven assisted solutions. One of which is the ToolCaddy. This cart is a turn-key solution product that has features of the welded sheet steel frame, durable Rubbermaid dual shelf cart, high tech speed controller, neutral throttle braking, variable speed twist grip, battery discharge indicator and more. Added features can include a safety horn, foam filled non-marking tires, emergency stop switch, maintenance-free batteries, and a ride-on sulky.

Other variants exist on the market that has a scissor lift option and also walled cart options. These all include the features from above and sometimes more. All offer the customer features of reducing risk to users, increased productivity and improved efficiency.

These are the only current market options available on the market today through our research.

Focus System: Drive System

In the market today there are several options for powered assisted carts. These options majorities use a motor and gear set to transmit power parallel to the drive axle. There are few designs that use a motor and worm drive gear set to power the drive axle perpendicularly. The worm gear design is not utilized heavily due to manufacturing costs and speed restrictions. The drive systems that can be used for the assistive powered carts are a chain, belt, gear, hydraulic, and pneumatic. Each of these drive systems poses benefits and drawbacks respectively. Chains are able to carry heavy loads and are durable over long periods of time if properly maintained. Chains, when a failure occurs it can damage other components. Belts come in a variety of sizes and dimensions allowing many options when in the design phase. Belts wear out eventually but are quiet and maintenance free during their life cycle. Gears can be contained in a sealed box and submerged in oil. This prevents dirt wear, contains and protects the drive system. Gears do require maintenance and must be properly lubricated to run efficiently. Hydraulic drive systems are very powerful and effective at moving heavy loads, but units are often large and require an engine to pressurize the system. Pneumatics are a compact, but lower energy drive system to hydraulic. Pneumatics still requires compressed air tanks or a compressor to operate, these items can be bulky to generate enough power.

There are power systems that allow high power output, but many are hazardous or bulky. The power system that provides the most efficient design is electric motors and batteries. This system is compact, programmable, and robust. Gas and diesel engines have many requirements and this ultimately makes them bulky and not ideal for an assisted cart.

End User

The end user of this product are companies that utilize manual utility carts that could be with our solution. End users that would purchase this product would be seeking to ease the fatigue of the material handlers who use manual carts daily. Even more so, the material handlers specifically required to move heavier objects that exceed labor’s manual carrying capacity who transverse long distances. The current solutions for fatigue reduction are fully assembled carts that are bulky and cumbersome. The solutions are also not cost efficient for many companies due to the large initial and ongoing investment costs associated with those who already use manual carts. This creates a demand for a device that can be retrofitted onto existing manual carts.

Summary of Research

In conclusion to the research of the customer, current market, an issue to be addressed we know, a considerable amount more. The knowledge gained is that the end user requires a cost-efficient solution and possess the ability to be retrofitted to standard utility carts that companies already use. Features of the solution must contain: safe operation for the operator and bystanders of the cart, long runtime from a sleek compact solution that fits under the utility cart neatly, and a low knowledge requirement for use (this includes charging, operation, and safety alerts).

Quality Function Deployment

Customer Features

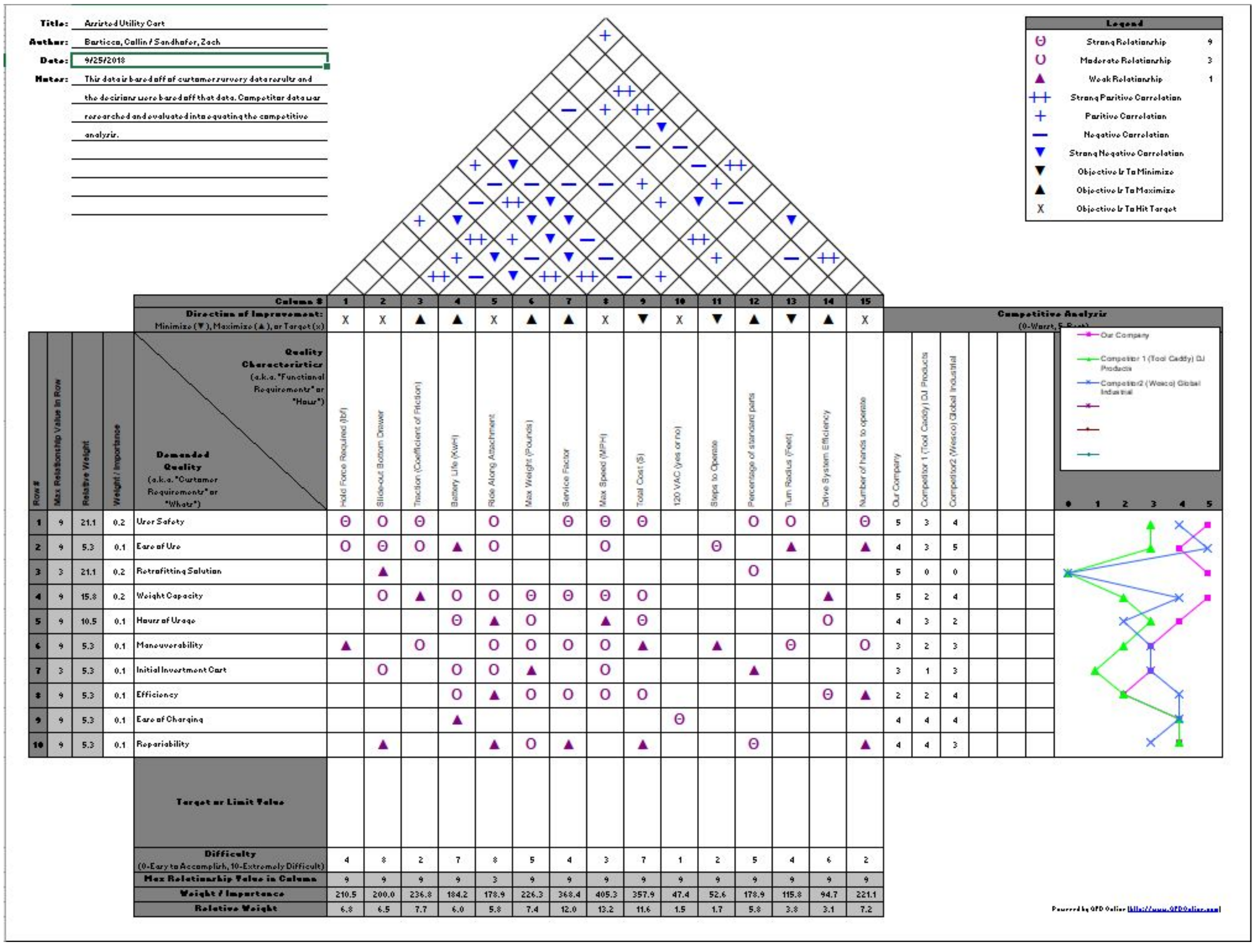
In order of importance from the collected data of our surveys:

1. User Safety
2. Weight Capacity
3. Repairability
4. Ease of Use
5. Hours of Usage
6. Retrofitting Solution
7. Ease of Charging
8. Initial Investment Cost
9. Maneuverability
10. Efficiency

Engineering Characteristics

1. Hold force required
2. Slide-out Bottom Drawer
3. Traction
4. Battery Life
5. Ride Along Attachment
6. Max Weight
7. Service Factor
8. Max Speed
9. Total Cost
10. 120 VAC
11. Steps to Operation
12. Percentage of standard parts
13. Turn Radius
14. Drive System Efficiency
15. Number of hands to operate

House of Quality



Title: Assisted Utility Cart

Author: Barticca, Collin / Sandhofer, Zach

Date: 9/25/2018

Notes: This data is based off of customer survey data results and the decisions were based off that data. Competitor data was researched and evaluated into equating the competitive analysis.

Legend		
Θ	Strong Relationship	9
O	Moderate Relationship	3
▲	Weak Relationship	1
++	Strong Positive Correlation	
+	Positive Correlation	
−	Negative Correlation	
▼	Strong Negative Correlation	
▼	Objective Is To Minimize	
▲	Objective Is To Maximize	
X	Objective Is To Hit Target	

Row #	Max Relationship Value in Row	Relative Weight	Weight / Importance	Demanded Quality (a.k.a. "Customer Requirements" or "Whats") / Quality Characteristics (a.k.a. "Functional Requirements" or "Hows")	1 Hold Force Required (lbf)	2 Slide-out Bottom Drawer	3 Traction (Coefficient of Friction)	4 Battery Life (KwH)	5 Ride Along Attachment	6 Max Weight (Pounds)	7 Service Factor	8 Max Speed (MPH)	9 Total Cost ($)	10 120 VAC (yes or no)	11 Steps to Operate	12 Percentage of standard parts	13 Turn Radius (Feet)	14 Drive System Efficiency	15 Number of hands to operate	Our Company	Competitor 1 (Tool Caddy) DJ Products	Competitor2 (Wesco) Global Industrial
				Direction of Improvement: Minimize (▼), Maximize (▲), or Target (x)	X	X	▲	▲	X	▲	▲	X	▼	X	▼	▲	▼	▲	X			
1	9	21.1	0.2	User Safety	Θ	O	Θ		O		Θ	Θ	Θ			O	O		Θ	5	3	4
2	9	5.3	0.1	Ease of Use	O	Θ	O	▲	O			O			Θ		▲		▲	4	3	5
3	3	21.1	0.2	Retrofitting Solution		▲										O				5	0	0
4	9	15.8	0.2	Weight Capacity		O	▲	O	O	Θ	Θ	Θ	O					▲		5	2	4
5	9	10.5	0.1	Hours of Usage				Θ	▲	O		▲	Θ					O		4	3	2
6	9	5.3	0.1	Manoeuverability	▲		O		O	O	O	O	▲		▲		Θ		O	3	2	3
7	3	5.3	0.1	Initial Investment Cost		O		O	O	▲		O				▲				3	1	3
8	9	5.3	0.1	Efficiency				O	▲	O	O	O	O					Θ	▲	2	2	4
9	9	5.3	0.1	Ease of Charging				▲						Θ						4	4	4
10	9	5.3	0.1	Repariability		▲			▲	O	▲		▲			Θ			▲	4	4	3
				Target or Limit Value																		
				Difficulty (0-Easy to Accomplish, 10-Extremely Difficult)	4	8	2	7	8	5	4	3	7	1	2	5	4	6	2			
				Max Relationship Value in Column	9	9	9	9	3	9	9	9	9	9	9	9	9	9	9			
				Weight / Importance	210.5	200.0	236.8	184.2	178.9	226.3	368.4	405.3	357.9	47.4	52.6	178.9	115.8	94.7	221.1			
				Relative Weight	6.8	6.5	7.7	6.0	5.8	7.4	12.0	13.2	11.6	1.5	1.7	5.8	3.8	3.1	7.2			

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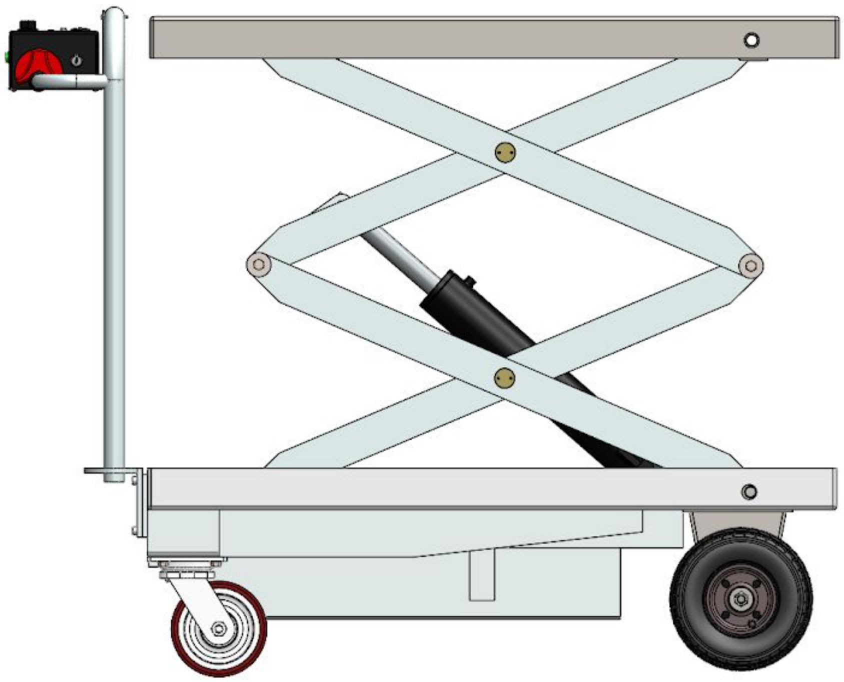
Product Objectives

Based on the data collected and the results found from our customer, the following Product Objectives were specified:

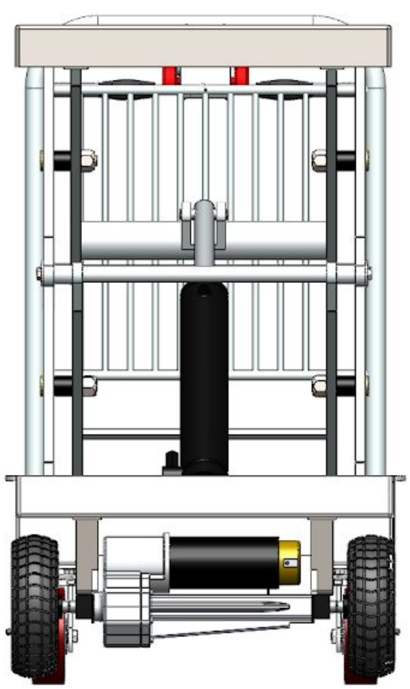
Retrofitting Solution	Weight Capacity	Hours of Usage	Maneuverability	Initial Investment Cost	Efficiency	Ease of Charging	Repairability	Overall Cost
Easily Attached	High Volume	Longer workable hours	Low turn radius	More capital for other costs	Less fatigue	Standard outlet usage	Standard Parts	Standard Parts
Standard Equipment	Robust Wheels	Less need to charge	Access to tight spots	One time purchase	Minimal maintenance required	Automatic battery charge turn off	Modular Design	Low Initial Cost
Universal Braketing	Less trips	Longer distances	Precision driving	Quick implementation	Limited Trips Needed	Battery Indicators	Easily accessible components	No integral parts required
Little time needed for assembly	Lower Fatigue	Less downtime	Stable during turns	Little to no training required	Standard parts	Charge level indicators	Low maintenance requirements	Not a full cart solution
Low investment cost	Stablility under heavy loads	Decreased maintenance costs	Tight form factor	Hassle free	Reduced utility cost	Self reeling charge port	Low voltage system	Consolidation of Tasks

Concepts Drawings

Concept 1: Side

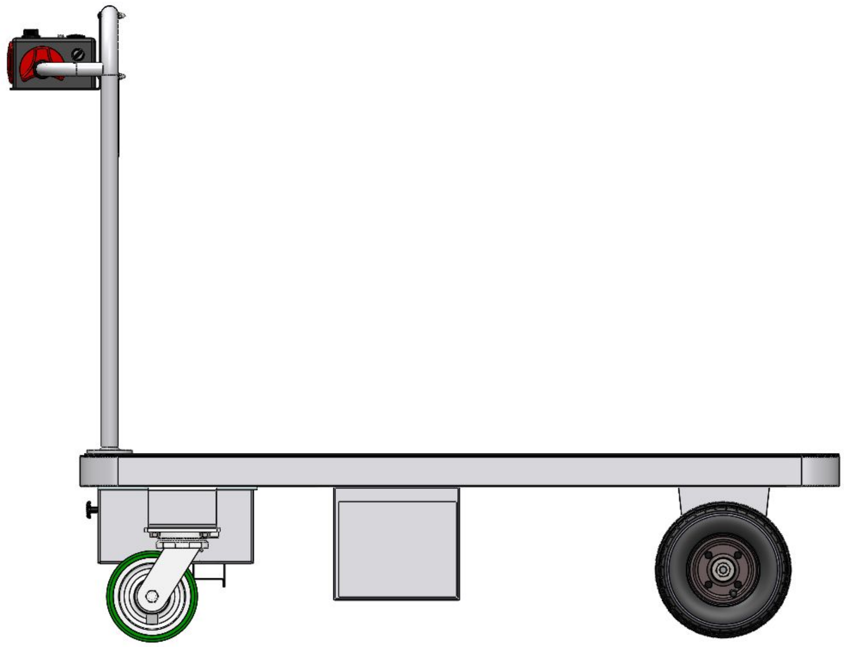


Concept 1: Front

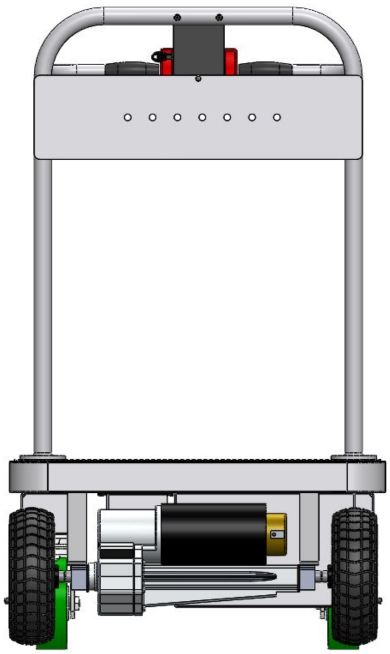


Concept 1: Top

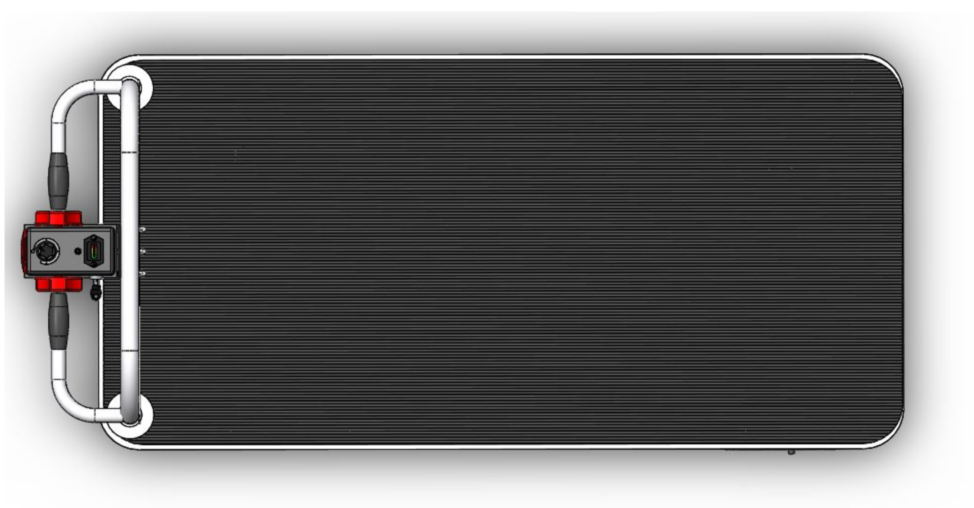
Concept 2: Side



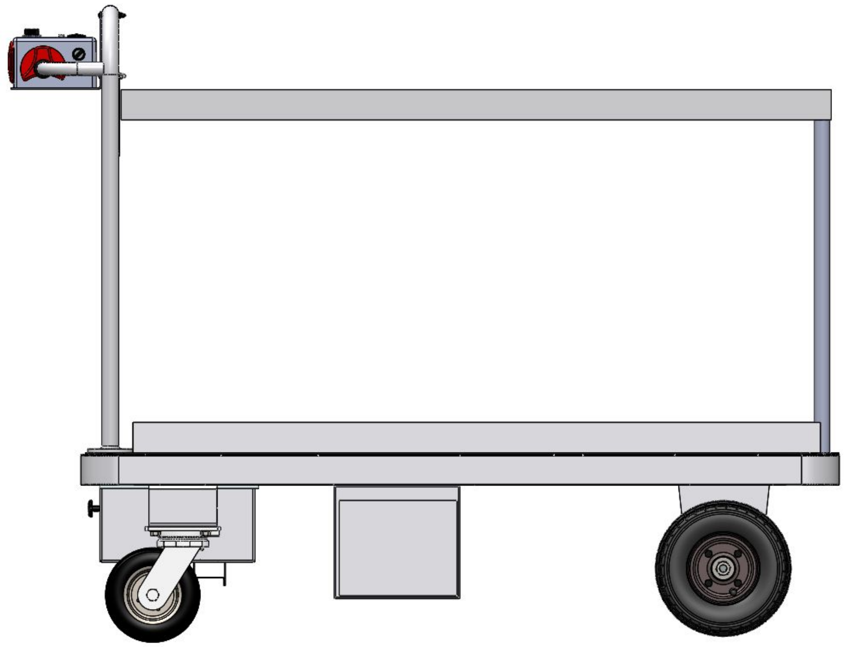
Concept 2: Front



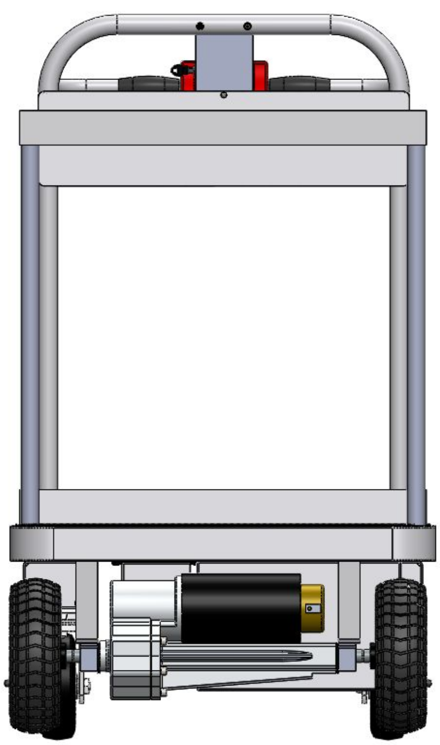
Concept 2: Top



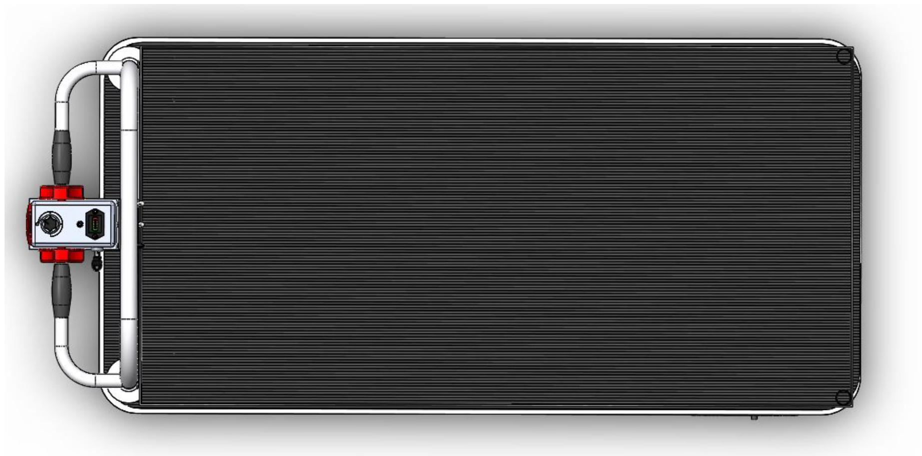
Concept 3: Side



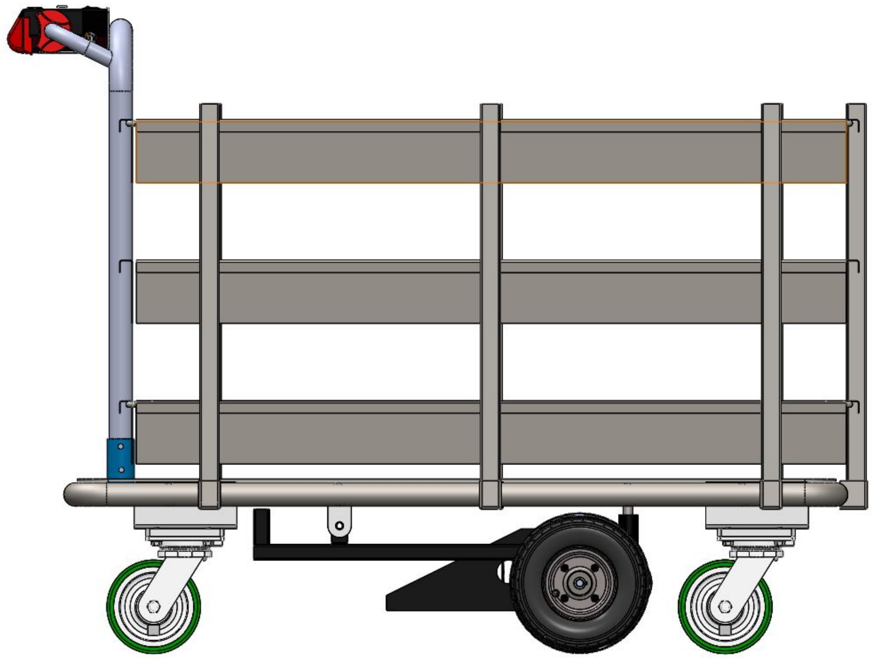
Concept 3: Front



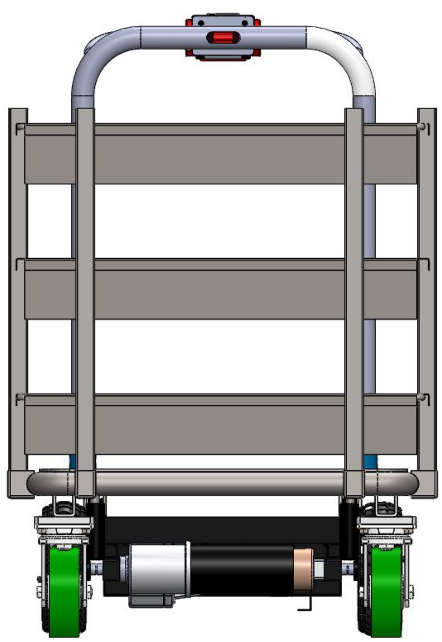
Concept 3: Top



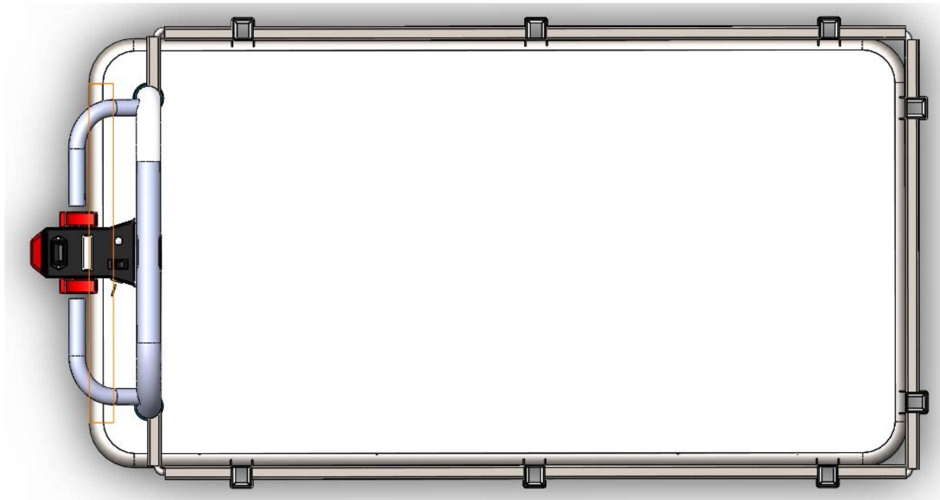
Concept 4: Side



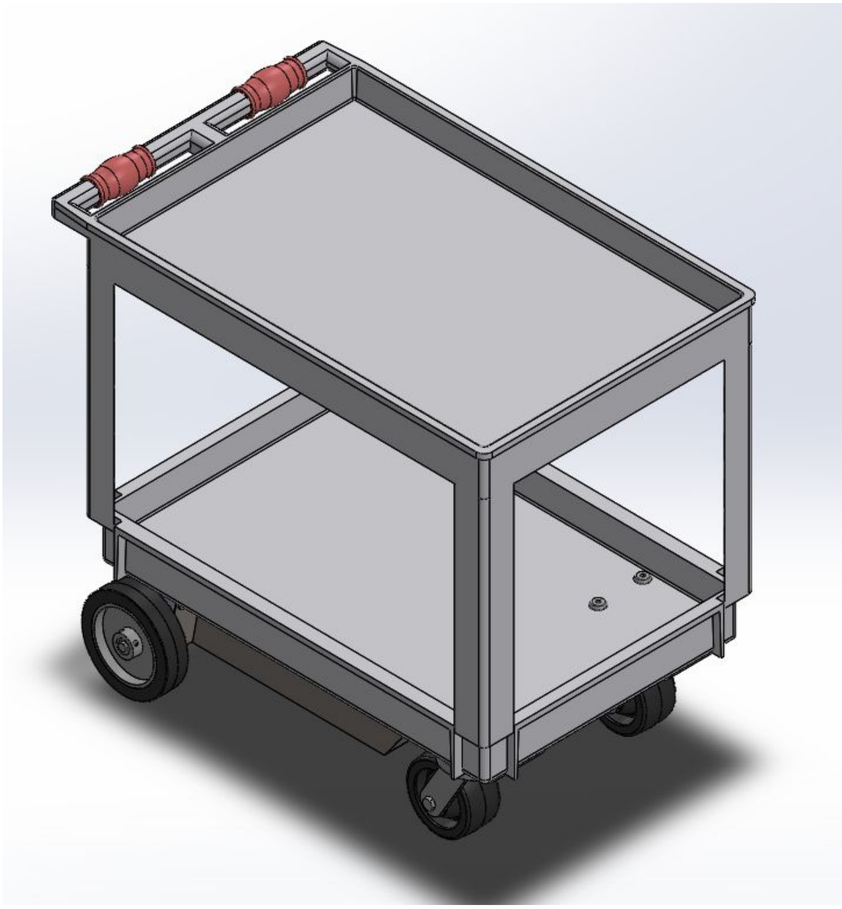
Concept 4: Front



Concept 4: Top



Concept 5: Iso-View



Design Analysis:

The Concepts Pros & Cons Comparison

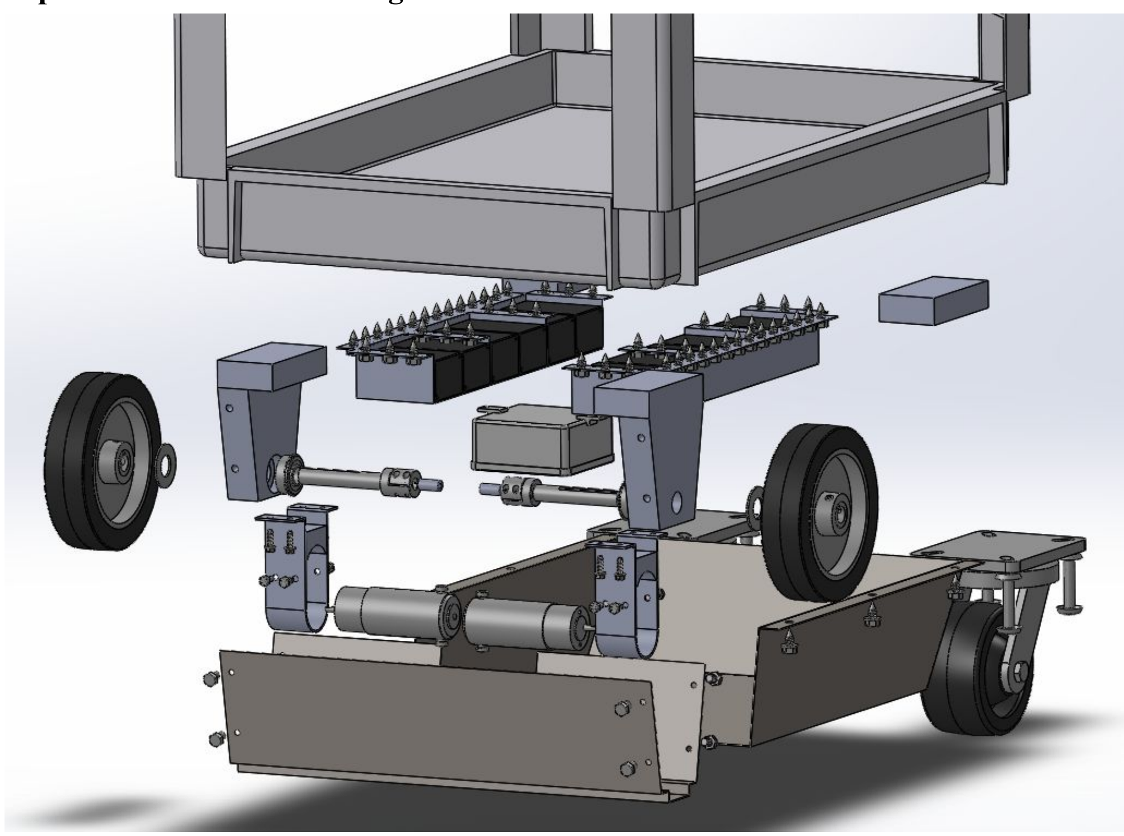
Comparison of all cart designs is important in establishing which cart will answer all of the customer requirements. A break down of all the cart concepts will also establish a project winner. There were two rounds of design concepts before a final concept was formed. This was done to ensure that all failures could be foreseen and prevented without having to revise a single concept multiple times. All design concepts were specified to carry 1000 pounds and incorporated a power pack, powertrain, and user controls. Beginning first with comparing the scissor lift table design to the overall customer requirements was the first step. It was determined that the height of the cart was adjustable and beneficial for preventing fatigue of the user. This design included a scissor lift powered by a hydraulic cylinder. This lifted a flat lipped surface from a low height to the few inches above handle height. the downfalls of this design were that it incorporated foam tires and lacked the stability of load at height. The stability is compromised due to no edging being present and the height adjustment to the center of gravity when loaded. Either the part would slide off or the entire cart would roll over due to instability in turning. The design was inclusive to a transaxle powertrain and had a overall unloaded, curb weight of approximately 250 pounds. This is a customer targeted project and this design was a very niche market, usage was limited for applications, and complexity of design was very high.

The second concept that was developed was the opposite of the Scissor Lift table design. The Collector Bin design utilized a fence like a wall that came up from the platform of the cart to several inches below the handle height. This design was to display the potential for containment of many small objects. This feature came at the price of a deep reach to access the bottom floor of the bin. This was the failure of this cart as it would increase the current user fatigue by forcing the user to always have to bend into the cart to reach objects. The collector bin design rolling mechanics were also differing by the addition of two more casters. The powertrain was pushed slightly toward the middle, from the front position that was used in the Scissor Lift Table design. This supported the potential for overloading that could come with such high walls for containment of items in the cart. The six-wheel design was highly stable at low speed, but due to the drive train being not on the leading edge of the cart, pulling the load, it would be prone to roll over at higher speeds. This was a high concern for the first customer requirement, User Safety. This design's overall weight was 300 pounds, this is a 50-pound increase from the Scissor Lift Table due to the fence like rails being steel and addition of framing for support of the moved powertrain and caster mounts. This concept included foam tires and a transaxle drivetrain. The basket/ bin is excellent for many lightweight objects, but the deep reach to access the floor of the bin is user fatigue that is mandatory for use and unacceptable by the customer requirements.

In the second round of conceptualization for solutions, two designs emerged. These designs took the information gained from the evaluation of the first round concepts. The main improvements were a load-bearing platform design to support and stabilize the load while in motion. The first concept to come out of the second round of conceptualization was a basic design, Single Flat Bed cart. This cart captured the stability at speed of a low center of gravity. High strength casters were selected and drive was located on the leading edge of the cart. The handle does not have bracing making it potentially difficult to control the cart. The second concept was a Double Flat Bed design. This design had heavy duty casters located in the read and foam tires on a transaxle drivetrain on the leading edge. This design features a two tier shelving which allows ease of loading and distributed weight. Both designs are all metal frames, this makes the design heavy and requiring of lots of fabrication.

Combining all the information gathered the comparison began to define the best design. A comparison of the designs and pro-con of each concept revealed the best features for the final design. These features were: light weight, two tray design, high strength casters, independent drive wheels, and long battery life. Fabrication of a metal cart would pose intensive labor and costs for a final design. The decision was made to create a retrofittable design that could mount to existing carts that customers already have. This lead to design of a drive train, power bank, and user controls to headline the design. The frame design is to be adjustable in the manufacturing process to enable marriage of a wide variety of standard carts in the industry.

Exploded View of Final Design



In the above diagram, the final cart selection is in its exploded view. The components can be clearly seen for all of the design. The drive wheels are attached to the drive shafts. The drive shafts are supported by the drive blocks. The drive blocked precision milled L-shaped brackets that support the back side of the cart. The drive shafts continue to the drive motors. The drive motors are supported by the motor mounts. These are machined support blocks that will hold the motors in place. Additionally, there are heavy duty casters in the front of the cart. These rest on the caster support blocks, in turn, are attached to the retrofitted cart. The battery housings are made of sheet steel reinforced to support the 8 batteries. The guarding underneath the cart is to protect the retrofitted solutions under the cart and to support aerodynamics.

Industry Codes, Specifications, Standards
(OSHA, ASME, ANSI)

Several different factors of safety are connected to this project. In order to protect the consumer from injury, there were a few codes that needed to be followed from OSHA. These being; 1910.137 Subpart I: Electrical Protective Devices, 1910.178 Subpart N: Powered Industrial Trucks, 1910.219 Subpart O: Mechanical Power-Transmission Apparatus. All of these codes were enforced to help make sure all mechanical and electrical components in the design had the safety of the consumer in mind. ASME had coded for dimensioning standards. The code enforced here was Y14.5-2009: Dimensioning and Tolerancing. This assisted to further develop the cart's drive system and develop what type of tolerancing was required to be up to code. Finally, ANSI had ANSI/ITSDF B56.1-2005 Safety Standard for Low Lift and High Lift Trucks. This standard helped in designing the cart height and what would be allowed to make sure the cart was centered balanced and could support an off-centered load.

All standards are important in designing a new product. They help to establish a baseline and to make sure all products are looking after the better interest of all of those who use them. At first, the design can be fairly far fetched, however, having standards helps to guide the product design along the way to define what is safe and what not is safe in a product.

Planned Testing and Proof of Design

The cart, once complete, will be put through a round of rigorous testing. There will be two (2) different types of tests conducted. The tests will be weighted cart time trials and loaded trials for rollover safety. First, the plan is to set a timed trial to make sure the cart is going the max speed of 3.5 mph to follow safety protocols/ standards. It will be performed under controlled settings for all tests to verify that all parameters that can be controlled will be controlled. Next, loaded trials will begin. The cart will be loaded under controlled quantities and tested for turning accuracies. The concept is to make sure the cart does not roll over and potentially hurt the user. This test will also act as a chance to fine-tune the drive speeds at which the cart may turn.

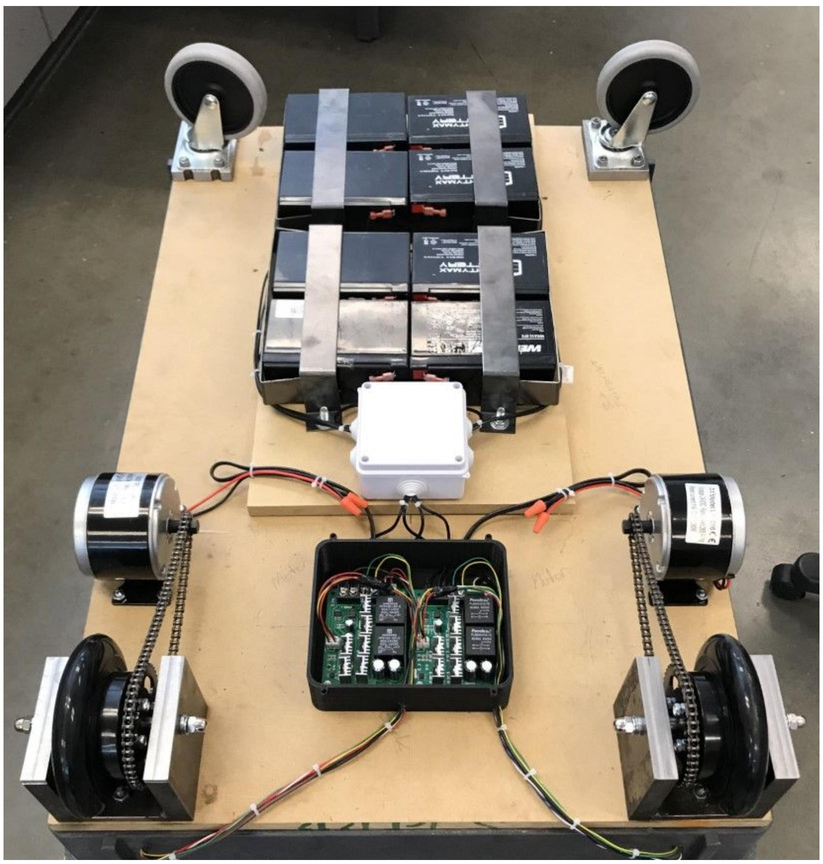
Manufacturing and Development

The cart was developed in a few steps that allowed for simplicity and to remain on schedule. These steps could be broken up into the following for overall manufacturing: battery framing, cart framing, drive support mechanism, electrical component design, and shroud. All of these components allowed for the cart structure to develop correctly and, over time, with accuracy. In the next section of discussion, it will be discussed how these steps were followed out and completely manufactured.

The battery framing began with the question, how do we maintain safety while also establishing a compact system. The original concept included a fully shrouded concept. This proved to be a very difficult concept. It was not manageable and nearly out of capability for students. Due to monetary and time constraints, the design of straps came into play. Not only did this concept help to establish that it was manageable, but it also was a cost saving and a weight savings. Merely based off of the weight of the batteries, it became apparent the cart needed to lose weight to maintain overall maneuverability. The strap concept would keep the batteries motionless while also making sure the integrity of the cart would be maintained. These straps were developed by taking mild steel and cutting it to roughly 1.5” wide. This process was done by using a sheet metal cutter. Once this was complete, the sheet metal strips were then cut using the metal cutter to the appropriate lengths. After all edges were deburred, the strips were processed using the brake. This allowed for perfect 90 degree bends. From here, the strips were

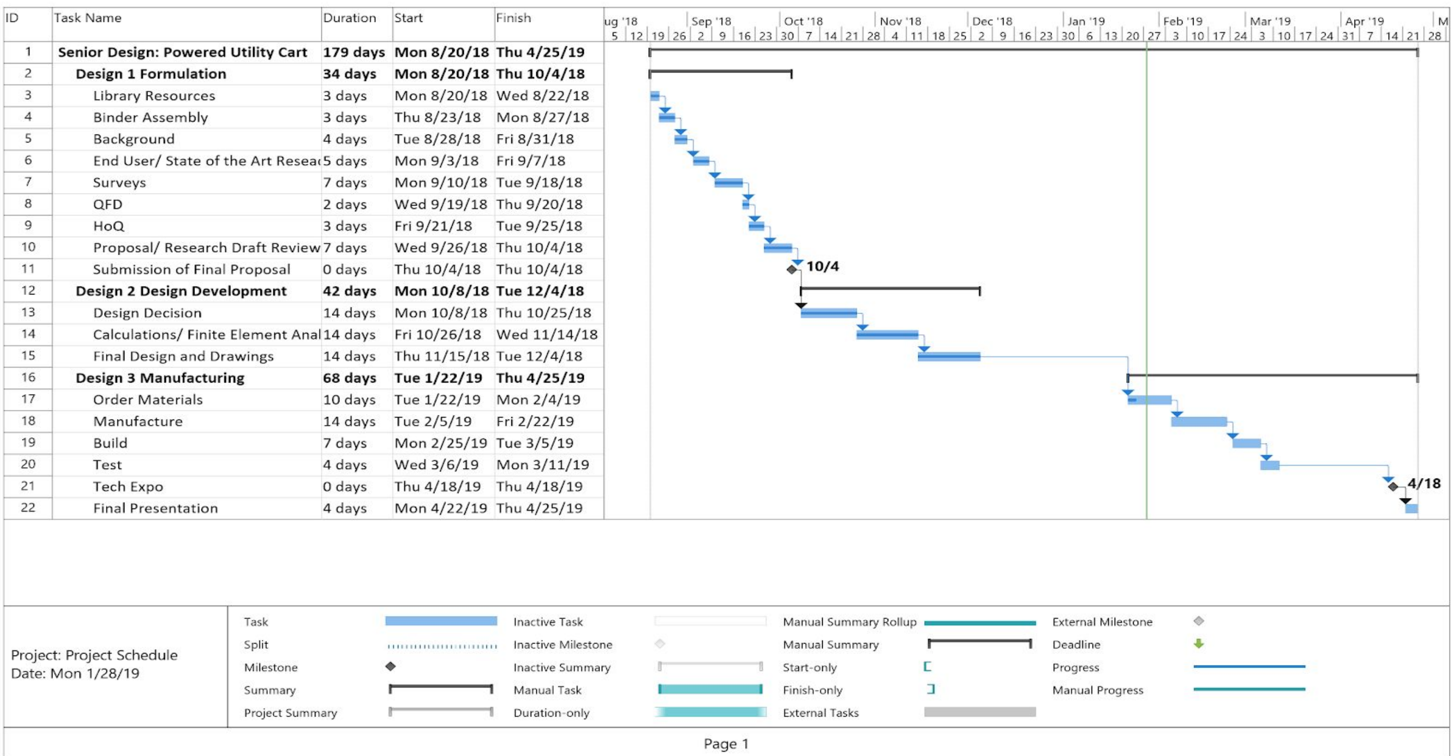
spot welded to take the shape of the final design. The process was repeated three more times. The battery framing was put together and bolted to the cart framing using through bolting.

After the battery framing was established, the cart framing and drive support mechanism could begin. This included all drive system components, and front caster positioning. First, holes were drilled into the plywood located over the original caster locations on the cart. This would help establish an easy mounting to the cart. Furthermore, helping to show that the design is retrofittable to many cart types on the market today. Next, the back support blocks could begin. The milling and machining process process began with mild steel at roughly .75” thick. Using the band saw, the support arms and base were milled to size. From here, the arms and base were welded together using the MIG machine. The machine needed a high feed rate and high current to make sure the bracings were welded together well. These mounts would be under enormous pressures from the above weight of the cart and the rest of the retrofit system. Once the mounts had rested and cured, they were then milled using the Tormach end mill. The mounts were squared up and then zeroed out to make sure we had precision holes for the wheel shafts. Once the holes were drilled for the shafts, mounting holes were drilled. This was completed using the same drill as before. 4 of these holes were tapped using a tap to allow for screw in bolts to be used. These would be the mounts for the underside of the cart. With the mounts complete, they were bolted to the cart framing. Through bolts were used, along with lag bolts. The front of the cart needed to be lifted to be level with the back. Therefore, two more pieces of mild steel were cut to size and mounted to the front of the cart. Motors were positioned based on the final mounting locations for the drive mounts. These were also through bolted to the cart framing.



Finally, the shroud process could be completed. This was done by using 16 gauge sheet metal. It was completed using three different sections. Using the brake and sheet metal cutter, the material was cut and bent to size. The pieces were then positioned to verify correct fit/placement on the cart. After this stage, the shroud was ready for welding. The spot welder was used for this application. The welds were placed in locations where the stresses would be greatest. The shroud needed some spots removed for wires to go to the motors. These were developed using the angle grinder. After the shroud was completed, it was mounted to the cart.

Project Management



ID	Task Name	Duration	Start	Finish
1	**Senior Design: Powered Utility Cart**	**179 days**	**Mon 8/20/18**	**Thu 4/25/19**
2	**Design 1 Formulation**	**34 days**	**Mon 8/20/18**	**Thu 10/4/18**
3	Library Resources	3 days	Mon 8/20/18	Wed 8/22/18
4	Binder Assembly	3 days	Thu 8/23/18	Mon 8/27/18
5	Background	4 days	Tue 8/28/18	Fri 8/31/18
6	End User/ State of the Art Resea	5 days	Mon 9/3/18	Fri 9/7/18
7	Surveys	7 days	Mon 9/10/18	Tue 9/18/18
8	QFD	2 days	Wed 9/19/18	Thu 9/20/18
9	HoQ	3 days	Fri 9/21/18	Tue 9/25/18
10	Proposal/ Research Draft Review	7 days	Wed 9/26/18	Thu 10/4/18
11	Submission of Final Proposal	0 days	Thu 10/4/18	Thu 10/4/18
12	**Design 2 Design Development**	**42 days**	**Mon 10/8/18**	**Tue 12/4/18**
13	Design Decision	14 days	Mon 10/8/18	Thu 10/25/18
14	Calculations/ Finite Element Anal	14 days	Fri 10/26/18	Wed 11/14/18
15	Final Design and Drawings	14 days	Thu 11/15/18	Tue 12/4/18
16	**Design 3 Manufacturing**	**68 days**	**Tue 1/22/19**	**Thu 4/25/19**
17	Order Materials	10 days	Tue 1/22/19	Mon 2/4/19
18	Manufacture	14 days	Tue 2/5/19	Fri 2/22/19
19	Build	7 days	Mon 2/25/19	Tue 3/5/19
20	Test	4 days	Wed 3/6/19	Mon 3/11/19
21	Tech Expo	0 days	Thu 4/18/19	Thu 4/18/19
22	Final Presentation	4 days	Mon 4/22/19	Thu 4/25/19

Key Milestones

Design I (formulation) –

Library Resources

Binder Assembly

Background

End User / State of the Art Research

Surveys

- QFD
- HoQ
- Proposal / Research Draft Review
- Submission of Final Proposal

Design II (design development) –

- Design decision
- Meet with shop technicians
- Calculations / Finite Element Analysis
- Final design and drawings
- Design Presentation – January 28th, February 1st

Design III (manufacturing) –

- Order Materials – At least 3 months before Expo
- Manufacture – 3 months before Expo
- Build – 6 weeks before Expo
- Test – 3 weeks before Expo
- Tech Expo – April 18th
- Final Presentation April 22-26th

Project Budget

	Part	Link	Price	Qty	Total Price
	Motors	https://www.amazon.com/	$44.25	2	$ 88.50
	Wheels	https://www.monsterscoot	$19.99	2	$ 46.48
	Chain	https://www.monsterscoot	$7.99	2	$ 22.48
	Batteries	https://www.amazon.com/	$99.99	1	$ 99.99
	Cart	https://www.amazon.com/	$105.03	1	$ 105.03
	Twist Handles	https://www.amazon.com/	$16.99	2	$ 33.98
	Control Board	https://www.amazon.com/	$15.99	3	$ 47.97
	Control Box	https://www.amazon.com/	$9.49	1	$ 9.49
	Wood Board	In store	$12.82	1	$ 12.82
	Strip Steel	Trade for Other Metal	$0.00	Per	Unknown
	Bolts	In store	$25.89	1	$ 25.89
	Purchased Steel	At Scrap Yard	$55.00	1	$ 55.00
	Subsequent Purchases		$28.91	1	$ 28.91
	Subsequent Purchases		$13.82	1	$ 13.82
	Subsequent Purchases		$31.98	1	$ 31.98
	Wire (lamp)	In store	$9.99	1	$ 9.99
	Wire (5 strand)	In store	$15.99	1	$ 15.99
	Switch (estop)	Owned	$0.00	0	$ -
	Wire Nuts	In store	$1.29	1	$ 1.29
	Zip Ties	In store	$0.99	2	$ 1.98
	Screws	In store	$4.02	1	$ 4.02
					$ 655.60
		Prize Money Reduction			-$250.00
	-Drive Train				
	-Control System	Final Total Cost			$405.60
	-Structure				
	-Misc.	Per Partner			$205.60
	-Optional/ Unforseen				

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