NORTHERN ARIZONA UNIVERSITY
College of Engineering, Forestry & Natural Sciences

GO BABY GO – D

Final Report

Hussen Alajmy
Saleh Almasary
Shahah Eshkanani
Yousef Alenezi
Yousef Alraqem

Northern Arizona University
ME 486C, Spring 2017

PROJECT SPONSOR: DR. SARAH OMAN
FACULTY ADVISOR: DR. SARAH OMAN SPONSOR
MENTOR: DR. SARAH OMAN
INSTRUCTOR: DR. SARAH OMAN

DISCLAIMER

This report was prepared by students as part of a university course requirement. While considerable effort has been put into the project, it is not the work of licensed engineers and has not undergone the extensive verification that is common in the profession. The information, data, conclusions, and content of this report should not be relied on or utilized without thorough, independent testing and verification. University faculty members may have been associated with this project as advisors, sponsors, or course instructors, but as such they are not responsible for the accuracy of results or conclusions.

EXECUTIVE SUMMARY

The team was tasked by the sponsor Dr.Sarah Oman with creating a design that aimed in helping the children with limited mobility to receive the needed exposure to socialization. The team was tasked with the following design requirements:

- Accelerating system
- Low Cost
- Unique and creative system

In order for the team to meet the design needs, another list of requirements was created to meet the design and customer needs. The following table illustrates how each requirement was met.

Table 1 Project Requirements

CRs & ERs	Unit	Can't exceed	Target	Tolerance	Final design	Reqs. met?
Weight	**Lbs.**	120	105	115	118	✓
Price/Cost	**$**	700	500	600	541	✓
Battery Life	**Hrs.**	2	4	3	6	✓
Multiple Speeds	**Mph**	6	6	5	0-6	✓
Ordered Parts	**days**	10	7	8	5	✓
Creative Steering Option	**N/A**	N/A	N/A	N/A	-	✓
Soft Edges	**N/A**	N/A	N/A	N/A	-	✓
OSHA Standards	**N/A**	N/A	N/A	N/A	-	✓
Power system **Acceleration controller** **Brakes system**	**Mph**	-	-	-	-	✓
Physical **Comfortable seats**	**N/A**	-	-	-	-	✓
Operating system **Easy to operate**	**N/A**	-	-	-	-	✓
Financial	**$**	1500 (Budget)	400	500	541	✓

ACKNOWLEDGEMENTS

Northern Arizona University, Department of Mechanical Engineering:

- Dr. Sarah Oman.

Auto Rehab Auto Repair Shop.

- Location: 799 Historic Rte 66, Flagstaff, AZ 86001
- Derek Tungmala

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1 BACKGROUND

1.1 Introduction

Go Baby Go (GBG) is a project that aims at helping children with special needs to move just like normal children. This was accomplished by building toy cars that they can ride on by themselves without the help of any other person. This is not a commercial exploit and the cars built through this program are gifted for those who are in need. Our team is one of many teams across the world that is doing this kind of work.

The team intended to make a unique design of a child toy car. The team came up with its own prototype, found the funds used towards the project, and proceeded in building the design. The team hoped that after the completion of the project that we helped one or more baby to be able to ride it independently. This project was also a chance for the team to give back to society what it truly deserves, as well as offering an avenue through which to give through the funding of this project.

The GBG project started with research on the development of young children and the impact on how they live their lives in the future. The pioneer of the project, Professor Cole Galloway from Delaware University, conducted the starting of the GBG program. Per Galloway, if a child had a vibrant childhood, they tend to grow into a normal adulthood. He also stated that children ought to play and have all the fun in the world even in spite of their disability because if they do, they will be no different from any other child when they grow up.

Some of the benefits that the child will get is having a better intellectual capacity. When children are playing, moving about, and discovering things, it builds their intellectual capabilities. The second benefit is that it allows them to relate well with other people. When children play together, they are building relationships with each other, which is something that they will be able to do in the future if they are able to have fun with their cars at a young age. Finally, it will be a form of rehabilitation for children, as it will help to strengthen bone weakness for example. One of the main goals of this project is to offer disabled children an opportunity to play and interact with other children normally, without their disability getting in the way.

1.2 Project Description

Children with limited mobility often do not receive the much-needed exposure to socialization to cognitively develop at a normal rate. Existing research showed that equipping young children with a capacity for self-control over their own environment can have a meaningful impact on the long term outcomes of impairments such as cerebral palsy or muscular dystrophy. The GBG project, which began at the University of Delaware, has developed a set of DIY cars for families with children who suffer from mobility restrictions. These cars have been designed on commercially available ride-on toy car platforms (like Power Wheels) and have been deployed worldwide by the GBG team. These cars have proven to be a cost-effective means of enabling young children to move and interact with their peers. The goal of this project will be to design and build a new version of the GBG retrofits – specifically, to design a universal control for children with extremely limited mobility of their body except their hands.

1.3 Original System

This project involved the design of a completely new Pressure Pad GBG. The project included a number of new designs that the team worked on in order to prepare well for the construction of a new, highly developed GBG car. Other retrofits of GBG are mostly old-fashioned since they all depend on a car and require some modifications. Other models that are currently there are scoot, original GBG retrofit, scooter, etc.

1.3.1 Original System Structure

The original system is something that is unique and completely different from all previous ideas and designs for the GBG mission. In this case, it will be a toy car with a lot of modifications. The GBG team would like to establish a toy ride that satisfies the needs of the disabled child, incorporating the latest technologies such as a hand pressure system that would allow the child to wander around by themselves without the help of a parent. Another new technology would be to implement a renewable energy source for the car to make it environmentally friendly. These are just two of the modifications that the team will develop throughout the project. The objective of this project is to build a low-cost car with the latest technologies to help serve the child as well as possible.

2 REQUIREMENTS

The GBG team met with the client, Dr. Oman, to check the current requirements, which includes customer, and engineering requirements. Based on the project description that provided to the team, the final product must meet these requirements.

2.1 Customer Requirements (CRs)

The GBG team has five main customer requirements (CRs) which will be weighted using a scale of 1 to 5 (5 = top, 1=bottom), depending on the importance of each CR. The client approved the following customer requirements.

In the table 2, there is a list of specific CR's. Each requirement was accompanied by a brief description to clarify customer requirements clearly.

Table 2 Customer Requirements (CRs)

Customer Requirements	Description
Power system Acceleration controller Brakes system	The system should include an acceleration controller, and safety brakes to ensure the safety of the child and satisfy the client's requirement.
Physical Comfortable seats	The system should have comfortable seats, so that the child with limited mobility feels comfort while using the system.
Operating system	The system must be easy to operate so that the child can use it independently and with ease
Financial	The system must be at a low cost, and a maximum budget is $1500
Safety	The system should ensure the safety of the child at all times through the inclusion of a seatbelt harness and bars that covered with pool noodles.

2.2 Engineering Requirements (ERs)

GBG team created the following engineering requirements in order to ensure the delivery of the Customer requirements as listed in Table 1. In the next table provided (Table 3) a list of engineering requirements, with each requirement followed by a brief description to clarify.

Table 3 Engineering Requirements

Engineering Requirements	Description
Weight (lb.)	The final solution should not exceed a total weight of 100 lb., so that it can be easily moved or carried
Price/Cost ($)	The final solution should cost up to $400 to complete
Smooth Sides	The system should have smooth angles (no sharp edges/points) to secure the safety of the user.
Suspension (lbf/in)	The system should have springs to ensure that there is no jerking motion when the system is used on uneven roads.
Store Energy (w)	The system should generate and store electrical energy.
OSHA Standards	The system should meets OSHA’s standards to ensure the safety of the child.
Multiple Speeds	The system should have at least three different speed settings (for example: low, medium, high).
Steering Options	The system should incorporate a new steering option instead of a regular steering wheel.

2.2.1 Revised Engineering requirements

The team went through many detailed changes in the final design that made the team try to update the house of quality, to satisfy all the requirements. The sponsor approved the updated Engineering requirements.
Table 3 below illustrates the updated engineering requirements. Ordering parts and battery life were added to the ERs, and suspension was removed from the ERs, since it is not concerned as a problem anymore.

Table 3: Engineering Requirements

Engineering Requirements	Description
Weight (lb.)	The final solution should not exceed a total weight of 120 lbs., so that it can be in the range of the benchmarking.
Price/Cost ($)	The final solution cost should not exceed $700 to create.
Battery Life (hrs.)	The system should be working for at least 2 hours as tolerance.
Multiple Speeds (mph)	The system should have at least three different speed settings (for example: low, medium, high), or a range of accelerating speed from (0-6)
Ordered Parts	The team has a maximum period of ordering parts,10 days as a tolerance and 7 days is the team's target.
Creative Steering Option	The system should incorporate a new steering option instead of a regular steering wheel.
Soft Edges	The system should have soft edges to secure the safety of the child.
OSHA Standards	The system should meet OSHA's standards to ensure the safety of the child (no uncovered electric wires, no sharp edges, etc.).

2.3 Testing Procedures (TPs)

Testing procedures (TPs) focuses on how attributes help cover the range of engineering requirements. Not every engineering requirement has a testing procedure. The table below (Table 5) links each engineering requirement with a description of the testing procedure.

Table 5 Testing Procedures (TPs)

Engineering Requirements	# of TPs	Description for testing procedures
Weight (lb.)	4	The combined weight of the device consists of the weight of each material that will be used. As such, each material will be weighted in order to consider whether it exceeds the target/tolerance of the house of quality using a big scale to take the readings of the whole system.
Soft Edges	N/A	Checking the goods that the team intends to purchase for the project beforehand to ensure that there are no sharp edges/points, or covering up the sharp and solid edges by pool noodles (for steel bars) and sponges.
Multiple Speeds (mph)	5	Checking if the system having different speed options, or keeping on an accelerating range. The system having a hoverboard system that ensures accelerating,(tested through trying to accelerate using the final solution).

Battery Life (hrs.)	5	The hoover board has an estimated time, but with the body added to it, the weight has increased which takes more energy. (the testing procedure will be taking the time while having it fully charged).
Ordered Parts (days)	3	The team has a maximum period of ordering parts,10 days as a tolerance and 7 days is the team's target. Based on checking the market, the ordered parts that is needed to build the design did not exceeded 6 days.

2.4 Design Links (DLs)

Design links introduced how each engineering requirement was satisfied through the construction of the proposed design. Every engineering requirement has a design link. Below is a table of each engineering requirement listed alongside its respective design link (Table 6).

Table 6 Design Links (DLs)

Engineering Requirements	# of DLs	Description for design link
Weight (lb.)	5	The final design meets the weight target with the help of predictions based on the research. The weight will be within a tolerance of 55 lb.
Price/Cost ($)	1	The final solution budget was maintained. The cost was under the target of the house of quality.
Battery Life (hrs.)	4	The testing procedure will be taking the time while having it charged. Then we will be satisfying that by double checking the time life of the battery by taking the time from fully charged to empty battery.
Multiple Speeds (mph)	2	The final system has no speed option, which fits the team's target - it accelerates from zero to the maximum speed and rests on whatever speed the child is comfortable driving.
Ordered Parts (days)	7	The team has a maximum period of ordering parts, 14 days as a tolerance and 7 days is the team's target. Typical to the market, none of the ordered parts exceeds 6 days.
Creative Steering Option	3	The final design incorporates a pad through which steering can be controlled.
Soft Edges	8	The design has smooth angles and sharp edges covered to ensure the safety of the child and achieves the target of having soft edges.
OSHA Standards	N/A	The design is covered with pool noodles for the steel bars of the base, and sharp edges covered with sponges to ensure the safety.

2.5 *House of Quality (HoQ)*

The following house of quality (HOQ) is a diagram that helps determining how the customer needs are being valued and weighted concerning the product. Table 7 below shows the HOQ for the GBG project.

Table 7 House of Quality (HOQ)

House of Quality (HoQ)										
Customer Requirement	**Weight**	**Engineering Requirement**	Weight << (120 lb)	Price/Cost << (700$)	Battery life >> (2 hrs)	Multiple speeds >> (0-6 mph)	Ordered parts << (10 days)	Creative Steering Option	Soft Edges	OSHA Standards
1. Power system										
a. Control acceleration	5		9	5	0	9	0	9	0	9
b. brakes	5		5	0	0	9	5	5	5	9
2. Physical										
a.Comfortable seats	5		1	5	0	0	5	0	9	9
3. Operating system										
a. easy to operate	5		0	0	0	9	1	9	5	9
4. Financial	5		0	9	8	0	0	0	0	0
5. Safety										
a. Seatbelt harness	5		0	0	0	0	0	0	0	9
Units			lb	$	hrs	mph	days	N/A	N/A	N/A
Target			105	$500	4 hrs	6 mph	7 days	N/A	N/A	N/A
Tolerance			115	$650	3 hrs	5 mph	8 days	N/A	N/A	N/A
Testing Procedure (TP#)			5	N/A	5	5	4	N/A	1	N/A
Design Link (DL#)			5	1	4	2	7	3	8	N/A

3 EXISTING DESIGNS

There many existing designs for the GBG retrofits created out of similar ideas from wheel chairs, toys, and mobility games. Three different ideas caught the group's attention: the scoot, the current GBG retrofit (electric car), and the scooter. These products had some disadvantages that needed to be improved. The team started to think briefly in order to create a new idea for mobility that met the client's needs. The existing design element of this project was more important for the team and helped the project's completion.

3.1 Design Research

The Go Baby Go organization was established on November 2015. This organization took care of children with special needs by helping them to live a normal life as possible through the construction of mobility devices that they can use to play and commute [6]. Children with special needs are part of the community so the GBG program assists them in achieving their dreams and playing for fun. The organization faced some difficulties regarding designing the GBG retrofits because every single child had a particular profile of need(s). Consequently, this team faced similar challenges as well. Researches had shown that most of the ideas are similar and most of them are expensive to build. The team had a limited budget so the research did not look at those ideas which had proven to be too expensive. Most of the researches were done using online websites, which benefitted the team from the big number of ideas presented from students in ME 286 class at the Northern Arizona University (NAU). Other universities also had GBG programs. This created a simple competition between different schools to be creative in creating the GBG retrofit. However, most schools did not have a unique GBG design since most designs were based on retrofit that were just modified and not created from base.

3.2 System Level

The GBG project required a main system of mobility to transport a child from point A to point B. The current systems mainly depended on using a retrofit with tires to transport the child. The main system design depended on the customer requirements and on how it relates to the requirements. Accordingly, many different systems were used for each retrofit. In example, wheelchairs relied on human energy in order to move a patient from point A to point B. The three main system designs used in designing the project were the following:

1- Scooot
2- Current GBG retrofit (electric car)
3- Scooter.

3.2.1 Existing Design 1: Scooot

The scoot is a current main system that was used for both normal and disabled children to transport them from a point to another. This system could be used in three different ways – the first method is that it can be used by crawling. Crawling will help the child in exploring and strengthening the upper body muscles such as the abdominal area [2]. The second way to use this system is by scooting. Scooting allows the child to move while sitting up straight and using their legs. This will help the child move more freely to explore outer surroundings. The final way to use this device is by riding it. The device allows the parent to add a tire on each side, which will make the device act like a wheelchair. This system depended completely on human energy since there are no electrical components involved and the user has to move physically by himself or herself to maneuver it.

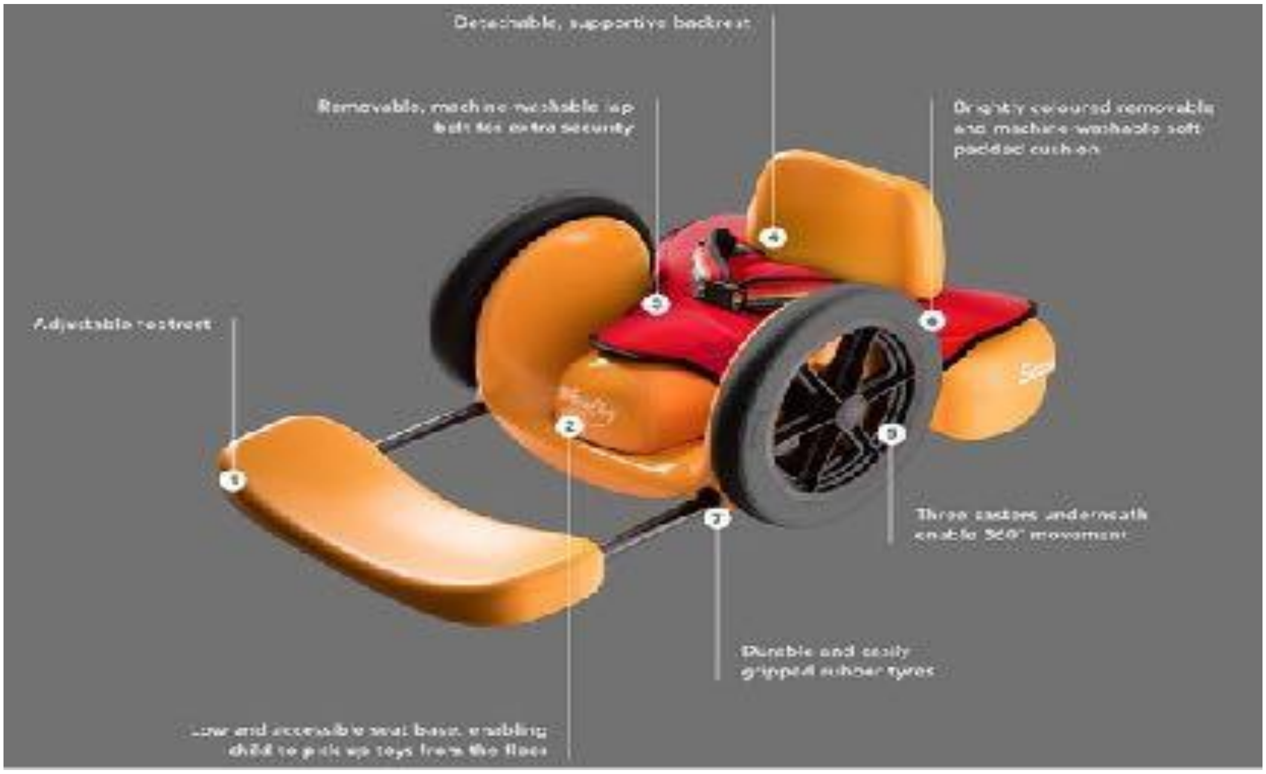


Figure 1: Scooot [2]

3.2.2 Existing Design 2: Current GBG Retrofit (Electric Car)

The current design for the GBG project was a great system for use by disabled children to socialize and transport themselves freely and independently. Current GBG retrofits were based on electric toy cars that were modified based on each requirement [1]. The cars were cost-effective and do not cost much compared to medical solutions that cost much more than the GBG retrofits. This current system relied on electrical power that was controlled by the child in order to accelerate and decelerate. The present solution mostly did not control acceleration as it was only adjusted to one speed. Each retrofit was designed differently depending on the disability of the child.

Figure 2: Current GoBabyGo Retrofit [1]

3.2.3 Existing Design 3: Scoooter

[The final existing system that was used is the toy scooter. The chosen system was a three-wheeler retrofit that depended on human energy in order to move [3]. This device was mainly used to transport the child from one point to another using the three wheels attached. Additionally, there was a stick which allowed the parent to control the movement of the child regarding the direction of the scooter. This will give the parents more control over the child in terms of their movement and will therefore not be able to meet the requirements for most disabled children

Figure 3: Scoooter [3]

3.3 Subsystem Level

Any machine or mechanical design must contain a support system for central system mobility – for example, controlling parts and energies. For the GBG project, the team followed the sponsor's requirement concerns the design to help non-disabled and disabled children. During the research stage, there were three main categories of subsystems: human power, electrical power, and central control system.

3.3.1 Subsystem 1: Human Power

The human power represented energy that transferred from the human body to power a machine into operating. This involved using one's arms and legs [4].

3.3.1.1 Existing Design 1: Arms

As shown below in Figure 4, arms were the source of human power of the scoot's central subsystem. It worked when a disabled child pushed and rolled the scoot's wheels to move from one place to another.

Figure 4: Scooot Wheels [2]

3.3.1.2 Existing Design 2: Legs

Legs are the most efficient power source for many transport machines, such as a scooter. In the scooter's existing design, we saw that children had the ability to move the scooter by pushing the pedals**.**

Figure 5: Scoooter Pedals [3]

3.3.1.3 Existing Design 3: Human Muscles

[Human muscles were another source of human power. For example, children who did not have arms and legs could use the shoulder muscles as a human power body part. Moving the muscles sideways and the design moved.

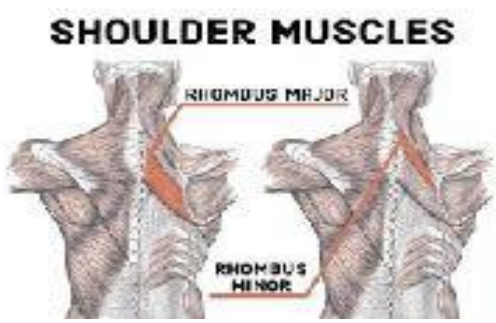


Figure 6: Shoulder Muscles [7]

3.3.2 **Subsystem 2: Electrical Power**

Electricity has used in everyday human life consistently because it is a strong source for machines. There are two existing designs, which display the usages of electrical power – this report will now outline two of those: batteries and electric motors.

3.3.2.1 Existing Design 1: Battery

Batteries are good sources of energy. They have chemical energy contained within the case, which converted into electrical energy. Some batteries recharged as well.

Figure 7: Batteries [8]

3.3.2.2 Existing Design 2: Electric Motor

Using an electric motor as a subsystem converted electricity into mechanical energy. Therefore, this piece of machinery helped with the GBG future design.

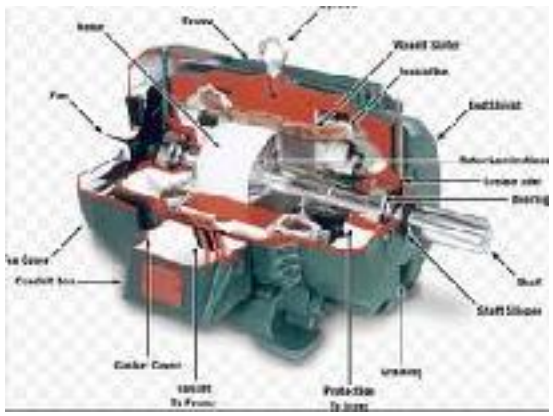


Figure 8: Electric Motor [9]

3.3.2.3 Existing Design 3: Solar Panel System

The solar panel system worked by collecting photons from the sun, then released electrons from the solar panel to the wires or any electrical device to run the machine.

Figure 9: Solar Panel System [10]

3.3.3 Subsystem 3: Main Control System

Every device has a spatial control system – in cars; this allows the rider to control the vehicle and display its duration. For this subsystem, a steering wheel and pressure pads has deemed the most efficient for the GBG project.

3.3.3.1 Existing Design 1: Steering Wheel

Just like other vehicles uses steering wheels for control purposes, our team used this control system type for the car.

Figure 10: Steering Wheel [11]

3.3.3.2 Existing Design 2: Pressure Pads

Self-balancing scoooters have become very popular today. They operate according to a clever idea – the pressure pads have fixed around the scoooter. They work by having many small systems implemented under the pads, so that human balance and nerves from the body control how the scoooter operates – to move, stop, steer and rotate [5]. The team designed a hand pressure pad instead of self- balancing pressure pads, which required the use of the legs. They used the notion of self-balancing scooters, which operates of pressure pads. These side pads helped children who suffered from disabilities involving their feet so that they could control the car by use of their hands.

Figure 11: Pressure Pads [14]

3.3.3.3 Existing Design 3: Joystick

The team also borrowed the idea of joystick control system in which it used a joystick as a control system for the car designs. By selecting any button on the joystick, the car would start functioning, and by moving it, the car would move to the directions that chosen.

Figure 12: Joystick [14]

4 DESIGNS CONSIDERED

The hypothesized functional model was an important aspect of the team report because it was what challenged one to know and understand the way the project works and functions. As for the material, energy, and signals used in the device created, they spelled precisely the content of the project, its performance and results. Creating the functional model gave our team the ability to understand how to work with the device and how it operates without the use of some sources of the device. Engineers are supposed to know how to reverse engineered projects. The models gave us a real understanding in determining the inputs, outputs, and the sub-functions of the project itself. The team learned exactly how to deal with the pressure pad and the signals that move it. In reverse engineering, one needed to know the ins and outs of the signals themselves to have a better understanding of the project. The group also learned that if in any case, the project becomes expensive. There are parts that can be reduced to lower the cost. A functional model taught us a lot about how to take care of the different elements of the project.

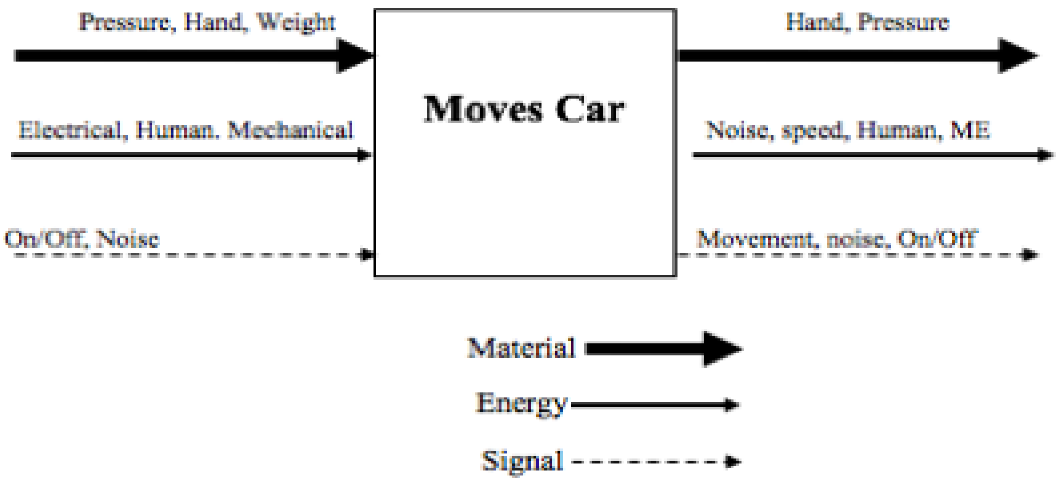


Figure 13: Black Box Model

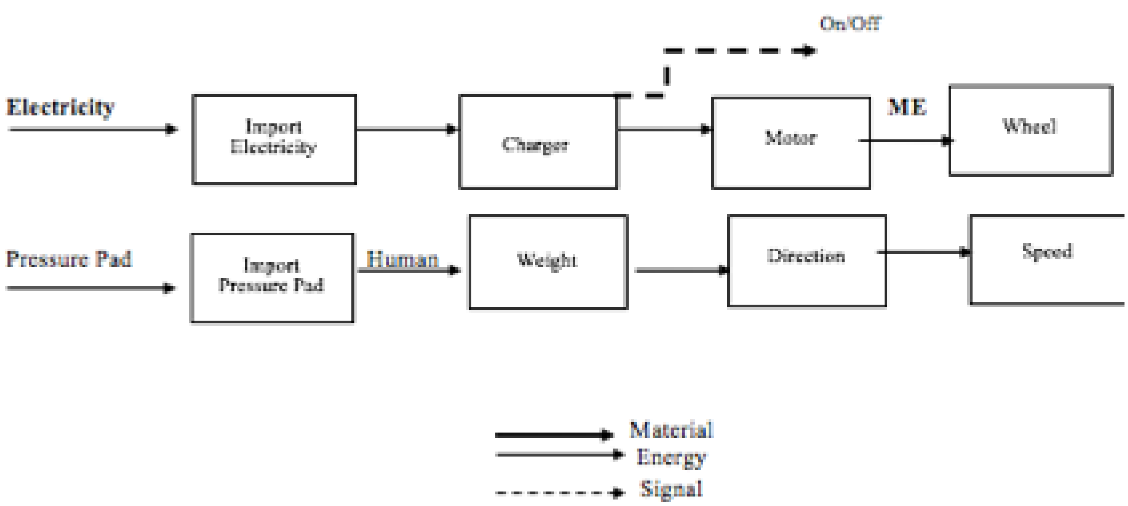


Figure 14: Functional Model

4.1 Design 1: Suspension Seat

In this design, there was a screen control system, back support attached to the seat with safety bars, and between the seat and the tires, there was connected suspension system.

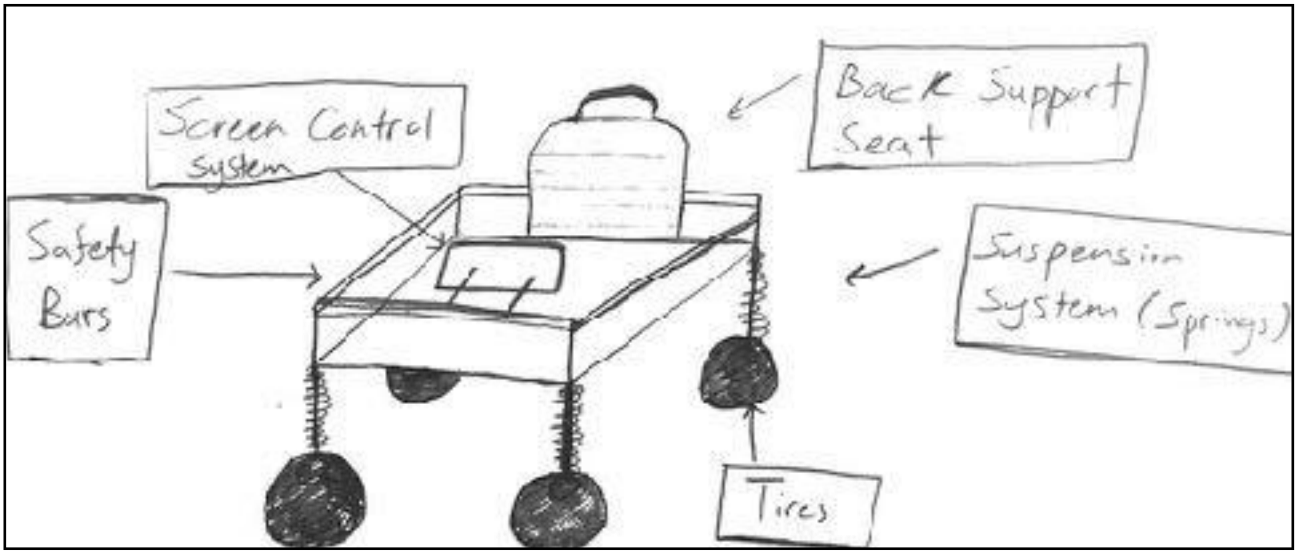


Figure 15: Suspension seat

Table 8: Design 1 Advantages and Disadvantages

Advantages	Disadvantages
No jerking motion due to suspension system	The height of the seat might not be pleasing to the child due to it not touching the ground
Safety bars	

4.2 Design 2: Hover-board Bed

This design inspired by the self-balancing hover-board pads system. There were new tires attached to the gear chain system. When the tires on the self-balancing hover-board pads rotated, the original tires also rotated.

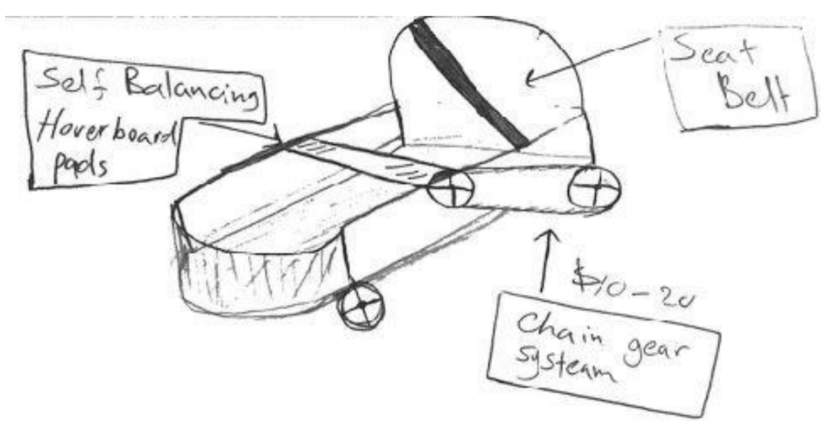


Figure 16: Hover-board bed

Table 9: Design 2 Advantages and Disadvantages

Advantages	Disadvantages
The seat belt offers extra safety to the child	The gear chain may dislocate
The car's low height means the child can ride with more ease and comfort	

4.3 Design 3: Monitor Scoooter

The design based on a standard scooter design with some changes. Instead of a scooter steering

wheel, the team decided to add a monitor touch screen system. Another change added was a comfortable seat with a seatbelt harness.

Figure 17: Monitor scoooter

Table 10 Design 3 Adv. and Disadv.

Advantages	Disadvantages
The touch screen means it is easy to control	The weight of the user may impact the balance of the chair
Safety can be extended by installing a seatbelt	

4.4 Design 4: Electric Scooot

This was a scoot design developed to minimize physical use. Instead, the team added a hand pressure pads control system to make it an electric scoot.

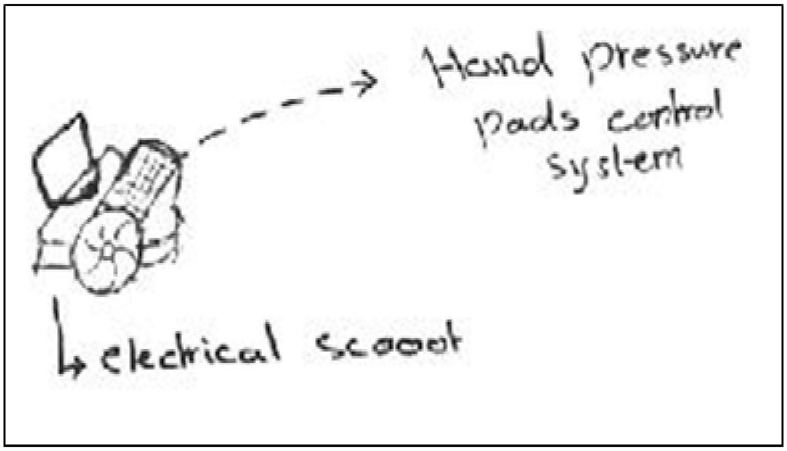


Figure 18: Electric scooot

Table 11 Design 4 Adv. and Disadv.

Advantages	Disadvantages
Comfortable seat	The device may be too low/close to the ground
The child can feel the ground	

4.5 Design 5: Hydraulic Baby Walker

This CV had a hydraulic system so that the child had a choice to move freely and the baby walker had a control panel system.

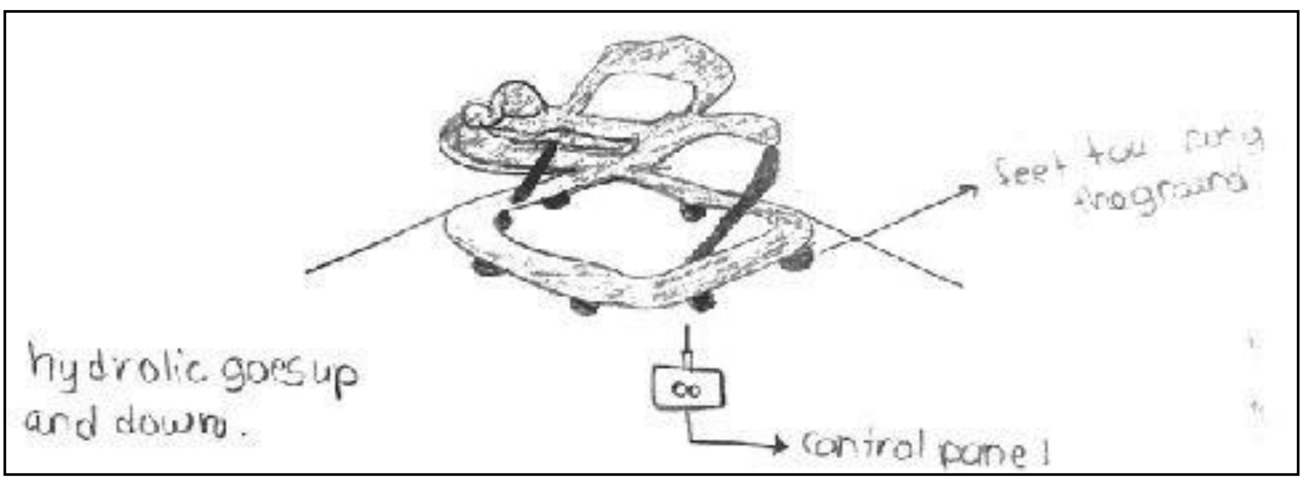


Figure 19: Hydraulic baby walker

Table 12 Design 5 Adv. and Disadv.

Advantages	Disadvantages
Due the to the hydraulic system, the child will be able to feel and move freely	There are not enough safety features, therefore, the parent/guardian will need to monitor use

4.6 Design 6: Baby Walker

This design was based on a regular baby walker, but the team chose to add an engine which could be controlled via a control panel.

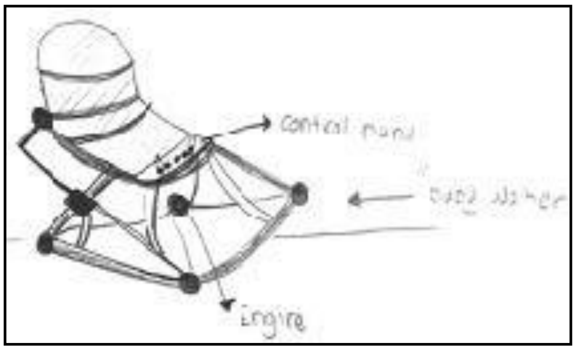


Figure 20: Baby walker

Table 13 Design 6 Adv. and Disadv.

Advantages	Disadvantages
The child has the ability to control the baby walker	The engine is underneath the child, but it is not enclosed in a safety box which is hazardous

4.7 *Design 7: Speed and Direction Controller*

This design had a speed and direction controller system, which required the use of the feet. Therefore, the steering wheel was simply an aesthetic and of no use. In addition, the design had both automatic and remote control brakes.

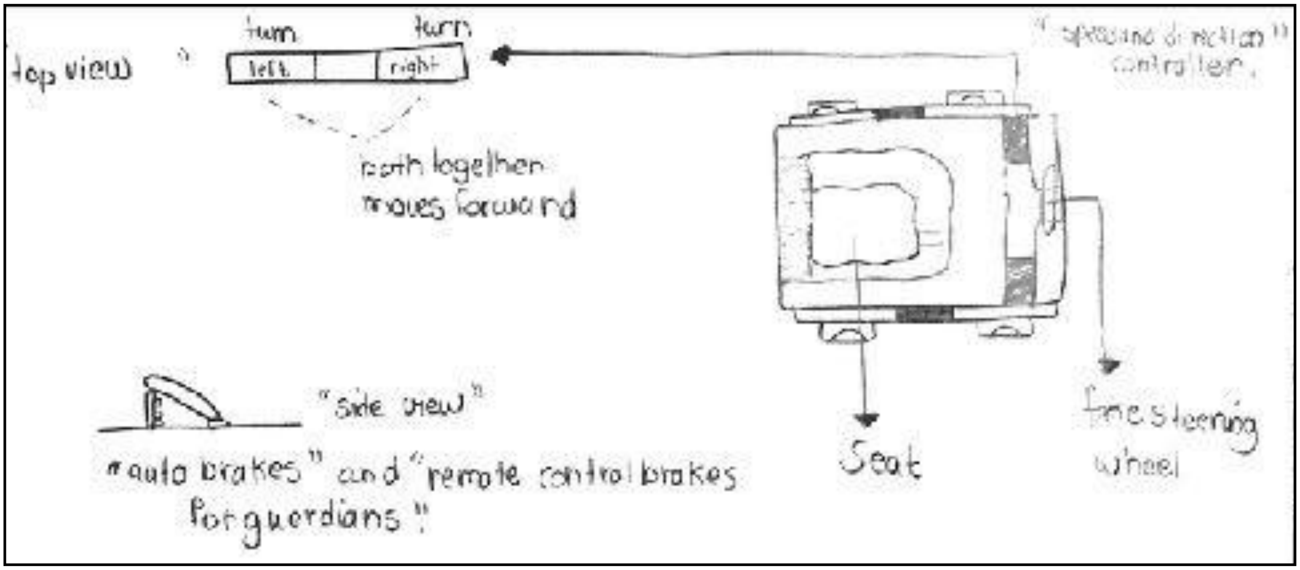


Figure 21: Speed and direction controller

Table 14 Design 7 Adv. and Disadv.

Advantages	Disadvantages
Comfortable seat	Since it is operated using the feet, the foot brake can be distracting.
Remote controlled brakes for parent/guardian	

4.8 *Design 8: Superman Bed*

A hospital bed inspired the idea of this design. The child could lay down on their stomach and use the controlled steering wheel, which attached to the engine for direction.

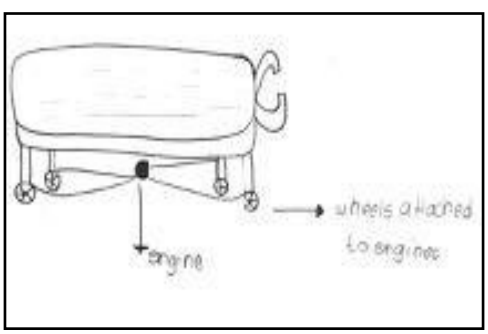


Figure 22: Superman Bed

Table 15 Design 8 Adv. and Disadv.

Advantages	Disadvantages
Very comfortable operating position for the child laying down	The bed may be too big to control

4.9 Design 9: Pumping Ball

This ball design could be used over water and grass. There is an oxygen motor for the user to breathe into, and it is through this that air can pumped into the ball.

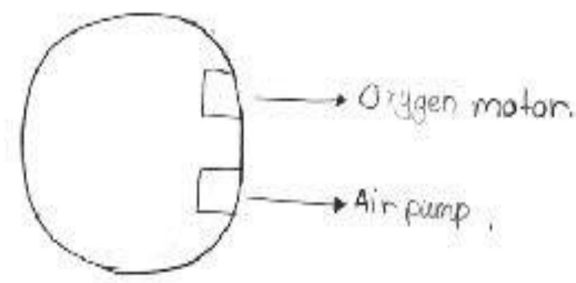


Figure 23: Pumping ball

Table 16 Design 9 Adv. and Disadv.

Advantages	Disadvantages
It is quite physical to operate which can improve the child's fitness over time	The ball may break easily
Easy to use in a swimming pool	

4.10 Design 10: Scoooter

For this scooter design, a comfortable seat with a harnessing seatbelt and a scooter steering wheel was included. This design had three wheels for additional stability.

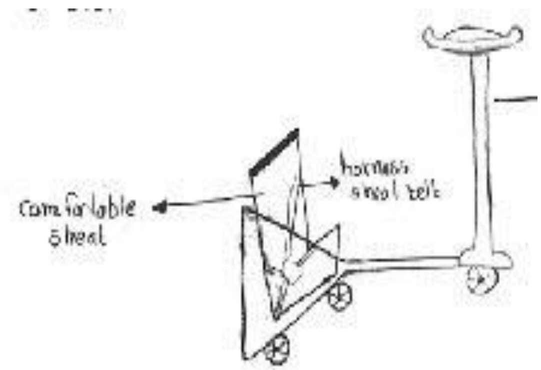


Figure 24: Scoooter

Table 17 Design 10 Adv. and Disadv.

Advantages	**Disadvantages**
Comfortable seat	The steering wheel may be too high to reach
Not dangerous to use	

5 DESIGN SELECTED

There were 10 main designs that the team created according to the black box model and functional model. Each design had some advantages and disadvantages. These advantages and disadvantages were listed below each design in a table form. The advantages and disadvantages gave the team a brief idea on how each design will perform if it was built in real life. The provided tables of advantages/disadvantages were not enough to choose the final design for the project and the team needed a better method to choose the final design of the project.

5.1 Rationale for Design Selection

In order to ease the selection of the final design and to make sure that the best design was chosen, the team followed a certain rationale for design selection. The design selection part consisted of two main sections, which were Pugh chart and decision matrix. In the Pugh chart, the team listed all 10 different conceptual designs in a table and started grading them using specific criteria. The criteria was based on different sections such as the cost, development risk, meeting customer and engineering requirements, etc. After that, the team chose the top four scores from the Pugh chart and used them in the decision matrix table to finalize the decision.

5.1.1 Pugh Chart

The team has created twenty concepts in order to finalize the design of the project. The concepts were created based on different customers such as able-bodied children and children with disabilities. The team then chose the top ten designs in order to compare them using the Pugh chart below. The Pugh chart allows one to make a comparison depending on the criteria listed below, where all the designs were compared to the CV9 design. CV9 was chosen since the design was an out-of-the-box design and the lowest in meeting the Pugh chart criteria. The chart below will display the most creative designs in order of having the most advantages. The winning designs in the Pugh chart were CV's 2; 4; 5. The winning designs later moved to be compared in the decision matrix in order to choose the final design.

Criteria

a. All material and construction costs must be under $1500

b. Development risk (will it work? What are the chances it won't?)

c. Technical difficulty (does the team have the skills/resources to create the CV?)

d. Schedule risk (will the team be able to finish the device by the due date?)

e. Does it meet the customer requirements?

f. Does it have jerking motion?

g. Is it accurate?

h. Is it made of standard components?

Table 18 Pugh Chart

Concepts	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
a	+	+	+	+	+	+	--	+		+
b	--	S	--	--	+	--	--	--	**D**	--
c	--	+	--	--	+	+	--	+		+
d	S	S	S	S	S	S	S	S	**A**	S
e	+	+	+	+	+	+	S	--		S
f	+	+	--	+	S	S	+	S	**T**	+
g	+	+	+	+	+	--	+	--		--
h	--	+	+	+	+	+	+	+	**U**	--
Σ +	4	6	4	5	6	4	3	3		3
Σ--	3	0	3	2	0	2	3	3	**M**	3
ΣS	1	2	1	1	2	2	2	2		2

5.1.2 Decision Matrix

After considering the three designs from the Pugh chart - CV 2; 4; 5 - the team used the decision matrix (Table 19) with the same criteria that were applied in the Pugh chart. The criteria weight had to total to a sum of one. Therefore, the team allocated a ranking for each criterion per design according to the most important to the least significant scale. After weighting according to the criteria, the team considered a raw weight out of 100 for each CV with each criterion. Then, the teams used the weight criteria and multiplied it by the raw weight to achieve the final weight of each CV. Finally, by summing up the final weight, the team arrived at the total weight for each CV, and ranked each CV, beginning with the highest total weight. The final design that the team will go ahead with is CV4 (the electrical scooter).

Table 19 Decision Matrix

Designs		CV2		CV4		CV5	
Criteria Weight							
All cost must be under $1500	0.1	80	8	85	8.5	40	4
Development risk	0.2	80	16	90	18	40	8
Technical difficulty	0.25	80	20	80	20	60	15
Schedule risk	0.15	90	13.5	100	15	75	11.25
Does it meet the customer requirements?	0.1	85	8.5	85	8.5	70	7
Does it have jerking motion?	0.05	100	5	100	5	80	4
Is it accurate?	0.1	70	7	75	7.5	30	3
Is it made of standard components?	0.05	85	4.25	85	4.25	100	5
Total Weight	1		82.25		86.75		57.25
Relative Rank			2		1		3

5.2 Design Description

It is important for every new project to have a parts research on what the project might face during the manufacturing process. Every component in the project has its difficulties therefore, each team member contributed on an individual research on specific analysis. The analyses were the following:

1- Hover-board analysis
2- Weight analysis
3- Budget analysis
4- Website analysis
5- Material analysis.

5.2.1 Hover-board Analysis

5.2.1.1 Introduction

Since its introduction, the hover-board has demonstrated widespread popularity across the country and globe in equal measure. The hover-board is also known as a two-wheeled and self-balancing scoooter. Over the last few years, the production of hover-boards has skyrocketed following a massive consumer demand for the technology, especially in 2015. However, mass production has led to poor production of some hover-board brands. As a result, the popularity of the technology took a hit as several incidents of fire were reported across the globe.

5.2.1.2 Problem statement

Hover-boards have been catching fire all over the country and indeed around the world. This has led

to the issuance of several bans across numerous countries and states. Apart from the UK, several states in the U.S have issued regulations to ban the production, sale, and use of hover-boards in a public area [14]. The bans are as a result of safety concerns from hover-board fires as well as several injuries associated with the technology. While a hover-board is a two-wheeled and self- balancing device, the safety and balance of the rider is not guaranteed.

These fires have been associated with complications as a result of Lithium-ion batteries. The batteries are made of a flammable electrolyte and very slim covers. While hover-boards are safely designed, the complications as a result of Lithium–ion batteries render them unsafe for use. However, it is imperative to note that the way the batteries are used and packed in the hover-board is also a source of the problem. The main reason for hover-board fires is due to the fact that the batteries used are more powerful as compared to those used in laptops and smart phones. Additionally, some of the batteries are of poor quality.

This project will attempt to address the current issue of hover-board fires by assuming a novel design that regulates the power consumption of the technology. Also, several design modifications will be made to the type of power source used for the hover-board design.

5.2.1.3 Components

A hover-board, a two-wheeled, auto-balancing scoooter, is made up of several different components: steel or aluminum frame with a central pivot, two wheels, a logic board, two gyroscopes, a lithium-ion battery pack, a motor, pressure pads, infrared sensors, a charger and a plastic shell. Additional accessories may include a remote control, Bluetooth, and LED lights. The logic board is used to regulate the speed of the hover-board. It is also used to control the tilt of each wheel.

The hover-board technology employs the use of a self-balancing steering system that is the same as a Segway unit. The pressure sensors configured on the technology are used to control the board. It is controlled through pressure sensing switch pads which are situated under the foot deck of the board. When the pressure pads are pressed backward or forward, they compress the switches beneath them thus blocking light from reaching a light sensor. An internal LED is used to generate light used in the pressure sensors. The board continues to remain immobile as long as the light is hitting the detector. The logic board is used to activate the matching motor to rotate in a specific direction when a section of the light is obscured from reaching a sensor.

5.2.1.4 Control logic

The operator can employ the use of this logic to control the speed of the board by shifting the amount of pressure in each foot pad. Additionally, the user can employ the use of the same logic to regulate the direction of movement through the use of opposite foot motion. The logic board plays a significant function in the operation and design of the board. It is responsible for the control of tilt and compression variables. These variables allow the user to utilize the logic board to change the direction and speed of the hover-board [14]. Alterations of the tilt variable are used to control the direction of the two-wheeled, auto-balancing scoooter, while the alterations of the compression variable are used to regulate or alter the direction of the hover-board.

5.2.1.5 Lithium Ion Battery

A hover-board employs the use of a lithium-ion battery pack as the main source of power. The lithium-ion battery pack is made up of a collection of individual lithium-ion cells. The battery pack used in hover-boards is rated for 36 V and has several thousand mAH capacities. The technology requires a lot of power since it is used for movement. Lithium-ion batteries are basically used for energy storage. It is used to transform chemical energy into electrical energy through a chemical reaction. Lithium ions move from the anode to the cathode through an electrolyte during the discharge phase. On the other hand, the opposite process occurs during the charging phase of the battery. Lithium ions move from the cathode, through an electrolyte, to the electrode. This process converts the chemical energy stored in the battery to electrical energy, which is used to power the hover-board.

This design will employ the use a fuse to prevent the over-current discharge or overcharging of the lithium-ion battery. Apart from a fuse, the design will employ the use of a cut-off switch to regulate the amount of current drawn from the lithium–ion battery. A cut-off switch or a fuse plays a significant role in regulating the rate and level of charging as well as the amount of current drawn from the battery pack. As a consequence, it addresses the current issue with hover-boards by preventing unwanted and explosive chemical reactions within the battery. It is imperative to also note that faults with the hover-boards can be attributed to the damages within the battery cells and the insulating material inside the battery which can result in internal shorting, thus leading to a fire.

There are several standards and tests that can be used to assess the design and aptitude of a battery to sustain normal operations and various types of misuse [13]. Customers and users of hover-boards can identify whether a product has attained the applicable regulations and rules through the use of the CE marks or statewide acknowledged testing lab mark. The standards for lithium-ion battery, UL 142, demands charge-discharge cycle testing, in addition to impact, shock and crash tests.

5.2.1.6 Equations for calculations and assumptions

To address the problem associated with the hover-board fires and explosions, it is imperative to analyze the amount of power stored or that can be drawn from the battery without causing overcharging or overheating. Additionally, it is crucial to determine the duration that the batteries used in the hover-board should be charged.

The discharge time of a lithium-ion battery is the mAh or the Ah rate divided by the current drawn by the hover-board [13].

Discharge time = current capacity of the lithium / load current

For instance, if the electrical components of the hover-board draw a load current of 300 mA and the lithium-ion battery is rated 2200 mAh, then the discharge time of the battery can be determined by the quotient of the two current ratings as follows:

- Discharge time = 2.2/0.3 = 7.3 hours.

On the other hand, the time taken to charge the lithium–ion battery depends on the charge current and the battery chemistry. The duration of charging is determined by the quotient of the battery rating and the applied current. That is:

- Charging duration = battery current rating/ the applied current

The equation used in determining the charging duration assumes that charge is 100 percent efficient. However, the lithium–ion batteries used in hover-boards are not ideal batteries. As a consequence, the equation is used to determine an estimate of the actual charging time. It is significant that it is necessary to keep the charging duration of the battery within the determined range so as to prevent overcharging the cell [13]. This equation plays a significant role in preventing fire and explosions

associated with overcharging lithium-ion batteries sued in hover-boards.

Additionally, it is worth noting that lithium-ion batteries have almost 100 percent charge efficiency, however, energy charge efficiency relies on the charge rate. In most cases, higher charge rates are associated with lower efficiencies due to increases in resistive losses towards the end of the battery charging phase.

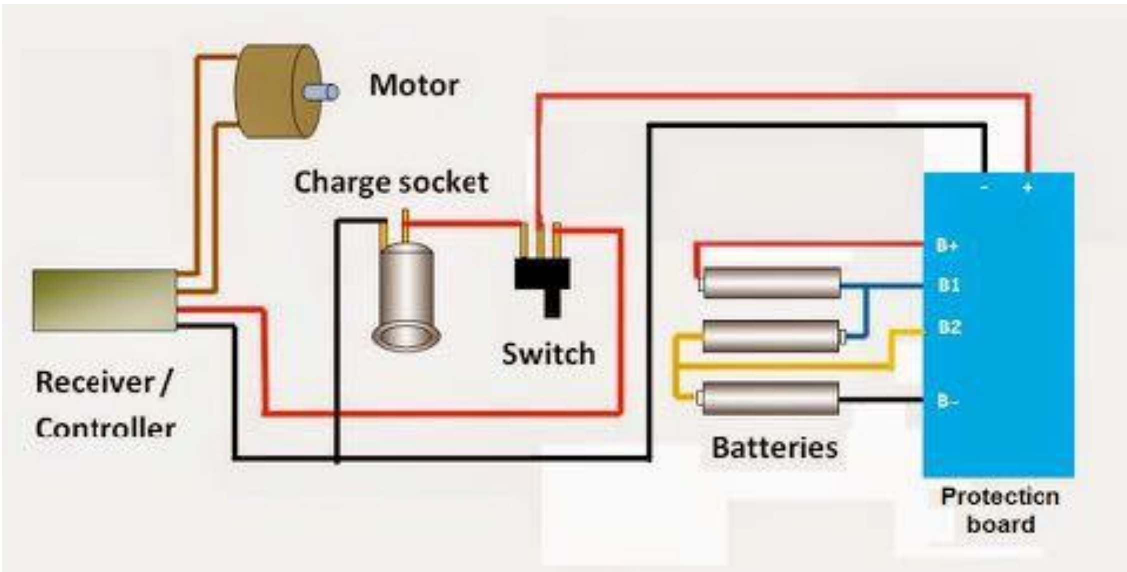


Figure 24: A diagram for balanced charging system for a hover-board [13]

5.2.1.7 Lithium-ion operating temperature

The performance of the hover-board and any other electrical device that uses the lithium-ion battery is affected by the operating temperature of the battery. It is crucial to point out that the working temperature of a lithium-ion battery is a significant factor that affects the performance of the hover-board. The battery temperature of lithium-ion varies during discharging and charging processes [14]. These variations in temperature call for analysis of the battery heat production rate. The rate of heat generation in lithium–ion batteries is affected by numerous factors such as; the battery aging effect, the operation current, temperature, and the state of charge. The produced heat during charging and recharging is made up of reaction heat and Joule heat.

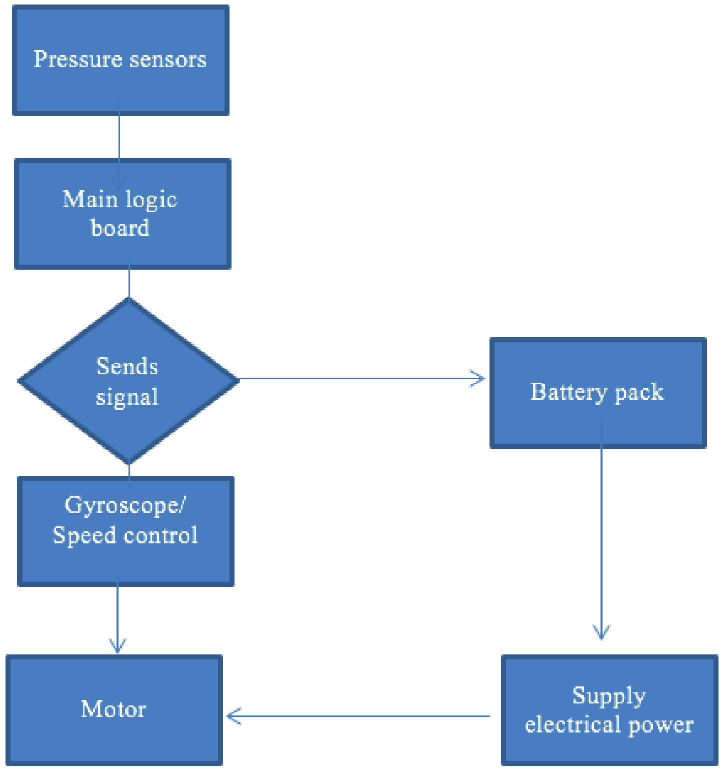


Figure 25: Flowchart

5.2.1.8 Details of physical modeling

There are several components that will be used for physical modeling of the hover-board project. A hover-board, a two-wheeled, auto-balancing scoooter, is made up of several different components: steel or aluminum frame with a central pivot, two wheels, a logic board, two gyroscopes, a lithium- ion battery pack, a motor, pressure pads, infrared sensors, a charger, and a plastic shell. Additional accessories may include a remote control, Bluetooth and LED lights. The logic board is used to regulate the speed of the hover-board. It is also used to control the tilt of each wheel.

The motor is the actuator which is used to convert the electrical signal from the battery to a mechanical motion, thus driving the hover-board. The most significant factor to consider is the power of the motor. It is imperative to select a motor with at least 300 watts in order to provide sufficient mechanical energy to drive heavy loads [15]. The motor will be connected directly to the wheel to provide a drive train. It is this direct connection between the motor and the wheels that allows the hover-board a rapid response.

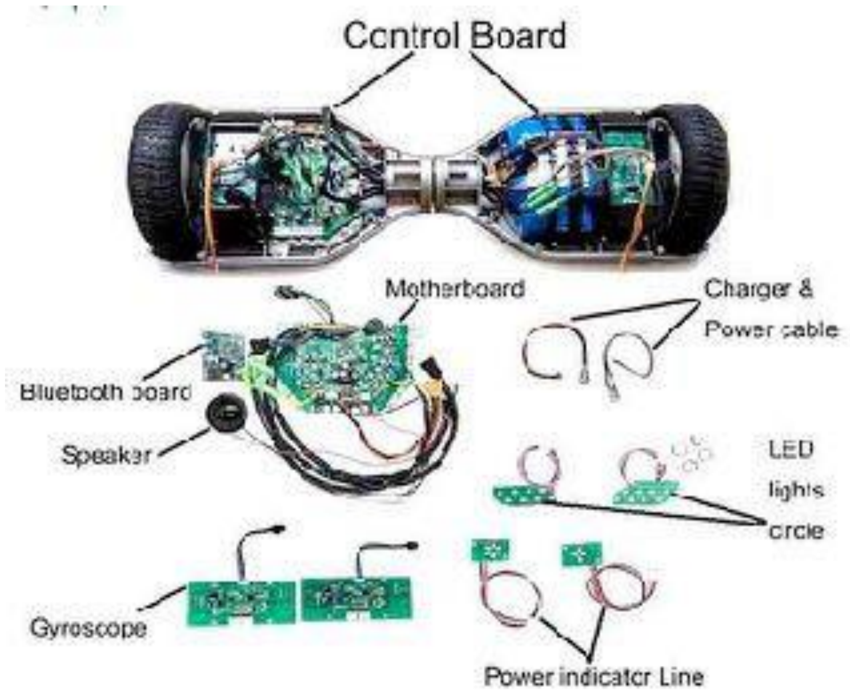


Figure 26: Physical component of a hover-board [16]

5.2.1.9 Conclusion

Hover-boards offer an alternative source of light and short distance transport. As compared to other types of scoooters, it is a simple and light design that provides numerous benefits to users. However, it is imperative to minimize power consumption by utilizing energy efficient components such as motors and sensors, so as to mitigate potential overcharging of the battery.

5.2.2 Weight Analysis

5.2.2.1 Introduction

The GBG project is a project that focuses and aims on children with disabilities and limited movement. This project will help children with limitations in movement to move freely and will ease the process of moving and living normally. Team 9 in the GBG project has designed some different concepts that involved more than twenty designs in order to find the best suitable design to fit the needs of the customer. The final solution that the team came up with was a creative design that used a hover-board in order to move the user from one point to another. This analytical report will mainly concentrate on the weight analysis of the device. Different perspectives of the weight analysis will be covered such as the average weight of the child, and a comparison between the minimum and maximum weights of users to operate the sensors of the hover-board.

5.2.2.2 Average Weight of Child

Since the design of the GBG project will be used by non-disabled children and children with disabilities, the average weight of normal children will be compared in order to cover the analysis. The project is mainly focused on children with disabilities but the project might still be used by normal children. The research is mainly focusing on children from the age of 2–12 years old. Table 20 below shows the average weight of normal children from the age of 2–12 years old for both females and males.

Table 20 Average Weight of Children [18]

Female Children			Male Children		
Age	Weight	Height	Age	Weight	Height
2 yrs	26.5 lb (12.0 kg)	33.7" (85.5 cm)	2 yrs	27.5 lb (12.5 kg)	34.2" (86.8 cm)
3 yrs	31.5 lb (14.2 kg)	37.0" (94 cm)	3 yrs	31.0 lb (14.0 kg)	37.5" (95.2 cm)
4 yrs	34.0 lb (15.4 kg)	39.5" (100.3 cm)	4 yrs	36.0 lb (16.3 kg)	40.3" (102.3 cm)
5 yrs	39.5 lb (17.9 kg)	42.5" (107.9 cm)	5 yrs	40.5 lb (18.4 kg)	43.0" (109.2 cm)
6 yrs	44.0 lb (19.9 kg)	45.5" (115.5 cm)	6 yrs	45.5 lb (20.6 kg)	45.5" (115.5 cm)
7 yrs	49.5 lb (22.4 kg)	47.7" (121.1 cm)	7 yrs	50.5 lb (22.9 kg)	48.0" (121.9 cm)
8 yrs	57.0 lb (25.8 kg)	50.5" (128.2 cm)	8 yrs	56.5 lb (25.6 kg)	50.4" (128 cm)
9 yrs	62.0 lb (28.1 kg)	52.5" (133.3 cm)	9 yrs	63.0 lb (28.6 kg)	52.5" (133.3 cm)
10 yrs	70.5 lb (31.9 kg)	54.5" (138.4 cm)	10 yrs	70.5 lb (32 kg)	54.5" (138.4 cm)
11 yrs	81.5 lb (36.9 kg)	56.7" (144 cm)	11 yrs	78.5 lb (35.6 kg)	56.5" (143.5 cm)
12 yrs	91.5 lb (41.5 kg)	59.0" (149.8 cm)	12 yrs	88.0 lb (39.9 kg)	58.7" (149.1 cm)

Children with disabilities do not average on a certain weight depending on each disability. Some children with disabilities weigh less than normal children as it all depends on the situation of the child. The average weight of a normal child or a child with disability will play a huge role in moving the device from point A to point B. This is due to the motion of the hover-board that mainly depends on the motion sensors and pressure pads to move.

5.2.2.3 *Minimum & Maximum Weight of User*

The hover-board is an important part in the design of the GBG project and the team's concept. The design essentially consists of two different parts. The first part is the seating part where the child sits and operates the device to move. The second part of the device consists of the hover-board, where it controls the movement of the device to other locations. The hover-board is triggered to

move by applying the users pressure on the pressure pads using his or her legs. In the design, the hover board will be controlled by the user using their hands instead of their feet to control the hover-board. Figure 18 shows the final conceptual design for the GBG project.

As shown in the design, the user will be able to sit in the middle with their legs below the hover- board and the hover-board will be controlled through the user's hands. In order to move the hover- board, the pressure pads need a certain amount of pressure to move in different directions. There are two types of weight to determine the pressure delivered, durability, and movement of the hover-board. The first type is to determine the maximum weight that the hover-board can withstand. The second type is to determine the minimum weight to operate the device. Figure 27 displays the main parts of the hover-board.

Figure 27: Hover Board Main Parts [17]

Hover Board Main Components [17]:

1. A steel frame with a central pivot
2. A logic board
3. Two gyroscopes
4. Two infrared sensors
5. Two electric motors (located inside the wheels)
6. Two tilt/speed sensors (located inside the wheels)
7. Charging port
8. Power switch
9. A battery pack
10. LED lights
11. Pressure pads
12. A plastic shell

There is a speed sensor in the tires of the hover-board that detects the amount of RPM's in the tire. This will be sent to the two gyroscopes where they will be calibrated to the user using the device [17]. This is where the weight is used to move the pressure pad. The maximum weight used in order to move the hover-board is different depending on the components used in each company's production line. Each company uses different types of batteries, speed sensors, and pressure pads. Additionally, the type of wheels used in a hover-board will determine the durability of that hover- board depending on the weight. The weight limit of the user averages around 220 lbs. (100 kg) and can go up to 325 lbs. (147 kg) [3]. Since the design built by the team depends on having the user use his or her hands instead of using of his or her legs, the minimum weight will be more important in this situation. To find the minimum weight appropriate for using the hover-board, the team was able to get a hover-board and test it using their hands. This testing procedure was performed by having a team member sit on a chair with the hover board laying on the member's lap. Pressure was then applied by the team member using their hands to see if the tires will move or not. The results showed that the device moved using hand pressure to get it as close as possible to the final design in figure 27.

5.2.2.4 Conclusion

In conclusion, the hover-board was the main component of the weight analysis in order to find the maximum and minimum weights to operate the hover-board. The team was able to test the hover board using hand pressure instead of finding the minimum weight of operation. It was

determined that the maximum weight for the user was not a problem that the team faced since the average maximum weight was determined to be 220 lbs. (100 kg) which is high compared to the average weight of a child. Different numbers emerged when seeking the average weight of a child. All in all, further testing will be required to have more conclusive results and to compare amounts of pressure required to move the device.

5.2.3 Budget Analysis

5.2.3.1 Background

The purpose of the project was to combine hoverboard technology with scooot® design. Two designs were chosen that integrate these technologies. The first, CV2, is based on Hoverboard design, while the second, CV4, is based on scooot® design

CV2 Hoverboard [19]

The Hoverboard is the new and recent design of a scooter driven by a pressure pads. The LED light and the sensor allows the user to be able to ride it using their emotions as it connects to the learning mode. Below are its engineering requirements:

- Hard ABS Outer Body Casing
- Aluminum Wheels with Rubber Tires
- Maximum Weight Limit: 220 lbs (100kg)
- Minimum Weight Limit: 44 lbs (20kg)
- Speed: 2 – 8 mph (3 – 12.8 km/h)
- Range: Up to 7 – 12 miles
- Charging Time: ~1 Hour
- Learning Mode
- Bright LED Lights (Headlights)
- Battery: Top Quality Brand Lithium with Sentry Shield
- Power: 36 Volts
- Size: 23w x 4h x 7d (inches)
- Product Weight:22 lbs (9.9kgs)[2]

CV4 Scooot® [21]

This kind of device is manually operated and designed to help primarily children with disabilities to be able to maneuver around. The scooot® is comprised of the following parts:

- Adjustable footrest
- Low and accessible seat base.
- Lap belt.
- Detachable.
- Three casters.
- Soft padded cushion.
- Gripped rubber tires [3]

On their cost comparison, below is a table showing the costs of CV2 and CV4 that are both available in the market.

Table 21 Price variations of main component of CV

CV type	Market name	Cost
CV2	Hover Board	$199-$499
CV4	Scooot® 3-in-1	$595

5.2.3.2 Material and Cost Analysis

As mentioned earlier the group decided on a new design that incorporates the ideas of both the CV4 and CV2. The design disadvantage the group is trying to avoid in CV2 is the use of a lithium battery, known to be very dangerous and possess significant risk to the user. Therefore, the team considered a CE FC ROHS battery as a safer idea.

The operation of the device will be managed from a pressure Pad to control the device as the LED head lights will help the kids move by providing better lighting in the direction of travel. The project will involve assembly of parts which are readily available on the market. For benchmark purposes, the table in Appendix A shows a catalog of the parts of for the new designs vis-a-vis their images and markets.

Table 2 below is the budget analysis of all materials that we will use so far in our project. The team started ordering the first item which was the K'Nex® building sets to make the prototype. This table lists actual price, expected variance, and final cost of each component. Expected variances might include price changes from the supplier such as shipping charges, tax rates, item cost, etc.

Table 22 Budget Analysis Table

Type of Items	Actual Cost	Expected Variance	Final Cost
Hover board	$199.99	$20	$219.99
Lap Seat Belt	$16.96	$5	$21.96
Adapter	$9.64	$5	$14.64
K'NEX Building Set	$31.50	$17.5	$49
550 Piece Metal Screws	$5.99	$3.99	$9.98
MDF Panel (Common: 3/4 in. x 4 ft. x 8 ft	$35.66	$0	35.66
Back Seat	$33.89	$3.99	$37.88
Insulated Electrical Wiring Wire	$20.98	$3.99	$24.97
Caster Set (2 Swivel/2 Locking)	$33.89	$5.99	$39.88
Wire Rope Clip, U-Bolt, 1/2In, Forged Steel*4	$16.94	$32.69	$49.63
48 in. x 1-1/4 in. x 1/16 in. Plain Steel Square Tube	$17.66	$0	$17.66
4 x (1-1/2 in. x 36 in. Plain Steel	$37.88	$0	$37.88
2 JLF 6mm Hollow 316L Shaft	$30	$5.99	$35.99
Minions Cotton Fabric	$10.95	$0	$10.95
2 Pack Pool Noodle	$1.88	$0	$1.88
High-Temp Split Loom - 3/8	$25.57	$7.99	$33.56
Foam Sheet, 24"L x 96"W x 1"H	$6.84	$0	$6.84
Foam Padding Blue	$2.49	$0	$2.49
TOTAL COST	**$538.71**	**$112**	**$650.71**

5.3.3.3 Conclusion

The overall budget analysis took into consideration other budgetary expenses such as price fluctuation on the high side and shipping costs for those parts that are not locally produced. The estimates were made in consideration of other commodities and terms dictated by vendors that were factored into the expected variance column to come up with the final cost as shown in Table 2. The final budget totaled $650.71, which is less than the budget ceiling provided, thus making it viable. This budget analysis is not final; it may change in the future depending on team and design requirements.

5.2.4 Website Analysis

5.2.4.1 Introduction

Each team member has his own analytical report to research on. Website analysis is what this report will cover going through some details. Having a website for the project is a sign of highly professional work, where the website may include details such as difficulties, challenges, and other such considerations. The report will cover areas that either are present or will exist on the website.

5.2.4.2 Background

This report about the website analysis should be considered as a short component of the project, since it does not need a lot of research or mathematical calculations. Creating a website for the project is important: through the website, the team has the medium through which to showcase how the project came along and what the challenges were while building the device, as well as providing all the references, resources, and contact details that are relevant. There are many examples of successful and unsuccessful websites. For unsuccessful websites, there could be a difficulty in navigating the website, or it may suffer from technical lapses, or a lack of coherent information. On the other hand, successful websites tend to have a very striking homepage, brief but relevant descriptions, and well-organized information flows. After much internet surfing, the team came up with its own criteria for determining the success of a website which would serve the team well for the building of its own website.

Creating a website presented many challenges, such as learning how to use the Dreamweaver software, which costs $153.95 for a full package. Luckily, it is provided through the university for the team's reference [26]. Another challenge was how to organize the information about the project so that the reader can understand the process that the team underwent. Other aesthete consideration: how should the main page look? Should it be divided into subsections with icons? These difficulties were faced during the creation and construction process of the website.

5.2.4.3 Conclusion

In conclusion, the website will act as a portfolio of the team's documents and proposals. In addition, it will illustrate the team's efforts which contributed towards fulfilling the requirements of the project. This website will be the team's future reference and will remain as evidence of the team's professional career long after this project.

5.2.5 Materials to be used for the project

There are four main materials that are used in this project. The materials are wheels, a wooden board frame, pressure pads, and steel. First, the wheels used in the project to control the car and allow it to travel from one place to another. Second is the wooden frame, which was made entirely out of wood. The wooden frame will be used to harden the GBG car and also to ensure that the electrical connections can fit underneath. This would make the GBG car look more neat and better organized. Third is the pressure pads, they're made from plastic, electrical wires, and a hardened plastic cover to ensure that it won't break while applying pressure "Pressing". The pressure pads are used to direct the GBG in any direction the user wishes to move towards. Last but not least, stainless steel used in the project as a main component. The team chose stainless steel because it is one of the best and cheapest types of steel that is available in the market today. The materials were bought based on their quality to ensure the GBG is of the best standard for the client.

5.2.5.1 The chassis of the scooot

The chassis of the scooot will be the functional backbone of the scooot. It will be the metallic base on which the components of the scooot will be marred. First, the wheels will be mounted on the chassis from the underside of the chassis. In our case, we shall have a pair of caster wheels and a hover- board on the underside. On the upper side of the chassis, we shall have the other components fixed. These include the headrest, the seating area, and the pushing sections of the scooot**.**

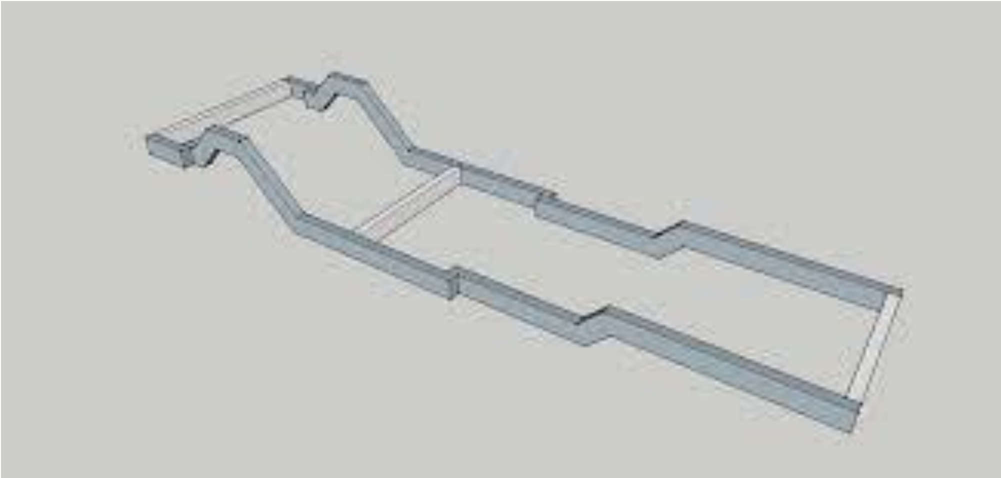


Figure 28: Chassis

5.2.5.2 Plastic seat and the head rest

In the model for our scooot, we need to ensure the scooot has a headrest and the seated rest is to be made from the same component. This will reduce the necessity of having to rivet the seat to the chassis at so many points. The headrest and the seat will both be made from plastic. The use of plastic is deliberate because it can assist in cutting down the cost of the device. With the two being conjoined, the seating pad is the one that will need to be riveted to the bottom.

Figure 30: Strap

5.2.5.3 Machine washable strap

The scoooter will be mounted by small children. Children do not always have a sense of safety and precaution when they play. This calls for the need of having a strap that will strap the child to the seat of the scooot. This strap could be made out of nylon or cotton or a similar textile. However, whatever material that is used here should be strong and flexible to secure the child but not to harm them. This is because the strap will not be used like the seatbelt of a car. The strap will have to cross several times over itself so that it holds the child firmly and in position.

Figure 30: Strap

5.2.5.4 Paddle cushion

Our desire is to make riding the scoooter an enjoyable experience for the the child is paramount. We will therefore need to ensure that the seating of the scoooter is soft and comfortable. Using soft cushioning is a way of making sure that the kid has a gentle seat and a headrest too. The cushion can be put on the seat and the headrest of the scooot.

5.2.5.5 Casters underneath

The casters are made so that they can turn at angles that are as large as 360 degrees. The casters have rubber tubing on the outer surface with a metallic housing that holds the axis of the small wheels of the casters. The casters will be placed near the ear of the scooot. This is because the scooot will need to make direction turnings.

Figure 31: Casters

5.2.5.6 Hover-board

We said that the caster wheels cannot be used on all the wheels of the scooot. This is because, at some point, there will be a need to have two steady wheels that will maintain the steadiness of the scoooter. The wheels of a hover-board would be the perfect match for this function. This is because they are steady and can be easily directed to go in a certain direction from them turning moments. This will be provided by the caster wheels.

Figure 32: Hover-board

6 PROPOSED DESIGN

This chapter showed how the design will look for the first time after following the selection of the design through the Pugh chart and Decision Matrix. The design was depicted using two methods: the prototype and the CAD design. An estimation of the materials that will be used for the manufacturing process has been included in the Bill of Material.

6.1 Prototype

Because the electric scoot was the final selected concept, it was chosen for the proof of concept prototype. Figure 33 shows the team prototype that was created using K'NeX kids building game with some duct tape and construction paper. The design being built using these supplies by trying to match the sketch project design. For the moment, the power supply is human power; one of the team members used his/her hand to push the scooter into movement.

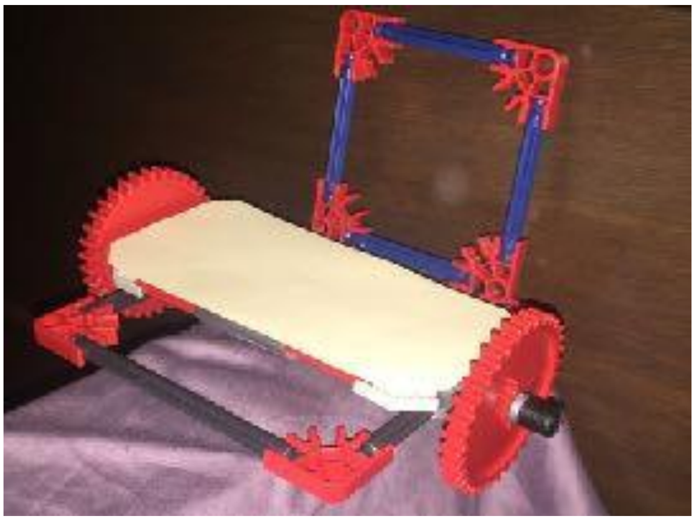


Figure 33: Final design prototype

6.2 Solid Work Design (CAD)

The following figure shows the solid work design for our project. As seen in the figure it consists of 4 wheels, a flat wooden frame to hold the seat, as well as the electronics (wires) which will go underneath them so that it looks neat. Furthermore, the rear two wheels are separated from the frame to ensure that the wheels move independently with the interaction of the frame. The metals that are attached to the frame are used to improve the movement of the GBG. This is drawn with solid-works to enhance a professional vision for the viewer of how the actual design will look. The front view of the solid-works design shows exactly how it will look when the design is completed.

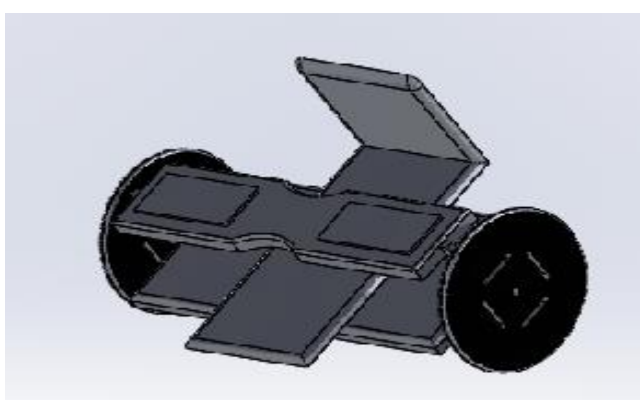


Figure 34: CAD Final Design

6.3 Bill of Materials

Appendix A shows the parts the group decided to use in the final design for this project. However, the group has two options for the seat that may be in the final design. Option A is the kid car seat made out of plastic, foam, and fabric. Option B will be using aluminum, foam, fabric and super glue or screws that the group will assemble together. The majority of the parts mentioned can be purchased online. The price of each part is listed including an allowance for price variance, such as taxes, shipping, changing prices, etc. The vendors listed here have sufficient supply to allow ordering additional quantities in the event of damage or design aesthetic improvements. These parts will provide additional safety features and high quality design to allow for a broader market. Additional materials may be used in the future and are included here as a possibility.

7 IMPLEMENTATION

This section explains how the team built the project. And the project was created by two categories:

1- structural base: In this category we build the base of the project with help from Auto Rehab sponsor. This garage provided the team place and used welding machine.

2- Subsystem: The group completed the wiring between the motherboard and the motors and applied the pressure pads to help the project work.

7.1 Design of Experiments

To improve the quality of the design of the project the team carried out three different experiments for different reasons. The first category is the battery; the team got a package of four/six-volt batteries. The second experiment involved the alignment of the device to ensure that it drives straight and does not move sideways. The final experiment involved measuring the maximum weight that the device can withhold and the weight of the material to ensure that it is appropriate and does not hinder the performance of the device. To increase the quality of the design for the project the team defined three different categories in the design of experiments part. The categories are the following:

A. Battery Voltage & current
B. Weight
C. Alignments

In category A, the team used three types of batteries. The batteries were different in some perspectives such as voltage and current. The first battery was 24V with 48A, the second battery was 36V and 48A, the final battery used was a lithium battery with 36V and 4.4A. Below is the DOE table for category A:

Table 23 DOE for Category A

Variable A	Results A	Comments
24V - 48A	Fail	High current burned the motherboard
36V - 48A	Fail	High current burned the motherboard
36V - 4.4A	Pass	Low current operated the device without burning

Table 23 showed the results section of the battery voltage and current section using three different variables. The first variable used a voltage of 24V and a current of 48A to operate the device. This battery resulted in burning the motherboard due to low voltage and high current. After replacing the battery and motherboard, the team used a new battery that had a voltage of 36V and a current of 48A. The team tried to increase the voltage to test the functionality of the final product with keeping the same current of 48A. The result was similar to the result of the first category and the team had to replace the motherboard and battery again. The final category used a lithium battery with a voltage of 36V and decreased the current to 4.4A after researching other batteries in the market. This category passed the test as the device was completely functional, and the motherboard did not burn.

In category B, three team members with different weights operated the final product to compare the efficiency of the product using maximum weights of adults. The used weights were 150, 200, and 250 lbs.

Table 24 DOE for Category B

Variable B	Results B	Comments
150 lbs	Pass	High speed
200 lbs	Pass	Average Speed
250 lbs	Pass	Low Speed, rear tires start to lean

Table 24 was divided into three sections covering different user weights. The weights considered in the table were for adults to maximize the results. User weights were from three team members by approximating their weights in lbs. The categories were 150, 200, and 250 lbs. respectively. The team noticed that speed kept decreasing when the weight increased and the rear tires started to lean on each side when operating with a maximum weight for the user.

The final category for the design of experiments part was category C. Category C had three different variables that were front tires, rear tires, and pressure pads. Category C tested how the final product operated while turning, how rear tires responded to higher weights, and the responsively of the pressure pads.

Table 25 DOE for Category C

Variable C	Results C	Comments
Front Tires	Pass	Front tires turn ok depending on the user
Rear Tires	Pass	Passed the test except when having weight of the user above 260 lbs where the tires start to lean.
Pressure Pads	Fail	This test failed and the team had to add joysticks on the pads since they were not responsive.

Table 25 displayed three categories for the design of experiments. The first category was by testing the front tires and how they operated while turning and moving forward. This test passed and the movement of the front tires depended on the user input. The second category was testing the rear tires. Using category B, the team observed the process with maximizing the user weight. This caused the rear tires to lean while operating due to heavier user weight. The final section of category C was testing the pressure pads, which failed. Failure of this section was due to the less responsively of the pressure pads. The team added a joystick on each pressure pad improving the responsively of the pads.

According to the DOE, all the variables of categories A, B, and C passed the experiments except for three variables that failed the test. In category A, variable (24V - 48A) and variable (36V - 48A) failed the tests since the motherboards were destroyed due to higher currents provided which made the team change the used batteries to the final battery (36V - 4.4A) Lithium. The final variable that failed the test was from category C where the pressure pads failed the test and the team had to add a joystick on each pressure pad in order to have a better responsive final product.

7.2 Design Changes

The design has completely changed from what was expected. Figure (35) shows the new design of the project. We have faced many problems while manufacturing our old design. The frame was too small to handle all the expected electrical work that was going to fit inside the Go Baby Go car. Instead of leaving the seat with the wheels attached to it, we implemented a bigger wooden frame that would fit the electrical work and the seat. The team saw that the wheels would not move if it was close to the seat so we widened the rear wheels with a metal attached to the frame and at the end of the metal we attached the wheels to it. This is to enhance the movement of the wheels. Furthermore, two wheels were not enough to make the car move freely and independently which was changed to 4 wheels with a rear wheel drive feature. This would give the rider a better way to steer comfortably from left to right.

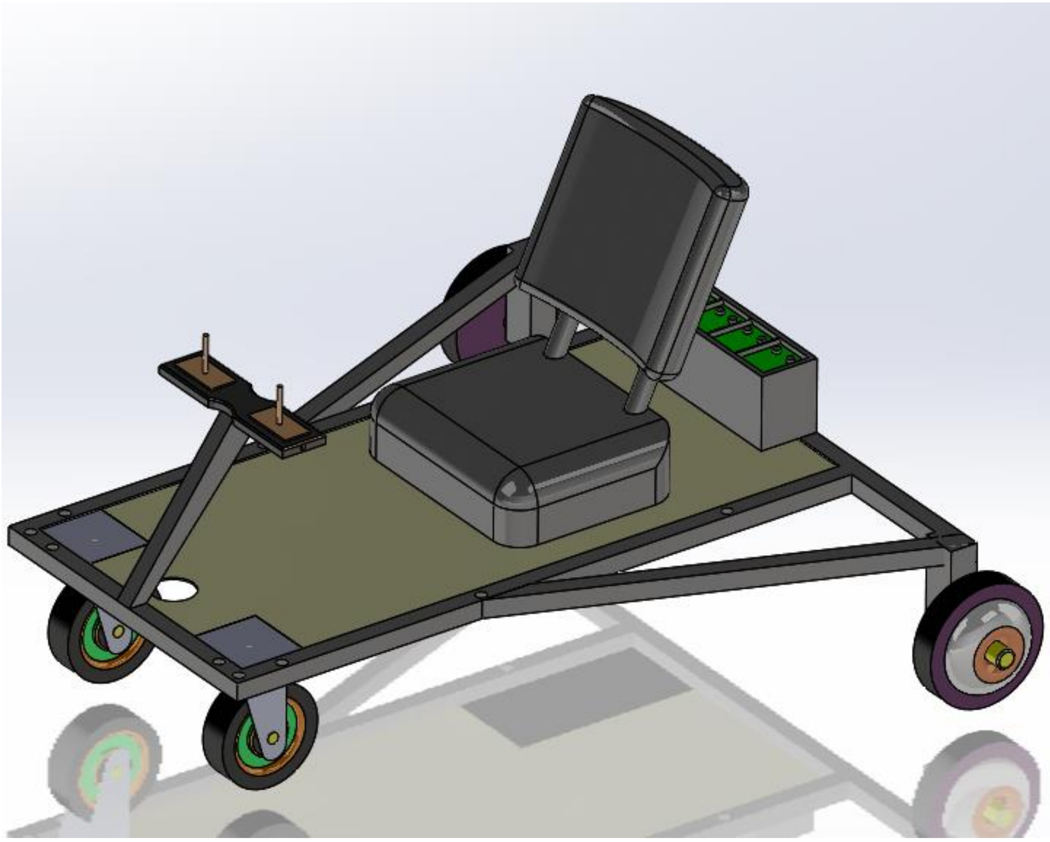


Figure 15: CAD final Design

7.2.1 Electric Scoot Manufacturing

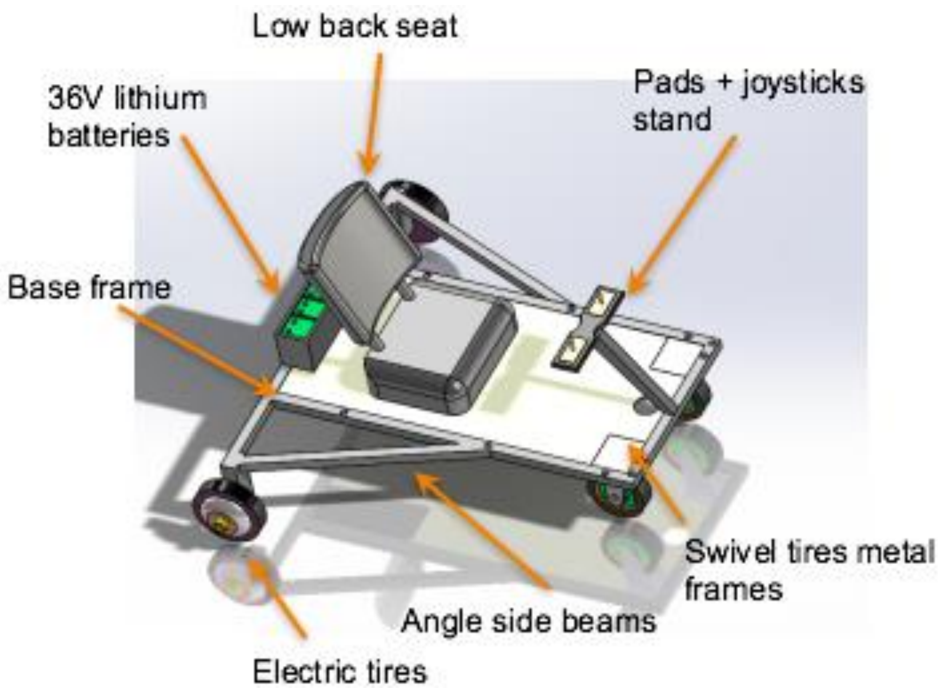
This section explains how to build the electric scooot with all the materials that shown in table 1 in the appendix. Noodle foam, sponge sheets, fabric sheets covered every sharp edge parts and padding sheets. Whereas, split loom covered the wires. The design is under two main categories the structural base and the subsystems.

7.2.1.1 The Structural Base

In this, part the user will need help from professionals in welding and drilling.

a. Weld four pieces of plain steel 36in back beam 36.5in both left and right side beams18.5in front beam to create a rectangular base frame shows in figure (36).
b. Drill holes in the base frame to attach the 36in height 18in width wood board by using screws. In the front of the wood board cut a rectangle shape 3in height 4in width from both left and right side for the swivel tires shows in figure (36).
c. Weld two pieces of plain steel square 24in on each side of the Base frame to create an angle side beam shape shows in figure (36). Weld the pieces start from under the end of the longest plain steel in the base frame.
d. Below the angle side, beams weld ½ in U-bolts to support the electric tires from any damage shows in figure (37).
e. Pads-joysticks stand 45 degrees down: weld two pieces of 14.5 in plain Steel Square to the middle point of the front base frame beam shows in figure (36). In addition, attach two pieces of 1in square shape flat steel sheet to support the stand first, 3in from the bottom second, 7in from the first square sheet that shows in figure (38).

f. Weld 1in plain steel square to the stand from the top in a vertical way shows in figure (38).
g. Attach 6in height 3in width wood board piece on the top of step (f) with screws shows in figure (38).
h. Weld 6.5in height 10in width plain steel to create rectangle boundaries for the batteries location. The boundaries stars from the inside left side of the base frame beam and the inside back base frame beam.



7.2.1.2 The Subsystems

This section explains the subsystems and their position. Every electric part took from the hover board.

a. Locate both electric tires inside the U-bolts and swivel tires using the metal attachment that comes with it in the front wood board cuts that discussed in chapter 4.1 step (b) and shows in figure (37).
b. Place the motherboard bellow the design near the left side of the electric scoot within 2in space from the base frame shows in figure (39). Use the extension wires to attach both electric tires to the motherboard that already attached in both pieces.
c. Use 55in wire extension shows in figure (40) to connect the motherboard all the way to the pads-joysticks electric boards. Place the electric pads-joysticks boards under the hover board metal base shows in figure (38).
i. Place the hover board case in the top of step (g) in chapter 4.1 using tighten robs from each side in the middle of hover board case.
d. Locate the low back seat on the wood board and tight it 15.5in height from the front beam and 2in width from the side frame beams shows in figure (36).
e. Connect the last wire extension of the motherboard to the batteries and locate them safely.
f. Attach the safety belt 1in the rectangle back base frame beam shows in figure (41).

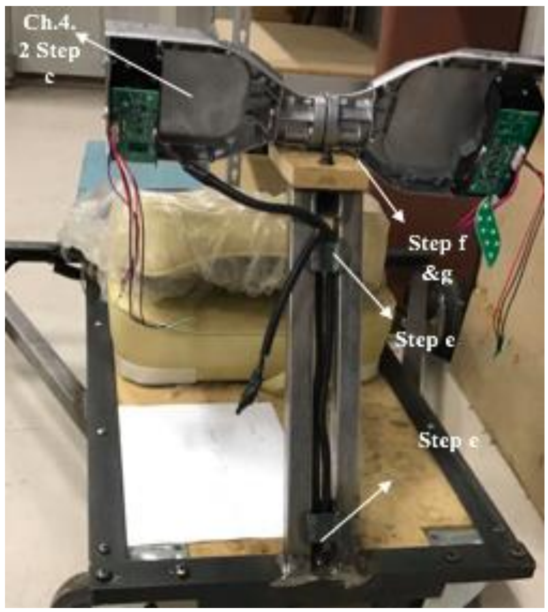


Figure 38 Close look to the design 1

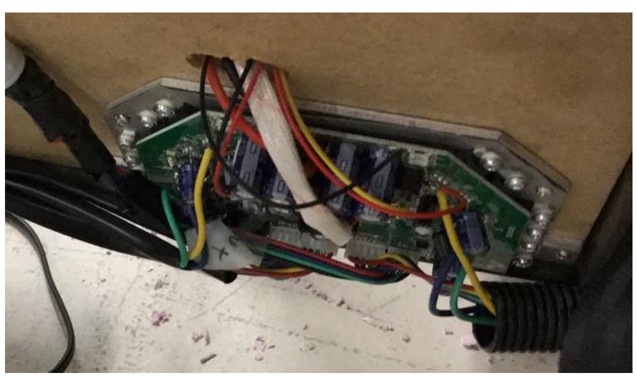


Figure 39 Motherboard

Figure 40 Wire extension

Figure 41 Safety belt

7.2.2 Electric Scooot Operation

This section explains how to operate the device by following the steps below:

a. Make sure the batteries are fully charged. The charging device will notify the user if the battery is fully charged by showing two different lights on (Orange = Battery is empty, Green = fully charged)

b. The device turned on by using the remote start button that placed underneath the device.

- To turn right press the right pressure pad with twist of -%5 only
- To turn left press the left pressure pad with twist of -%5 only
- To move forward push the pressure pad and let the pressure pad twist -5%
- To move backward push the pressure pad and let the pressure pad twist +5%

8 TESTING

[The final part of the project implementation towards getting an operating final design was testing. The testing part of the project helped the team check whether the design met the customer and engineering requirements or not. Testing gave the team the opportunity to test and check the final GBG retrofit from different perspectives. The following engineering and customer requirements were taken into consideration to determine the testing sections.

The main part of the testing was to check if the customer requirements and engineering requirements are met by testing the final product. The customer and engineering requirements were taken in to consideration to determine the testing sections to consider while testing. Below are both customer and engineering requirements used to determine the testing sections shown in table 25.

8.1 Customer Requirements:

1. Power system: control acceleration – Satisfied, since the pressure pads objective was to control acceleration in the system.
2. Physical: comfortable seat – Satisfied, multiple users used the seat ordered for the final product used in the design and no issues occurred.
3. Operating system: easy to operate – Satisfied, the final system was easy to operate with less required effort from the user except to balance the system.
4. Financial: Low final cost – Satisfied, as the final product did not exceed $550.00.
5. Safety: seat belt & frame padding – Satisfied, the final product included a seat with a seat belt attached to it to secure more safety for the child using the product. Additionally, the final product had paddings added to the edges of the final product.

8.2 Engineering Requirements:

1. Weight ≤ 140 lb. – Satisfied, the final product had an approximate weight of 119 lb.
2. Price/Cost ≤ $550 - Satisfied, as the final product did not exceed $550.00.
3. Battery life ≥ 2 hrs. - Satisfied, the engineering requirements required a final product that could at least provide two hrs. of usage from a fully charged battery. The final product provided 3-4 hrs. of usage depending on the users' input.
4. Multiple speeds (0-6 MPH) – Satisfied, the a speed of the final product could go up to approximately 6 MPH depending on the user input while controlling the acceleration from the pressure pads located on the top part of the product.
5. Ordered parts ≤ 7 days – Satisfied, most parts did not take more than seven business days to arrive to start manufacturing.
6. Creative steering option – Satisfied, since the steering option in the device was creative by using two joysticks attached to the pressure pads and it is a user-friendly solution.
7. Soft edges – Satisfied, the final solution had some sharp edges in the base structure of the device. The team added some paddings on the base structure to have a more secure product.
8. OSHA standards – Satisfied, OSHA safety standards met the final product.

Table 26: Testing & Results

Testing	Struggles	Results
Weight compatibility	Max. weight increased	Device Holds up to 260 lbs
Electrical circuits	Motherboard electric shortage Batteries over the power required (high current)	Motherboard replaced Batteries replaced (36V Lithium Batteries)
Pressure pads	Less responsive pressure pads	Pressure pads replaced Joy Stick style steering added
Heat generation	No struggles	No heat generated from the battery except when charging
Balance check	No struggles	Alignments of the device passed the test and the tires were parallel to each other

Table 26 is showing the testing sections and the results of the final product testing. The table had two different sections that are struggles and results. The following sections were used in testing the final product:

1. Weight compatibility – Tests how much weight the final product can withstand.
2. Electrical circuits – Tests the electrical circuits to power and operate the device.
3. Pressure pads – Tests how responsive the pressure pads are for the user to control.
4. Heat generation – Tests the heat generated from the device while operating and while charging the battery.
5. Balance check – Tests the alignments of the device.

The testing procedure was done after manufacturing the final product using the sections mentioned above. The first section's struggles were to increase the maximum weight of the user. As a results the maximum weight was reached for the device to hold up to 260 lbs. Electrical circuits were tested by connecting the device to three different power supplies (24V 48A, 36V 48A, Lithium battery 36V 4.4A) and check if the device operates and functions normally. The device operated with connecting the power supply and the team was able to check all functionalities of the product. The first two batteries (24V 48A, 36V 48A) did not function and unfortunately the team had to replace the motherboards. The final Lithium battery did operate and the product was functioning normally. The third testing section was testing the pressure pads. The pressure pads had to be adjusted since the regular pads were not responsive. The team had to add two joysticks with one on each pressure pad. This solution made the final product more responsive to accept the user input. After testing the power supply and the circuits, the team tested the generated heat from the product while operating and charging. The results from this section was that the device did not generate heat while operating except when charging the device while the device in not running. The final test was the balance check. This test was tested by having a team member use the device in different directions and the team observed the device in operation to check the alignments of the product. The rear tires were perfectly aligned and were parallel to each other. Overall, the final product passed all the tests with making the required adjustments to the final product.

9 CONCLUSIONS

In conclusion, the overall project from the very beginning was a great ambition to get the opportunity to work for the children who are in need. The team has accomplished the purpose and goals that has been stated in the team charter from the beginning of the capstone design. One of the reasons that the team was on a successes line was because all of the team charter were followed as written. The team had the advantage to create a new retrofit that implements new technologies in a Go Baby Go car this was because the team has followed all the time management techniques that were really time efficient. The hover board system that went inside the car has given the team a great thumb up to all the people who saw it, this was all due to the product of the quality that was implemented in the device. The negativity of the project went to the tough work on getting the hover board to work on hands rather than on legs. The team has put a great effort on both mechanical and electrical engineering work to get the project done. There were a lot of lessons that the team has learned throughout the two semesters. Time is a great aspect to take care of and know exactly how avoid obstacles that could take over in the project. Overall, the team had worked hard together in order to accomplish the dream that the team desired to accomplish this was all due to hard work and determination.

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Table 3 Bill of Materials

Parts	Image	Market	Price
Toolkit 550 Piece Metric Sheet Metal Screw Assortment - Contains 13 Popular Sizes [27] Option-B		Amazon	$5.99
BAA SHOP Two Wheels Mini Smart Self Balancing Scoooter (Adapter) [28]		Amazon	$10.99
Lap Seat Belt, Chrome Lift Latch, 60 Inch Length [33]		Amazon	$14.64

MDF Panel (Common: 3/4 in. x 4 ft. x 8 ft.; Actual: 0.750 in. x 48 in. x 96 in.) [35]		The Home Depot	$35.66
Wise Economy Low Back Seat [37]		Amazon	$33.89
SOLOOP 480Pcs 12 Size Assorted Insulated Electrical Wiring Wire Terminal Crimp Connector Kit Butt Spade Set [38]		Amazon	$20.98
Caster Set (2 Swivel/2 Locking) [39]		Global Industrial	$33.89
Wire Rope Clip, U-Bolt, 1/2In, Forged Steel*4 [40]		ZORO	$49.63

48 in. x 1-1/4 in. x 1/16 in. Plain Steel Square Tube [41]		Home depot	$17.66
4 x (1-1/2 in. x 36 in. Plain Steel Angle with 1/8 in. Thick [42]		The Home Depot	$37.88
Gold new Self balancing 2 wheel mini hover board electric scoooter hoverboard used		Amazon	$180
2 JLF 6mm Hollow 316L Shaft – Standard		paradisearcadeshop.com	$30
Minions All Natural~Cotton Fabric by Quilting Treasures~1649-24305-Zfor Quilting		Walmart.com	10.95
Product Title 2 Pack Oodles Monster 55 Inch x 3.5 Inch Jumbo Swimming Pool Noodle Foam Multi-Purpose		Walmart.com	$1.88

h-Temp Split Loom - 3/8"		Delcity.com	$ 0.25570
Morning Glory Foam Sheet, 24"L x 96"W x 1"H		Walmart.com	$6.84
MAXI Foam Padding - Blue		Walmart.com	$2.49